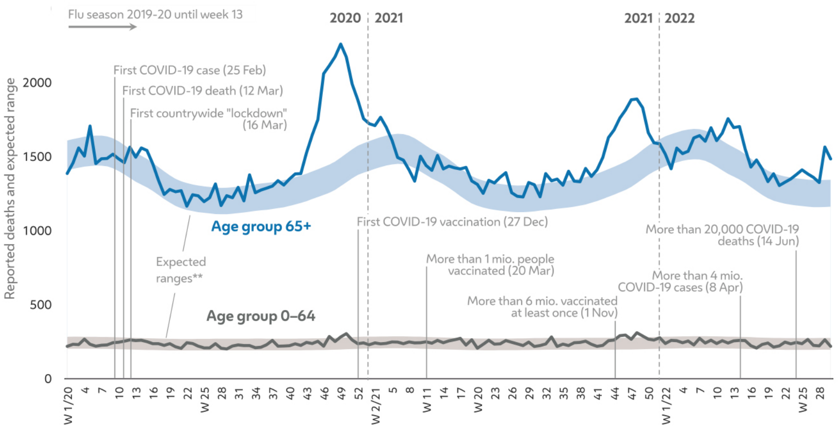
VIENNA YEARBOOK of Population Research 2022

Weekly deaths in Austria, January 2020 – July 2022



"Demographic aspects of the COVID-19 pandemic and its consequences"

Guest Editors: Paola Di Giulio, Anne Goujon, Guillaume Marois and Joshua R. Goldstein

Vienna Yearbook of Population Research 2022
Austrian Academy of Sciences, Vienna

Special issue on Demographic aspects of the COVID-19 pandemic and its consequences

Guest editors:
Paola Di Giulio, Anne Goujon, Guillaume Marois and
Joshua R. Goldstein

Vienna Yearbook of Population Research 2022 (Volume 20)

All articles in this publication were subject to international peer review.

Cover: Updated and edited Figure 5 from Bauer et al., this volume.

ISSN 1728-4414
ISBN 978-3-7001-8882-7

Copy editing: Miriam Hils, Bainbridge Island, USA
Layout: Sunrise Setting, Brixham, UK
Print: Prime Rate, Budapest, H
Publisher: Austrian Academy of Sciences Press, Vienna, AUT (https://verlag.oeaw.ac.at)
https://epub.oeaw.ac.at/vypr_collection

Made in Europe

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Preface

The COVID-19 pandemic has touched people's lives in many ways. All readers of this volume certainly have a COVID-19-related story to tell, and the pandemic will undoubtedly become a marker that people will remember, like where they were and what they were doing during these long and uncertain months, particularly during the first wave. As editors, we also experienced some of these consequences – though luckily none were fatal. Paola had to combine her own work (home office) and her children's work (distance learning) during the various school closures in Austria, the first of which in the spring of 2020 turned out to be just the beginning of a series of sequels unfolding like a successful TV drama. Anne moved to the Lombardy province in Italy to join the European Commission Joint Research Center in March 2020, at a time when the infection and the fatality rates had reached their highest levels, particularly in the province of Bergamo. Hence, the containment measures imposed in that province were among the earliest and the most stringent in all of Europe. Guillaume, whose main affiliation is with the Asian Demographic Research Institute in Shanghai, faced several challenges, starting with being unable to travel back to China for many months. Then, when it became possible for him to do so, he was affected by the zero-COVID policy, which had him stranded in his room on the campus in Shanghai for weeks in 2022. Josh was able to travel to Austria in the summer of 2021, but when he arrived in Vienna, there were limited opportunities to organise face-to-face meetings, as the city was still in lockdown at the time. As a result, the four guest editors of this special issue could never all meet in person. At the same time, we are aware that our experiences are by no means exceptional, and that the outbreak of the pandemic has disrupted the rhythm of life as we had previously known it in every country and in every setting.

This volume has been completed almost three years after the beginning of the pandemic. There is little doubt that the crisis has changed the way research is carried out. During most of the pandemic we met online and were required to learn new methods of organisation and interaction. This was easier in highly digitalised contexts, which further underscores the contrast between higher- and lower-income countries. But even in resource-rich contexts, the pandemic was harder on researchers in unstable positions, and on those with pressing family commitments, mostly women.

Finally, we would like to thank all of the authors who submitted a manuscript to our journal; the colleagues who patiently and constructively reviewed the submissions; and the colleagues who contributed to the finalisation of this volume.

In particular, we would like to thank the managing editor, Maria Winkler-Dworak, and the editor-in-chief, Tomáš Sobotka, who never ceased to provide support, to make suggestions, and to offer assistance when needed. It has been a long journey, but we never lost our good spirit.

Paola Di Giulio, Anne Goujon, Guillaume Marois and Joshua R. Goldstein
Guest Editors

Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 1–11

The population aspects of the COVID-19 pandemic in 20 papers: an introduction

Paola Di Giulio[1,*]***, Anne Goujon***[2,1] ***and Guillaume Marois***[3,2]

Abstract

The introduction to the 2022 Special Issue presents the 20 articles that discuss the demographic aspects and the consequences of the COVID-19 pandemic. It synthesises the main findings from the contributions, emphasising the demographic, social and economic characteristics that influenced the spread of infections and determined the number of deaths. We highlight the specific focus on measurement issues, often with a comparative framework across several countries, and at the regional level as well, both within and beyond Europe. We also summarise the impact of the measures imposed to contain the spread of the virus, such as lockdowns. Moreover, we explore the impact of the pandemic on the quality of relationships, the intention and the motivation to have children, and realised fertility. In addition, we present the authors' broader reflections on the risks faced by different communities of individuals, and the potential consequences for their life trajectories, including in relation to other current risks that overlap with the pandemic (recent armed conflicts), and for the achievability of the Sustainable Development Goals themselves.

Keywords: COVID-19; demographic impact; mortality, infections; fertility; economic impact; social impact

1 At the outbreak of the pandemic

In the first months of 2020, the world was hit by an epidemic emergency. The COVID-19 pandemic affected every aspect of our lives. The crisis also strongly

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DOI: 10.1553/populationyearbook2022.int01

impacted population trends, leading to upturns and fluctuations in deaths and mortality, short-term ups and downs in births and fertility, and a temporary freeze of migration due to government restrictions on mobility. Scientists, including demographers, sociologists, economists and medical scholars, soon started studying the impact of the pandemic shocks and the ensuing economic changes, as well as the effects of policy responses on population trends, producing a wide array of research (see Mayer, in this volume). The collection of the relevant data was accelerated, and new surveys were quickly designed to track life changes during the pandemic. New methods focused on estimating incomplete data, modelling and analysing the dynamics of the pandemic and its impact, and new approaches for designing appropriate policy responses, have evolved at breath-taking speed. With their strong background in data and methods, demographers and population researchers have made pivotal contributions to the rapid accumulation of knowledge on the coronavirus pandemic.

This volume of the Vienna Yearbook of Population Research, which is made up in part of presentations delivered at the Wittgenstein Centre Conference 2020,[1] is dedicated to the demographic aspects and the consequences of the COVID-19 pandemic, and showcases the breadth and the scope of the demographic research on this subject.

The Special Issue includes 20 contributions selected from more than 60 submissions. This is a remarkable number for a single issue of the VYPR, but it represents a tiny fraction of the research that has been published on this topic since the early months of 2020.[2]

We have organised the presentation of the contributions into four main directions. A large part of the issue is devoted to analysing the direct demographic impact of the crisis: i.e., describing the spread of the disease, estimating the number of infections, and analysing the COVID-19 mortality patterns and their impact on life expectancy. A second group of papers considers in more detail the indirect consequences of the pandemic, and the impact of the measures imposed to contain the spread of the virus, including prevention and mitigation policies, of which lockdowns (with varying degrees of strictness) were the most common component. A third group of papers looks at how the pandemic affected intentions and motivations to have children, and actual fertility. The volume also includes two contributions that reflect

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[1] The Wittgenstein Centre Conference 2020 (see https://www.oeaw.ac.at/vid/events/calendar/conferences/demographic-aspects-of-the-covid-19-pandemic-and-its-consequences) was the first international scientific conference stretching over several days that was entirely dedicated to the demographic aspects of the COVID-19 pandemic. It was held exclusively online, and was attended by a total of 450 participants from 54 countries.

[2] A quick search for the term "COVID-19 pandemic" on Google Scholar, limited to results published since 2020, yields a result of more than half a million entries (as of 23/09/2022). By comparison, a search using the term "depopulation", which has little overlap with research on the COVID-19 pandemic, yields a total of 50,000 hits over the last 20 years (16,000 of which are since 2020, indicating the increasing popularity of the topic that is the focus of the VYPR Special Issue for 2023).

more broadly on the risks that different communities of individuals faced during the pandemic, and the potential effects on their life courses; and that consider more generally the global impact of the pandemic on the Sustainable Development Goals agenda. We will start with the fourth group of papers.

2 Perspectives on the pandemic

Two compelling articles in the newly established *Perspectives* section open the Special Issue, offering a comprehensive overview of the pandemic's implications and consequences for the life course (by Mayer, in this volume), and for the Sustainable Development Goals (by MacKellar, in this volume).

As Mayer points out, the scientific field of demography, embedded in sociology, is well-positioned to study the consequences of the pandemic on the population. He opens the "toolbox of sociology" to unpack how social inequalities contributed to the spread of COVID-19 and its consequences, which in turn affected the life courses of populations, and may have fostered new inequalities over the longer term.

In his wide-ranging contribution, and with many interesting detours, MacKellar shows how the pandemic has affected the Sustainable Development Goals, and contrasts its impact with that of the on-going war on Ukraine by Russia – labelling them the "twin crises". He warns of a crisis in the global sustainable development project, also in relation to the current lack of adequate financial resources to effectively pursue its full scope. He calls for a shift in focus away from the micro narratives at the individual and the household level, and towards the larger question of "what demographic trends mean for global prosperity", while underlining the relevance of demography for dealing with the future global challenges.

3 This pandemic is about infections and deaths…

From a demographic perspective, one of the most obvious impacts of the pandemic is on mortality. To date, around 20 million people worldwide have died because of COVID-19.[3] As is the case for any infectious disease, the vulnerability of different populations to COVID-19 infection, morbidity and mortality was unequal,

[3] The officially reported number of COVID-19-related deaths globally was 6.5 million as of September 2022 (Source: Coronavirus (COVID-19) Deaths - Our World in Data, for details see Mathieu et al., 2020). However, this is an underestimation due to varying protocols and challenges in the attribution of the cause of death. Research based on excess death data suggests that the true global death toll from the pandemic is about 3–4 times higher: a Lancet study by Wang et al. (2022) estimated the total death toll at 18.2 million until 31 December 2021 (with a 95% uncertainty interval between 17.1 and 19.6 million), while a more recent estimate by The Economist (2022) puts the total death toll from the pandemic at 22.3 million as of 26 September 2022 (with a 95% uncertainty range between 16.1 and 26.7 million).

and depended largely on several factors. The demographic (Guilmoto, 2020), geographic (Goujon et al., 2021), socio-economic (Hawkins et al., 2020) and health (Guan et al., 2020) characteristics of populations were key components in their specific epidemiological risk levels, which were in turn influenced by their access to and the availability of medical resources. Several papers in this volume investigated how the virus affected the mortality trends of different regions of the world during different waves. It is clear from those papers that evidence of disruptions in mortality trends was found in all of the regions studied. In sum, the papers in the volume agree on the following points:

- COVID-19 outbreaks were correlated in time, in space and in intensity with excess deaths and mortality.
- Excess mortality was more concentrated among the elderly than among the younger population.
- Though the average age of the people who died from COVID-19 was high, the virus was severe enough to have caused a pronounced decline in life expectancy in the hardest hit regions.
- The decline in life expectancy was larger for men than for women.

The risk of dying from COVID-19 has been difficult to measure accurately because the ways that causes of deaths and cases of COVID-19 have been reported have varied over time and space. In this volume, this methodological issue is clearly highlighted by Vanella *et al.*, who found evidence of considerable variation in the COVID-19 case fatality risk over time and across countries, which the authors attributed to different sources of bias in the estimates, particularly from testing policies that targeted specific age groups, and thus overestimated the risk for other age groups. On the one hand, a lack of testing capacities might have resulted in some cases not being detected, which would have led to the underreporting of the number of deaths from the virus. On the other hand, depending on how the causes of deaths were registered, the much higher incidence of mortality for people with severe comorbidities might have resulted in the overestimation of the real impact of COVID-19 on the aggregate number of deaths over a given year.

For these reasons, most studies included in this volume looked at excess deaths, rather than at the number of registered COVID-19 deaths, to assess the impact of the pandemic on mortality trends. On this topic, Bauer *et al.* (in this volume) observed that in the Austrian provinces, there was a significant increase in the number of deaths in 2020 and 2021, and that excess mortality closely followed the waves of COVID-19 infections. Moreover, in the case of Austria, excess mortality matched the number of deaths caused by COVID-19.

Similarly, using all-cause daily death registrations data from the Italian Statistical Office, Ghislandi *et al.* (in this volume) were among the first researchers to measure the extent to which COVID-19 had affected life expectancy. They found that in the Italian provinces that were hit the hardest by the first wave in spring 2020, four-month life expectancy declined by 5.4 years to 8.1 years for men, and by 4.1 years to 5.8 years for women. These figures also reflected the differences between men and women in the risk of dying from the virus. In their spatial analysis of COVID-19 mortality by age, Baptista *et al.* (in this volume) also observed that in all regions of Brazil, the risk of mortality from COVID-19 was higher for men than for women, particularly during the first wave.

Kolk *et al.* (in this volume) focused on excess deaths and trends in life expectancy for 2020 in Sweden, which attracted a lot of international attention due to its unique response to the pandemic, in particular its decision to impose fewer epidemiological control measures than other countries did. They estimated that life expectancy in Sweden fell back to 2017 levels for men and to 2018 levels for women, while in neighbouring Nordic countries, where the virus was spreading much less rapidly in 2020, there was no decline in life expectancy.

Rousson *et al.* (in this volume) further compared the loss of life expectancy during 2020 with that during the 1918 Spanish flu in six European countries (Switzerland, Spain, France, Italy, the Netherlands and Sweden). Although COVID-19 has significantly reduced life expectancy in all of these countries, its impact has been much less dramatic than the aftermath of the 1918 pandemic, mainly because the latter was much deadlier among the younger population, while COVID-19 affected the elderly population in particular.

4 . . . but there is more at stake than just mortality

While also dealing with COVID-19 infections and mortality, the focus of the articles summarised in this section is on the indirect consequences of the coronavirus and the effects of the prevention and mitigation policies that were put in place to control the pandemic. The paper by Sánchez-Romero (in this volume) used National Transfer Accounts (NTA) data to assess the economic impact of the pandemic across different cohorts and countries. The author found that given the transfers across generations, lifetime consumption declined more for the 0–24 age group than for the 65+ age group due to the reduction in private transfers from parents to children, but also argued that this negative impact could be reversed if governments fully compensate workers for their labour income losses.

While COVID-19 infections and deaths were clearly stratified by income level, Sánchez-Páez (in this volume) took a macro perspective and examined the possible link between the levels of income inequality in European countries and the impact of the virus in terms of infections and deaths. The evidence does not point to the existence of a strong association, which could be due to the relatively low levels of socioeconomic inequality in these countries prior to the pandemic. However, the author found a robust association between the proportion of the population working in essential activities – who often belonged to the lower-income group – and infections.

As the article by Bellani and Vignoli (in this volume), reminds us, the consequences of the pandemic were not only economic, as they also spread to the sphere of relationships. Unsurprisingly, in the countries examined (Italy, Spain and France) the relationship quality of couples decreased during the highly restrictive lockdowns of the first pandemic wave. The authors presented evidence that the decline was mostly driven by emotional stressors triggered by an increased sense of loneliness and the inability of people to engage with their network, and was less related to paid work or organisational matters. They remarked on the absence of differentials within and across the three countries, noting that it might be attributable to the severity of the lockdown measures. These findings were partially confirmed by the study of psychological vulnerability (measured with self-reported stress, anxiety and depression scales) conducted by Xourafi *et al.* (in this volume) during the COVID-19 lockdown in Greece. However, their results were less homogenous across individuals, with women, young adults and the unemployed exhibiting higher levels of vulnerability during the lockdown.

Less intuitive are the results of the study on the link between crime prevalence before the pandemic and COVID-19-related mortality rates in the context of urban Mexico by Masferrer and Rodríguez Chávez (in this volume). They showed that the prevalence of homicides was negatively associated with mortality rates, while the prevalence of robberies was positively associated with mortality rates for both sexes. They end the article with a plea for more “research on the complex relationship between COVID-19 and its contextual determinants”.

Two papers highlighted the role of living arrangements and mitigation policies in containing infections and deaths by COVID-19. Li *et al.* (in this volume) demonstrated how the policies that were put in place in Hong Kong were able to substantially limit the number of infections and fatalities between January 2020 and February 2021, despite the territory having several features that would be expected make mitigation efforts difficult, such as a relatively old age structure, a high population density, poor housing conditions and a large migrant population.

Living arrangements played an important role in the COVID-19 mortality of elderly people residing in care homes, who were more vulnerable to the virus, and experienced higher death rates during the first wave than older people living at home. Mun Sim Lai (in this volume) studied this issue in Belgium and England and Wales, and found that the two main determinants of the excess mortality among older people in care homes were their frailty and higher infection prevalence.

5 The uncertain effect of COVID-19 on childbearing

While the impact of the pandemic on mortality, health, migration and well-being was clearly pointing in one direction, there was initial speculation that its implications for family formation and childbearing could go either way. On the one hand, external shocks are often associated with a baby bust. On the other hand, the lockdowns and the enforced closeness might have encouraged couples to fulfil their fertility plans, or to develop new ones (Aassve et al., 2020). So far, there is no evidence of a significant and lasting reversal in the number of babies born during the pandemic. Instead, most countries experienced distinct fluctuations in birth trends depending on the phase of the pandemic and on the context (Beaujouan, 2021; Sobotka et al., 2022). Among the papers in this issue that review the implications of the COVID-19 pandemic for fertility, the most common finding was that there is still uncertainty about the long-term effects of the pandemic on women's and men's reproductive experiences. The papers cover a broad spectrum of data, methods, topics and geographical areas. Using longitudinal and cross-sectional survey data as well as official register data, these studies explored short-term fertility motivations, fertility intentions, pregnancies and births, while focusing on different countries (Brazil, Italy, selected sub-Saharan African countries and the United States).

Regardless of the geographic context they were examining, all of the authors emphasised that it is difficult to draw a consistent picture of the impact of the pandemic on births (desired, expected or achieved). They noted that because the pandemic occurred in a context in which fertility rates were already trending downwards, determining what share of the most recent changes was attributable to the impact of the pandemic is difficult. However, they were able to establish that the prolonged proximity of partners enforced by the lockdowns did not result in a baby boom.

Based on the experiences of past crises, it is possible that there was a tendency during the pandemic to postpone births in response to the general sense of uncertainty, but that these postponed births might be "recovered" when the pandemic is over. All of these papers found that in the first year of the pandemic, when vaccinations were not yet broadly available, a tendency to postpone births to a later period was indeed prevalent. More surprising are the potential motivations behind this trend, which were explored in detail in the papers by Manning *et al.* for the US and by Guetto *et al.* for Italy, both in this volume. Analysing the reasons why people tended to avoid pregnancy (in the United States) or to revise their fertility intentions (in Italy) during the pandemic, the authors underlined that on their own, facing difficult economic conditions, experiencing or being afraid of experiencing health problems, or having labour market struggles due to the prolonged lockdowns could not explain people's decisions to have or to not have a (further) child. Instead, they found that people's perceptions of their relationship quality and their psychological well-being played a larger role in their fertility decisions. Thus, it appears that people's subjective perceptions, expectations, imaginaries and personal narratives of the future tend to influence their childbearing decisions in times of uncertainty.

Two further papers looked at how the pandemic affected pregnancies and births in sub-Saharan Africa and Brazil. Backhaus' article (in this volume) analysed longitudinal data on the pregnancy status of women of reproductive age in Burkina Faso, DR Congo, Kenya and Nigeria. Based on a comparison of data for 2019 and data collected at the turn of 2020/2021, he found no evidence of an increase in pregnancy rates, even though it had been anticipated that in low-income countries, limited access to modern contraception, combined with the persistence of early marriage and teenage pregnancy, and school closures, would lead to higher rates of unplanned pregnancies and births during the pandemic, particularly among the youngest and the least educated women. Lima *et al.* (in this volume) analysed births in six Brazilian cities for which good quality data were available. They concluded that the decline in births that was occurring before the COVID-19 outbreak continued and accelerated during the pandemic in most, but not in all, of these cities.

In summary, determining the impact of the pandemic on the number of births will require longer observation periods. It appears that during the early stages of the pandemic, people exercised caution in their fertility behaviour, at least if they did not have a strong desire to have (another) child.

6 The contribution of social sciences

The pandemic has prompted social scientists to study the impact of the virus on society as part of a gigantic collaborative effort that began immediately after the outbreak. The initial activities focused on sharing medical data and research that helped to contain infections and minimise hospitalisations and deaths in China. By the time the virus reached Europe in early 2020, it had become clear that the older age structure of the European populations could explain, at least in part, why the pandemic had much more devastating effects on European countries than it did on countries in Africa and Asia with younger populations (Dowd et al., 2020). Since then, population scientists worldwide have been advocating for the collection of higher quality and more detailed data, having shown that demography could indeed play a crucial role in describing and explaining the consequences of the COVID-19 pandemic for the population. The contribution by Rosero-Bixby and Miller (in this volume), for example, provided a formal look at the reproduction number R used for monitoring the epidemiological situation of the pandemic, with the main goal being to open a "black box" that would enable researchers to understand it, and to estimate it, in demographic terms.

All of the contributions collected in this volume describe the overwhelming uncertainty that accompanied what rapidly became a worldwide crisis. Some of the papers highlight the importance of finding the necessary data, refining the measures and the indicators, and interpreting the causes and the consequences of the spread of the virus. The analyses carried out in Italy, Brazil and Sweden clearly show that, especially in a context of acute uncertainty, it is important to take into account that the virus may spread unevenly in different regions. Nevertheless, many countries have adopted containment measures and lockdowns at the national level that have had varying degrees of success in protecting individuals and the population as a whole (Talic et al., 2021; Wong et al., 2020). By now it seems apparent that there are no simple and straightforward solutions to a complex problem such as a global pandemic. The vaccination campaigns that were supposed to help people live with the virus by reducing its most severe outcomes have been met with scepticism and harsh criticism among some parts of the population (Sallam, 2021), and have failed to fully reach the Global South (Lawal et al., 2022). The long periods of restrictions undoubtedly affected people's mental health and well-being in many ways. As well as causing incalculable losses of learning skills and knowledge for children and altering the pace of life for families, school closures also deprived children of the formative experiences associated with school life that are hard to make up (Engzell et al., 2021; Larsen et al., 2022; Pfefferbaum, 2021). Moreover, there is evidence of increasing inequalities in learning losses across different groups of students (Patrinos et al., 2022). Surprisingly, in most of the higher-income countries considered here, concerns about the economy and the loss of jobs and income seem to have played a smaller role in people's partnership and childbearing decisions than their subjective perceptions, feelings and expectations (Guetto *et al.*, Manning *et al.*, both in this volume). It is probably fair to say that the short-term and the long-term effects of the pandemic are not yet fully known, especially since its duration is still not foreseeable, and there is no end in sight. Moreover, other crises are overlapping with the pandemic, including the invasion of Ukraine by Russia and the accompanying displacement of millions of refugees, and climate change-induced disasters.

For all these reasons, we will welcome reflections and commentaries on the studies published in this volume in the online section "Letters and commentaries".

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PERSPECTIVES

Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 15–37

Aspects of a sociology of the pandemic: Inequalities and the life course

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Abstract

Over the course of the COVID-19 pandemic, the contributions of the social sciences to discussions about pandemic management have become more visible and more significant. In this essay, I review major aspects of a sociology of the pandemic. After providing an overview of the potential contributions of the different fields of sociology (the "toolbox" of sociology), I discuss two main domains: first, social inequalities and how they relate to the process of the spread of COVID-19 from exposure and infection, and to the consequences of the pandemic in the wider population; and, second, the potential long-term effects of the pandemic on the life course.

Keywords: COVID-19; pandemic; social inequality; life course; social networks; social norms

1 Introduction

Virology, epidemiology and mathematical modelling are among the leading scientific disciplines that promised and partially delivered the theoretical and empirical knowledge and the policy guidance needed to deal with the COVID-19 pandemic. Demography has also been at the forefront of the scientific disciplines involved in pandemic management, especially as the impact of the age structure of the infectiousness of the disease has become clear (Balbo et al., 2020). The research presented at the December 2020 Wittgenstein Centre Conference demonstrated the range and the depth of the demographic contributions to these issues. In this review, which is based on an invited keynote lecture to the Vienna conference, I would like to map the potential contributions and some of the actual contributions of sociology

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DOI: 10.1553/populationyearbook2022.per01

to these topics more broadly, and to specifically focus on how sociology intersects with demography in analyses of how the COVID-19 pandemic is related to social inequalities and the life course.

In the early weeks of the pandemic, no research results on its conditions and impact were available. Therefore, at that time, the main questions researchers tried to address were what is likely to occur based on developments during prior epidemics, from the Spanish flu of 1918 (Spinney, 2017; Sydenstricker, 1931/2006) to recent outbreaks, including the 2003 SARS outbreak; and which established research findings might be extrapolated to the present situation. Since then, the research literature on the COVID-19 pandemic has exploded in size. As no systematic review of this literature can be provided, I will rely in the current paper on selected empirical studies. Another aspect of the pandemic is that it is a "moving target." There is no simple dependent variable like a rate that can be used to track its development. Instead, the pandemic must be seen as an evolving process, which has now entered its third year. Thus, observations that might have been valid for the early months of the pandemic may no longer apply in the second and subsequent waves.[1]

First, I will give an overview of the potential contributions of the different fields of sociology, and – to the extent they are available – I will refer to specific studies and research activities. Second, I will examine socioeconomic inequalities as both causes and consequences of the pandemic. My major goal here is to develop a systematic schema of the ways in which inequalities relate to the process of the spread of COVID-19 from exposure and infection, and to the consequences of the pandemic in the wider population. Third, I will look at the potential long-term effects of the pandemic from the perspective of an area of research that is analytically very close to demography: i.e., the life course of birth cohorts. For this analysis in particular, we must rely on analogous events and disruptions to assess the likelihood that the COVID-19 pandemic will have specific effects, and the potential severity of these effects.

2 The toolbox of sociology

Sociologists have studied a wide range of topics related to the COVID-19 pandemic, including the impact of the pandemic on schooling, family, gender relations, fertility, work and mobility.[2] More systematically, we can unwrap the analytical toolbox of sociology and then ask what kind of questions are triggered by these "instruments."

1 This paper mostly reviews the literature covering the first wave of the COVID-19 pandemic in spring 2020. In the later phases of the pandemic, the various movements protesting government regulations and vaccination challenged sociological inquiry. They are not the object of my considerations here.

2 A good illustration of sociological perspectives and research topics can be found in the now almost two-year-long weekly Corona Colloquium of the Wissenschaftszentrum Berlin für Sozialforschung (2020/21), or in the special issue of European Societies (Lianos, 2021). See also the first major book on the sociology of the pandemic (Christakis, 2020).

- *Social action and social norms.* What are the conditions that support the emergence and acceptance of social norms? What roles do purposive/rational vs. expressive/symbolic forms of action play in this context?
- *Social relations and social networks*. What do we know about social networks and their consequences for contact and infection rates?
- *Social structure and social inequalities*. Are all members of society equal in the context of the COVID-19 pandemic? Is the pandemic a leveler or a driver of social inequalities?
- *Life courses and social change.* What are potential medium- and long-term effects of the pandemic on individual lives? What are prototypical "trajectories" of pandemics?
- *Social systems: institutions and subsystem differentiation*. How do the relative weights and relationships between markets, the state and civil society change during and after the crisis? How do the activities and relationships within and between schools, families and workplaces change?
- *Culture and knowledge*. What cultural schemata determine our perceptions of and strategies for coping with the pandemic? Does the COVID-19 crisis lead to social anomie, or does it strengthen collective identities and orientations?

I will make a few brief remarks about some of these areas, and will then analyze in more detail the impact of the pandemic on social inequalities and on people's life courses.

2.1 Social actions and social norms

An issue policymakers have faced throughout in the COVID-19 crisis is the question of how to ensure the population's acceptance of and conformity with rules regarding social (i.e., physical) distancing, personal hygiene and mask-wearing. Under what conditions are social norms accepted and followed? How can conformity with social norms be enforced?

The textbook answers to these questions seemed quite straightforward, and were already provided in the early recommendations of the German National Academy of Sciences (Leopoldina, 2020). It was assumed that levels of acceptance of COVID-19-related social norms would be higher if they were simple (e.g., the A-H-A rule[3]), transparent, universal, scientifically based and widely shared in the community (Opp, 2001). While these "norms on norms" were rhetorically followed by policymakers, they were not always adhered to in practice. Even the principle of voluntariness as a precondition of acceptance tended to be controversial and inconsistently applied. However, the contributions of sociology to this discussion could have been even more specific, and thus more helpful. Diekmann (2020) has argued convincingly that it is important to distinguish between norm acceptance

[3] The A-H-A rule stands for Abstand-Hygiene-Alltag mit Maske (distance of 1.5 m – hygiene – mask-wearing).

in "cooperation games" and norm acceptance in "coordination games" (see also Ullman-Margalith, 1977).

In coordination games, the actors themselves benefit from adhering to norms, while in cooperation games, others or society at large benefit from such adherence. Correspondingly, norms that ensure that the individual following the norms does not get infected, such as washing hands, maintaining physical distance and wearing a filtering face piece mask (FFP2), should be more easily accepted than norms that only prevent others from contracting the disease (such as wearing a surgical mask or using COVID-19 apps). Thus, it may be assumed that only the latter types of norms need to be enforced by sanctions.

Moreover, too little attention has been paid in this context to the basic distinction between rational-instrumental behavior on the one hand and emotional/symbolic action on the other. Thus, wearing a mask can be seen not only as a means of preventing infection, but also as a sign of wanting to belong to a norm-complying collective.

2.2 Social relations and social networks

Knowledge about the structure of social networks should be directly relevant to the issue of the diffusion of infection. Examining the density of network relations, the length of networks distances and the nature of the bridges between networks should reveal likely patterns of the spread of disease. It has been argued that having differential knowledge about networks could circumvent the need for full lockdowns. Currently, however, surprisingly little is known about the overall patterns of social networks in advanced societies, or about the specific ways diseases can spread through networks. In a seminal review article about "social networks and health," Smith and Christakis (2008) reported on the different ways in which diseases are connected to networks: "Social networks affect health through a variety of mechanisms, including (a) social support (. . .), (b) social influence (. . .), (c) social engagement, (d) person-to-person-contacts (. . .), and (e) access to resources." Their examples of obesity, sexually transmitted diseases, drug use and HIV infection do not, however, point to common patterns. Brückner and Bearman (2005), for instance, described the transmission of sexually transmitted diseases among high school students as a "spanning tree": i.e., as a single major pathway like a telephone pole and its connected phone lines. The authors also found no evidence of high activity hubs for HIV/AIDS.

Meyers et al. (2005) used network theory to predict the outbreak diversity of SARS. Commonly used COVID-19 modeling assumes fully mixed populations: i.e., that every individual has an equal chance of spreading the disease to every other person. But highly heterogeneous contact patterns with different speeds of infection spread might lead to very different infection rates. For example, in very sparse networks, an infected person may infect no one else or only one person; while in very dense networks, so-called "superspreaders" may act as catalysts of the infection. Based on a study conducted on Vancouver Island, Meyers et al. (2005) estimated that health workers had the densest contact patterns, followed by school children, working adults and non-working adults. The authors found that cutting contacts by, for instance, 50% had different consequences depending on each individual's contact patterns, resulting in a reduction of risk of 17% for a non-working adult and of 33% for a health worker (Meyers et al., 2005, p. 79).

Mossong et al. (2008) conducted a large-scale, internationally comparative study on "social contacts and mixing patterns relevant to the spread of infectious diseases" that involved 7,290 participants with 97,904 contacts in eight European countries. Their findings indicated that the participants' contacts were highly concentrated by age, especially among high school students and young adults. Contacts that lasted at least one hour or that occurred on a daily basis tended to be physically closer, while those that lasted for shorter periods of time or that occurred less frequently tended to be physically more distant. Contacts that took place at home, at school or during leisure time tended to be closer than contacts that occurred at work or while traveling. The results were found to be robust across countries. Again, these findings strongly contradict the assumption made in most aggregate models that there is an equal probability of infection.

Block et al. (2020) demonstrated with the help of simulation studies how knowledge about network structures can be used to inform strategies for reducing infections by limiting certain types of contacts. Networks with the same numbers of contacts can have different infection rates if the network distances differ. The authors distinguished between the following policy recommendations aimed at encouraging people to restrict their contacts and to reconfigure their contact networks: (a) "seek similarity," i.e., individuals are advised to choose contact partners with similar characteristics; (b) "strengthen communities," i.e., people are encouraged to restrict their interactions to mutually interconnected people within a community; and (c) "build bubbles through repeated contact," i.e., individuals are encouraged to restrict their contacts to people with whom they have repeated interactions, which should enable them to build up disconnected bubbles over time. As *seeking similarity* reduces the number of bridges to geographically or socially distant persons or individuals in other organizations, it should help to contain the disease in localized areas. *Strengthening communities* implies avoiding interactions with individuals who have many outside ties. *Creating bubbles* implies reducing the number of contact partners rather than the number of interactions by, for instance, always interacting with the same classmates or work team members. Following such simple behavioral rules based on network insights can go a long way toward keeping infection curves flat.

2.3 Social systems: institutions and subsystem differentiation

While discussions about social action and social networks refer to individuals, a social systems perspective focuses on the institutional structure of whole societies.

Under normal conditions, societies are highly functionally differentiated, and each subsystem follows its own logic. The COVID-19 crisis massively impacted the relative weights and the interrelations between the state, markets, associations and communities. By defining rules of behavior and by mobilizing resources, the state shifted the balance of power away from firms, families and individuals. The separation of workplaces, schools and families, which had been a major characteristic of modern societies, was weakened and partly reversed. Family homes became workplaces and satellite places of learning. The crisis restricted production and market exchanges, as well as patterns of consumption (Nassehi, 2020).

3 Socioeconomic inequalities: Is the COVID-19 pandemic the "great leveler"?

Adam Tooze, the eminent Columbia University historian, called the late sociologist Ulrich Beck the "prophet of uncertainty" and the "most important intellectual of the pandemic and its aftermath." (Tooze, 2020, 2021). This was likely because in his book entitled "Risk Society," Beck (1986) argued that there has been a secular shift away from class differential disadvantages and toward the emergence of new kinds of risks that are often invisible. He characterized these risks as collective, inescapable threats that have an impact "beyond classes, regions and nations." Although Beck was more focused on man-made risks like nuclear disasters and climate change, his vision of collective risks and of the ensuing uncertainties can also be applied to pandemics in which "nature strikes back." Beck already foresaw the ambiguous role of scientists in such developments as both experts on and messengers of an otherwise opaque reality.

Likewise, early in the pandemic, Bude (2020) articulated arguments that the COVID-19 pandemic could act as a "great leveler." He observed that in the pandemic, everyone is equally exposed to the risk of infection, and is equally subject to state-mandated anti-pandemic measures. Thus, everyone may be expected to be similarly dependent on the support of others and on others' compliance with precautionary measures. At least in Germany and in similar welfare states, each person who becomes infected can expect to receive equal treatment in the health care system. Therefore, everyone seems to be in the same boat in dealing with the pandemic.

Since then, however, the debate has clearly shifted, as massive inequalities have been observed in both the risk of contracting the disease and the distribution of the pandemic's economic effects and other consequences. But when considering the validity of the "COVID-19 pandemic as the great leveler" thesis, the argument that social inequality is driving the pandemic might be too radical. To assess this claim, we need to distinguish between the many different facets of the COVID-19 pandemic in which inequalities come into play, and to ask what we can theoretically assume and what we already empirically know about the effects of inequality. Rather than examining the causes of inequality in general, we need to look at the specific mechanisms through which inequalities translate into risks.

Specifically, we should start by distinguishing between the following risk groups and risk types. Ideally, we would then not only combine *risk groups* and *risk types*, we would also consider their degrees of vulnerability and resilience, as well as their processes of accentuation and compensation.

3.1 Risk groups

We can distinguish between four kinds of groups who differ systematically in their exposure to or ability to cope with COVID-19-related risks:

- *Socioeconomic and socio-cultural inequalities.* These can be of a gradational or a categorical nature (Blau, 1977; Tilly, 1999). For example, inequalities may exist along a continuum of economic resources like disposable income, or they may be based on categories of social exclusion, like the category of migrants.
- *Socio-demographic groups.* These groups are defined by their living conditions, household characteristics or family status, such as individuals living alone, solo mothers, families with more than two children, multi-generational households, individuals living in nursing homes and people living in crowded housing (e.g., seasonal workers).
- *Occupational groups.* These groups may be based on employment status (e.g., self-employed individuals, hourly workers or salaried employees), economic sector (e.g., manufacturing, retail or services) or closeness to clients (e.g., kindergarten teachers, cashiers, health workers or bus drivers) (AOK, 2021; Chen et al., 2021).
- *Ethnic and minority groups*. There have been numerous indications that members of ethnic minorities have experienced higher rates of COVID-19 infection and of COVID-19-related mortality (Bambra et al., 2021, pp. 21–22; Drefahl et al., 2020). Since most of the existing evidence on this topic is based on urban regions, whether this is also the case on the individual level has been disputed (FAZ, 2022).

3.2 Risk types

In the debate about how inequalities and the pandemic interact, global claims have been made about the impact of social inequalities on the COVID-19 pandemic, and about the impact of the COVID-19 pandemic on social inequalities. However, the sizes and even the direction of these potential effects may differ significantly. Thus, it is important to distinguish between the different types of risks and the corresponding inequality effects (see also Bambra et al., 2021, pp. 8–9), including:

- the probability of having social contacts (exposure);
- the probability of being infected through contacts (susceptibility);
- the probability of transmitting COVID-19;
- the probability of having symptomatic illness;

- the probability of developing severe illness and of being hospitalized;
- the probability of dying;
- the probability of experiencing medium- and long-term effects after a COVID-19 infection;
- the probability of experiencing unequal effects of public policies (e.g., lockdowns); and
- the probability of experiencing unequal socioeconomic consequences.

3.3 Social contacts and exposure

The intensity of social contacts is probably lowest among infants and young children who stay home with their parent(s) or caretaker(s), and among the elderly who live alone without permanent caregivers. The intensity is generally higher in public transportation than in individualized transportation, and is usually higher in the workplace than in the home. People's social contact levels vary depending on their household and family size and their kinship ties. The intensity of social contacts tends to be higher in kindergartens and schools, in nursing homes and hospitals, and among young adults and highly social people.

If the number of social contacts a person has increases the risk of contracting COVID-19, does having a lower class or social status also increase a person's risk? The intensity of social contacts (conviviality, going out for dinner and to cultural events, participating in costly sports like skiing) may be a status asset, especially if it is dependent on economic resources. For example, a manager may have contacts with multiple employees. Although having higher social status might increase an individual's exposure to risk via contacts, this is not always the case. Higher status individuals are more likely to travel to work by car than by public transportation. If they are eating out, they tend to dine in less crowded places. If they live in large families, they typically live in larger houses or apartments. By contrast, lower class individuals, and especially those living in migrant families, might have closer kinship ties, and thus more social contacts.

When examining the relationship between social class and social contacts, we should also consider people's situations before and during the pandemic lockdowns. Obviously, all members of occupational groups who directly interact with infected individuals, like ambulance drivers, hospital workers and doctors in private practice, have a much higher risk of contracting COVID-19. After the lockdowns, members of higher status groups could more easily employ a strategy of "contact thinning." Many could, for example, use private cars instead of public transportation, or continue working from home (while enjoying spacious and comfortable conditions). By contrast, people working as parcel deliverers had higher numbers of contacts. The available empirical evidence shows that after the lockdowns ended, members of higher income groups were able to reduce their spatial mobility more than members of lower income groups (Chang et al., 2021), and were more likely to be able to work from home (Kohlrausch et al., 2020).

3.4 Infections given contacts (susceptibility)

By November 2020, around 2% of adults in Germany had been infected with COVID-19 (Hoebel et al., 2021). It has been estimated that of the people who are infected, 80% have only mild symptoms (Rommel et al., 2021), 10–20% become ill and have more acute symptoms, 5% are hospitalized and 1% need intensive treatment. As new mutations continue to be reported, it is expected that almost everybody in a given population will eventually become infected (Drosten, 2021).

There is very little is systematic evidence about the social factors that influence the probability of contracting COVID-19 based on the intensity of social contacts (Wachtler et al., 2020a; Zelner et al., 2021). Hoebel et al. (2021) conducted a seroepidemiological study in Germany, and found that people with lower levels of education and vocational training had higher rates of infection. Survey data collected up to spring 2021 show that the incidence of infection was 7% for lower social groups, 5% for middle social groups and 3% for higher social groups (Corona Datenplattform, 2021, p. 26). Compliance with social distancing and hygiene rules might be related to better access to and acceptance of health information, and thus to higher education. Compliance with social distancing norms is probably related to social status in a curvilinear manner: i.e., it is lower at the bottom and at the top and is higher in the middle. Deviance from social norms appears to be sanctioned more by those who can gain status by extending state authority, who are often assumed to belong to the lower middle classes. At least at the beginning of the COVID-19 crisis, access to disinfection materials, masks (especially FFP2 masks) and COVID-19 tests was costly, and was therefore subtly related to disposable income.[4]

Bambra et al. (2021, p. 15) summarized different facets of social status inequalities in the impact of COVID-19 pandemic in England: "....45% of patients admitted to hospital with COVID-19 were from the most deprived 20% of the population. COVID-19 admissions to critical care were also far greater in the most deprived areas, with over 50% of admissions coming from the 40% most deprived areas. A study of primary-care patients in England found that people living in deprived areas were more likely to test positive for COVID-19. Likewise, wide-scale analysis of positive cases by Public Health England (PHE) (from 1 March to 9 May 2020) found that diagnosis rates were highest in the most-deprived quintile (over 300 cases per 100,000), for both men and women – almost double that of the least-deprived quintile (around 200 cases per 100,000). Indeed, the rate in the most-deprived quintile was 1.9 times the rate in the least-deprived quintile among men, and 1.7 times among women" (Bambra et al., 2021, p. 15).

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[4] For the "effects" of social capital (as measured by participation levels in the prior EU election) in seven Western European countries, see Bartscher et al. (2020). Very early in the pandemic, high social capital levels were positively correlated with infections per capita. Between mid-March and mid-May 2020, social capital slowed the increase in infections, but after the introduction of lockdown measures, there were few differences between high and low social capital regions.

The elderly, and nursing home residents in particular, are a special case. It has been estimated that in the first wave of the pandemic, between one-third and one-half of all deaths linked to COVID-19 happened in nursing homes. A survey conducted in Germany in spring 2020 of people aged 80 or older found that 20% of respondents living in nursing homes reported that they were "ill" from COVID-19, compared to only 4% of respondents living in private homes (Hansen et al., 2021). The connection to social class operates via the fact that in many countries, the probability of living in a nursing home not only varies greatly, it is also socially selective. Bernardi et al. (2020) showed in a study based on SHARE survey data from 13 countries that the likelihood of living in a nursing home is much higher for people with lower education; and that the probability of living in a nursing home is higher in Scandinavian countries and in France and Belgium, while it is lower in Italy. However, the risk of contracting COVID-19 has been especially high in (northern) Italian multigenerational families, and this pattern may be inversely related to class (Balbo et al., 2021). British newspapers reported that nurses from the Philippines were several times more likely to contract the disease than nurses with British citizenship. It is unclear whether this was because the Filipino nurses had different areas of activity or worse access to protective gear, or because of other factors.

Another special case is that of workers in large slaughterhouses, among whom very severe outbreaks of the disease occurred. Their high rates of COVID-19 infection have been attributed to their cramped working and living conditions. The contributions of international travel and of private and informal care arrangements to these outbreaks are less well documented, but likely also accelerated the transmission of the disease.

Social epidemiology has generated overwhelming evidence that adverse social and economic conditions have an impact on health (ALLEA, 2021; Mackenbach, 2019). However, there is less consensus on the mechanisms that underlie this relationship (health information, nutrition, risky behavior), in part because they differ depending on the disease. It is well established that certain health conditions, including obesity, diabetes, high blood pressure, asthma, alcohol consumption, smoking and high cholesterol, are related to social class and status, whereas mental disorders are less closely related to class. It has been shown that the health conditions in this first category are also associated with higher rates of COVID-19 infection (even after accounting for the higher vulnerability of the elderly). This causal connection therefore provides the most important bridge to understanding the impact of social class on the risk of contracting COVID-19.

The differential infection rates of highly exposed occupational groups also represent a crucial bridge to capturing the relationship between COVID-19 infections and socioeconomic inequalities. Compared to the average risk for all occupational groups, kindergarten teachers have a threefold risk of infection, while nurses in hospitals and care homes, medical doctors and bus drivers have a twofold risk of contracting COVID-19 (AOK, 2021).

3.5 Access to medical care

In societies with comprehensive health insurance coverage like Germany or Austria, or with national health systems like the UK and the Scandinavian countries, access to hospitalization and intensive care for COVID-19 patients, and the quality that care, should not be related to the patients' social class or income. While both access to care and the quality of care are likely to be lower in rural than in urban areas, these disadvantages might be offset by the lower population density, and thus the lower likelihood of having contact with infected individuals, in the countryside (Goujon et al., 2021). The lower infection rates in some German federal states like Mecklenburg-Vorpommern, and the higher infection rates in city states, might be circumstantial evidence that this is indeed the case. However, this pattern might also be due to differential rates of testing. But even in a national health system like that in the UK, it has been shown that the quality of hospital care and the likelihood of dying from COVID-19 vary between areas with different economic conditions. For example, Dowd et al. (2020) found evidence of variation in the quality of care even within England and Wales.

In a study based on a large-scale sample of health insurance records for Germany, Wahrendorf et al. (2021) found that being short-term unemployed had a large impact on the likelihood of being hospitalized for COVID-19 (odds ratio of 1.34), and that being long-term unemployed had a massive impact (odds ratio of 1.74). They also found that receiving special benefits from social assistance was associated with higher rates of hospitalization (odds ratio of 1.21).[5]

3.6 Differential mortality

The penultimate criterion for assessing the impact of social inequalities on the risk of contracting COVID-19 is the question of whether individuals of a lower status or class, or who are in an underprivileged position, are more likely to die than individuals of a higher social status. This is, of course, not to deny the possibility that the likelihood of developing long-term and severe ailments after a COVID-19 infection might also be subject to social selectivity. At the onset of the pandemic, the likelihood of dying from COVID-19 was higher in the socioeconomically advantaged regions of Germany, but this gradient quickly reversed after April 2020. In the socioeconomically most deprived areas, COVID-19-related deaths were 70% more frequent among men and 50% more common among women than they were in the least disadvantaged areas (Wachtler et al., 2020b; RKI, 2021).

[5] Initial cross-country analyses using SHARE survey data seem to indicate that there were marked inequalities in the access to medical treatment, as well as differential consequences of health behavior; see the presentation of Axel Börsch-Supan at the WZB Berlin Social Science Center Corona Colloquium on March 17, 2021.

Similar results have been documented for England: “In the early phase of the pandemic … the death rate in the 20% most-deprived English neighborhoods were 128.3 deaths per 100,000 compared to 58.8 deaths per 100,000 in the least-deprived 20%. Even in the summer of 2020, when the death rates in all areas fell considerably, they were still double in the most-deprived at 3.1 deaths per 100,000 versus 1.4 deaths per 100,000 in the least-deprived neighbourhoods …” (Bambra et al., 2021, p. 16).

In an excellent and highly informative study on differential mortality based on Swedish registry data (Drefahl et al., 2020) covering deaths between March 13 and May 20, 2020, Drefahl and colleagues analyzed differential mortality not only from COVID-19, but also from all other causes. Their results indicated that divorced and never married men faced a higher risk of dying from COVID-19 than married men. For all these groups, the magnitude of the risk of dying from all causes was about the same as the risk of dying from COVID-19, but men with secondary education had a relatively higher risk of dying from COVID-19 than from all other causes. Migrant men and women from low-income countries, who generally had a lower mortality risk, were more than twice as likely to die from COVID-19 than their non-migrant counterparts. This risk was especially pronounced for migrant men from Middle Eastern countries. Individuals with lower incomes had a higher risk of dying from COVID-19 and elevated all-cause mortality. However, COVID-19-related deaths were relatively less frequent than deaths from all causes among the lowest income group. Non-married women had a higher mortality risk than married women, but their relative risk of dying from COVID-19 was even higher. Less educated women had an elevated risk of dying from all causes, and an even higher risk of dying from COVID-19: “We demonstrate that being male, having less individual income, lower education, not being married all independently predict a higher risk of death from COVID-19 and from all other causes of death. Being an immigrant from a low- or middle-income country predicts higher risk of death from COVID-19 but not for all other causes of death. The main message … is that the interaction of the virus causing COVID-19 and its social environment exerts an unequal burden on the most disadvantaged members of society” (Drefahl et al., 2020, p. 2).[6]

3.7 Unequal effects of COVID-19-related policy measures

The COVID-19 pandemic has affected people’s lives in a variety of ways. In response to the pandemic, governments imposed restrictions on mobility, and many people were subject to voluntary or involuntary quarantines and lockdowns. During the pandemic, education and training were disrupted; transitions into and

6 See also Andrasfay and Goldman (2021) for differential COVID-19-related reductions in life expectancy in the U.S. for Blacks, Latinos and Whites; and Goujon et al. (2021) for regional characteristics of excess mortality. For an inverse income gradient in Belgian COVID-19 mortality, see Gadeyn et al. (2021).

across the labor market were greatly reduced; and there were large-scale furloughs, reductions in working hours and employment losses. Depending on the relative cushions provided by the welfare states in various countries, the pandemic has led many people to experience considerable losses of income from work, as well as the depletion of their savings. Since COVID-19 mortality hit the elderly and the very elderly disproportionately hard, many inheritances have been passed down to surviving children “prematurely.” The restrictions on international travel have blocked or greatly reduced labor migration, the migration of seasonal workers and international student exchanges.

While only a minority of people within a given population have suffered from COVID-19 symptoms, and even fewer people have been hospitalized or died during the pandemic, everybody has suffered from the consequences of restrictions on mobility and economic activity. Large shares of the population have been exposed to the risk of unemployment, reduced working hours and income losses (Möhring et al., 2020; Naumann et al., 2020). It is quite plausible that a process of polarization occurred between the groups who were almost completely protected, like pensioners, civil servants and public sector employees; and the groups who lost all of their ordinary income, like illegal care workers from Eastern Europe, “minijobers” with marginal income, workers without unemployment insurance protection and individual entrepreneurs in the retail and restaurant industries. In between these groups were the workers who were forced to accept short hours, and whose labor income was reduced by 60–80%.

Studies that looked at the early phases of the COVID-19 crisis give important hints about the social distribution of its impact. In the early months of the pandemic in 2020, only one-fifth of the population in Germany reported a loss of income, and the likelihood of losing income varied greatly between people in different categories of disposable household income. While the imposition of short hours did not vary between income groups, it did vary between workers with different levels of education. Workers with lower education were twice as likely as their higher educated counterparts have their working hours reduced (Schröder et al., 2020). Kohlrausch et al. (2020) reported that about one-third of all households experienced income losses, arranging from one-half of households in the lowest income group to one-quarter of households in the highest income group. In sharp contrast to these findings, two prominent German research institutes, ifo and IAB, have reported an average reduction in gross income of only 3%, ranging from 4% for households in the lowest income decile to 3% for households in the highest income decile. Due to massive public transfers, the average reduction in net household income was around 1.1%, with families in the lowest income deciles even enjoying a slight increase in income, mainly because they were receiving the so-called “child bonus” (*Kinderbonus*) allowance, which was designed to support families during the COVID-19 crisis (Bruckmeier et al., 2020).

4 The (potential) effects of the COVID-19 crisis on life courses

How will the COVID-19 pandemic shape life transitions, trajectories, turning points and other life outcomes? Very early in the pandemic, a group of well-known scholars in the area of life course research systematically explored the potential impact of COVID-19 on people's life courses (Settersten et al., 2020). In particular, they looked at the impact on health, on personal control and planning, on social relationships and family, on education and training, on work and careers, and on migration and mobility. When examining the effects of the pandemic on health, personal planning and social relationships, these scholars concentrated on evidence of the immediate impact, like the age distribution of infections and deaths, reports of feeling a loss of control, and the impact of distancing and lockdowns on social contacts. But the more challenging questions are how the pandemic will affect later life outcomes, and whether there will be "pandemic cohorts" who are scarred for the rest of their lives.

To address these issues, we cannot rely on current observations, but must instead draw on our knowledge of comparable emergencies that occurred in the past. What theoretical models and approaches do we have to answer the question of how COVID-19 might affect people's life courses?

The COVID-19 pandemic could be described as a "critical life event." It was unexpected; it was associated with loss (of social contacts, employment, loved ones); and it was largely "uncontrollable." The literature on the impact of critical life events has shown that people who are exposed to such events can experience deep shocks, but it has also reported that the impact on individuals of events like divorce or the death of a child or a spouse is often temporary, lasting to up to about one year.

Some scholars have also argued that there are "sensitive periods" (Blossfeld, 1989) of life during which critical life transitions typically take place. The underlying assumption of this perspective is that certain transitions should be managed within a given age range or in specific life phases, and that if they are not, individuals are likely to experience long-term negative effects. Such transitions may include completing a certain level of education or training (e.g., by passing an exam), entering a qualification period, transitioning to the labor market, or having a child before the onset of infecundity.

The adaptation of individuals to the consequences of the COVID-19 pandemic might be age-specific in the sense that the amount of time remaining in, for example, a person's working life might have huge consequences for the individual's ability to adjust by retraining or starting a new career.

The combination of "sensitive" and "historical" periods produces cohort effects. The collective experience of exposure to adverse conditions at a given age can distinguish birth cohorts from each other. These experiences include, for instance, being affected by budget shortfalls that hinder young people's opportunities to enter the civil service or advance in their career within an organization. The COVID-19 pandemic might produce not just age-specific cohort effects, but even "generations" of the kind described by Karl Mannheim (1928): i.e., age groups whose attitudes and values differ, but who are developing something like a collective consciousness of "before" and "after" the pandemic, and of how it has affected certain birth cohorts (and groups within them) in specific ways. Some sociologists (Bude, 2020) have already speculated about the emergence of a new sense of solidarity and a higher level of trust in the state, and about the demise of neoliberalism.

However, when we are discussing the negative effects the pandemic is expected to have on people's life courses, we should also consider the "counter-hypothesis" that there will be no such long-term negative effects. In line with the theory of critical life events, the impact of the pandemic might be large but temporary. If the duration of mobility restrictions, unemployment and income losses is relatively short, then the impact of the pandemic might be relatively small. This is especially likely to be the case if, for instance, income losses are compensated for by policies such as higher unemployment insurance benefits or subsidies for workers with temporarily reduced working hours (*Kurzarbeit* schemes). Missed exams or other education and training accreditations can be made up. Transitions such as starting training, entering the labor market, switching jobs or making career advances may just be delayed, without having any longer-term adverse effects.

The long-term impact of the pandemic will largely depend on how disruptive the economic shocks on both the demand and the supply side will prove to be, and on how states balance their efforts to claim new powers to regulate and control with efforts to mitigate the economic consequences of the pandemic through measures aimed at compensating workers for income losses. We also know from the theory of stress and coping that when adverse events are shared by many or even all people, the individual consequences are less severe, especially if people do not have to attribute the adverse events to their own actions.

Are there historical precedents that would be useful to consider when discussing the potential impact of the COVID-19 pandemic on people's life courses? We have some evidence on how large-scale epidemics affected the long-term life courses of the populations involved. Understanding the impact of the Spanish flu, which resulted in 40–60 million deaths worldwide, is difficult because the effects of the pandemic were closely intertwined with the economic and political upheaval at or after the end of World War I (WWI). However, Mamelund (2004) has shown for Norway, which was neutral in WWI, that the flu pandemic had a positive impact on fertility, with a post-pandemic baby boom occurring in 1920.

Other historical developments, such as those covered by the German Life History Study (Mayer, 2015), might give us some insight into what the effects of the COVID-19 pandemic on life courses might be.

When we examined the impact of World War II (WWII) on people's life courses in Germany, we expected to find that the war greatly disrupted people's lives, as many men served in the military for long periods of time, and some were held as prisoners of war for up to 13 years (from 1939/40 to the return of the last prisoners of war from Russia in 1953). To our surprise, this is not what we found. Instead, our analysis showed that the cohorts most hurt by WWII were those born around

1930/1931. Indeed, despite experiencing the "economic miracle" of the 1950s and 1960s, these cohorts never caught up, and were disadvantaged in their occupational lives and in retirement. This is likely because these cohorts missed a critical life transition: namely, the transition to an apprenticeship just after the end of the war. Thus, these cohorts had the largest proportions of unskilled workers ever observed in the German context (Mayer, 1988).

The potential adverse long-term effects of experiencing difficult conditions might be prevented if they are addressed through political debate and political measures. A good example of such a case was the West German government's response to the problems the baby boomers born around 1964 faced in getting an apprenticeship. Through a joint political campaign of the federal government and the employer associations, many additional apprenticeships were created. However, less political attention was paid to helping these now large cohorts of young women and men who were finishing apprenticeships transition to the labor market. This lack of political action, in combination with a less favorable business cycle, led to this cohort having particularly high levels of unemployment during this transition phase (Hillmert and Mayer, 2004). However, in contrast to the German cohort born around 1930, the 1964 cohort fully recovered across their working lives (Manzoni et al., 2014), most likely due to their solid educational and vocational training resources.

The age-specific impact of disruptive events has been clearly demonstrated by a number of studies that examined the consequences of the economic meltdown and the mass unemployment that occurred in the course of German unification. While young people who had already mostly completed their occupational training periods did surprisingly well in the transition, people who were over age 55 were pushed out of work altogether, and people who were between ages 45 and 50 had high levels of unemployment or state-provided employment because their remaining working lives were too short to allow them to start from scratch (Diewald et al., 2006; Mayer and Schulze, 2009).

Several studies have documented the impact of the Great Recession (2007-2009) on young people's transitions to the labor market (Schoon and Bynner, 2017). Very few of these studies were able to compare the experiences of these cohorts before, during and after the Great Recession, and the period since the downturn ended has been too short to allow for an analysis of the longer-term cohort effects. Blossfeld (2017) found no evidence that the Great Recession had an impact on shorter-term unemployment, on wages or on downward career mobility among workers in Germany.

There are, however, two areas in which we can currently make empirical observations about the likely effects of the COVID-19 crisis on young people's subsequent life courses: schooling deficits and problems in the vocational training market.

Grewenig et al. (2020) and Woessmann (2020) have estimated that in the fall of 2020, about one-third of a school year had been lost in Germany due to the closing of schools in the spring. On average, pupils reduced their daily learning time of 7.4 hours by about half, and the reductions were larger for low achievers (4.1 hours) than for high achievers (3.7 hours). Based on these findings, the studies concluded that the lifetime labor income of these young people will likely be reduced by 3–4%.[7] To arrive at this estimate, Grewenig and co-authors ingeniously used evidence from four sources: wage differences between individuals based on the number of years of schooling they completed, the natural experiment of halving the length of the school year due to the beginning of the school year having been moved in the 1960s in West Germany from the spring to the fall, the "summer gap" in learning that has been well-documented for the U.S. (and differentiated by race) and the fallout from teacher strikes. Meanwhile, Woessmann and his co-authors conducted their own surveys and systematically reviewed the German and the international evidence (Werner and Woessmann, 2021a, 2021b). Based on their findings, the authors reached the following conclusion: "There is clear evidence that the COVID-19 pandemic seriously impeded the cognitive and socio-emotional development of many children." The study also found that children with more disadvantaged socioeconomic backgrounds suffered more than children with more advantaged backgrounds (Werner and Woessmann, 2021b, pp. 33–40).

With regard to the impact of the COVID-19 crisis on vocational training, strong concerns were raised that the pandemic would greatly undermine the supply of traineeships offered by firms, and the whole process of matching applicants to training opportunities. In Germany, the number of apprenticeship contracts fell by 11% in 2020, and improved only marginally in 2021. This adverse development might have been offset by the fact that the overall size of the cohort (i.e., the number of potential applicants) declined. Another factor, which has also been observed in earlier crises, seems to have contributed to current trends as well: i.e., more young people decided to stay in school, which may lead to improvements in the average qualification levels of the "COVID-19 generation" (Bundesagentur für Arbeit, 2021).

5 Outlook

In this paper, I have reviewed some of the potential and actual contributions of sociology to understanding the causes and the consequences of the COVID-19 crisis. Given the dynamic (and sometimes even counterintuitive) nature of many the effects of the COVID-19 pandemic, a large degree of caution is needed when considering these issues. For instance, while levels of trust in government were very high during the early months of the pandemic, they now appear to be eroding rapidly. Similar changes in the economic and labor market effects of the pandemic are even more likely to occur.

There have been substantial sociological insights and reliable research results on the COVID-19 pandemic in some subfields, such as research on the emergence of

[7] For the potential effects of home-schooling and possible remedies, see Helbig (2021).

and compliance with social norms, and the differentiation and new intermeshing of societal subsystems like family, work and politics. However, in other subfields, especially those that focus on social networks, the failure to provide useful knowledge on the diffusion of the pandemic is both surprising and worrying.

The almost hegemonic narrative of the COVID-19 crisis leading to a deepening and a polarization of inequalities turns out to be somewhat less convincing when we look more closely at the empirical evidence. Two lessons are, however, obvious. One is that inequalities must be carefully distinguished based on their impact on contacts, infections, treatments, mortality and the population-level consequences of COVID-19 policies. It even appears that there are some paradoxical and counterintuitive effects of inequalities, like the association between high status and numbers of social contacts. The types of inequality also seem to matter, with exclusion and discrimination based on migrant status having a greater impact than mere differences in income. Moreover, the redistributive impact of social policies appears to play an important role, such as in relation to reductions in working hours.

The other lesson is that the inferences made about the impact of socioeconomic inequalities must be closely connected to the underlying mechanisms. In this context, it is crucial to consider the role of occupational groups in shaping contacts, proximity, mobility, the likelihood of working from home and the risk of infection.

Regarding the impact of the COVID-19 crisis on people's life courses, the assumption that the pandemic will have severe negative effects is quite plausible. However, as historical analogies to the cohorts who experienced the effects of WWII, the baby boom and the Great Recession suggest, the final outcomes will not be known until long-term observations of the birth cohorts involved can be made.

In sum, while sociology offers a wealth of insights and hypotheses for understanding the COVID-19 crisis and its consequences, and there has already been an explosion of empirical research on this topic, a proper assessment of the effects of the pandemic will only be possible in the years to come.

Acknowledgements

This paper owes its beginnings to an invitation by Jutta Allmendinger to present to the Corona Colloquium of the Science Center Berlin (WZB) in April 2020, and by Alexia Fürnkranz-Prskawetz to give a keynote address at the Wittgenstein Centre (WIC) Conference on demographic aspects of the COVID-19 pandemic and its consequences in December 2020. Gustav Feichtinger, Paola di Giulio, Tomáš Sobotka and his co-editors provided invaluable comments and encouragement.

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Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 39–81

COVID-19, the Russo-Ukrainian War, the global sustainable development project and post-crises demography

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Abstract

The global sustainable development project as currently conceived is foundering, and the twin crises of the COVID-19 pandemic and the Russo-Ukrainian War have driven a stake through its heart. Some of the reasons for this failure are fundamental design flaws, while others are practical. The resources to bring the project – or its successor, and any other global sustainable development project of similar design and ambition that might emerge – to a successful conclusion do not exist, and never did. What lessons are we learning, and how can they inform post-2030 sustainable development goals? In this essay, the effects of the catastrophes of the COVID-19 pandemic and the Russian invasion of Ukraine on the global sustainable development project are enumerated, SDG by SDG, with special attention being paid to the implications for demography. In closing, recommendations for reforms of the project are presented, as are some suggestions for the field of demography in the changed global context. The most concrete, feasible immediate recommendations are to make up recently lost ground, specifically in the areas of vaccination and education; and to reform the profoundly flawed international asylum and refugee system.

Keywords: sustainable development; COVID-19; Russian invasion of Ukraine; demography

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DOI: 10.1553/populationyearbook2022.per02

1 Introduction

The world is reeling from two nearly simultaneous generational shocks: the COVID-19 pandemic of 2020-? and the Russian invasion of Ukraine (hereafter, the Russo-Ukrainian War) of 2022-?[1] These shocks have been inflicted on a world that was already far from having reached a demographic equilibrium due to radically divergent growth rates starting around 1960. Africa, North Africa and the Middle East – the least stable, the most climate-vulnerable and the most conflict-prone regions of the world – are the dominant sources of population growth, while other regions, such as China and Europe, face population decline and stagnation.

In this essay, I discuss – with some temerity, given that we are still in an early stage of this long game – the impacts of these twin crises on the global sustainable development project and the field of demography, both directly via the immediate need for research, and indirectly through the changed context.

The direct near-term impact of the COVID-19 pandemic on demographic research is easy to estimate, since the research needed – given that, outside of the most cloistered monasteries of theory, demographic scholarship is demand-driven – can be sorted into three boxes. The *first* box contains studies on the impact of the COVID-19 pandemic on demographic parameters, with the principal dimensions being mortality, fertility and migration (more distally, urbanisation, spatial distribution, family structure, living arrangements) and the resulting age and workforce structures. The *second* box contains research on the effects of demographic parameters on the incidence and the impacts of the COVID-19 pandemic by age, sex, residence, ethnicity, household living arrangements and so on. The contents of the *third* box include studies on the impacts of the COVID-19 pandemic on demography as a research discipline; on data needs, methodological opportunities and research design more generally; but also on practical issues related to the reproduction of the field, such as effects on researchers, on graduate education, etc. The differential impacts on women and researchers in developing countries are of special concern.

Regarding the Russo-Ukrainian War, the *first* box will start to quickly fill up with studies of war-related mortality, fertility and migration (notably, the displacement and refugee dimensions, plus return migration). There will be analysis of population vulnerability and resilience, disaggregated along the usual demographic axes, but this just amounts to substituting "war" for floods, droughts and other catastrophes that were already on demography's list. By rights, the *second* box should contain studies that examine how demographic factors contributed to the Russo-Ukrainian War, but it is hard to see a causal link. Perhaps we have one state in demographic

[1] The term Russo-Ukrainian War is not sanctioned by any international organisation, and the preferred term seems to be "Russia's invasion of Ukraine". With all the respect that is due to the niceties of international diplomacy, the term Russo-Ukrainian War appears to be the most accurate description of the situation, at least *ad interim*. It could be argued that said War actually began in 2014 with the annexation of Crimea.

decline choosing an opportune moment to pick off a neighbouring state in demographic decline, but no one seriously believes that this was a proximate cause of the conflict. Only somewhat more plausible is the argument that a state on the verge of broad decline (including demographic) is picking off another in order to forestall its inevitable weakening, which may also apply to China and Taiwan. There will be a need for studies of the ethno-linguistically and religiously fractured demography of the Eurasian shatterbelt (Cohen, 2013; Romaniuk and Gladun, 2015; Snyder, 2010). As for the *third* box, there is an immediate need for the field to grapple with the impact of the conflict on the illustrious Russian and Ukrainian research establishments.

These are all direct effects. But more broadly, the COVID-19 pandemic and the Russo-Ukrainian War will change the global context that presents demography with the broad range of issues that need to be addressed. So, to consider the problems that will be assuming greater prominence, we need to look at the global sustainable development project as a whole, and the impacts the twin crises are likely to have on it. The motivating observation is that a very large chunk of demography, or at least of policy-relevant applied demography (which accounts for a good nine-tenths of the whole), now resides in either the core or the near periphery of that project.

2 The global sustainable development project: Origins and evolution

The global development project was jury-rigged in the early 1950s on the war-shattered rubble of the Western imperial project. As originally conceived, the development project was an enlightened effort to enrich (the bright side), albeit with an undertow of subalternity (the dark side; Said [1978] is still the most scathing spokesman for this view), what Sauvy (1952) called the Third World, now better referred to as the Global South. Globalisation, which had been rudely interrupted in the inter-war period, recovered and picked up to a trot in the 1960s with Eurolending, or the extension of hard currency credit to soft currency countries; i.e., to countries that were borrowing outside their monetary orbit. Globalisation sped to a canter in the 1970s, when the oil crisis generated enormous hard currency wealth in countries that could not put anywhere near all of it to good domestic use ("absorb" is the term of art), and that did not have enough mattresses to stuff it into. At the same time, the oil crisis produced enormous hard currency demand in the countries that needed it, and enormous profits for the banks that moved it ("recycled" is the term of art) from North to South. The Washington Consensus – a set of policies that promoted monetary and fiscal discipline, combined with regulatory reform and trade liberalisation – was born, and performed well in macro-economic terms, but with a great deal of collateral damage for the poor, particularly when the Eurolending bubble predictably burst in the early 1980s (the so-called LDC Debt Crisis). By then, as fax and, eventually, email and the internet replaced the telex, globalisation *redux* had broken into an undisciplined (i.e., unregulated), old-time Western shoot 'em up gallop. Information became nearly instantaneous, placing those who had the skill and the capital to exploit it at an overwhelming advantage over those who did not.

Outrage over inequalities contributed to a sense of grievance in the South and guilt in the North. The two themes that increasingly infused the development project were equity and global public goods (notably the climate). Us-versus-them rhetoric (the Population Bomb, the Communist Threat, the Immigrant Peril) was replaced by We-are-all-in-this-together rhetoric, as crystallised in the title of the 1987 Brundtland Report, *Our Common Future*. The concept of sustainable development emerged from that report: *Development that meets the needs of the present without compromising the ability of future generations to meet their own needs*. This definition, anodyne to the point of being tranquilising, was the result of a bitterly-negotiated political compromise between pro-growth (South) and pro-environment (North) forces.

It is important to make a distinction between sustainability as a concept, which long predated Brundtland, and the sustainable development project as a means of implementing and achieving what Brundtland defined it as being. Some approaches to sustainability are linear and Gothic. For example, if a piece of capital, whether natural (renewable or non-renewable; physical or biological), man-made, human or financial, produces an annual scarcity rent, and that rent, but not a penny more, is translated into consumption, then the flow of consumption benefits will continue (up to depreciation) *ad infinitum*. Other approaches are curvaceous and Baroque, building in distribution, static (current) and dynamic (intergenerational) equity, *ditto* justice and fairness, catastrophic risk (fat risk distribution tails; guard rails), the Earth as a human life support system, etc.

Outside theology, concepts (say, God) do not have material interests until they are instrumentalised in the form of projects, whereas projects (or at least the people behind them) have interests from their inception phase, and look for concepts to advance them. The concept of sustainability, as it has evolved to serve the purposes of the Brundtland global sustainable development project, is Baroque. As a result, it suffers from weaknesses and contradictions, just like (absent a stronger and more costly foundation) a tall, non-rectangular building is shakier than a short, box-like one. It glosses over the distinction between human needs and wants (Douglas and Ney, 1998).[2] It requires speculative welfare comparisons that are not only

[2] While needs can be physiologically estimated by nutritionists, sleep experts, physiologists and experts in other walks of scientific life, wants are constructed through propaganda, advertising, the desire to keep up with the Joneses, and other aspects of Madison Avenue capitalism that attracted the criticism of the Frankfurt School.

interpersonal, but intercultural and intergenerational, as well.[3] It privileges equity over growth and prudence over risk-taking, and it underestimates the potential for technological progress. It is locked into a narrow, poverty-focused "Do No Harm" and "No One Left Behind" logic. It is structurally rigid, constructing rights holders as victims and duty bearers as oppressors, absent transformative change (another term of art in the sustainable development discourse). Despite, or perhaps thanks to, these simplifications, for those actors in the global sustainable development complex that implement the project – which is no less tangible or consequential than Eisenhower's military-industrial one – *Our Common Future* remains not only a touchstone, but a foundation myth – as if sustainability was invented in 1987,

[3] Focusing on climate change, Thomas Schelling expressed the view in a lecture at the International Institute for Applied Systems Analysis (IIASA) in Vienna ca. 2000 that Northern-financed climate change mitigation is not an investment; i.e., consumption foregone today for consumption in the future by one's self, one's descendants or at least one's familiars. It is, rather, an interpersonal transfer from today's demographically small and slow-growing North to tomorrow's immense South – whose inhabitants will, absent global catastrophe, be much less poor than they are today; who will live in a world that is technologically incomprehensible to us Northerners today; and who, regardless of any global melting-pot, will be culturally distant from us in the North today. Beckerman and Pasek (2001), while endorsing a moral obligation of the present to future generations, made short work of the concept of intergenerational rights-holders and present duty-bearers, since the presumed rights-holders do not yet exist (an issue, albeit far from one addressed by these authors, of particular relevance in the present American abortion debates). Groucho Marx demolished the flimsy idea of intergenerational rights with admirable economy: "Why should I do something for posterity? What did posterity ever do for me?" [Groucho] Marx must have been well-read, because his source was obviously Addison (1714/1853) in *The Spectator*:

> Most people are of the humour of an old fellow of a college, who, when he was pressed by the society to come into something that might redound to the good of their successors, grew very peevish; 'We are always doing', says he, 'something for posterity, but I would fain see posterity do something for us'.

There is also the legal issue of the Rule of Perpetuities, related to the British constitutional question of Parliamentary sovereignty – whether a present Parliament can constrain a future one, to which the conventional answer is "No." We in the present can manage the Earth in trust for a few future generations, but eventually an interest must vest, and the Brundtland definition of sustainability smells like a rolling trust that is renewed *ad infinitum* by each generation, raising the issue of how we in the present generation can impose on generations far in the future the role of trustee for generations even further removed.

An important distinction can be made between intergenerational rights and the Demeny voting proposal (Demeny, 1986; Sanderson, 2007). Demeny voting only transfers the rights of future voters in trust to their parents. Those children already exist, and, subject to negligible mortality, will survive to voting age. People who do not exist do not have rights, weakening if not invalidating entirely the concept of intergenerational justice, and more so that of intergenerational equity, which can only derive from justice.

Cf. Barry (1997) for a vigorous opposing view of intergenerational justice.

like sexual intercourse was for Larkin in 1963.[4] These are the 17 Commandments; and no overachievement on one can atone for backsliding on another. The global sustainable development project, which seeks to unite households, firms and governments in a mission of planetary survival, is a hegemonic one. Discouraging words are as unwelcome in it as they were in the equally hegemonic sexual liberation project of the Swinging Sixties.

3 COVID-19, Ukraine and the sustainable development goals (SDGs)

The global sustainable development project officially consists of the 17 Sustainable Development Goals (SDGs), to which almost every nation in the world is legally committed.[5]

4

Up to then there'd only been
A sort of bargaining,
A wrangle for the ring,
[. . .].
Then all at once the quarrel sank:
Everyone felt the same,
And every life became
A brilliant breaking of the bank,
A quite unlosable game.

Annus Mirabilis (1967, published in Larkin, 1974).

5 It is important to appreciate the political economy of the transition to the SDGs from the previous Millennium Goals (MDGs), adopted with the strong support of U.S. President George W. Bush at the Monterrey Summit of 2000, and with a target date of 2015. The MDGs were (fairly) accused of being preachy, paternalistic and instructing Southern signatories *à la baguette* on their shortcomings. In the negotiations leading up to the succeeding SDGs, the South (sullen) and its allies in the North (sheepish) agreed that the SDGs would be sufficiently broad and ambitious that all parties, North and South alike, would receive their fair share of abuse for the inevitable failure to meet them. From a transactional perspective, think of the SDG contract as embedding an implicit option that the call holder (the global sustainable development complex) can exercise on the put holder (the Northern taxpayer) to obtain additional (post-SDG) resources when the project fails. The SDGs were far from universally acclaimed: Easterly (2015) suggested that they should stand for Senseless, Dreamy, Garbled; and commented that only the UN could come up with a document as worthless as Agenda 2030.

The Sustainable Development Goals

Goal 1. End poverty in all its forms everywhere.
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
Goal 3. Ensure healthy lives and promote wellbeing for all at all ages.
Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
Goal 5. Achieve gender equality and empower all women and girls.
Goal 6. Ensure availability and sustainable management of water and sanitation for all.
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10. Reduce inequality within and among countries.
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable.
Goal 12. Ensure sustainable consumption and production patterns.
Goal 13. Take urgent action to combat climate change and its impacts.
Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

The SDGs' target date is 2030, and while the objection might be raised that 2030 is already baked into the cake, it is safe to assume that there will be a successor to the SDGs, and a successor to the successor. A simple Google search will bring up multiple international development agency and civil society organisation analyses of the devastating impacts of the COVID-19 pandemic and the Russo-Ukrainian War, and of the specific impacts of these crises on the SDG of particular concern to each agency or organisation (e.g., child health for UNICEF, hunger for FAO and the WFP, education for UNESCO, gender for UN WOMEN, energy security for the IEA/OECD). The choir of the deserving is large, and each member tries to outsing the other. The most common theme is "a decade lost", which is an appropriate metaphor, since the COVID-19 pandemic and the Russo-Ukrainian War hit almost precisely 10 years after the global economy started picking itself up from the global financial crisis (2008) precipitated by the collapse of Lehman Brothers.

The most important impact of the twin crises on efforts to achieve the SDGs is that the money for the global sustainable development project is not there; in fact, it never was. To appreciate why this is the case, a basic understanding of global development finance and the political economy of moving money from North to South is required. Some readers have this knowledge; others probably do not. For those who need it, a primer on these subjects is provided in an annex. For those who do not need it, we can get straight to the question: How will the twin crises affect the likelihood that the SDGs will be achieved, and, through the changing context, demography?

This discussion of the SDGs is divided into four parts. The first subsection examines the goals related to income, food security and inequality (SDGs 1, 2 and 10), then broadens to include the emerging theme of happiness as a welfare measure. The second subsection focuses on the goals that are directly affected by the crises, particularly by the COVID-19 pandemic: i.e., those related to health, education and gender (SDGs 3, 4 and 5). The third subsection looks at sectoral goals that are indirectly affected by the crises, since they require a budget to pursue. Finally, the fourth subsection is devoted to the most intangible, but also the most important goals, because none of the others can be attained without them: Peace, Justice and Strong Institutions (SDG 16) and Partnerships for the Goals (SDG 17).

3.1 Income poverty (SDGs 1 and 10), food security (SDG 2) and happiness

As the examples of China and India show, the strongest correlate of income poverty reduction is GDP growth, particularly in the medium and the long term, when cyclical vagaries are smoothed out.[6] Only the analysis of disaggregated data from household income and expenditure surveys (and complementary exercises, such as USAID's Demographic and Health Surveys (DHS) and UNICEF's Multiple Indicator Cluster Surveys (MICs)) emerging in the coming months and years will fully illuminate the effects of the COVID-19 pandemic and the Russo-Ukrainian War. But important issues have emerged even before we have access to empirical data for the world, and sufficient time to examine them.

Whereas the COVID-19 pandemic has had direct income effects in the form of medical costs, lost employment and income, etc.; the War's effects, outside of those on the combatant nations and the areas directly affected by the conflict, will be diffuse, and will mostly take the form of rising food and energy prices. It would be

6 For a historical perspective emphasising the need for economic growth, see Ravallion (2020). He is not entirely pessimistic on the prospects for improvement, but draws attention to a serious lack of coherence between "social" and "environmental" goals.

reckless to offer a comparison of the scale of these effects, but they differ starkly in terms of incidence, with the COVID-19 pandemic affecting the households experiencing cases of sickness most acutely, while the effects of the War are far broader. China is *sui generis* because of its "zero-COVID" lockdown policy, the effects of which are still emerging.

Perhaps the most important question is whether the greatest impact of the crises will be on extreme poverty, the steep reduction of which has been one of the triumphs of the last decade.[7] The 2022 *World Development Report* estimated that the number of extremely poor people increased by 80 million in 2020 as a result of the COVID-19 pandemic, which represents a generational reversal in a world that saw the number of people in extreme poverty fall by one billion in the preceding decade. Given the importance of energy and especially of food in the budgets of the very poor, it is reasonable to assume even before the data roll in that the Russo-Ukrainian War is causing the number of people who are food- and energy-poor to rise, and not just in poor countries.

Another issue, more subtle than that of extreme poverty, is the impact of the crises on people who are close to the poverty line, and who will find it harder to climb out and easier to fall into poverty; a point that has been emphasised by Garroway and Reisen (2015). And, leaving poverty aside, a third issue – which has been the subject of human interest stories in the press, but will require much closer analysis – is the negative effects of these crises on middle-class households in all countries, through the loss of earnings and medical costs in the case of the COVID-19 pandemic, and through the loss of purchasing power in the case of the War. Poverty reductions have been only part of the development success story; the explosion of the global middle class has been equally important from a long-term structural point of view, and is a story that is not told in SDG monitoring because of its poverty and No One Left Behind orientation.

Why do we worship at the altar of income? For some time, there has been an argument that wellbeing (or happiness, or life satisfaction; we will use these interchangeably, with the understanding that they are subjective, self-assessed, and no doubt debated by psychologists) should not be reduced to income or material living conditions (which are objectively measurable).[8] Scepticism about using national income as a welfare measure was evident at least as far back as Abramowitz (1959). In fact, it can be traced back to the ideological disputes at Lionel Robbins' London School of Economics, where war was waged between cardinal and ordinal utility and the contribution to national welfare of a pound's worth of milk versus a pound's worth of whisky was disputed on the grounds that some preference rankings

[7] The World Bank defines extreme poverty as living on less than roughly two dollars per day in purchasing power parity (PPP) terms.

[8] A view that has even made inroads at the OECD, hardly a fount of heterodox economics (OECD, 2020).

were to be preferred to others.[9] Easterlin (1974) found essentially no correlation between national income and happiness at the country level; a finding refuted by Stevenson and Wolfers (2008) who found a monotonic increasing relationship. Kahneman and Deaton (2010) found in the U.S. that, in a sort of Kuznets effect, emotional wellbeing peaked at a level of about USD 75,000 per year, while life satisfaction continued to increase. Wilkinson and Pickett (2009) put the threshold much lower, at about USD 25,000. In short, the evidence is mixed and inconclusive.

Casting empirics aside, in defence of the traditional approach, there is a tendency to set up a straw man GDP (or, more accurately, net national income) per capita as the ideal measure of the human condition, and then to knock it down. This has contributed to statistical embarrassments such as Gross National Happiness in Bhutan, the now-emerging corporate position of Chief Happiness Officer, and academic money spinners such as the newly introduced MA in Happiness Studies at Centenary University in New Jersey.[10] While GDP per capita is a far from perfect welfare measure, those who tilt at this windmill have almost certainly not studied the UN's System of National Accounts (SNA) to appreciate the subtly and sophistication of the GDP measure and its satellite frameworks designed to incorporate issues such as unpaid household activity with its gender and family labour components, health system accounts, and natural resources and the environment. Through the SNA, GDP is articulated into current and capital accounts, income and expenditure accounts, financial accounts, production accounts and balance sheets; all with sector/actor disaggregation and double-accounting consistency. Apart from basic sector/actor disaggregation – which is often demographic in nature – this is a feat that alternative welfare measures cannot hope to attain.

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9 Hirschman (1984) is relevant here, because he addresses head-on the issue of competing (or shifting) preference rankings. Let A prefer (X to Y). From de Graaf's welfare economics point of view (see below), all is done and dusted. Concentrating on shifts in rankings, let something happen so that A now prefers [(A prefers Y to X) to (A prefers X to Y)]. Hirschman points us towards a critical assessment of the current phenomenon of "wokeness", a condition of the tolerably well-off, and Huntington's concept, discussed in the annex, of the "Davos Man".

10 The mother of all GDP per capita alternatives is the Human Development Index (HDI), originally a weighted average of GDP per capita, life expectancy and literacy; now refined by more modifications than it would be possible to count on both hands. The importance of health, education, literacy and other reasonably objective indicators as useful and necessary complements to income is universally accepted. However, the political economy of the HDI's origins in the late 1980s is revealing. At the time, UNDP was looking to make its upstart annual *Human Development Report* a credible competitor with the World Bank's flourishing *World Development Report*, which reflected the liberal Washington Consensus. Not long after the introduction of the HDI, Kelley (1991) observed that HDI and GDP per capita were almost perfectly correlated. It would be difficult to overestimate the subjectivity of how the HDI components are weighted, however, many are added, whatever the averaging method used. In its 20th Human Development Report, UNDP greatly reduced its implicit weight on longevity in poor countries relative to rich ones, and raised the value of schooling to many times its economic returns (Ravallion, 2012).

American jazz pianist Thomas ("Fats") Fats Waller (1904–1943) may have boiled this issue down the best with the common-sense observation: "I never knew a situation so bad where having more money made it any worse". With the important qualification that the public slice of the pie is spent to promote the welfare of the people, GDP per capita can be considered a lens through which happiness is refracted; darkly, as St. Paul put it (1 Corinthians 13:12), but without too much distortion. At the macro level, the obvious exception to GDP as a national welfare measure is in resource-rich (usually extractive) economies. Economic accounting for natural resource exploitation is not only complicated, but in most of these countries, the repartition of its proceeds is opaque and inequitable for reasons related to the political economy, not to the SNA. Apart from special cases such as these, the statistical correlation between income and happiness tends to be pretty close, at least at the macro level – absent the unlikely eventuality that widespread satiation or boredom sets in.

At the same time, it is beyond debate and in need of no empirical investigation that strict welfare economics in the style of de Graaff (1957), while aesthetically appealing for its parsimony and rigour, requires supplementation to maintain practical policy relevance, not to mention a stiff dose of political economy and social choice theory to deconstruct the social welfare function. De Graaff exhausted the space offered by neoclassical welfare economics –there was nothing but footnotes to add after that admirably slim volume was published. In favour of broader approaches, psychologists and social welfare experts credibly warn of cohorts that will bear the scars of COVID-19-associated depression for years or even decades. For those, mostly in the Anglosphere, who have dutifully accumulated financial asset portfolios to achieve a comfortable retirement, the emotional scars of today's bear market will not be healed quickly. And perhaps, as any event that disturbs global geostrategic confidence would, Russia's invasion of Ukraine is leading to widespread anomie of the original Durkheimian variety in which the old rules do not make sense anymore; in which millions are left shaking their heads and asking themselves, "Who'd a thunk it?"[11] Fats Waller aside, cash transfers cannot address the depression of COVID-19- and Ukraine-related isolation, uncertainty and anomie.[12]

3.2 Reduced inequalities (SDG 10) and happiness (again)

The COVID-19 pandemic has worsened inequality because the poor are more vulnerable to its effects than the rich. The War is causing food and energy prices to rise, which, in accordance with Engel's Law, take up a disproportionate share of the household budgets of the lower income deciles of the population. English

[11] A question that occurs in Salinger's (1961) *Franny and Zooey*.

[12] And may, at least according to the Editorial Board of *The Wall Street Journal*, make things worse: https://www.wsj.com/articles/the-high-cost-of-free-money-harvard-exeter-study-stimulus-handout-low-income-well-being-health-personal-agency-poverty-covid-11658166372?page=1.

grain prices did not regain their post-Black Death levels until the superimposed commodities crises of the Napoleonic Wars and the Year Without a Summer (1815). Without meaning to imply that the COVID-19 pandemic and the War, even taken together, are of a scale comparable to that earlier pandemic catastrophe, there are newspaper reports that prices are rising day by day, and that there is hunger among the poor. The prices of milk and bread in the UK have skyrocketed, and it is rumoured that the Germans may soon be limited to lukewarm, perhaps even cold, showers. Northern governments have the fiscal room and borrowing power (albeit limited by current macro-economic conditions) to cushion the blow to their populations, but Southern governments do not. Reports from the field, e.g., from the World Food Programme, are grim.

Inequality must be approached the way Graham Greene approached love in his novels, with a sliver of ice in the heart. At the global level, growth for all is practically assured by, if nothing else, advancing technology and productivity gains. The growth advantage associated with raising income levels in today's poor countries to the income levels in tomorrow's rich countries – and thus to close the gap, the goal of the global sustainable development complex – is unattainable absent hallucinatory, efficiency-insulting, forced and deeply resented reallocations of financial resources.[13] But, inequality, which was always certain to persist, will now be worse thanks to the COVID-19 pandemic and the War.

The relationship between inequality and wellbeing has been studied most in the area of public health, where it is possible to escape a reliance on self-assessed wellbeing by statistically examining the relationship between inequality

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13 *For ye have the poor always with you* (Matthew 26:11). Matthew lived at a time of no long-term economic growth, and with no prospect or even concept of it. The modern paradox is that the poor will not always be poor, or at least in misery, which brings us to the inequality issue. Let North start at 100 and South at 50. Let both grow at two per cent per year (which flies in the face of the historical Southern growth advantage, but we err on the pessimistic side). Then, a half-century hence, the relative income gap will remain unchanged at 100 per cent, but the South will be 35 per cent better off than the North was at the starting place. For the global sustainable development community, the question never effectively addressed is that of comparators. The issue is one of relative versus absolute welfare, and, as is discussed in the next paragraph, the future poor and rich may be as unhappy as they ever were, whatever their income growth paths.

Ausubel (2004) has made a more subtle case for persistent inequality based on the argument that success (whether at the individual or the national level) depends on a discrete sequence of good outcomes, like repeatedly making a winning cast of the dice at Step A, Step B, etc., through, he reckons, eight steps – a statistically rare event, unless (moving well beyond Ausubel) the dice are loaded, which would be the Marxist argument, and deserves to be taken seriously. But say the loaded dice are discovered and the party who loaded them is exposed. A fair set of dice are substituted. In this event, the bottom does not rise to the top; the two rather meet somewhere in between, just where is to be determined by a combination of neoclassical efficiency and political economy, both of which are likely to favour the party who loaded the dice in the first place. "Fairness", in other words, is not an absolute, but a socially and politically constructed concept that invariably reflects comparative advantage and power relations.

and mortality and morbidity statistics – that is, by using welfare measures that are still not perfect, but are as objective as we are likely to find.[14] Consider a society of rich and poor people, each with a baseline level of happiness or wellbeing. Each experiences an instantaneous equi-proportional boost in income – manna from heaven. A plausible result is that each experiences an equi-proportional increase in happiness. But, as plausible as that scenario may appear since relative inequality remains the same, neither experiences such a happiness boost; they are as miserable as they ever were once the euphoria of money illusion wanes. Now let the rich get richer while the income levels of the poor remain the same; that is, the manna rains harder on the wrong, from a social welfare point of view, side of tracks. A plausible result is that the rich then get happier, while the poor remain equally unhappy, or become less happy on account of the widening gap. But what if the rich lose happiness (or their gain is smaller than might be expected) because they perceive the worsening inequality (preference rankings being fixed), or (if preference rankings are plastic) they become more tender-hearted through a process of moral improvement that might accompany an increase in income? Now, let the rich be materially stuck while the poor get richer; that is, the manna rains on the socially correct side of the tracks. Do the rich lose happiness because they have lost privilege, or do they gain happiness because their guilt is diminished? These arguments, as static as they are, are not simple to resolve.

3.3 The SDGs directly affected: Health (SDG 3), education (SDG 4) and gender (SDG 5)

The impact of Russia's invasion of Ukraine on health, education and gender is no different from that of any brutal conflict: it has led to the destruction of infrastructure; the disruption of lives; the horror of rape and torture in a time of war. Yet it must be remembered that in no war in living memory has it been so easy for the affected populations to escape to sympathetic neighbouring states. There is no such escape from COVID-19, and it is the pandemic, with its focused impacts, that is the major concern in this subsection.

Good Health and Wellbeing. The most dramatic near-term direct impact of COVID-19 is on health, and a large body of health-related demographic research will be produced in response to the pandemic. Calculations of the impacts of COVID-19 on life expectancy and years of healthy life lost abound, and let us leave the estimation of these indicators to specialists. As the world recovers, a much simpler and more consequential question is whether developing country health policy, which was evolving in the direction of dealing with non-infectious

[14] Not that the escape is complete. Self-assessed health is still widely used in surveys. A well-known bias is that affluent and well-educated respondents are better able than poor respondents to realise the dire state they are in, and are more willing to report it.

(non-communicable) disease, is forced to return, in defiance of the epidemiological transition, to dealing with infectious (communicable) disease.

Since the publication of the WHO's annual *World Health Report* of 2000, the party line of the public health establishment has been that health policy should concentrate on a broad strengthening of the health system with a primary health care orientation, and not on specific diseases (malaria, HIV-AIDS), conditions (disability) or populations (mothers and children, adolescents). With their need for publicity material and photo opps, international health donors have, for the most part, not succeeded in adopting this approach (the EU, which provides sector-wide health budget support, and the World Bank, which supports health system finance reform, are praiseworthy exceptions). During the COVID-19 pandemic, when even the meagre supply of donor-provided vaccine doses were often discarded because they could not be administered before they became outdated, the weakness of poor country health systems has been exposed.

Because they feed the news cycle's hunger for viewer-captivating human interest stories, reports of the worldwide impact of the pandemic on health care workers, and especially stories of staff burnout, have received substantial public attention. These reports have focused not just on physicians and nurses, but also on hospital cleaners, mortuary attendants and grave diggers. Elder-care facilities in the North have, in particular, lost staff, in part because the COVID-19 pandemic has disrupted immigration. In developing countries, health sector brain and skills drain will worsen as wealthy countries seek to replace lost human resources by facilitating medical immigration and certification, which will, in turn, lead to predictable political debates, as Northern medical professional associations argue that better pay and working conditions, not immigration, are the answer.[15]

Two other aspects of the pandemic deserve particular attention. The impact of long COVID on labour markets and health systems is unknown, because our clinical understanding of the condition and its treatment is still rudimentary. Suffice it to say that the direct, indirect and induced costs could be staggering. Other, even greater forms of collateral damage caused by the COVID-19 pandemic include reductions in basic child vaccination rates (largely DPT3 and measles), overstretched public health systems, reduced access to clinics and schools, increased difficulties in getting children to clinics, and the rampant spread of anti-vaccination misinformation. Some public health experts speak not of a decade, but of three decades of progress in combatting childhood disease being lost.[16]

Quality Education. The second-most directly affected sector is education. Having tracked the beneficial effects of education as it has expanded in poor countries,

[15] Some years back, this argument from the British Association of Nurses and the Royal College of Nurses quashed plans for a Commonwealth nurse circular migration and training scheme. Sadly, in response to the pandemic, there has been a flood of nurse immigration from Zimbabwe, one of the African countries that has been worst affected and least able to cope.

[16] https://www.nytimes.com/2022/07/14/health/childhood-vaccination-rates-decline.html?searchResultPosition=2

we will now have to track the losses incurred as the cohorts who were of school ages during the COVID-19 pandemic grow older. The digital divide is a yawning gap, especially in low-income settings. Remote education, at all levels and in all material settings, is an imperfect substitute for the real thing, not only because remote pedagogy is not as effective as in-person learning, but also because it implies a lack of person-to-person interactions and group socialisation. Data from the U.S. already indicate that among primary school students, literacy and numeracy levels have slipped relative to pre-lockdown levels, with very young children and Black and Hispanic students suffering the worst effects. Notch effects in cognitive skills and in personality traits will be discernible for decades to come in all countries, and not just among the children of the poor. In developing countries, it is likely that the negative effects of the pandemic on education will be especially acute for secondary education, which is expensive both in budgetary terms and in terms of the loss of potential household labour income. This is a bitter blow, given that research points to the critical importance of education beyond the primary level. Among teachers in the U.S., a lack of job satisfaction with remote instruction and low teacher salaries in a tight and skills-short job market are leading to an exodus from the profession that is as serious as the exodus from the health care sector, leaving school systems scrambling to hire often inferior replacements. Frustration with parental interference in what can and cannot be taught – a consequence of the identitarian politics of the culture wars – has accelerated the exodus.

Gender Equality and Women's Empowerment. There is anecdotal but very credible evidence that the stress of the COVID-19 pandemic and confinement at home have led to an increase in levels of interpersonal violence worldwide, including intimate partner, gender-based and other forms of domestic violence (including violence against children and among siblings). This trend is plausible, but is hard to document because social distancing made it more difficult to report mistreatment to the authorities, to community civil society organisations, or even to friends and relatives.[17] How lasting this effect will be is difficult to assess. The impacts of the pandemic on female education and labour market participation are easier to document, and will be long-lasting. There is considerable evidence from the 1997 Asian financial crisis and similar events that when household finances are under pressure, it is girls who are pulled out of school first to take on family work duties, whether in the house or in the field. Girls are also the first to see their share of the family food budget cut, as the intrafamily comparative advantage shifts from brains to brawn. In the worst cases, girls are attracted to or are forced into the less savoury parts of the dollar economy.

In upper- and upper-middle-income countries, female labour force participation (and participation in university and post-graduate higher education) has declined as women have taken on more home production responsibilities, especially child

[17] Anderberg et al. (2022) used internet searches to estimate a post-pandemic increase in the prevalence of domestic violence several times larger than police reports would indicate.

care, as in-person schooling has been replaced with remote instruction. The situation has been acute in the United States, where the commercial child care industry has shrunk, and there is no public alternative. Some of these changes will be unwound, but some will persist. Women have been especially affected because of their over-representation in service industries (retail and hospitality, for instance).[18] An optimistic view expressed by Goldin (2022) is that remote work will offer excellent opportunities to middle-class women who want to have a flexible schedule and to engage in stay-at-home multi-tasking. This will be of cold comfort to the woman behind the supermarket checkout counter. It is, moreover, equally possible that remote work will reinforce, not break, the glass ceiling; and that it will strengthen the walls of the pink-collar ghetto made up of women working in back-office departments, such as human resources, bookkeeping, IT and payroll. Only time will tell whether there has been any lasting gender re-balancing of home production, a research area that has attracted increasing interest from demographers in recent years, both because of the increasing availability of time-use data, and because the gender balance of the profession itself has shifted.

3.4 The SDGs less directly affected

While some of the effects of the COVID-19 pandemic and the War are direct, many are indirect, and are mediated through insufficient budgets. Thus, the fiscal space for a transformative agenda has shrunk.

Clean Water and Sanitation, Affordable and Clean Energy, Climate Action, Life on Land, Life below Water, Responsible Consumption and Production. There will be less money for Clean Water and Sanitation (SDG 6), although a beneficial effect of the COVID-19 pandemic has been to draw attention to the lack of basic water and sanitation infrastructure in many low-income country health facilities. Similarly, there will be less funding for the biodiversity goals associated with SDGs 14 and 15 (Life on Land and Life below Water). When it comes to SDG 12, Responsible Consumption and Production, public economic policy in response to the COVID-19 pandemic has concentrated on sustaining existing consumption patterns. While this approach is sensible in the near term, it runs the risk of entrenching consumption habits that could prove unsustainable over the long term.

[18] But this may work in women's favour, as well, due to productivity growth spurred by the pandemic. Baumol's Law was born of the observation that because there is limited scope for productivity growth in services (it will always take 20 minutes for a barber to cut a head of hair or a hotel cleaner to make up a room), the relative wages of those who provide services must rise relative to those who provide goods. This is because those who employ them must compete with the wages of non-service providers as the latter's productivity rises. Baumol's Law might have positive gender equality effects at present because those benefitting would be disproportionately low-wage workers whose physical presence is required, and who are disproportionately women. But a counterargument is that technological change – automatic supermarket checkout counters, artificial intelligence-governed online systems, etc. – may weaken Baumol benefits for service workers.

The fiscal impact of the War on SDGs 7 (Affordable and Clean Energy) and 13 (Climate Action) will be especially severe. As a direct result of the War, the EU has been forced to drastically scale back the energy and climate change commitments that were the centrepiece of the von der Leyen presidency. As Germany's sudden nostalgia for coal and nuclear energy demonstrate, commitments to achieving net zero carbon emissions by 2050, the circular economy, etc. – in short, the entire European Green Deal – have been revealed as the empty promises that they always were. De-carbonisation has been replaced by re-carbonisation. Frightening as the thought of the global long-term consequences may be (we are already reaping the near-term consequences), the War on Carbon has been put on pause.

Sustainable Cities. SDG 11 (Sustainable Cities) has also been put on hold, although it will be interesting to see whether the brutal pandemic-related acceleration of the long-term trend towards population de-concentration in middle- and upper-income countries will persist. The principal issue is the impact of the COVID-19 pandemic on agglomeration economies via the remote work revolution; which, however, predated the pandemic, and was only accelerated by it.[19] As the transfer of call centres to remote locations indicates, services have always been footloose. In New York City, the *classe dorée* fled at the first sign of crisis to their stately Hamptons pleasure domes, though it appears that they are returning as the city's cultural life and night life revive. The Manhattan real estate market has bounced back smartly, as have rents overall, and the concert halls are filling, even if they are still not full. Beyond the New York elite, the COVID-19 pandemic encouraged the American middle class to move to suburbs in order to slide down Alonso's (1964) bid-rent curve; or to the outer boroughs of New York City; or to secondary cities; or even to rural areas if they wished to escape urban burnout, like Umbricius moving from Rome to Cumae in Juvenal's *Third Satire,* or the ageing William Burroughs moving from the Lower East Side to Kansas. Preliminary results for 2020 from U.S. Census Bureau show a continuation of the exodus from blue states to red states, especially to Texas and Florida; the *Wall Street Journal* has attributed this trend to high blue state taxes, as would be expected. More recently, it has been confirmed that large U.S. counties are losing population to medium and small counties.[20] In France,

[19] More precisely, agglomeration economies of two types. The first ("localisation economies") arise from propinquity of firms (e.g., the Diamond District in New York City, or Silicon Valley in California) and of persons within firms; hence (at least pre-pandemic) the trading floor, the newsroom and the birth of the open cubicle-based office. The second ("urbanisation economies") arise from city scale; the agglomeration of multiple industries and diverse functions, all requiring services. A speculation is that localisation economies will remain strong, as relationships are formed over drinks and deals are done over lunch, not Zoom or Teams. Urbanisation economies, by contrast, are likely to be decreasingly relevant, particularly since many primate cities are already well into decreasing-returns territory due to congestion, pollution, social pathologies associated with overcrowding, exposure to catastrophic risk, etc.

[20] https://www.census.gov/newsroom/press-releases/2022/population-estimates-counties-decrease.html.

there has been an exodus of the young, creative and Linked-In workers from Paris to Marseilles (a distinctly secondary city from the Parisian perspective), and even to once-dying villages. Through CNN reporting and the internet, news of the one-euro houses being offered in villages in Italy has gone viral. It is not just a matter of remote work. Increasing mobility and connectivity, and technological changes that provide near-global access to everything from movies and music to medical consultation, mean that, apart from the psychic costs of physical distance from one's familiars and home culture, it no longer matters very much where you live. Moreover, the press is filled with reports of bourgeois bohemians ("bobos"; e.g., lawyers, accountants, web designers, IT specialists, life and fitness coaches, etc.) re-evaluating their work-life balance.

Perhaps American Midwestern realism and European Christian pastoral poetry will eventually stage a comeback, but this author doubts it. Country life is a luxury of the well-to-do that has been skewered by sources as diverse as the classic 1960s American television situation comedy *Green Acres* and the *Communist Manifesto* (para. 28, the idiocy of rural life).[21] History moves from rural to urban, not the other way around. A dark side of the COVID-19 pandemic in India is a reversal of the Lewis model, as urban workers have returned to lower-productivity work in the village. Only the iron fist of the state has prevented a return to the countryside in China, while in Vietnam, workers were confined in factory compounds during the early days of the pandemic to prevent them from returning to their villages. During the depths of the LDC Debt Crisis, there was a re-ruralisation of African life, both via city dwellers returning to the villages and the flourishing of urban small-plot agriculture. After the 1998 currency crisis, there was hardly a Russian liberal professional who was not digging potatoes, onions, carrots and cucumbers out at the *dacha*.

Decent Work and Economic Growth. Some of the effects on the Decent Work agenda (SDG 8) have just been alluded to. In all economies, but especially in developing economies, what will be most important are the effects of the pandemic- and the War-related price shocks on informality. During the COVID-19 pandemic, formal employment contracts were broken (or became impossible to obtain), and families were forced to adopt survival strategies. With the rise of remote work, informality will grow in middle- and even upper-class labour markets. This shift may prompt a critical examination of the very concept of "decent work" – which, after all, emerged from an unlikely alliance between the anti-poverty lobby, representing the poor, and organised labour, representing the worker aristocracy. It will be interesting to see how the ILO, the keeper of the Decent Work flame, will react to this

[21] This is actually a blunder by Samuel Moore, translator of the Authorized English Edition of 1888 (Draper, 1978, p. 344f.). *Idiotismus*, in the 1848 German original, has nothing to do with mental deficiency. It derives from the Greek ἰδιώτης, meaning an unaffiliated individual, and specifically in the context of Athenian democracy, someone who lived in isolation and took no part in political life. Marx and Engels meant no insult to the countryside; they were making a reasoned observation with serious intent.

development, as antipathy to informality and self-employment (the two typically go hand-in-hand) is in its DNA. The COVID-19 pandemic has reinforced the synergy between outsourcing and digitalisation, to the benefit of developing-world workers, and to the discomfort of developed-world bobos. A simple Google search reveals that it is possible to hire a UK-trained lawyer living in Bangladesh to draft an uncomplicated contract for a fee of 50 euros an hour. Everything from legally sound boilerplate rental leases, sales contracts, pre-nuptial agreements, applications for a disability pension, etc. are available on the web for every significant jurisdiction, which is why American and English law graduates are facing the worst job market in memory. Moving to the fringe of the labour market, the pandemic has reportedly given some impetus to the anti-work ("slacker") movement, whose foundation text is *Bonjour, paresse* (Maier, 2004).[22] A current catchphrase of this trend is "quiet quitting", which refers to staying on the job but not working very hard at it, while harbouring no illusions of advancement, or of the value of the work.

Industry, Innovation and Infrastructure. SDG 9 is related to industry, innovation and infrastructure. The twin crises of the COVID-19 pandemic and the Russo-Ukrainian War have amplified already-existing concerns about the fragility of supply chains, especially for manufactured products and components from Asia. For example, the pandemic has clearly shown the risk of over-reliance on sourcing from China, whose zero-COVID strategy is crippling industry and seizing up the wheels of trade and commerce around the globe. Meanwhile, the War has, of course, revealed that Russia and Ukraine, along with the United States, are the wheat breadbaskets of the world.

Supply shocks originate locally on the production side, and then spread globally. That is why the disruption of Ukrainian and Russian agriculture has been driving up food prices around the world. Demand shocks, by contrast, are local in impact, even if they are global in origin. Take the case of the COVID-19 pandemic, in which the spread of the virus was global, but the demand spikes took the form of peak-load local health sector crises. In New York, this led to outrage, as critically ill patients were left in hallways and cadavers were stored in refrigerator trucks. In poor countries, already threadbare health care infrastructure was similarly overwhelmed. However, no engineer, business manager or owner can deal with peak load – whether in demand for health services, transportation, electricity or snow shovels – by brute strength and spare capacity/inventory, as the opportunity costs are too important. Only a lobbyist for the medical equipment industry would suggest a massive post-pandemic expansion of intensive care capacity, much of which would likely remain idle until the next pandemic or localised catastrophic event. Adopting such a strategy

[22] The pun is on Sagan's (1954) precocious and sensational *Bonjour, tristesse*.

would be to fall into the boom-and-bust cycle captured by the cobweb model characteristic of all but subsistence farming and the extractive industries.[23]

The impacts of the crises on research and innovation are depressingly predictable, as they will result in reductions in overall budgets, and will concentrate resources on the sectors most directly affected: health in the case of the COVID-19 pandemic, and defence and security (military, but also food and energy security) in the case of the War. The pandemic has already accelerated the progression towards the emergence of a digital surveillance society, and this trend is likely to continue with the Russo-Ukrainian War, which is the first major conflict to be followed with real-time remote surveillance, digital tracking, social media and an unparalleled deployment of the (mis)information weapon.

The race for a COVID-19 vaccine is a reminder that, apart from the most arcane pursuits, research in Science, Technology, Engineering and Mathematics (STEM) is ultimately driven by profit – by the off-chance of making money out of a scientific discovery. The outcome-level performance of the profit-driven global pharmaceutical industry in its response to the COVID-19 pandemic has been exemplary – and has been far superior to the performance of the policy and political establishments, who struggled to deploy the vaccines, and, more recently, struggled to deploy the treatments that were so rapidly developed. The exquisitely post-modern Science and Technology Studies community will have valuable insights into how poorly scientific advances played out in public policy and society, and will call for more participatory consultative processes to overcome distrust, for engaged post-normal science, etc. But they will have to live with the fact that the Whitecoats burst out of the laboratory crying *Eureka!* in a mere 12 months after the virus emerged – having admittedly built on preceding basic research that was largely publicly funded. Consider the dreadful shape we would be in now if it had taken an additional six months to a year – which had been widely expected – to develop vaccines. Consider, as well, how the mRNA technology behind the Pfizer and the Moderna COVID-19 vaccines may revolutionise the clinical arsenal in the coming years. The failure of efforts to achieve global vaccine equity – or, less ambitiously than that, an epidemiologically optimal global distribution of vaccinations – lie not in failures of research and innovation, but in the vacuity of partnership talk, as discussed below.

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23 Assuming COVID-19 becomes endemic, with viral mutations every year, normal influenza provides guidance. When there is a bad flu season, vaccine is scarce and the public is outraged by stock shortages and long lines. When there is a mild flu season, warehouse shelves groan under the weight of vaccine doses that no one showed up to be jabbed with. That is the “cobweb model” in a nutshell. The cobweb model is complicated but analytically comprehensible; commercial farmers have long dealt with it – they talk poor when prices are booming because they know there will be a glut on the market come the next harvest. But introduce mild random shocks, which are sure to occur as the virus mutates, and the dynamics change from complicated to complex and incomprehensible save through the application of non-analytical stochastic approaches. It is in the form of the cobweb model that complexity first tiptoed into economics (Muth, 1961).

The sustainable development community rightly calls for local solutions to local problems, but it is important to not confound invention, which emerges from research; with innovation, which allows for inventions to be disseminated and applied differently depending on the economic, social, geographic and cultural context.[24] The first is the domain of scientists, and to lesser extent of engineers and mathematicians; and it benefits enormously (outside of, perhaps, mathematics) from agglomeration economies, particularly those that arise from propinquity. The second is the domain of entrepreneurs, and to lesser extent of engineers and households. Somewhere in that complicated chain lie designers. And, cutting across all this complexity is the reality that we now live in an age of the scientific amateur of a kind not seen since the 17th century thanks to the information and computing revolutions that have put data and statistical analysis on every desktop. Other than promoting the sorts of scientific mobility, exchange and collaboration that are now reasonably well established, there is no pressing need to further globalise basic hard science, at least in terms of bricks-and-mortar infrastructure. What is developed in the laboratories and accelerators of the U.S., the UK or China will, if properly disseminated and applied, be fit for purpose in other countries, as well.[25] It is, however, important to further develop the networks and infrastructure that feed real-time data monitoring, sharing and analysis. This is especially critical in the area of the global environment.

With that caveat, there is a pressing need for internationalisation in the social and policy sciences to help us better understand how to get scientific inventions working on the ground. In public health, the COVID-19 pandemic has laid bare the challenges that poor countries face in getting vaccines into arms and pills down throats – not that the public health community did not anticipate these problems. A lack of money is the main reason why these challenges remain, although it is not the only one. To promote innovation, we need to understand the local incentives and attitudes that lie beneath the surface; i.e., at the levels where household consumers, entrepreneurs, government (including local authorities) and technology interact. That can only be accomplished through interdisciplinary social science research, and it will require the involvement of local researchers. Lessons should be learned from the global response to HIV/AIDS, a disease that is much more fraught with cultural and social issues than COVID-19 is.

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[24] The foundational analyses are Hagerstrand (1967) on the diffusion of television in Sweden and Griliches (1957) on the diffusion of high-yielding corn varieties in the United States.

[25] The historical counter-example would be the Green Revolution, but there, developing countries served as case studies for the application of the emerging agronomic technologies, not as sources of the technologies themselves.

3.5 The SDGs that enable progress on all the others: Peace, Justice and Strong Institutions (SDG 16) and Partnerships for the Goals (SDG 17)

Regardless of their standing in international law, these are not so much SDGs, as narrowly defined, as they are cross-cutting themes that must be mainstreamed to achieve all of the other SDGs. While some links with demography are developed in this section, most of it describes the changed world in which demography will be situated.

Peace. While the COVID-19 pandemic did not shift the world order, Russia's invasion of Ukraine has, especially as it has led to an unlikely Russo-Chinese alliance that is a non-intervention pact in all but name. As Alain Frachon of *Le Monde* has written (19.05.2022), this realignment is likely to remain stable even if Russia falters, because it is an alliance of two nuclear powers seeking to replace the present world order with a new one that is *dirigiste* in terms of economics; is *laissez-faire* in terms of human rights; and is comfortable with the application of power through force.[26] David Brooks of the *New York Times* has written (08.04.2022) that globalisation, modernisation and convergence have all moved into reverse. Citing World Values Survey findings, he believes there is now a global culture war between shrinking liberal cosmopolitanism and expanding illiberal identitarianism (sometimes national, sometimes sub-national; typically ethnic, religious or linguistic in origin). Rich (2017) has described the rise of authoritarianism as a crisis of democracy.

The evidence is mounting that the world is splintering into competing blocs, with a return to a new form of bipolarity. Something approaching an anti-West *entente cordiale* with Russia has emerged in Africa, Asia (both South and East, with minor exceptions such as Korea, minus China), the Middle East and Latin America – this development is obvious in the UN General Assembly voting patterns since the start of the War. The world is turning into "The West and the Rest", with the latter collectively sulking, despite its diversity, in resentment of the former. But "the Rest", apart from Russia and China, will be bit players in the big show. Henry Kissinger's East-West axis of history is reasserting its primacy over the upstart North-South axis that shaped the global sustainable development paradigm.

Among the features of this shift in the geopolitical matrix to a Kissinger basis may be a return to irritating proxy conflicts. Russian influence, exercised through

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[26] Thucydides, *History* 5.89 (Melian Dialogue): *δυνατά δέ οί προύχοντεζ πράσσονσι καὶ οί ὰσθενεῖζ ξνγχωροῦσιν*. In C.F. Smith's often-quoted translation for the Loeb Classical Library, "The strong do what they can, while the weak suffer what they must". Add to this the politics of resentment: Russia's for its persistent underdevelopment and the collapse of the Soviet Union; China for its shabby treatment by the West before Mao and economic transformation.

mercenaries, is already apparent across Africa, from Libya to Mali to Burkina Faso to the Central African Republic to Mozambique (Ramani, 2022). Moreover, Russia has recently offered to provide military training and equipment to the region. What influence Russia has not recently appropriated through military support, China acquired fair and square on commercial and diplomatic terms long ago (French, 2015), or has gained through the Belt and Road Initiative by providing financing on terms that amount to debt servitude. France, whose cultural arrogance is resented, is retiring from the Sahel; and it may be doubted whether the U.S. was ever a serious player to begin with in that part of the world. With the G5 Sahel collapsing, there is a strong possibility that the entire region will become the new de facto Islamic State caliphate. Imperialism's rude good health, under Chinese and Russian management, must have Rosa Luxemburg laughing in her grave.

The issue is whether the impact of the twin crises on peace will affect the demographic research agenda. The answer is: probably not much. There is a large body of demographic literature on the consequences, though not the causes, of violent conflict, in places such as Rwanda (mortality), Iraq (marriage age), Burundi (fertility) and Nepal (net migration), As was described at the beginning of this essay, the War may add a bit to this highly focused strand of literature. The literature on the demographic causes of conflict dates back to Malthus, who observed that imperial conquest was driven not by ego, but by the need for food (one theory is that an important motive for Russia is control of Eastern Ukraine's energy resources). Thompson (1946) applied the Malthusian view to the emerging post-World War II order. Most demographers will be familiar with the Arab Spring youth bulge hypothesis: i.e., that the turmoil was fuelled by a large cohort of young people disaffected by the lack of freedom and socio-economic progress under entrenched authoritarian gerontocracies. Since population data are universally available, and there are credible conflict databases such as that maintained at Uppsala, journals of international relations, political science, peace research and the like have been filled with studies, virtually all regression-based, on how population size and structure contribute to the likelihood of either internal or cross-border violent conflict. However, few of these studies are by authors who would self-identify as demographers.

The exacerbation of poverty by the twin crises will increase the danger of conflict in areas where the renewable natural resource base is under pressure from population density, and especially in places where there is ethnic or religious diversity. The 1984 U.S. National Academy of Sciences report on population and development found no link between population and the scarcity of non-renewable resources, which are well-allocated by markets. However, the report also warned of a significant and troubling link between population and renewable resources, noting that because property rights and access to these resources are blurred, the markets for them are less efficient. The work of (e.g., Homer-Dixon, 1999) on this topic is canonical, and uses the Rwandan genocide and central African Great Lakes cauldron as the reference case.

As the International Organization for Migration (IOM) never tires of pointing out, migration is related to all of the SDGs. The role of conflict and violence in generating refugee flows (Ukraine, Afghanistan, Syria, Central America) is clear. The combination of environmental deterioration, much of it related to climate change, and population pressure is contributing to migration out of fragile areas of Africa. However, the trigger of migration is more often conflict and insecurity than drought – to which must be added a lack of local opportunities, the tantalising proximity of Europe with its dysfunctional asylum and generous social protection systems, and the effective marketing of the migrant smuggling industry (MacKellar, 2021). The same dynamics, substituting the United States as the destination, apply even more obviously to Mexico and Central America, where the environmental pressures are not as strong.

Justice. While the COVID-19 pandemic has unleashed a furious debate over the rights of the individual versus the state, the issue is really a matter of trust in institutions, which will be discussed below. Russia's invasion of Ukraine, by polarising the world into liberal and authoritarian blocs, is having a more fundamental effect, because it reinforces the global debate over what the Rule of Law, the purpose of which is to deliver justice (that much is common ground), really means. The Rule of Law concept lies in contested ideological terrain, not only outside, but in the heart of the Western project itself, in which populist authoritarianism (e.g., Poland, Hungary, Turkey) has emerged as an acceptable alternative to the Rule of Law as conceived in Brussels. Until a few years ago, when asked to provide a definition of the Rule of Law, the go-to response would have been clear: Bingham (2010), with his lucid human rights-based liberal conception. Dworkin (1986), more turgid with his emphasis on fairness, would have been a close second. The ideological fracturing of recent decades has made the situation more complicated. The Rule of Law equivalent of the Antichrist was once Nazi legal philosopher Carl Schmitt (e.g., 1932/2007), but he is enjoying a well-deserved second look now that his work has been rediscovered as essential to understanding justice in the world of Putin, Xi, Orbán and Erdogan.

The link between population and the Rule of Law has never received serious attention apart from intergenerational rights and justice equity arguments that are, as pointed out above, of dubious validity when they extend beyond a generation or two. Mainstream development researchers have found that strong property rights, good bankruptcy law, independence and impartiality of the judiciary, access to justice, absence of corruption and the like are conducive for development. There does not appear to be much of a demography hook there, except perhaps a Boserup-Simon argument that population pressure leads to virtuous innovation in the laws of property, tort, contract, etc. It is a credible line of thought – just think of enclosure. Increasing population density contributed to the development of the English common law and improved access to it, leading to a post-13th-century secular decline in interpersonal violence. Lawsuits have everywhere replaced duelling to the point of virtually extinguishing the practice outside of Western movies. The disadvantages of population sparseness are clear everywhere. Remote and/or scattered populations across the world, from the mountains of Central Asia to the wastelands of the Sahel, face barriers in access to justice, forcing many to resort to informal or traditional institutions that dispense what English lawyers used to contemptuously call "palm-tree justice", which was often highly unfavourable for women. But apart from these extreme settings, the judicial benefits of population density are long in the past, especially in an age when e-justice is feasible for all but highly consequential cases. And past a certain point, population size impairs, through congestion effects, the operation of the machinery of justice, even as it can burden the institutions responsible for education and health, or give rise to urban diseconomies of scale.

Strong Institutions. The COVID-19 pandemic has been a shock to public health institutions, albeit one that was long predicted (e.g., Osterholm, 2007; Smil, 2005 and many other public health experts; MacKellar, 2007). More broadly, even an analysis as neoclassically astringent as the 1984 National Academy of Science study of population and development acknowledged that political and public institutions of all kinds would find it easier to accommodate moderate population growth than growth at the high end of the spectrum. But would the health systems of low-income countries have fared better in the COVID-19 pandemic had population growth been a few tenths of a percentage point lower over recent decades? Probably, but not by much, given how large their problems unrelated to population are (*ditto*, the justice institutions discussed above).

If there is any demography-institutions-COVID-19 pandemic nexus, it lies in the damage that the pandemic has done to faith in the institution of science, and particularly in science as reflected in public policy.[27] Populist discontent against the administrative state if you are American, the nanny state if you are English, the *Beamtenstaat* if you are German and the *Papa-État* if you are French was already high – witness QAnon, *Querdenker* and the *gilets jaunes* – but boiled over with the COVID-19 pandemic. Science, once broadly perceived by the non-scientific public as empowering – "Better Things for Better Living … Through Chemistry" was Dupont's corporate slogan; the Chairman of the U.S. Atomic Energy Commission predicted in a 1954 address to the National Association of Science Writers that electricity would be "too cheap to meter" – is now instead viewed by a significant portion of that public as disempowering.

This trend must be of concern to demographers, whose duty it is to report population trends and to express opinions on their implications without fear or

[27] Ausubel (1999) was prescient in his discussion of the reasons to be worried about the future. One is the rejection of science and engineering. Others include a declining taste for work (*Bonjour, paresse* and quiet quitting there) and a loss of libido through the over-prescription of psychotropic drugs, both of which have been side effects of the pandemic. On the over-prescription of antidepressants for middle-aged women, see Andrea Peteron in the *Wall Street Journal* (02.04.2022), and on the current American conservative war against common selective serotonin reuptake inhibitors (SSRIs), such as Prozac, that are associated with the side effects of reduced libido and sexual function. On the declining taste for work, see Eberstadt (2016).

favour. There is need for deeper thought about the relationship between demography and Big Data, which the field has moved rapidly to exploit, and is practically synonymous with the surveillance of daily life that has been accelerated by the COVID-19 pandemic. Demographers have always been concerned about data security, and the role of demographic data in Nazi Germany has been the subject of study (Seltzer, 1998). Foucault (1976, apparently his first use of the term, in a work much more cited than read) saw population enumeration as a manifestation of what he termed biopower (*biopouvoir*) – but then power was to Foucault as Communism was to American FBI Director J. Edgar Hoover: he saw it everywhere. Nonetheless, the level of responsibility of the field to adhere to ethical standards and to communicate transparently is high.[28] Designing, implementing and reporting an accurate census can result in being purged or worse, as under Stalin.[29] The politicisation of the 2020 census in the United States was of a kind that might be expected in a banana republic. The once obscure conspiracy theory of *le Grand Remplacement* (Camus, 2011), picked up from its French origins by the American right-wing fringe, has risen through capillary action into mainstream politics and the halls of Congress.

An old saying is that the first casualty of war is truth, and, like the COVID-19 pandemic, the Russo-Ukrainian War is promoting the weaponisation of information via the internet and social media. The impact of the War on institutions is an issue that lies mostly in the domain of political scientists, and will take years to sort out. The inability of the United Nations to prevent a murderous war of aggression on Europe's doorstep weakens that institution, and demonstrates the dysfunctionality of the Security Council. Closer to the conflict, the European Union's Common Security and Defence Policy has been unable to muster even joint training and manoeuvres. The much-discussed steeling of NATO's resolve may persist, or it may not. The Council of Europe, probably the most effective human rights organisation in the world, has felt compelled to expel Russia – a bitter blow for an institution that once viewed the membership of Russia as close to a *raison d'être*. Multilateralism, which never really recovered from George W. Bush's Second Iraq War (2003–2011), is weakening further, with the major powers, China, Russia and the U.S., becoming increasingly willing to act unilaterally. The collateral damage is that international conventions – the UN Convention on the Rights of the Child; the UN Convention on the Elimination of All Forms of Discrimination Against Women: the UN Convention against Transnational Organized Crime; the Council of Europe Istanbul

[28] A topical example of biopower in an area of interest to demographers has to do with mobile telephones. In a number of U.S. states, legislation is currently in force or under consideration to criminally penalise abortion, or to make it subject to civil action. In such cases, a woman's mobile telephone could provide highly probative evidence in the form of GPS and menstrual period tracker app records (*Le Monde* 14.05.2022, https://www.lemonde.fr/international/article/2022/05/14/est-ce-que-mon-cycle-menstruel-est-espionne-les-americaines-s-inquietent_6126053_3210.html; *New York Times* 19.05.2022, https://www.nytimes.com/2022/05/19/opinion/privacy-technology-data.html).

[29] The names of the executed are to be found in Heran (2017).

Convention on Violence Against Women; the UN Security Council Resolution 1325 on Women, Peace and Security; the Paris Climate Accords; the European Convention on Human Rights; and many others – are increasingly scraps of paper to be signed, toasted in a spirit of bonhomie, and then ignored.

Partnership for the Goals. Partnership has both a broad and a narrow meaning in the sustainable development context. Broadly speaking, it refers to social solidarity, the "we are all in this together" philosophy of Brundtland, and the SDGs that emerged from it. More narrowly, it is a term of art that is now required in development prose at all levels, from programme and project documents up to global strategies. The partners include donors; recipient governments; implementing organisations, agencies or firms; civil society organisations; direct beneficiaries (e.g., ministry trained staff); ultimate beneficiaries (e.g., out in the village) – and, ultimately, all of us in the global village.

In the real world, partnership has a concrete meaning: namely joint and several liability in an enterprise to which all have contributed capital. That is, if the partnership fails, we all fail; worse, if you blunder, I am on the line, too. But in the global sustainable development project, partnership is a hortatory, even precatory term. Foreign aid, as Bauer (1975) bluntly put it, is a transfer from Northern taxpayers via Northern governments to Southern governments to be held in trust for the ultimate beneficiaries, with a great deal sloshing out at every stage of the bucket brigade along the way to the village (Easterly, 2006; Okun, 1975).[30] Partnership talk cannot sugar-coat the fact that donors are still donors, and beneficiaries are still beneficiaries; the first group are still the ones with the money and the second group are still subaltern in all but name. The two groups share some interests; others, they do not. Competing donor-beneficiary incentives cannot be papered over by substituting "cooperation" for "assistance"; and "partnership" for what is self-evidently a patron-client relationship, hierarchical, albeit with reciprocal obligations.[31]

Partnership requires solidarity, which has failed during the COVID-19 pandemic, and not only along the North-South axis. Consider how the Northern older populations, whose lives are mostly over, have been supportive of locking down and of shifting burdens onto working-age and particularly younger populations, for whom the damage is likely to linger over a much longer period of time. This is an example of an issue of intergenerational equity in the here-and-now. When it comes to international solidarity, the COVID-19 pandemic has laid bare the fact that no country, however big-hearted, will ship a single vial of vaccine abroad until its own needs have been satisfied – whatever the non-linear scientific

[30] Some Northern funds go directly to national civil society, but this is a miniscule slice of the cake.

[31] It is not coincidental that DG DEVCO (Development Cooperation) in Brussels is now DG INTPA (International Partnerships). And it is ironic that "partnership" has taken over sustainability precisely when that form of business organisation has been disappearing on Wall Street – in Big Banking, Big Law, Big Accounting and Big Insurance (de-mutualisation) – because it cannot possibly mobilise the financial resources that are on offer from the capital markets.

arguments for doing so that are advanced by epidemiologists. Even when the mathematically optimal solution is to vaccinate elsewhere, and not at home, it is voter perceptions that will rule. With science scepticism at a new high, as was discussed above, there is little chance that counterintuitive optimisation solutions from computational epidemiology will be politically feasible. While the operations research journals offer learned articles examining, by means of complex dynamic optimisation models, optimal lockdown strategies, there is no evidence that these have had the slightest influence on public health policy, which has instead attuned itself to the balance of public resignation and resentment. Although international initiatives to tackle the spread of COVID-19 – such as Chinese shipments of medical equipment, the COVAX scheme for equitable global access to vaccines, and the EU's Team Europe initiative to package European COVID-19 actions together – certainly helped to mitigate the crisis, they were initially undertaken largely as publicity exercises to show that something was being done. Vaccination rates remain pathetically low in the poorest countries, converting their populations into mixing bowls for new virus variants going forward. As for Russia's invasion of Ukraine, it is difficult to see it as having any effect other than to further dispel the partnership illusion underpinning the sustainable development project.

4 What is to be done? Recommendations

This essay has had three purposes. The first has been to advance the view that the global sustainable development project is foundering in its current form, and that the twin crises of the COVID-19 pandemic and Russia's invasion of Ukraine have driven a stake through its heart. The old battle cries of equality, equity and No One Left Behind will not revive it. As was observed above, the financial means to pursue it were always insufficient, and are entirely out of reach since the pandemic and the start of the War. Moreover, the crisis of the project reflects design flaws more fundamental than a lack of wherewithal to implement it; a number of these were called out above, and do not need to be repeated here. The failure of the project to deliver Peace, Justice and Strong Institutions (SDG 16) and Partnerships for the Goals (SDG 17) has impaired, if not doomed, the achievement of the other goals. To conclude, the present global sustainable development project is unsustainable, and when its failure becomes evident, there is a risk of backlash. North and South might retreat further into mutual resentment and recriminations. The winner would be the illiberal forces seeking to impose their dystopian world order.

The second purpose has been to forestall that dystopia by providing a platform for discussing what we can learn from the death throes of the current sustainable development project, as now embedded in the SDGs, and to ask how we can do better. What have we learned, and how do we move forward? The post-SDG project, which was referred to above as the SDGs+, has already started to be discussed.

The third has been to position the scientific field that this author knows best, demography, in the context of that foundering project. The study of population size, structure and distribution, and of its dynamics in the form of mortality, fertility and migration, will need to come to terms with the deteriorated and more complex situation in which it needs to provide policy guidance. Many of these research needs are self-evident, and can be found in the review of the SDGs above, while others may emerge from the broader analysis of the present global sustainable development project.

4.1 The global sustainability development project

What can be done to get global sustainable development back on an achievable track? To take sustainable development seriously?

- Every policy is a narrative, and every implementation of that policy is a performance. If the performance is poor, the narrative loses credibility, and, eventually, legitimacy. *The global sustainable development narrative should abandon grand, hortatory razzmatazz* in favour of goals that have a chance of being achieved – or, even if they are not achieved, of being at least practical enough that some useful lessons can be learned from the failure to realise them. The drafters of the SDGs were so tipsy on ambition that they forgot to recognise – let alone analyse and prioritise – the trade-offs. U.S. President George W. Bush reportedly said: “If everything is a priority, nothing is a priority”. Quite. The SDGs+ should not be approached as the road to a new and transformed world; instead, they should be approached as a way to alleviate the miseries of the current world as humanity limps, as it ever has and will, into an uncertain future. Tub-thumping, transformative narratives, so common in current sustainable development-speak, have a distinctly mid-20th-century vibe. *That stinks!*, wrote the critics, and the shows – notably the Nazi and the Communist productions – closed well ahead of schedule. To paraphrase Lord Salisbury: “Why should we transform? Aren’t things bad enough already?”
- Whither the wherewithal? *The mother of all revenue sources to finance Southern development is and will remain the South*, supplemented by capitalist finance from the North and, perhaps, loan-shark finance from China. “Aid” is negligible and dwarfed by migrant remittances, which are purely capitalist in origin. The stunning development success stories – France during *les Trente Glorieuses*, Germany and Austria during the *Wirtschaftswunder* years, China, Japan, Korea, Southeast Asia, India – did not borrow their way to growth; they saved their way there. (In Europe, the 1948-51 Marshall Plan provided the platform for subsequent growth, but was characterised by a degree of donor control that would be intolerable today.) The process was not pretty and had little to do with capital markets. The savings were accrued by governments, either by taxing households and firms directly; or by confiscating private savings and depositing them in the state banking system, from which technocrats could allocate the funds competently, as they did in

East Asia (or squander the funds incompetently, as they did in Africa and Latin America). Governments lacking legitimacy cannot employ either strategy, and there can be no legitimacy without the Rule of Law. *That is the secret to mobilising massive Northern private-sector funds, as is discussed in the annex.* However, donor support for the Rule of Law has always been subordinate to aid for material results, and anti-corruption has never been taken seriously as a condition for aid, the argument being that continued engagement is best in all but the most egregious cases. Without overreacting to every bagatelle, *donors need to take beneficiary legitimacy more seriously*. That means stating frankly and transparently when and why they override the Rule of Law for commercial or security interests.

- *The Washington Consensus is overdue for a degree of rehabilitation.* With apologies to Keynes, outside the least practical and the most romantic of circles (*Le Monde Diplomatique*, say), global development is impossible without a stable, market-based, reasonably free-trade environment. The mere mention of the Washington Consensus raises European blood pressure because of the widely accepted canard that the World Bank and the IMF have forced or instructed countries to fire teachers, close hospitals, subject domestic farmers and producers to ruinous competition, reduce pensions to a pittance, etc. All the Washington Consensus did was state that a globalised economy is unforgiving of attempts at inward-focused fiscal, monetary and trade autarchy – a piece of advice that has stood the test of time. If there is an irony, it is that the unfortunate consequences of the Washington Consensus arose precisely from the Bretton Woods institutions' acquiescence to the partner countries' priorities, which are the *sine qua non* of the development partnership today. Ministries of Health and Education starved while Ministries of Defence and Interior grew fat. Both the World Bank and the IMF eventually embarked on a campaign of introspection and an expansion of their in-house social sector capacity, an area in which they now excel, but it was too little, too late.
- *Some retreat from globalisation is inevitable, but let it be a strategic one, not a rout.* The response to supply shocks that trade economics recommends resembles the recipe for a dry martini: four parts diversification of foreign suppliers to a whisper of autarchy. While this does not always work in the near term, as we are now observing with the shocks originating in China and Russia/Ukraine, even these crises are unlikely to erase the comparative advantage and the long-term gains from trade. *Autarchy is not an option*. We are mutually dependent, and not necessarily in a good way. Climate change has brought this home to us. For all our environmental dedication in the North, at the end of the day, we are dependent on what China, India and Brazil are going to do.
- Hobbes has never looked better: *The world needs a Leviathan* (Rich, 2022). Today's putative Leviathan is the United Nations, whose legitimacy has weakened to the point of making the institution little more than a useful idiot to implement tasks that no else wants to undertake. While there is

no shortage of proposals for reforming the UN, the single most convincing of these is to sharply reduce veto power in the Security Council, which means *reining in the United States, China and Russia;* as well as the greatly diminished supernumeraries of France and the UK. *Ad interim*, absent a stronger Leviathan, the e*xisting global institutions will struggle to apply the hard-headed approaches needed. Thus, bi-lateral negotiations or alliances may be the only way forward.*

- Everyone agrees that the long-term, and ever-nearer, threat is climate change. No doubt a more controversial proposal is needed: *a strategic truce, in the form of a measured policy shift from climate change mitigation to climate change adaptation, should be declared in the long war on fossil fuels*. This is already occurring, so we might as well make it official. The current energy crisis has illustrated that lofty goals such as net carbon neutrality by 2050 are not only impractical, but are socially immiserating and politically destabilising. This does not mean abandoning the goal of transitioning to sustainable energy; instead, it requires us to recall the life lesson that sometimes, when you have dug yourself into a hole, you have to dig yourself in a little deeper in order to get out. Adaptation (greater resilience through stronger human capital, more effective social protection systems, better insurance mechanisms, better climate risk monitoring, etc.) can deliver now because it need not involve bricks and mortar; whereas mitigation does require bricks and mortar, and will take decades.
- Repairing the damage by *getting back on track in the areas of education and vaccination* is a priority so obvious that it sounds almost trivial. However, these efforts are cheap; the operational responses involved are well understood; and the gains kick in fast, over a five- or 10-year interval.
- The North's main concern when it comes to the developing world is to manage uncontrolled migration exacerbated by climate change. As climate and climate-related conflict emergencies grow, and as instability in Africa increases, another piece of low-hanging fruit is *reform of the dysfunctional international asylum and refugee system.*

4.2 The field of demography

The preceding discussion opens a rich field of issues and questions for demographers to address.

- *The direct implications of the twin crises for the demographic research programme (largely spelled out in Section 1) are modest in direct substantive terms, confirming that the discipline rests on a foundation that is sound enough for the purpose*. All can be dealt with, sector by sector, in the determinants and consequences framework introduced by the United Nations

Population Division in 1953, given that our theoretical and empirical understanding of the links between the two has expanded since then. Some issues of importance have been identified or can be inferred from Section 3 above.

- *This is not to suggest a sort of intellectual primitivism*. Multi-state demography has expanded to account not only for age, sex and rural-urban residence; but also for level of education, literacy, cognitive ability, health status, poverty status, labour force status, living arrangements, self-assessed happiness and life satisfaction, and other indicators of wellbeing. This growth on the extensive margin has enriched the relevance of demography to policy issues at every level, from local to national, to regional to global. It sharpens the relevance of the discipline to analyses of population vulnerability and resilience; two themes that will certainly figure in the SDGs+, as they do in the SDGs. It does not represent a paradigm shift of the sort that might result from a breakthrough on the intensive, presumably theoretical, margin; but none is needed at present. *What is needed more is a modelling and computational breakthrough, with data to feed it, in which age- and sex-specific dimensional vectors are endogenously linked, including lags, and, potentially, even expectations and stochastics.*
- *Demography, like all other fields, will suffer from the weakening of faith in science engendered by the COVID-19 pandemic*. This will especially affect science as filtered through government policies. A more speculative, but plausible hypothesis, is that trust in science will be reduced by the overall sense of anomie resulting from the Russo-Ukrainian War and the crumbling of a global security structure once perceived as solid in our lifetimes. A loss of faith in science will likely stimulate the spread of obscure and, perhaps worse, obscurantist predictions of demographic catastrophe, once typified by *The Limits to Growth,* and now represented by *le Grand Remplacement*. *Demography will increasingly need to counter misinformation and the appeal of baseless or deeply flawed theories and predictions disseminated through social media and the internet*.
- *There is greater need for the globalisation of the social and policy sciences than of the hard sciences*. Perusal of any major social science journal will reveal a deficit of publications from the Global South, and any editor will report that the main problem is the shortage of high-quality submissions.
- A downside of the global sustainable development project's focus on vulnerability, resilience, poverty, equity, Do No Harm, No One Left Behind, rights-based claims, and so on is that this emphasis has encouraged demography to turn away from a handful of grand narratives and towards a plethora of micro narratives at the level of the individual and the household. Data, computational power and the accompanying development of advanced quantitative methods have encouraged this approach. It has also been driven by the hunger, which is so difficult to satisfy at the macro level, for credible (i.e., positivist) causal linkages, which can often be found with the help of randomised or natural experiments. *Demography should give micro-level narratives a*

deserved interval of benign neglect, and return to the larger questions that once preoccupied it. What do demographic trends mean for global prosperity, and thus for economic growth, technological advances and innovation? What do they mean for global peace and security? What do they mean for global biogeochemical systems? Such a shift in emphasis would contribute to a policy-effective and scientifically self-reflective demography for the post-COVID-19 pandemic, post-Russo-Ukrainian War world.

Acknowledgments

The author gratefully acknowledges his stylistic debt to Robert Burton (1577-1640), of whose *Anatomy of Melancholy* (1621) it was said that no detail was too trivial for the author to magnify; with the result that the apparatus was more interesting than the text. He also acknowledges the Wittgenstein Centre in Vienna, which has given him the opportunity to write a forward-looking critical appreciation of its first decade of research output. Among the readers who have offered comments on this text are Andreas Wörgötter, Kurt Bayer, Joanne Linnerooth-Bayer, David Horlacher, Helmut Reisen, Stefan Gavell, Jesus Crespo-Cuaresma, Geoffrey McNicoll, Solon Ardittis, Zuzana Smidova, Peter Rosen, Karl Pichelmann, Georg Fischer, Roland Rich and William Butz. Their time is deeply appreciated, but they bear no responsibility for any of the thoughts expressed.

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Annex

Financing the sustainable development project: (i) sources and uses and (ii) getting the money from North to South

(i) Sources and Uses

Technology and consumer tastes held constant, a business-as-usual extrapolation of current production and consumption trends spells global trouble, perhaps even catastrophe; that is (mostly) common ground. What is needed is a transition to clean energy, efficient agriculture, a circular economy, eco-friendly production and consumption, and so on; a transition to which advances in technology can and will contribute. But it also means that an enormous chunk of the global capital stock must be replaced with more expensive gear (the sustainability edge does not come free).

In a wide-ranging survey of SDG costs published just before the COVID-19 pandemic (Vorisek and Yu, 2020), World Bank economists estimated the infrastructure-related SDG needs in the low- and middle-income countries alone to be USD 1.5–2.7 trillion per year, or 4.5–8.2 per cent of their GDP.[32] The authors also cite an IMF estimate of USD 1.3 trillion per year for health and education, both forms of investment in human, rather than physical, capital. The funds to finance these investments must come from someone's pockets, either in the North or in the South, which means that the global saving rate needs to be boosted by, say, three or four or five percentage points. But then households, governments and firms – which exhausts the set of economic agents – must tighten their collective belt.

The sources and the users of funds can be public or private, but the point is that the funds must come from somewhere and must go somewhere, respecting the tyranny of double-entry accounting. The set of feasible alternative strategies for achieving that tightening is easily enumerated in the form of three C's. *Constraining* through regulation forces change, but the belt-tightening is achieved by the resulting increase in prices, as cheap but dirty public infrastructure, private capital stock and consumption habits are regulated down and replaced with more expensive green alternatives (compare the prices of non-organic and organic products at the supermarket). *Cajoling* boils down to moral suasion ("awareness raising" is the term of art in sustainable development circles). But, we are a fickle species, and discounting (especially of the hyperbolic variety, which dominates as the time frame gets longer) being what it is, the yield of this approach is likely to be meagre.[33]

Convincing is typically achieved through incentives, the most effective of which are taxes.[34] There are four things that can be taxed: consumption (including sumptuary and sin taxes), income, wealth and transactions. *Consumption* taxes, which are especially needed on dirty energy, are attractive; but consumption taxes are always regressive, and particularly in impoverished settings.[35] *Income* taxes do

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32 There is some risk that conventional infrastructure needs estimates are made assuming the centralised, top-down, "hard" approach to infrastructure that today's development bankers apply in project finance. To some extent, this bias cannot but reflect a desire for the commercial advantage that comes from the export of current Northern technologies. But conventional bricks-and-mortar costs should be a reasonable order-of-magnitude guide.

33 The discounting debate, brought into sharp focus by the Stern Review, essentially boils down to ethicists vs. positivists (say, Solow vs. Beckerman). The treatment of discounting in climate change that stands head and shoulders over all others comes not from economics, but from law: Weisbach and Sunstein (2009).

34 Subsidies are simply taxes in mufti, because it is taxes that finance them. In practice, despite efforts to target subsidies, they are typically regressive.

35 Carbon taxes hold promise (as well as cap and trade mechanisms), but such taxes are not yet applied widely, and are regressive unless offset by tax reductions in other sectors. History does not bode well for this approach.

not work because, up to second- and higher-order effects, households will demand less of the clean and the dirty in roughly equal proportions; or, more likely, will favour the cheap and the dirty over the expensive and the clean due to the income effect. Corporate income taxes (i.e., on profits) reduce firms' incentives to undertake capital investment projects, which is precisely what we wish them to do. They also, to the extent that dividends are reduced, weaken households' incentives to invest their savings in firms in return for a piece of the profit pie. This is why, at a hint of an increase in taxes, firms cloak themselves in virtue and cry investment in sustainability to the heavens – a tactic known as "greenwashing".[36] It is often argued that *wealth* taxes discourage entrepreneurship, and while the OECD (2018) has found evidence for that claim to be weak, their other findings have led them to favour income over wealth taxes. A fundamental problem with wealth taxes is that they have proven very hard to implement, as it is difficult to measure wealth other than that held in publicly traded assets. But the real problem is that there is simply not enough wealth to tax – *pace* Piketty (2013) and his ilk, who have justifiable outrage on their side, but not the numbers to get from here to where they want to go. The *transaction* tax discussed the most is the Tobin tax on cross-border financial transactions, which has been repeatedly proposed as low-lying fruit. However, this is a self-defeating stamp tax in a world that depends on global economic and financial integration to respond to global challenges.[37]

There is current enthusiasm in sustainable development circles for a Global Public Investment (GPI) fund into which all countries, not just the rich nations, would pledge to put a given (presumably graduated, not flat) share of their income earmarked for global public goods and poverty reduction, eliminating once and for all the donor-beneficiary mentality and giving the poorest countries, to use the American slang phrase, skin in the game. But this is just a return to the tithe or *zakat*, and the problems in implementing a GPI fund are daunting. In the case of

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[36] Closely related to "greenwashing" is the massive growth in private money directed at Environmental, Social and Corporate Governance (ESG) asset funds. It has been estimated that ESG assets under management are growing 15 per cent per year, and will reach one-third of the $140 trillion total investment assets by 2025. Following the argument that the fiduciary responsibility of asset managers is to maximise asset holders' wealth, not to promote high, vague and debatable principles, there are stiff U.S. legal challenges to the ESG movement. There is also, in the U.S., a plethora of competing and inconsistent non-financial disclosures that can result in wildly differing classifications of companies.

[37] It is argued that the Tobin tax can be tailored to affect only speculative transactions, but this is easier said than done. The vast majority of international transactions are in derivatives markets (mostly in credit default and interest rate swaps). They do not arise from sales and purchases of real assets, or sales and purchases of equity interests, or cash transfers. It is an iron law of financial economics that at the one end of a trade is a risk-loving (hence, buying) speculator, and at the other end is a risk-averse (hence, selling) hedger. Each is a will 'o the wisp from the standpoint of identifying who is who, and whom it is better to tax from a social welfare or moral perspective (the two being by no means always the same). Identify the speculator and tax him, and the hedger will be left searching for scarcer, more expensive cover. Identify the hedger and tax her, and the speculator will suffer the pangs of risk deficiency.

the tithe, the church (and not only the Catholic church, hence the *minuscule)* took a generous skim for management expenses; a sort of ecclesiastical *seigneurage* that has bequeathed us (in the Catholic case) the magnificent cathedrals of Europe. What are the running costs of this fund? All of the leakages discussed in the next section will apply. Who decides who gets what out of the community chest? How should voting rights be assigned? How can the board be voted out?

Tennyson observed that a young man's thoughts turn to love in spring. In a crisis, a politician's thoughts turn to borrowing, which has, since time immemorial, meant debasing the currency; a little if times are good, which they seldom are in a crisis, and a lot if they are bad, which they usually are. The strategy boils down to borrowing good money and paying back bad money; monetary history and Gresham's Law from numismatics are unequivocal on this point. This is not necessarily bad policy, because according to all sound macro-economic reasoning, in an economic crisis, you should throw money at the problem – that is, you should borrow to scrape by in the present while assuming that repaying in the future will not be as painful because the crisis will be past, growth will have intervened, and money will be cheap. From a micro-economic point of view, this is valid consumption smoothing. But do not look at the time of this writing to the *legerdemain* of creating cheap money to get us out of the COVID-19 and Ukraine crises. The global economy has been drowning in liquidity since the birth of "quantitative easing" in the wake of the financial crisis, which is conventionally dated to the collapse of Lehman Brothers in 2008, and the inflationary chickens have come home to roost. For the first time since the 1970s, it appears that central bankers will not bail the global economy out of crisis. They will need years to mop up the flood of liquidity that got us out of the COVID-19 pandemic, even as they are still dealing with the clean-up from the previous crisis. Add to this the significant possibility that the labour shortages that became evident during the COVID-19 pandemic and the higher energy prices triggered by the Russo-Ukrainian War will make current inflation structural, not transitory – this is not a universal view, but it is a credible one.[38]

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[38] There are two common views: the ethicist and the positivist. The *Wall Street Journal* (channeling Nicholas Eberstadt's research [2016]) frets over the decline in American work commitment, which, like comedian Danny Kaye's get-up-and-go, got up and went; and warns of high interest rates for years to come due to labour shortages. The *New York Times* (via columnist Paul Krugman) points out that food and energy prices are well off their peak, and warns of panicked, over-hawkish central bank responses.

To summarise, there is frankly not that much money out there to pursue global sustainable development without avoiding steep consumption cuts.[39] And, to the extent that the sources of money are mostly in the North and the users of money are mostly in the South, the following question presents itself: How do we get the money from here to there?

(ii) Getting Money From North to South

One option can be dismissed, but it raises nice issues. Sometimes explicit and sometimes implicit in sustainable development talk is a massive transfer of wealth from North to South, to be interpreted as compensation for past injustices and indignities inflicted by the North. Like John Barleycorn in the old English folk song, the idea refuses to die; but unlike little Sir John, it is unlikely to prove the strongest man at last. Although such a North-South transfer at the global level is politically doomed, it offers food for serious thought, or at least mathematical recreation. The practical challenge (disregarding the interpersonal and intergenerational welfare comparison riddle, which is insoluble) would be working out the costs and benefits of, say, colonialism – to take the major issue – in order to calculate a transfer that would neither fall short in forcing present and future generations in the North to pay recompense, nor lead to the unjust enrichment of present and future generations in the South. Other factors that must be taken into account are past and future population growth and homogenisation (migration, intermarriage and the like), and how wealth extracted from the South financed technological progress that benefitted everyone, contributed to the development of global trade and financial markets, and so on. To make matters worse, this is in the cut-and-dry world of tort; add criminality (which many activists would, in the form of a crime against humanity, and their argument is not without merit), and we are taken from compensation to reparations. The sky becomes the limit.

Returning to Earth, the global macro-economic challenge of financing the SDGs is made more daunting when the detailed process by which buckets of money are transported from North to South, is examined. U.S. General Omar Bradley said: "Amateurs talk strategy. Professionals talk logistics".

[39] Which explains why the EU has, to the fury of European environmental NGOs, backpedaled on the energy component of the European Green Deal by classifying nuclear and gas as clean sources. Without them, net zero carbon would have to be achieved by energy price increases forcing consumption reductions so steep as to immiserate significant portions of the European population, with terrifying consequences for political leaders.

To achieve this finer resolution, a side excursion into data and accounting issues is required; however, this is consigned to an extended footnote.[40] Of great importance is to underscore from the outset that, when we are dealing with North-South financial flows, we are speaking of official transfers to the governments of low- and lower-middle-income countries (LICs and LMICs). But it is underappreciated by the public at large that upper-middle-income countries (UMICs) – such as Brazil, Chile, South Africa and many others – are not only ineligible for development assistance, but are donors in their own right, albeit not terribly significant ones. When countries "graduate" from LMIC to UMIC status – Vietnam, Colombia, Kazakhstan and a long list of others – they are no longer eligible for the type of support described here. In a nutshell, the countries discussed here are today's left-behinds, explicitly privileged in the sustainable development agenda.[41]

The World Bank (2021) has combined OECD Development Assistance Committee Creditor Reporting System (CRS) data with data from the Bank's own Debtor Reporting System (DRS), and the resulting financial aggregate thus calculated – Official Financial Flows, or OFF – is probably the closest we can come to estimating the Northern financing available to the South in pursuit of the SDGs. Two 800-pound gorillas – foreign direct investment (FDI, the acquisition by Northern investors of

[40] Official Development Aid (ODA) is tracked by the OECD's Development Assistance Committee (DAC) through the Creditor Reporting System (CRS). Only funds from official sources, whether bilateral (i.e., national government agencies like U.S. AID or Swedish Sida) or multilateral (e.g., UN or World Bank or EU), to official recipients (i.e., sovereign entities) are reported. Only that component of the flow that is a concessional contribution to finance recipient-country development programmes is admissible, which can lead to debates over whether a given activity is, to use the jargon, "DACable" (https://www.oecd.org/dac/financing-sustainable-development/development-finance-standards/What-is-ODA.pdf). Loans are DACable so long as they contain a sufficiently high concessional element; typically an interest rate subsidy or repayment delay. Export credits are not DACable, since they serve the commercial interests of the originating country. Military aid and aid designed to strengthen the security of the donor country are not DACable. Only the least developed, low-income (of whom the least developed are a subset) and lower-middle income countries as classified by the World Bank are eligible for ODA.

The CRS covers only financial flows from the 29 country members of the DAC (with the EU counted as one member), plus DAC member funds funneled through the UN, the World Bank, the EU and the regional development banks. Left aside is the massive finance provided to official entities by China, largely in the form of loans; and the smaller but significant funds provided by Brazil and India (South Africa being a member of the DAC), the non-concessional private official financial flows, and the grants by private philanthropies, which have assumed increasing significance in some sectors such as health. Left aside as well is private financial institution lending at market rates to sovereign entities. Also missing, since the recipients are not-DAC eligible, are official flows to upper-middle-income countries. Thus, the CRS gives only a partial picture, albeit one that allows for a great deal of disaggregation by sector and other characteristics.

[41] Leaving serious questions regarding the poor in the countries that have graduated. "'Leave No One Behind' (LNOB) is the central, transformative promise of the 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs)". (https://unsdg.un.org/2030-agenda/universal-values/leave-no-one-behind).

equity stakes in Southern firms) and migrant remittances – are absent from the OFF room. But FDI must be financed by Northern savings (not quite, UMIC sovereign wealth funds such as Malaysia's are significant investors), and migrant remittances must, if they are to be translated into investment, be additional to household savings in the South (i.e., they must represent an increase net of crowding out). Thus, neither omission gets us off the sources-users hook described in the previous section. Missing are flows from non-official sources, such as private philanthropical institutions, whose significance in development finance has grown in recent years, but mainly in health, education and other social sectors.

A helicopter, executive summary-level view of sustainable development finance emerges from the World Bank's analysis of OFF in the years between the end of the global financial crisis (roughly 2010) and the onset of the COVID-19 pandemic (roughly the end of 2019). The findings do not bode well:

- The steady growth of North-South OFF between 2010 and 2019 was mostly due to private, not public, finance; that is, Northern bank lending to Southern sovereign entities and Northern investor purchases of Southern sovereign bonds, both at market-determined rates. In 2010, public flows represented nearly two-thirds of the annual total; in 2019, public and private flows were roughly equal. In 2020, they together represented about USD 300 billion (2019 prices). That amounts to perhaps a tenth of the developing-country SDG financial requirements reported above for infrastructure alone.
- As private has replaced public finance, indebtedness ratios have risen *pari passu,* and creditworthiness has declined, placing future borrowing in jeopardy.
- The share of OFF not allocated to specific countries – which essentially consists of emergency humanitarian responses, invariably in the form of grants, to provide relief for natural catastrophes and conflict situations (including support to refugees in destination countries, whether rich or poor) – has quadrupled, and now amounts to about one-fifth. In other words, OFF are increasingly devoted to firefighting, not to finance for development, as they were traditionally conceived.

In rhetoric, closing on a down note is generally inadvisable. It leaves the reader or listener disconsolate and confused, because the penultimate down begs for a concluding up. But it is difficult to find an upbeat note on which to end this section. An explosion of North-to-South public (or private) charity in the form of grants is unlikely since the North faces problems of its own. Outside the ranks of the subspecies of *Homo sapiens* that Huntington (2004) called Davos Man – the capitalists who sow the seeds of their own destruction, as Schumpeter (1942) observed – post-colonial "wokeness" with cash to back it up is hard to find, despite all efforts at awareness raising. There is justifiable suspicion that, 75 years into the development project, many of the problems of the poorest countries have been self-inflicted, or, even if they were inherited from an unfair pre-project global system, have been unaddressed other than through enabling a privileged class to profit from them, and are now self-perpetuating.

The Global South is not worth lending to these days for the reasons discussed above, and FDI is stymied by low scores on what the World Bank terms "ease of doing business", and the Heritage Foundation calls "economic freedom".[42] These institutions, at opposite ends of the ideological spectrum, share the same concerns: corruption; weak Rule of Law as it concerns corporate governance, contracts, tort and property rights; administrative red tape; and a lack of transparency and accountability overall. In the poorest countries, where the needs are the greatest, there is impatience with the inability of dubious governments to collect the taxes they are owed, and with the haemorrhage of money into another three C's: corruption, criminal enterprise and capital flight. Outside of unsavoury sources – principally China, which is always willing to lend to gain strategic advantage – increasing private finance to the countries that are most in need of it would require drastic improvements in governance – which are precisely what China does not demand.[43]

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[42] Conventional wisdom is that investment in developing economies should reward investors both based on economic fundamentals (capital is scarce and labour is abundant there, the opposite of the situation in the developed world), and because myopic Northern investors overestimate the risk premium (cultural and linguistic unfamiliarity, information asymmetry, perhaps more than a pinch of racism). Alas! Over the last decade, American mid-cap stocks have outperformed emerging economy equities by a furlong, while U.S. high-yield bonds have outperformed emerging economy debt. These are roughly comparable equity and fixed-income asset classes. If anything, the combined COVID-19-Ukraine shock may lead to a significant rebalancing of global financial portfolios out of the South and into the North (see the natural interest rate comment below) – presumably with a preference for American markets because of the exposure of Europe to Russia.

[43] The list of borrowers from China now in distress is long, but Sri Lanka, Pakistan, Zambia and Ethiopia give an idea of the global range. The traditional venue for international debt workout is the Paris Club, which since the 1960s has operated effectively on the simple principle that when things go wrong, both borrowers and lenders must take a hit, after which they can pick themselves off the floor and get on with business. China (not a member) rejects that model, simply offering borrowers who are in trouble new loans, a technique known to the public as throwing good money after bad, but to those in finance as "evergreening" (https://www.nytimes.com/2022/07/22/opinion/china-debt-belt-road.html). The charitable view is that China is simply a newcomer to international finance and has yet to learn the rules of the game. Also not to be overlooked are Chinese equity interests, which are often hidden in the political and military shadows where the writ of Generally Accepted Accounting Principles (GAAP) does not apply: for example, Cambodia, Lao and Myanmar have been bought lock, stock and barrel.

RESEARCH ARTICLES

Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 85–106

Effects of income inequality on COVID-19 infections and deaths during the first wave of the pandemic: Evidence from European countries

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Abstract

Evidence from research on infectious diseases suggests that income inequality is related to higher rates of infection and death in disadvantaged population groups. Our objective is to examine whether there was an association between income inequality and the numbers of cases and deaths during the first wave of the COVID-19 pandemic in European countries. We determined the duration of the first wave by first smoothing the number of daily cases, and then using a LOESS regression to fit the smoothed trend. Next, we estimated quasi-Poisson regressions. Results from the bivariate models suggest there was a moderate positive association between the Gini index values and the cumulated number of infections and deaths during the first wave, although the statistical significance of this association disappeared when controls were included. Results from multivariate models suggest that higher numbers of infections and deaths from COVID-19 were associated with countries having more essential workers, larger elderly populations and lower health care capacities.

Keywords: COVID-19; income inequality; first wave; European countries

1 Introduction

In early 2020, a new coronavirus, SARS-CoV-2, also called COVID-19, arrived in Europe from China. Mass outbreaks were first recorded in Italy and Spain, and the virus then spread rapidly across the continent. Although European governments adopted emergency measures to contain the pandemic's advance, differences in the

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DOI: 10.1553/populationyearbook2022.res1.1

numbers of infections and deaths have been observed between countries. While studies on the socioeconomic differences in the levels of COVID-19 infections and deaths have been conducted in several European countries, none of these studies compared these differences between countries.

The previous literature on this topic has pointed out that a disease can affect societies differently depending on the vulnerability of their populations due to conditions such as inequality or poverty. For instance, there is some evidence of a positive association between income or wealth and self-reported health status (Bor et al., 2017). Thus, health economists have argued that people with lower socioeconomic status face worse health outcomes than their counterparts with higher status, and that these differences can be explained in large part by two mechanisms: health behaviour and access to health care (Bor et al., 2017; Santerre and Neun, 2012). The first mechanism refers to the tendency of poorer and less educated people to be less well informed and less careful due to a lack of knowledge and awareness of their health. The second mechanism refers to evidence that poorer and less educated people tend to seek medical care less often, either because they cannot stop working, or because they are concerned about the costs associated with illness. Moreover, in the case of respiratory infectious diseases, social interaction is a crucial determinant of the likelihood of becoming ill. When infected people engage in economic or social activities, the risk of infection increases for healthy individuals (Jung et al., 2020). In the current pandemic, wealthier individuals have generally had more resources to self-isolate and telework, while people with lower incomes have often been performing essential or manual work that cannot be done remotely (Brown and Ravallion, 2020; Jung et al., 2020; Lekfuangfu et al., 2020; Papageorge, 2020; Takian et al., 2020). Thus, the transmission pathways and risk exposure levels have differed between socioeconomic groups. These societal inequities have highlighted the vulnerability of the least favoured groups.

Income inequality is one of the non-biological factors that has been used to explain adverse health outcomes, as it can affect the prevalence and consequences of poor health within societies. Compared to middle- and high-income households, low-income households tend to have lower life expectancy, higher mortality and worse health status, even in developed countries (Bor et al., 2017; Jijiie et al., 2019; Kawachi and Kennedy, 1999; Krisberg, 2016; Lynch et al., 1998, 2000; Meara et al., 2008; Neliss, 1999; Olshans et al., 2012; Pickett and Wilkinson, 2015; Rehnberg et al., 2019; Shkolnikov et al., 2007; Villegas and Haberman, 2014). Historically, life expectancy and mortality have been unequal between the richest and the poorest populations (Ahmed et al., 2020). In addition, more unequal societies tend to spend less on income redistribution policies, such as strengthening health care systems (Mello, 2006).

Disparities arising from income inequality have also been observed in analyses of the effects on populations of infectious respiratory diseases of viral origin. Studies on the impact of seasonal influenza have found associations between socioeconomic status and mortality, morbidity and symptom severity (Crighton et al., 2007; Tam et al., 2014). Evidence from research on the Spanish flu, a pandemic comparable to

COVID-19 in terms of its global reach, indicates that mortality rates were higher among the poorest people (Bengtsson et al., 2018; Grantz et al., 2016; Mamelund, 2006; Murray et al., 2006; Sydenstricker, 1931). However, no such mortality differences by socioeconomic status were found in countries with low levels of economic and social inequality (Rice, 2005; Summers et al., 2014). The findings of research on the effects of a more recent pandemic, the 2009 H1N1 influenza, were similar. For example, several studies have found that H1N1 influenza mortality was higher among the most deprived social groups in developed countries (Biggerstaff et al., 2014; Lowcock et al., 2012; Rutter et al., 2012), while a cross-country analysis showed that H1N1 influenza mortality was higher in low-income than in high-income countries (Charu et al., 2011). The socioeconomic disparities in H1N1 influenza mortality and morbidity have been attributed to differences in levels of exposure to the virus, susceptibility to the disease, and access to health care once the disease had developed (Rutter et al., 2012).

The evidence that large income differences have damaging health and social consequences is, therefore, strong. Moreover, it has been argued that the COVID-19 pandemic could exacerbate these differences, as inequality could increase the pace of the spread of the disease (Ahmed et al., 2020; Brown and Ravallion, 2020). For instance, it has been observed that people in countries with greater income inequality have been less likely to adopt preventive health measures, such as isolation, physical distancing, and the use of masks and hand disinfection (Elgar et al., 2020; Papageorge, 2020; Pirisi, 2000). In addition, initial findings on the effects of the pandemic suggest that people in the lower socioeconomic groups have been facing more severe consequences, and that income inequality might explain the differences in the numbers of cases and deaths within and across countries. Results from the United States show that infection and mortality rates from COVID-19 are higher in the states and counties where income inequality or poverty levels are higher (Brown and Ravallion, 2020; Chen and Krieger, 2020; Jung et al., 2020; Mollalo et al., 2020; Mukherji, 2020; Oronce et al., 2020). For Brazil, there is evidence of a positive and significant correlation between income inequality and COVID-19 mortality (Demenech et al., 2020; Martines et al., 2021). Studies conducted in Germany, Israel and Spain have shown that infection rates in these countries have varied based on income inequality, with socioeconomically disadvantaged populations being more likely to be infected (AQuAS, 2020; Arbel et al., 2020; Wachtler et al., 2020). A comparative study of the 10 countries worldwide that have been the most affected by the pandemic used a multidimensional index, including income inequality, to show that the worse off a country is, the greater the impact of COVID-19 has been (Ruiz Estrada, 2020). A study comparing the number of deaths per day in 80 countries concluded that mortality tends to increase more rapidly in countries where inequality is greater (Elgar et al., 2020).

During the first pandemic wave, one of the measures governments used to deal with the threat was the imposition of severe restrictions on mobility, which in most cases meant that the population was ordered to stay home whenever possible. Teleworking became widespread for all non-essential workers. However, essential workers, mostly in manual or machine-based activities, had to continue working face-to-face and commuting to their workplaces, or risk losing their jobs (Adams et al., 2020; Ahmed et al., 2020; Lekfuangfu et al., 2020). Studies conducted in England and Wales and in Thailand found that the use of public transport to commute to work was associated with increased risk of COVID-19 infection (Lekfuangfu et al., 2020; Sá, 2020). Analyses of geolocation data from the United States showed that lower-income workers continued to move around during lockdowns, while higher-income workers tended to stay at home and limit their exposure (Buchanan et al., 2020). Another study concluded that the U.S. counties with the highest levels of income inequality had higher rates of infection, as the lower-income workers in these counties were less able to maintain social distancing because of their work activities (Brown and Ravallion, 2020).

The research to date has analysed the effects of income inequality on variations in COVID-19 infections within countries. However, only a few cross-country comparative studies have analysed how the COVID-19 pandemic has affected countries depending on their socioeconomic differences, and none of these studies has focused on Europe. Thus, our objective is to examine whether there was an association between income inequality and the numbers of cases and deaths during the first wave of COVID-19 in European countries. Although Europe is considered to have lower inequality than other regions, evidence from past pandemics has shown that even in European countries, there have been differences in health outcomes associated with income distribution. Due to the rapid spread of the virus, and to a lack of knowledge about how to combat it among both scientists and the general public, governments did not have a plan for protecting the most deprived social groups. Thus, analysing the effects of the first wave of the COVID-19 pandemic on European countries can help us examine the differences in health outcomes associated with socioeconomic inequities. More unequal countries were already more likely to have adverse health outcomes and weaker health care systems. Therefore, income inequality may have played a significant role in exacerbating these existing vulnerabilities during the COVID-19 pandemic.

2 Data and methods

To conduct our analysis, we use as dependent variables the cumulated number of infections and deaths at the end of the first wave. We have collected the daily number of COVID-19 cases and deaths from Our World in Data (2020), one of the specialized data repositories that has compiled global information on the evolution of the pandemic.

It should be noted that although the virus spread rapidly through Europe, not all countries were affected at the same time, and the evolution of the disease differed from one country to another. Therefore, we have harmonized the analysis period by estimating the duration of the first wave for each country using the reported number of cases per day from January 2020 to January 2021. To do so, we first smoothed the daily number of infections using a seven-day moving average. Then, we used a local polynomial regression – i.e., locally estimated scatterplot smoothing (LOESS) – to fit the trend. As the result is a sinusoidal type pattern due to the multiple waves, we considered the first wave to be the first hump of the LOESS fit. We defined the onset as the day on which the 100th case was reported, and the end as the day on which the slope of the fitting curve did not show a statistically significant decrease after the number of cases per day was at least half that at the peak.

For illustrative purposes, Figure 1 shows the smoothed trends and fitting curves in several countries. For most European countries, the first wave lasted from mid-March to late June, and it did not go beyond August 2020 in any European country. Although the number of infections per day was already declining by the end of January 2021 in Moldova and Ukraine, these two countries were excluded as they showed no signs of having completed the first wave. Table 1 displays the details of the first wave.

Our variable of interest is income inequality. To measure income inequality, we use the Gini index, which is distributed from zero, indicating totally equal distribution, to 100, indicating totally unequal distribution. We collected the latest reported Gini index results from the World Bank Open Data repository (World Bank, 2020). Figure 2 displays the Gini index values across the countries included in our sample. The Gini index values range from 24.2 to 40.4, and the sample mean is 31.7. Europe is considered the most egalitarian continent in the world. At the regional level, the Scandinavian and Eastern European countries generally have the most egalitarian income distributions, while income inequality tends to be highest in the Balkan countries.

Since recent studies have found that certain socioeconomic and demographic characteristics can help to explain how COVID-19 has affected a particular country, we include them in our analysis to control our estimates. Most of these studies agree that the relevant characteristics include age structure, as age might reflect the incidence of pre-existing health conditions (Brown and Ravallion, 2020; Esteve et al., 2020; Gardner et al., 2020; Kashnitsky and Aburto, 2020; Nepomuceno et al., 2020); poverty and education, as they are strong determinants of health outcomes (Bor et al., 2017; Brown and Ravallion, 2020; Santerre and Neun, 2012); numbers of essential workers, as these workers are more exposed to infection because they use public transport and have face-to-face contact (Adams et al., 2020; Ahmed et al., 2020; Lekfuangfu et al., 2020; Sá, 2020); population density, as infected and uninfected individuals are more likely to interact in denser settings (Brown and Ravallion, 2020); social contact, as the risk of infection increases at higher levels of social contact (Aparicio and Grossbard, 2020; Cristini and Trivin, 2020); and health care capacities, as the pandemic has exposed vulnerabilities in health care systems (Hopkins Tanne et al., 2020; Mollalo et al., 2020; Nepomuceno et al., 2020), and health care capacities have played a role in how hard each country has been hit by the disease. To include these controls in our analysis, we collected information from various sources, while always using the latest reported data for each variable.

Figure 1:
Smoothing and fitting the number of infections per day in selected countries over a 180-day period

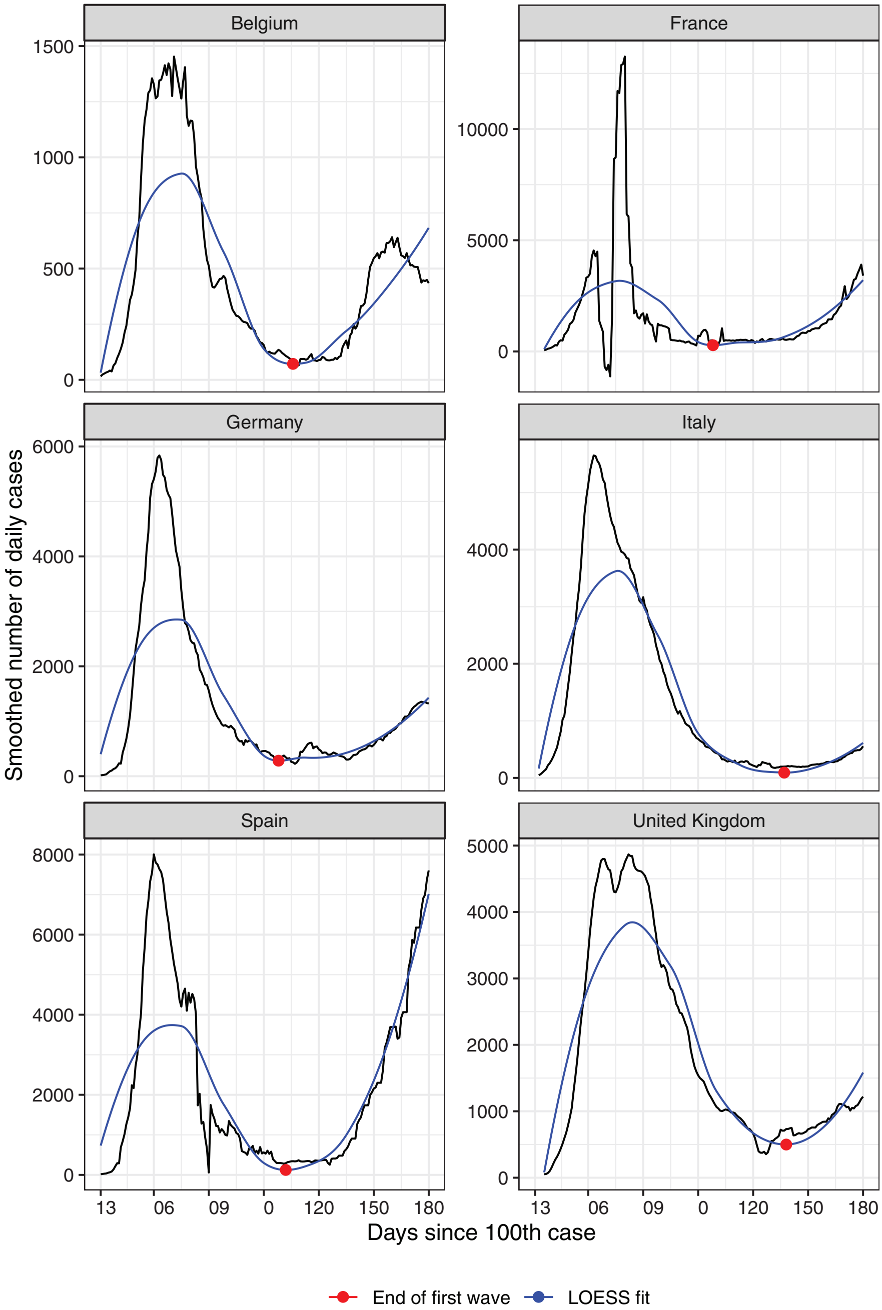
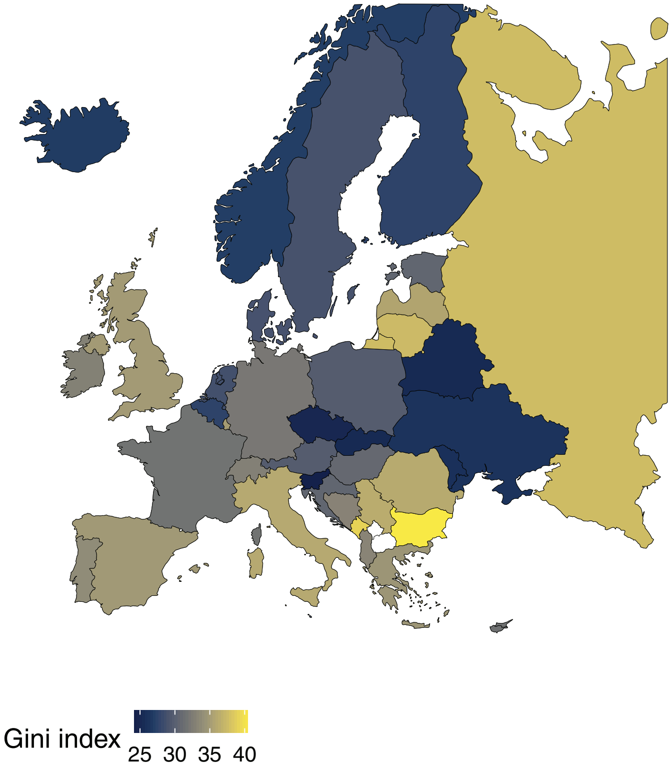


Table 1:
Details of the first wave of COVID-19 in European countries

		First wave				
Country	**1st case**	**Start**	**End**	**Days**	**Total cases**	**Total deaths**
Albania	March 09	March 23	May 14	53	898	31
Austria	February 25	March 08	May 22	76	16,436	635
Belarus	February 28	March 30	August 17	141	69,589	613
Belgium	February 04	March 06	June 19	106	60,476	9,695
Bosnia and Herzegovina	March 05	March 22	May 28	68	2,462	153
Bulgaria	March 08	March 20	May 25	67	2,433	130
Croatia	February 25	March 19	June 02	76	2,246	103
Cyprus	March 09	March 23	June 23	93	990	19
Czechia	March 01	March 13	May 20	69	8,721	304
Denmark	February 27	March 10	June 24	107	12,815	603
Estonia	February 27	March 14	July 04	113	1,993	69
Finland	January 29	March 13	July 09	119	7,273	329
France	January 24	February 29	June 05	98	192,450	29,114
Germany	January 27	March 01	June 06	98	185,450	8,673
Greece	February 26	March 13	May 28	77	2,906	175
Hungary	March 04	March 21	July 03	105	4,172	588
Iceland	February 28	March 12	May 23	73	1,804	10
Ireland	February 29	March 14	June 30	109	25,473	1,736
Italy	January 31	February 23	July 08	137	242,149	34,914
Latvia	March 02	March 20	June 23	96	1,111	30
Lithuania	February 28	March 22	June 09	80	1,727	72
Luxembourg	February 29	March 17	May 23	68	3,990	109
Malta	March 07	March 23	June 24	94	665	9
Montenegro	March 17	March 31	May 29	60	324	9
Netherlands	February 27	March 06	June 22	109	49,866	6,109
Norway	February 26	March 06	June 28	115	8,855	249
Poland	March 04	March 14	June 30	109	34,393	1,463
Portugal	March 02	March 13	August 02	143	51,463	1,738
Romania	February 26	March 14	June 07	86	20,479	1,333
Russia	January 31	March 17	August 12	149	900,745	15,231
Serbia	March 06	March 19	June 01	75	11,430	244
Slovakia	March 06	March 18	June 02	77	1,522	28
Slovenia	March 05	March 13	May 27	76	1,471	108
Spain	February 01	March 02	June 11	102	242,707	27,136
Sweden	February 01	March 06	August 29	177	83,958	5,821
Switzerland	February 25	March 05	June 05	93	30,936	1,921
United Kingdom	January 31	March 02	July 17	138	294,803	41,060

Figure 2:
Gini index in European countries



To account for (i) age structure, we use the latest projection of total population from the World Population Prospects (United Nations, 2020) to compute the share of people aged 65 and older. For (ii) education, we use the share of population with at least upper secondary school for the population aged 25 and older[1] (UNESCO, 2020). For (iii) essential workers, we use the share of people working in industry[2] (ILO, 2020). For (iv) population density, we use the share of the population living in urban areas (United Nations, 2018). For (v) social contact, we use the number of flight departures (domestic and international) (World Bank, 2020). For health capacities, (vi) we use the number of physicians – i.e., generalist and specialist medical practitioners – per thousand inhabitants (World Bank, 2020), and (vii)

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[1] Path to data is SDG/Sustainable Development Goals 1 and 4/Sustainable Development Goal 4/Target 4.4/Share of population by educational attainment.

[2] This information can be found as part of the "Employment distribution by economic activity" indicator.

the number of hospital beds per 10,000 inhabitants (WHO, 2020). In addition, to account for any possible effects of a government's response to the crisis, we include two controls: the number of days between the first case and the localized or national lockdown (Dunford et al., 2020), and the ideological orientation of the government (CIDOB, 2021). In the first case, we consider the possibility that a late response could have contributed to the pandemic hitting the country harder. It should be noted that only Belarus did not adopt a lockdown policy. Therefore, we use the duration of the first wave as the number of days. In the second case, we consider the possibility that the ideological orientation of the government may have had an effect on the dependent variables and the variable of interest through the unobserved preferences (of individuals or governing parties) regarding income redistribution, or through measures taken to control the pandemic. To account for this possibility, we include a dichotomous variable that takes the value of one when the ideology is right or centre-right, and a value of zero for other ideologies.

We use data from all European countries with complete information. Thus, we include 37 European countries in our study, and our sample covers 94% of Europe's population.

We first estimate a bivariate model for each dependent variable, including only the Gini index as an explanatory variable. Second, we estimate multivariate models that include the controls specified above. The reported numbers of cases and deaths are the count data. Poisson distribution is used for modelling the number of times an event occurs in an interval of time or space. Poisson regression assumes that the logarithm of its expected value can be modelled by a linear combination of its parameters:

$$\log(E(Y \mid X)) = X\beta$$
$$E(Y \mid X) = e^{X\beta}$$

where X is a vector of independent variables, and β is the set of parameters. While a Poisson model assumes that the variance ($var(Y)$) is equal to the mean ($E(Y \mid X) = \mu$), this assumption does not always hold true. When the variance is greater than the mean – i.e., when there is overdispersion – either quasi-Poisson or negative binomial regression models are more appropriate (Ver Hoef and Boveng, 2007). Quasi-Poisson models assume that the variance is a linear function of the mean, $var(Y) = \theta\mu$, where θ is an overdispersion parameter. Negative binomial models assume that the variance is a quadratic function of the mean, $var(Y) = \mu + \alpha\mu^2$, where the overdispersion is the multiplicative factor $1 + \alpha\mu$. Overdispersion tests on our sample showed that the null hypothesis $var(Y) = \mu$ is rejected. Then, following Ver Hoef and Boveng (2007), we have performed a diagnostic analysis (not shown) plotting the fit of the variance, using averaged squared residuals, to the mean. The results suggest that the quasi-Poisson model fits the variance-mean relationship better.

Finally, it should be noted that the values of the number of infections and deaths vary widely across countries due to their different population sizes. Thus, we include in all regressions the log of total population as an offset,

$$\log(E(Y\,|\,X)) = \log(pop) + X\beta$$

then,

$$\log(E(Y\,|\,X)) - \log(pop) = \log\left(\frac{E(Y\,|\,X)}{pop}\right) = X\beta$$

3 Results

In Europe, the first wave lasted an average of 98 days (see Table 1). During this time period, there were 2,581,181 confirmed COVID-19 cases and 190,564 confirmed deaths from the disease in the 37 countries included in our study. The longest first waves were in Sweden (177 days), Russia (149 days) and Portugal (143 days); while the shortest first waves were in Albania (53 days), Montenegro (60 days) and Bulgaria (67 days).

The upper panel of Figure 3 shows the cumulated number of infections per million population (p.m.p.) during the first wave by country. The solid line represents the average of the sample, which was 3,707.5 infections p.m.p. It is not a coincidence that the countries with the highest numbers of infections were Sweden (8,313.3 infections p.m.p.) and Belarus (7,364.4 infections p.m.p.). In both countries, no measures were taken to restrict social contact, which also explains why Sweden had the longest first wave. The countries with the lowest numbers of infections, coinciding with the shortest first wave durations, were Slovakia and Greece (both with 279 infections p.m.p.), followed by Albania (312 p.m.p.) and Bulgaria (350.1 p.m.p.).

The lower panel of Figure 3 displays the cumulated number of deaths during the first wave of COVID-19. The solid line shows the average in our sample, at 273.7 deaths p.m.p. Belgium had the highest mortality rate by far, at 836.5 deaths p.m.p., followed by the United Kingdom (604.8 deaths p.m.p.), Spain (580.4 deaths p.m.p.), Italy (577.5 deaths p.m.p.), Sweden (576.4 deaths p.m.p.) and France (446 deaths p.m.p.). Except in Sweden, a higher infection rate in a country did not necessarily predict higher mortality. Among the possible explanations for this finding are that complications from infections might have been exacerbated by vulnerabilities at the individual level, and that the responsiveness of the countries' hospital systems could have varied.

The upper panel of Figure 4 plots the Gini index and the number of infections. Pearson's correlation estimation suggests that there was a moderate positive association of 0.287 (95% CI = 0.076–0.474) between these two variables. The per capita risk of infection increased by 1.08 (95% CI = 1.03–1.14, se = 0.028) for every unit of increase in the Gini index (see column [1] of Table 2). After including controls (see column [2] of Table 2), the association became weaker (1.04), such that the confidence interval now included one (95% CI = 0.98–1.09, se = 0.027).

Figure 3:
Cumulated number of infections and deaths per million population (p.m.p.) during the first wave of COVID-19

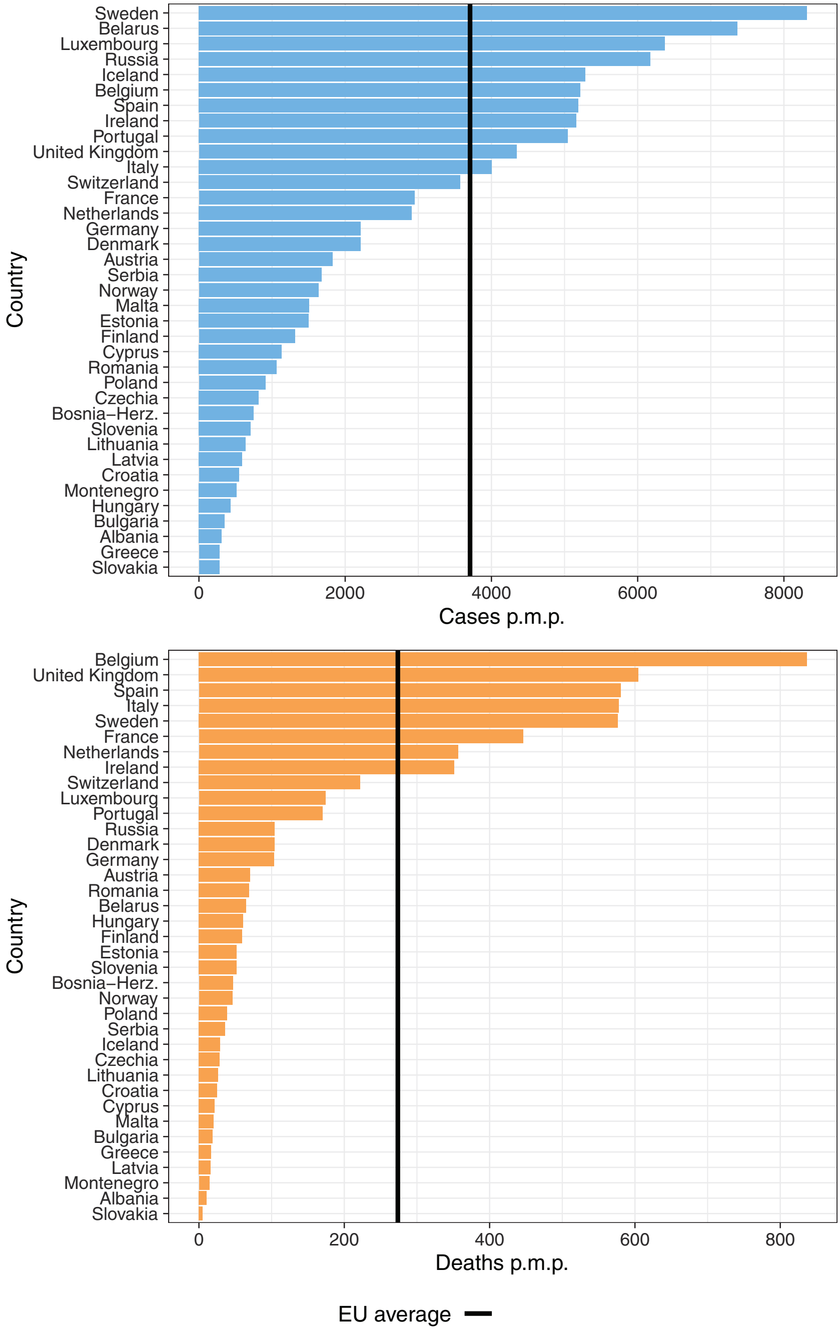
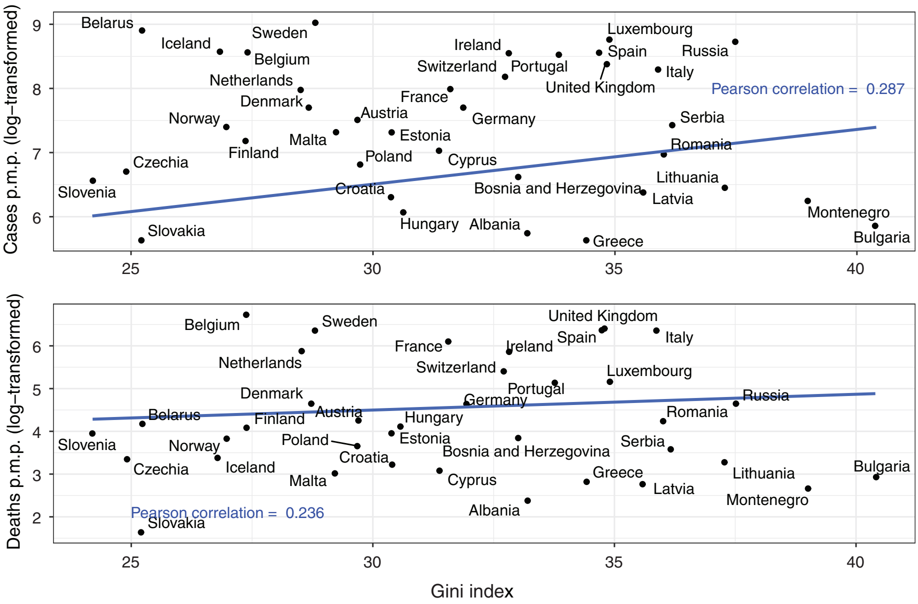


Figure 4:
Number of infections and deaths per million population (p.m.p.) during the first wave of COVID-19 and the Gini index



The lower panel of Figure 4 shows a positive correlation between the Gini index and the number of deaths, although it was weaker than the correlation found for infections. The Pearson's correlation estimation was 0.236 (95% CI = 0.02–0.43). The per capita risk of death increased by 1.01 (95% CI = 0.93–1.10, se = 0.043) for every unit of increase in the Gini index (see column [3] of Table 2). In this case, the per capita risk increased to 1.05 after the controls were included (see column [4] of Table 2), but the confidence interval still included one (95% CI = 0.97–1.14, se = 0.042).

The results for the other covariates are presented in columns [2] and [4] of Table 2. A higher share of the population with at least upper secondary school was connected to lower per capita risk. Our results indicate that the share of better educated people was associated with a reduction in the risk of infection of 0.99 (95% CI = 0.97–0.99, se = 0.008), and with a reduction in the risk of death of 0.98 (95% CI = 0.96–0.99, se = 0.011). Consistent with increased exposure to risk, the per capita risk of infection increased by 1.04 (95% CI = 1.01–1.09, se = 0.027) with the proportion of industrial workers. However, the evidence does not necessarily suggest that the proportion of industrial workers was related to the risk of death.

The more people who travelled, whether internationally or domestically, the faster the virus spread. Our results show that the risk of infection was 1.15 (95% CI = 1.01–1.34, se = 0.070) higher in countries where more flights departed. Similarly,

Table 2:
Per capita risk of the number of infections and deaths during the first wave of COVID-19. Quasi-Poisson regressions including log of population as an offset. Standard errors are in parentheses, and 95% confidence intervals are in brackets

	Cases		Deaths	
Variable	**[1]**	**[2]**	**[3]**	**[4]**
Gini	1.08 [1.03–1.14] (0.028)	1.04 [0.98–1.09] (0.027)	1.01 [0.93–1.10] (0.043)	1.05 [0.97–1.14] (0.042)
Education		0.99 [0.97–0.99] (0.008)		0.98 [0.96–0.99] (0.011)
Workers		1.04 [1.01–1.09] (0.027)		1.00 [0.93–1.08] (0.038)
65+		0.83 [0.77–0.90] (0.038)		1.07 [1.01–1.13] (0.049)
Urbanization		1.03 [1.01–1.06] (0.013)		1.05 [1.02–1.09] (0.017)
Flights		1.15 [1.01–1.34] (0.070)		1.30 [1.02–1.79] (0.144)
Physicians		1.32 [1.06–1.64] (0.112)		0.57 [0.39–0.79] (0.179)
Beds		0.99 [0.98–1.00] (0.005)		0.99 [0.98–0.99] (0.006)
Lockdown		1.01 [1.00–1.01] (0.004)		1.00 [0.97–1.02] (0.011)
Right party		0.74 [0.50–1.09] (0.201)		0.65 [0.34–1.18] (0.312)
Goodness of fit				
Deviance	704,869.71	195,864.68	147,246.63	20,676.46
Dispersion	20,177.68	7,048.83	4,126.82	851.25
Chi sq.	706,218.67	183,269.47	14,4438.64	22,132.6

the decision to impose restrictions on movement helped to slow the spread of the virus. According to our estimates, each additional day that a government delayed taking measures to restrict movement, such as lockdowns, increased the risk of infection by 1.01 (95% CI = 1.00–1.01, se = 0.004). On the other hand, having a right-wing or centre-right government was associated with a lower risk of infection, at 0.74 (95% CI = 0.50–1.09, se = 0.201), and of death, at 0.65 (95% CI = 0.50–1.09, se = 0.312).

Per capita risk increased with urbanization. As in the case of infections, a higher share of the population living in urban areas was associated with the virus spreading more rapidly. In our sample, the risk increased by 1.03 (95% CI = 1.01–1.06, se = 0.013) for each additional percentage point of urbanization. The higher risk of death (1.05, 95% CI = 1.02–1.09, se = 0.017) may be explained by the saturation that existed in hospitals during the peak of the pandemic. The countries where a higher proportion of the population was aged 65 and older had a lower risk of infection, at 0.83 (95% CI = 0.77–0.90, se = 0.038), but a higher risk of death, at 1.07 (95% CI = 1.01–1.13, se = 0.049). These findings show the two faces of this pandemic: i.e., most of those infected with COVID-19 were under age 50, while mortality was concentrated among the elderly.

The COVID-19 pandemic has tested the capacities of countries' health care systems, and has revealed weaknesses in many of them. Increasing one hospital bed per 10,000 inhabitants slightly decreased the risk of death from COVID-19 by 0.99 (95% CI = 0.98–0.99, se = 0.006). Of all of the variables included in our analysis, we found that the highest per capita risk was associated with the number of doctors. Increasing one physician per thousand population decreased the risk of death by 0.57 (95% CI = 0.39–0.79, se = 0.179). However, the presence of more physicians was associated with a higher risk of infections, at 1.32 (95% CI = 1.06–1.64, se = 0.112). One possible explanation for this result is that the presence of more physicians increased the likelihood of detecting infections, either because there was a greater capacity to test for COVID-19 when tests were carried out in physician practices, or because there was an increase in the number of doctor visits by symptomatic individuals who were subsequently referred to testing.

4 Discussion

Evidence from past pandemics has shown that the rates of infection and mortality tend to be higher in the most vulnerable socioeconomic status groups, especially in countries with higher levels of social inequality (Bengtsson et al., 2018; Grantz et al., 2016; Mamelund, 2006; Murray et al., 2006; Sydenstricker, 1931). Moreover, evidence from recent country case studies has suggested that this pattern has persisted during the COVID-19 pandemic. Our cross-country study focused on the question of whether varying levels of income inequality were associated with differences in the numbers of infections and deaths across European countries during the first wave of the pandemic.

Unlike other studies that analysed the effects of COVID-19 during its first stage, we did not use an ad-hoc analysis period. Instead, we developed a method to determine the duration of the first wave of the pandemic. To do this, we started our analysis period on the day on which the first case was reported, and ended it on the last day for which we could update the data (January 2021). Thus, our potential study period covered one year. Then, by smoothing the daily cases and fitting the smoothed trend, we determined the duration of the first wave for each country. To the best of our knowledge, this is the first study that has used this approach to homogenize the comparisons between countries.

After analysing the bivariate relationships, we found a moderate positive association between income inequality, as measured by the Gini index, and the numbers of infections and deaths during the first wave of COVID-19. To some extent, the Gini index captured the presence of groups living under vulnerable conditions within a given population. Previous evidence indicates that deprived groups tend to have worse health outcomes (Bor et al., 2017; Santerre and Neun, 2012). The positive relationship we found in the bivariate models suggests that the pandemic had a disproportionate impact on disadvantaged populations.

Based on our results, we draw several conclusions. First, unlike other known pandemics, the COVID-19 pandemic triggered a simultaneous global response aimed at stopping the spread of the virus. Thus, governments around the world imposed restrictions on movement and closed borders. In Europe, the pandemic-related lockdowns lasted approximately three months, and began an average of 20 days after the first case was reported. It appears that these measures protected countries with the highest levels of social vulnerability from the effects of the pandemic during the first wave. Indeed, there is evidence that the infection and death rates were higher during the second and third waves (Our World in Data, 2020), when the mobility restrictions were milder. We will analyse these differences in further research.

Second, methods for collecting the number of deaths varied from one country to another, which has led to underreporting in some cases (Harries, 2020; Hirsch and Martuscelli, 2020). In other words, the observed number of deaths varied across countries depending on the (unobserved) reporting policy, which may have led to biases. We intend to test our hypothesis using excess mortality as the dependent variable once data for all European countries (and for less developed countries) become available. Similarly, the number of infections may have been affected by differences in testing policies between countries. Testing levels were lower during the first wave than they were during subsequent waves.

Third, one of the characteristics of this pandemic has been the rapid speed of the spread of the virus across populations. Although the proportion of people infected with COVID-19 during the first wave who became severely and critically ill can be considered low, given the large numbers of people who were infected, this relatively small proportion resulted in high absolute numbers of critically ill people, which, in turn, placed great pressure on health care systems. In general, European countries have public and universal health care systems, which may reduce the effects of social inequity. However, our results show that even in Europe, there were differences between countries in the risk of death associated with more doctors and greater hospital capacity during the first pandemic wave. A potential explanation for this finding is that more unequal societies devote fewer resources to redistributive policies, such as health care (Mello, 2006).

Fourth, during the first pandemic wave, not everyone had the option to stay home and telework. Essential workers continued to commute to their workplaces, and were more exposed to the virus than white-collar workers (Adams et al., 2020; Ahmed et al., 2020; Lekfuangfu et al., 2020; Sá, 2020). In turn, the work activities of these individuals increased the risk of infection for their cohabitants (Aparicio and Grossbard, 2020). Our estimates show a clear relationship between infections and the proportion of the population working in essential activities. Given that most of these workers had lower incomes, our results show another dimension of the link between income inequality and the pandemic.

In summary, we found a moderate positive association between income inequality and the numbers of COVID-19 infections and deaths in our models without controls. However, after the controls were included, the statistical significance of this association disappeared. Thus, the link between socioeconomic inequalities and infectious diseases was no longer obvious once the correlations among multiple covariates were accounted for (Brown and Ravallion, 2020). Our results are consistent with previous evidence showing that the effects of socioeconomic inequalities on health outcomes tend to be smaller in countries that already had relatively low levels of social and economic inequality prior to the onset of the pandemic (Rice, 2005; Summers et al., 2014). In further research, we intend to explore this association at the subnational level (e.g., NUTS II level), or at the individual level.

Turning to the policy implications of our findings, we recommend that governments constantly prioritize the protection of vulnerable groups in their contingency plans. On the other hand, further research is needed about, among other pandemic-related topics, the effects of lockdowns. For instance, the closure of non-essential businesses across Europe has contributed to increased unemployment, poverty and inequality. Moreover, the impact on mental health of remaining isolated, of increased uncertainty, and of feeling vulnerable when social interactions are re-established should be assessed.

Acknowledgments

The author would like to thank Ashira Menashe-Oren, Benjamin-Samuel Schlüter and Bruno Schoumaker for their comments on a previous version of this manuscript; and Damien Courtney, Alexia Fürnkranz-Prskawetz and Miguel Sánchez-Romero for providing useful feedback during the presentation of this research at the Wittgenstein Centre Conference 2020.

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Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 107–141

Assessing the generational impact of COVID-19 using National Transfer Accounts (NTAs)

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Abstract

An important aspect of the current COVID-19 crisis is that not all age groups are equally affected by the pandemic. To account for the generational impact of COVID-19, a dynamic overlapping generations model with realistic demography, human capital and NTAs is constructed. The COVID-19 crisis is modelled through two unexpected and temporary negative shocks: an economic shock that reduces labour income, and a demographic shock that increases the mortality hazard rates of those infected. The model is applied to 12 countries for which full NTA data are available. Results are presented for two extreme fiscal policies: one in which governments compensate workers for 0% (without fiscal support) of their total labour income losses due to the pandemic, and another in which governments compensate workers for 100% (with fiscal support) of these losses. In addition, I analyse the impact of these policies on public debt. The results show that COVID-19 is affecting the financial situations of people aged 25 to 64 and their children more than those of older people. By compensating workers for their income losses, the economic impact of COVID-19 has been more evenly distributed across cohorts, reducing the burden on people aged zero to 64, and increasing the burden on people aged 65 and older. Moreover, the simulation results show that a 1% decline in labour income leads to an average increase in the debt-to-total labour income ratio of between 1.2% (without fiscal policy) and 1.6% (with fiscal policy).

Keywords: COVID-19; National Transfer Accounts; overlapping generations; lifecycle model, generational accounts; debt

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DOI: 10.1553/populationyearbook2022.res1.2

1 Introduction

The COVID-19 pandemic has affected all aspects of economic and social life. From a demographic perspective, the COVID-19 pandemic has caused many deaths, an increase in morbidity among those infected, the postponement of many planned migration flows and an unequal fertility response based on socioeconomic conditions (Aassve et al., 2020).[1] From an economic perspective, the COVID-19 pandemic has caused disruptions to both the supply and the demand side. On the supply side, the evolution of the pandemic has reduced the labour supply and caused disruptions in the supply of goods and services. On the demand side, the loss of income and the worsening of economic prospects, which have been more pronounced during lockdowns, have reduced household consumption.

Most economic models developed during the COVID-19 pandemic combine susceptible-infected-recovered (SIR) models with computable general equilibrium models. These models are well-suited for analysing the economic and epidemiological consequences of different policies, as well as the impact of these policies on the behaviour of agents (e.g. Eichenbaum et al., 2020; Krueger et al., 2020). One common feature of these models is that they assume that all generations are equally affected by COVID-19. Some exceptions are Brotherhood et al. (2020) and Glover et al. (2020), which analysed the impact of the pandemic on two generations (see a summary of this literature in Bloom et al. (2020) and Brodeur et al. (2021)). However, the COVID-19 pandemic has affected each generation differently. While elderly people have faced a higher probability of dying in case of a COVID-19 infection, their income has been protected through public transfers via pension systems. By contrast, workers with children and young workers have borne the economic consequences of lockdowns, either through reductions in the effective time worked, or through income losses. To mitigate the negative effects of this crisis and of other future pandemics, which hit some generations harder than others, the generational economy should be investigated. To complement the recent literature on this topic, models should be developed that use economic information by age, and by the extent to which different age groups are supported through familial and public transfers, such as the information provided by the National Transfer Accounts (NTA) project, to assess the impact of the COVID-19 crisis on the generational economy.

In this article, we develop an overlapping generations (OLG) model that uses data from the NTA project. The NTA project (https://ntaccounts.org) provides cross-sectional age profiles that are fully consistent with National Accounts (Lee and Mason, 2011). NTAs are theoretically founded on the OLG models developed by Samuelson (1958), Tobin (1967), Arthur and McNicoll (1978), Willis (1988), Lee (1994) and Bommier and Lee (2003), among many others. An OLG model is characterised by a population composed of several agents who are born in

[1] Research on the impact of the COVID-19 pandemic on fertility can be conducted using the Short-Term Fertility Fluctuations from the Human Fertility Database (https://www.humanfertility.org).

different years and have a finite length of life. Consequently, the model allows agents from different generations to overlap, which enables the analysis of the economic consequences of the interaction of agents with different ages, while controlling for compositional changes of the population (i.e. changes in the age structure and in the composition of each age over time). Thus, although the main goal of the NTA project is to improve our understanding of the impact of changes in the population age structure on national economies, by combining the NTAs with an OLG model, many other questions can be studied in a dynamic framework. For instance, NTAs can be used in OLG models to examine the impact of the COVID-19 pandemic on the generational economy in the short and the long run.

As well as drawing on NTA data (2019), the OLG-NTA model combines realistic demographic data from the UN Population Division (2019), and human capital data from the WIC Human Capital Data Explorer (2018). The model includes an unexpected economic shock and an unexpected demographic shock. The economic shock due to the lockdown measures is assumed to have a direct negative impact on labour income, and an indirect negative effect on consumption, on public transfers (i.e. reducing fiscal revenues) and on private transfers (i.e. reducing transfers from parents to children). Following Sánchez-Romero et al. (2021), the demographic shock is modelled using the fraction of people infected with COVID-19 during 2020. The demographic shock is assumed to increase the death rate of people who are infected in 2020, and to leave around 10% of individuals who are infected and survive with long-term health conditions, which permanently increases the death rate (Marshall, 2020).[2] See the details in Appendix A.1. Hence, the demographic shock has a direct negative effect on public health care transfers due to both the additional expenses associated with providing care for people infected with COVID-19, and the reduction in the stock of human capital as a result of the person-years lost. The demographic shock also has indirect effects on consumption, private transfers and public transfers because of the changes in life expectancy and in the age distribution of the population.

The OLG-NTA model is applied to 12 countries for which NTA data are available (Australia, Austria, Brazil, Colombia, Costa Rica, Finland, Hungary, Italy, Japan, Slovenia, Sweden and the US). For the sake of comparability across countries, we use the same parameter values in all countries. The parameters were calibrated to Austrian NTA profiles in the year 2010. The estimated negative impact of the COVID-19 pandemic on labour income across the selected NTA countries ranges from −5.6% in Australia to −16% in Italy, with an average decrease of −10.2%.

2 This number may represent the lower bound of the proportion of people left with long-term health conditions after being infected with COVID-19. Given that the fraction of people infected who required hospitalisation was around 20% of the total cases detected, and that 70–80% of these individuals may have developed long-term health conditions (Lopez-Leon et al., 2021), it is likely that the fraction of people with long-term health conditions due to COVIDs-19 is slightly higher than 10%. However, these numbers should still be interpreted with caution, since the likelihood of experiencing long-term health conditions might not be associated with the severity of the disease (Townsend et al., 2021).

To reflect the difficult trade-offs governments face during the pandemic, two extreme policy options are analysed. In the first option, governments do not compensate workers for their labour income losses caused by the restrictions imposed to control the spread of the pandemic. This option will lead to a higher unemployment rate that will complicate the recovery of the economy. This option is introduced by assuming that half of the labour income losses from 2020 will persist in 2021, and that a quarter of the labour income losses from 2020 will persist in 2022. In the second option, governments fully compensate workers for their labour income losses due to the pandemic restrictions. While this policy option will improve the chances of an economic recovery and offset workers' pandemic-related labour income losses in 2021 and 2022, it will raise public debt levels and increase the burden on future taxpayers. These two extreme policies provide information on the minimum and maximum impact that a pandemic such as COVID-19 may have on fiscal revenues and on public debt. The main results of the OLG-NTA model on aggregate consumption, public debt and tax revenues are as follows:

- All age groups experience a decrease in consumption in 2020 due to the COVID-19 pandemic. However, the decline in consumption is greater for the 25–64 age group than for other age groups.
- A 1% decrease in labour income leads to an average increase in the debt-to-total labour income ratio of between 1.2% (without fiscal support) and 1.6% (with fiscal support).
- Assuming that the debt-to-GDP ratio is reduced by 10% per year from 2022 onwards, a 1% decrease in labour income leads to an average increase in the total tax revenue during the 2020s of 0.074% if the government does not compensate workers for their labour income losses, and of 0.104% if the government fully compensates workers for their labour income losses.

The economic and demographic consequences of the current pandemic will likely have effects not only over the short term, but over the medium term as well. Therefore, to analyse the impact of COVID-19 on each generation, it is necessary to take a lifecycle perspective. To do so, we have used two longitudinal measures: lifetime consumption and lifetime transfers. Lifetime consumption may be defined as the present value, survival weighted, of the remaining consumption until death; while lifetime transfers may be defined as the present value, survival weighted, of the remaining total net transfers (i.e. public and private net transfers) until death. These two measures take into account both the economic shock and the demographic shock. The main results of our analysis on the impact of a pandemic such as COVID-19 on the generational economy are as follows:

- Without fiscal support, a 1% decrease in labour income leads to an average decline in lifetime consumption of 0.73% for the 0–24 age group, of 0.94% for the 25–64 age group, and of 0.32% for the 65+ age group. However, when governments fully compensate households for their labour income losses, a 1% decrease in labour income leads to an average decline in lifetime consumption of 0.24% for the 0–24 age group, of 0.46% for the 25–64 age

group, and of 0.40% for the 65+ age group. Therefore, when workers are compensated for their losses, the economic impact of COVID-19 is more evenly distributed across cohorts, significantly reducing the burden on people aged 0–24 and 25–64, and increasing the burden on people aged 65+.
- The impact of the COVID-19 pandemic on lifetime consumption is mainly explained by the changes in lifetime transfers, which shows that NTAs can be used to account for both public and private transfers.
- Compensating workers for their labour income losses has a positive effect on total lifetime transfers for the 0–24 age group. Indeed, a 1% decline in labour income leads to an average decline in total lifetime transfers of 0.61% without the additional support from the government, and of only of 0.29% with the additional support from the government.
- The positive effect of the additional fiscal support on the lifetime transfers of children is due to an indirect positive effect on private lifetime transfers, and not to an increase in public lifetime transfers. Without fiscal support, parents reduce their transfers to their children in response to the decline in their labour income. However, when the government compensates parents for their labour income losses, the level of transfers from parents to their children does not change.
- The impact of the COVID-19 pandemic on public lifetime transfers for the 65+ age group is ambiguous without the additional government support and is negative when the government compensates workers for their labour income losses.

This article is organised as follows. In Section 2, we list the NTA profiles used for constructing an NTA-based model with a dynamic overlapping generations model (hereafter, the OLG-NTA model), and its necessary adjustments. In Section 3, we show how the NTA profiles may have been affected by the COVID-19 pandemic in 2020. In Section 4, we analyse the impact the COVID-19 pandemic has had on labour income, debt and taxes. In Section 5, we analyse the impact of the COVID-19 pandemic on consumption, private transfers and public transfers for the generations alive in 2020. All of the results presented in Sections 4 and 5 are based on two extreme scenarios that reflect the minimum and the maximum increase in debt caused by the COVID-19 pandemic. In the final section, we discuss the main assumptions, limitations and potential extensions of the OLG-NTA model. The article also has an Appendix in which we explain the formulas needed to construct the OLG-NTA model, and that allow for the replication of this analysis in other countries with current NTA data.

2 Constructing an OLG-NTA model

To better represent the microeconomic behaviour of households of different ages, rather than to just account for compositional changes, the OLG-NTA model uses a selected set of NTA profiles. In addition, to make the NTA profiles consistent with a simplified version of an OLG model, we need to introduce several assumptions, which are listed in Box 1.

Box 1. Assumptions

The following assumptions are borrowed from the OLG literature in order to make the NTA profiles consistent with the OLG-NTA model implemented here: credit markets are perfect, individuals have perfect foresight, there is no bequest motive, individuals fully annuitize their wealth and public and private transfers are non-distortionary. The interest rate is determined in international capital markets, and the wage rate per hour worked increases at a constant rate. In addition, we assume that agents take the number of hours worked in the market as given, and only make decisions about the consumption of the household. Households are comprised of a household head and a number of dependent children. Hence, household heads take the revenues from the market and optimise consumption for all household members. Over the lifecycle of each household head, the number of dependent children varies because of fertility, mortality and children leaving their parents' home. For simplicity, we also assume that all children leave their parents' home at the same age. In reality, children leave their parents' home at different ages, which could be captured using different home leaving rates. However, to take these differences into account, households that are settled at different ages of the household head would have to be modelled. There is one representative neoclassical firm that produces, using a Cobb-Douglas production function, a single good that can be stored or consumed. The government is assumed to run a balanced budget without the COVID-19 pandemic, and to allow the public budget to become imbalanced during the COVID-19 crisis, which raises public deficit and debt levels. Finally, it is assumed that these debts will be paid in the future through additional taxes.

Although OLG models can be computed without the stringent assumptions specified in Box 1, any deviation from these assumptions will impose theoretical restrictions on the OLG-NTA model that significantly increase its complexity. Nonetheless, these assumptions will allow us to model the standard demographic compositional effects (changes in age, size and education), as well as the behavioural effects. The next subsection specifies the NTA profiles that are used to construct the NTA-based model. The detailed derivations of each of the following profiles is given in Appendix B.

2.1 Per capita profiles

The OLG-NTA model is comprised of three sets of per capita profiles that differ by the degree of complexity in their construction:

i. Raw NTA profiles,

ii. Exogenously constructed NTA profiles and
iii. Endogenously calculated NTA profiles.

The first set of NTA profiles (*raw NTA profiles*) are taken directly from the NTA database, and are assumed to change over time at the same rate as labour income. The *exogenously constructed NTA profiles* are not taken from the NTA database. Instead, a specific set of formulas are used to generate these profiles. The *endogenously calculated NTA profiles* are also not taken from the NTA database. Instead, these profiles are derived by solving the household problem using optimal control. Next, we list the profiles contained in each case.

i. Raw NTA profiles

All raw NTA profiles change each year at the same rate as the average labour income between ages 30 and 49. We use the average labour income between ages 30 and 49 to reduce the importance of the educational and retirement decisions in the simulation results. Table 1 shows the raw NTA profiles used in the OLG-NTA model.

ii. Exogenously constructed NTA profiles

In this category, we have four profiles: (i) labour income (YL); (ii) public transfers, health (TGH/CGH); (iii) social protection, unemployment; and (iv) inter-household

Table 1:
NTA flow accounts used

Private consumption			
Education	CFE		
Health	CFH		
Private transfers			
Inter-household transfers (net)	TFB		
Public transfers, in-kind, inflows		**Public transfers, in-kind, outflows**	
Education	TGEI/CGE	Education	TGEO
		Health	TGHO
Other in-kind	TGXI/CGX	Other in-kind	TGXO
Public transfers, in-cash, inflows		**Public transfers, in-cash, outflows**	
Pensions	TGSOAI	Pensions	TGSOAO
Social protection other than pensions	TGSI	Social protection other than pensions	TGSO
Other cash	TGXCI	Other cash	TGXCO

transfers from retirees to adult children. These four profiles are derived from datasets that contain economic and demographic information that vary by cohort and over time (e.g. WIC Human Capital Data Explorer, UN Population Database). As the constructed labour income profiles are assumed to be sensitive to the level of education and experience, they differ across cohorts and countries. The public health and social protection (unemployment) transfer profiles explicitly capture the higher costs in the health care sector caused by the COVID-19 shock, and the increase in cash transfers in response to the labour income losses caused by the lockdown measures. The social protection profiles account for the government programs implemented to mitigate the income losses produced by the lockdown measures. The profiles of the interhousehold transfers from retirees to adult children capture the assistance provided by public pension recipients to their adult children.

iii. Endogenously constructed NTA profiles

A profile is endogenously constructed when it is the result of an optimisation process. Three NTA profiles are endogenously calculated in the OLG-NTA model:

- Private consumption other than health and education (CFX),
- Intra-household transfers (TFW) and
- Private asset-based reallocations (RAF).

2.2 Aggregate profiles

Aggregate profiles are obtained by multiplying the per capita profiles, listed in Section 2.1, by the population size at each age. The sum across ages of the aggregate profiles gives the macro totals from the National Accounts. This step is important because the aggregate totals affect the inflows and/or the outflows of public transfers, which are always constrained by public budgets. Since public budgets are affected over time by different political parties, to simplify the calculations, we assume that governments run a balanced budget in all years except for those affected by the COVID-19 pandemic. Thus, this strategy allows us to analyse the marginal effects of the pandemic on the public budget.

When the age structure of the population changes with respect to the base year of the NTA profiles, a mismatch between the inflows and outflows arises. To adjust all public NTA profiles forwards and backwards in time and to avoid this mismatch, we introduce a temporal adjustment factor that guarantees that aggregate inflows and aggregate outflows are balanced. In particular, we assume that in-cash public transfer outflows and public transfer outflows for health care are adjusted to finance all of the in-cash public transfer inflows (i.e. pensions, social benefits, unemployment, etc.), as well as health care public transfer inflows (TGHI). Since in-cash transfers and health care spending are mostly received by elderly people, this adjustment implies that the social contributions and taxes that pay for social benefits and health care will increase in the future, and were lower in the past. In contrast, given that in-kind public transfer inflows for education and other in-kind services are mostly received during childhood, we adjust the levels of in-kind public transfer outflows (i.e. taxes). Therefore, in-kind public transfer outflows will either decrease or remain the same relative to labour income in the future, and were higher in the past.

To isolate the economic impact of the COVID-19 pandemic, the balanced budget assumption is relaxed from 2020 onwards. We use two alternative populations: one population that is based on the UN Population Division data, which is labelled with subscript 0; and a second population that is affected by the COVID-19 crisis, which is labelled with subscript 1. The construction of each population is explained in Appendix A. Given that most countries have chosen to implement expansionary fiscal policies to reduce the economic burden of the COVID-19 pandemic, the OLG-NTA model assumes that the per capita public transfer inflows remain unchanged during the economic crisis caused by the COVID-19 pandemic, and that only the public transfer outflows (i.e. taxes and contributions) are adjusted downwards because of labour income losses. Consequently, governments will run deficits, and their debt levels will increase.

3 Impact of the COVID-19 pandemic on NTA profiles

The last step needed to finalise the OLG-NTA model is to specify the economic shock and the demographic shock. The economic shock caused by the COVID-19 pandemic is assumed to have a direct impact on public health care transfers, due to both the additional spending required to take care of people infected by the virus, and the labour income losses caused by the lockdown measures imposed by the government. The labour income losses are modelled as a decline in working hours. Government fiscal balances are also affected by the COVID-19 pandemic due to the decrease in labour income, which, in turn, leads to a decline in tax revenues and social contributions. The demographic shock is modelled using the fraction of people infected since the beginning of the pandemic, which is assumed to increase the death rate of those infected.

To represent the impact of the COVID-19 pandemic on the NTA profiles, we have chosen two countries that differ in terms of their stage of the demographic transition and their per capita income level. Figure 1 shows the impact of the COVID-19 pandemic on the NTA profiles in 2020 in Brazil (top panels) and in the US (bottom panels). Figure 1 displays in the left-hand panel the NTA-based model results for per capita labour income (red), public transfers (blue), private transfers (green) and total consumption (purple). The panel on the right-hand side shows the aggregate profiles (i.e. multiplied by the population size at each age) for labour income (red), public transfers (blue), private transfers (green) and total consumption (purple). The dashed lines represent the NTA profiles in the hypothetical case in which neither the lockdown measures nor the COVID-19 pandemic occurred. The solid lines represent the expected NTA profiles given the COVID-19 pandemic and the assumed impact of the lockdown measures on working hours. The differences between the two types of lines correspond to the marginal impact of the COVID-19 pandemic on each NTA profile in 2020. The increase in public transfers (TG) reflects the decrease in tax revenues and social contributions due to the labour income losses, as well as the increase in social benefits and the rise in health care spending. Private consumption declines due to the containment measures implemented to encourage social distancing (Eichenbaum et al., 2020), which leads to a reduction in total consumption. The green solid line shows that due to the decrease in consumption by parents, children receive lower private transfers, which, in turn, negatively affects their consumption as well. As a result of the decline in consumption in response to the COVID-19 pandemic, none of the age groups is better off in 2020.

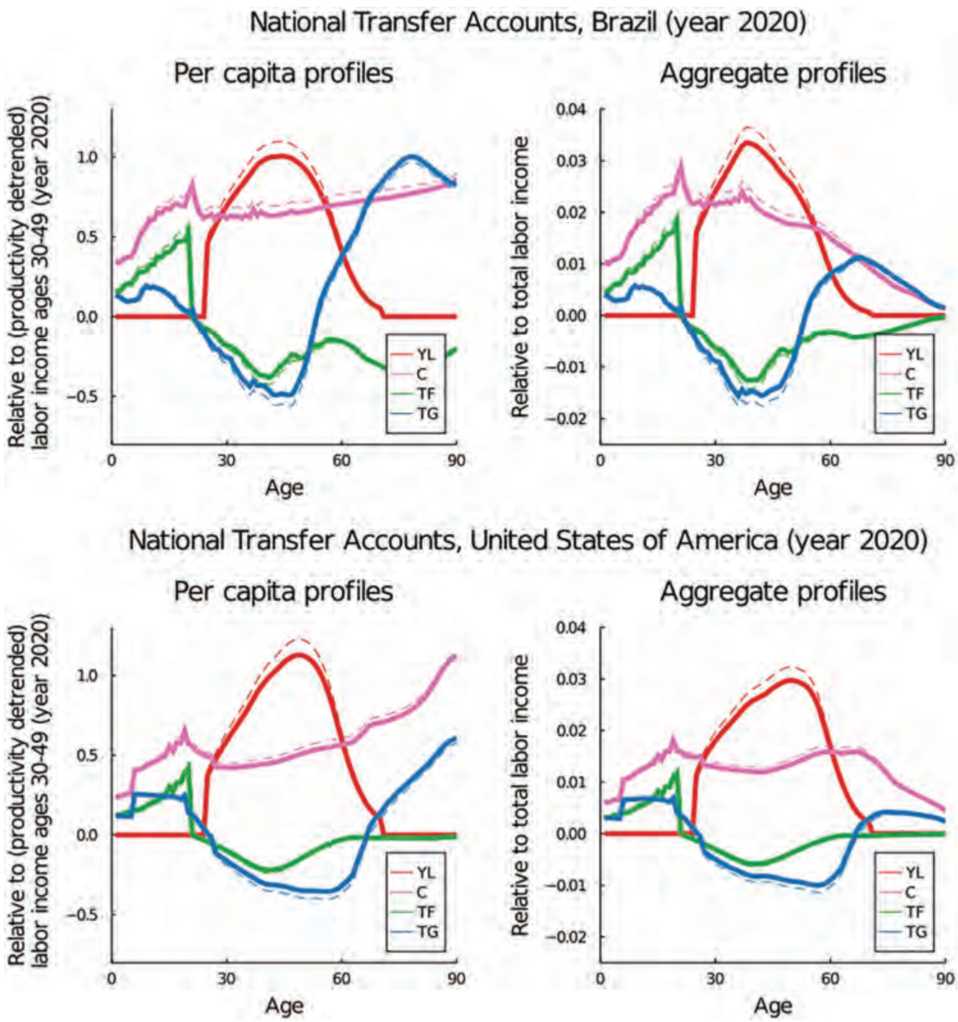
The NTA profiles for the 10 remaining countries are shown in the Supplementary Material (Section S3, available at https://doi.org/10.1553/populationyearbook2022.res1.2). In addition, the list of countries for which the OLG-NTA model can be calculated is shown in Table S10 in the Supplementary Material (Section S5).

4 Impact of the COVID-19 pandemic on labour income, debt and taxes

The OLG-NTA model can also be used for analysing the evolution of macroeconomic aggregates (i.e. total taxes, total public and private consumption, total labour income, debt, etc.), and, hence, the macroeconomic impact of the COVID-19 pandemic. To assess the aggregate economic impact of the demographic and economic shocks produced by the COVID-19 pandemic, it is necessary to compare the OLG-NTA model results with and without the shocks (c.f., solid and dashed lines in Figure 1).

In addition, we should not forget that the macroeconomic impact of the COVID-19 pandemic can be exacerbated or be mitigated through public policies. However, the implementation of these policies is associated with difficult trade-offs. For instance, governments are adopting large-scale fiscal packages to support businesses and workers who have lost revenues and labour income. This policy raises public debt levels, which, in turn, increases the burdens on future taxpayers. However, a failure to financially support businesses and workers may lead to bankruptcies and unemployment, which could complicate the recovery of the economy once the pandemic is controlled. To incorporate this trade-off into the OLG-NTA model, we consider two options. If the government does not compensate workers for their labour income losses, it is assumed that half of those labour income losses from 2020 will persist in 2021, and a quarter of the labour income losses from 2020 will persist in 2022. In contrast, if the government compensates workers for their labour income losses, these fractions are assumed to be reduced by the same proportion as the fraction of labour income losses compensated by the government in 2020. Thus, if governments compensate workers for all of their labour income losses from 2020 onwards, we assume that from 2021 onwards, the level of employment will

Figure 1:
Simulated economic lifecycle in Brazil (top panel) and the US (bottom panel) in 2020: Pre COVID-19 (dashed lines) vs. post COVID-19 (solid lines)



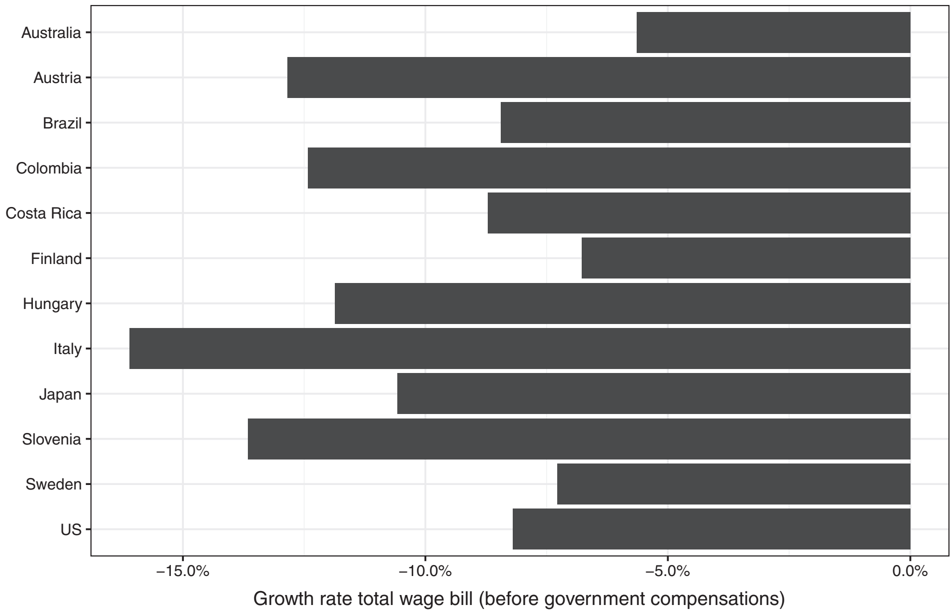
Source: Own calculations.

Notes: C is total consumption, YL is labour income, TF is net private transfers, and TG is net public transfers.

remain at the pre-crisis level. While not fully realistic, these two options reflect the minimum and the maximum increase in debt that a government can incur.

Not all countries have been hit equally hard by the pandemic. Figure 2 shows the estimated growth rate of the total wage bill in 2020 across the selection of 12 NTA

Figure 2:
Growth rate of the total wage bill in 2020 before government compensation



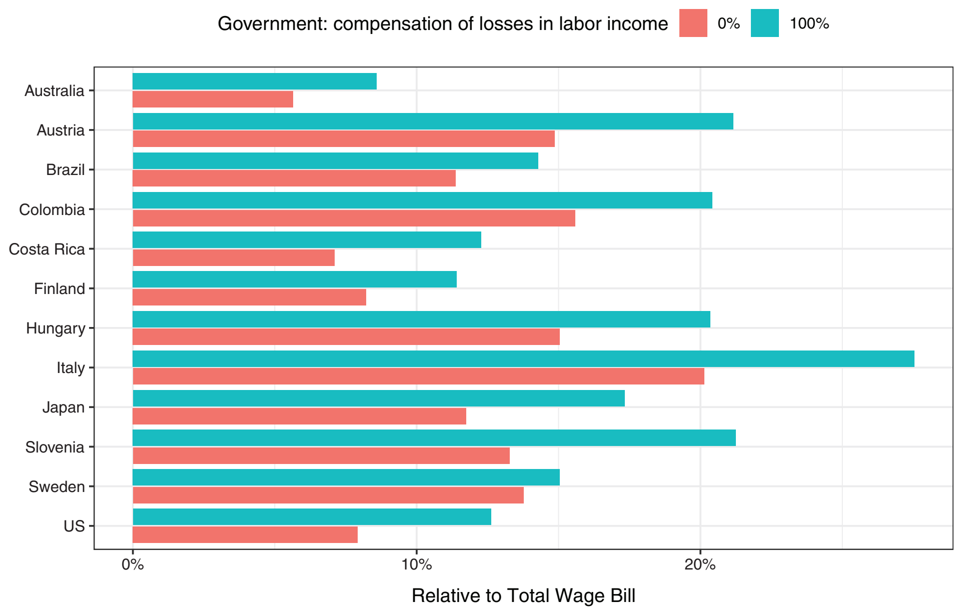
Source: Own calculations using data from Eurostat and Sánchez-Romero et al. (2021).
Note: Details of the derivation are provided in the Supplementary Material (Section S2).

countries. Figure 2 shows that the negative impact of the COVID-19 pandemic on labour income (before government fiscal support) across the selected NTA countries ranges from −5.6% in Australia to −16% in Italy, with an average impact of −10.2%. These numbers reflect the direct link between the fraction of people infected with COVID-19 and the decrease in economic activity. Indeed, the regression results shown in the Supplementary Material (Section S2) suggest that a 1% increase in the fraction of people infected leads to a decline of 0.25% in the annual value added.

4.1 Impact on debt

The cross-country differences in the impact of the COVID-19 pandemic on labour income implies that some countries will have a greater imbalance in their public coffers than others, and that this gap will be more pronounced in countries where the decline in labour income has been greater. During the crisis, tax revenues and social contributions that are generally used to finance in-cash (e.g. public benefits) and in-kind (e.g. public consumption) public transfers are reduced. Using the OLG-NTA model, Figure 3 shows for a selection of NTA countries the additional debt accumulated due to the pandemic. Thus, following Wyplosz (2020), we use the value of the debt in 2022, which coincides with the assumed recovery of the pre-crisis labour income levels. Each country has two coloured bars, which correspond to two extreme policy options that a government can implement to compensate workers for their labour income losses. The red bars show for each country the additional debt needed to support all in-cash and in-kind public transfers, given the decline in taxes and contributions collected by the government. The turquoise bars differ from the red bars in that they include the additional increase in debt caused by fully compensating workers for their labour income losses. The red bars indicate that those countries that have the largest decreases in labour income (see Figure 2) are also those that have the largest increases in debt. Thus, the additional increase in debt (relative to the total wage bill) caused by the COVID-19 pandemic across the selected NTA countries ranges from 5.6% in Australia to 20% in Italy, with an average increase of 12%. The turquoise bars show that if the government fully compensates households for their labour income losses, the additional increase in debt (relative to the total wage bill) is higher, and ranges from 8.5% in Australia and 27.5% in Italy. Another interesting result is obtained by comparing the estimated

Figure 3:
Expected impact of the COVID-19 pandemic on debt: By level of labour income losses compensated by the government



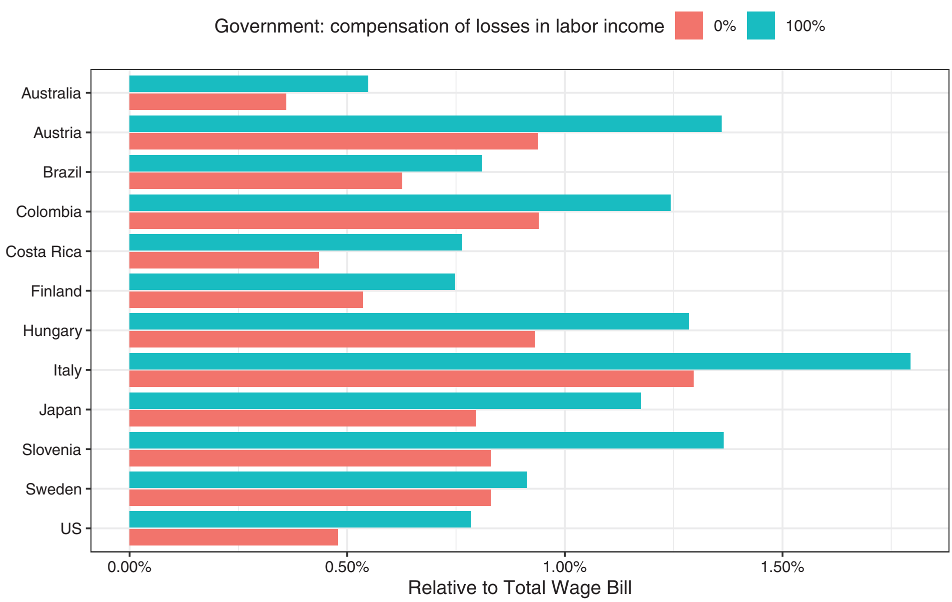
Source: Own calculations.

impact of COVID-19 on labour income (see Figure 2) to the estimated impact of the COVID-19 pandemic on debt. This comparison suggests that if the government does not compensate workers for their labour income losses, a 1% decrease in labour income leads to an average increase in debt of 1.2% relative to the total wage bill. However, the turquoise bars suggest that if the government fully compensates workers for their labour income losses, a 1% decrease in labour income leads to an average increase in debt of 1.6% relative to the total labour income. Therefore, according to the OLG-NTA model, a 1% decline in labour income leads to an average increase in debt of between 1.2% and 1.6% relative to the total labour income.

4.2 Impact on taxes

The additional debt accumulated will be paid by future taxpayers. Figure 4 shows the resulting average increase in total tax revenues relative to the total wage bill during the 2020s if the debt, relative to GDP, is reduced by 10% per year. Figure 4 shows that if the government does not compensate workers for their labour income

Figure 4:
Increase in total tax revenues (relative to the total wage bill) to pay for the additional debt caused by the COVID-19 pandemic from 2021–2030: By level of labour income losses compensated by the government



Source: Own calculations.

losses, taxes will increase from 0.36% in Australia to 1.3% in Italy. In contrast, Figure 4 also shows that if the government compensates workers for their labour income losses, taxes will increase from 0.55% in Australia to 1.8% in Italy.

A comparison of the estimated tax increases (see Figure 4) and the estimated labour income losses (see Figure 2) across countries suggests that a 1% decline in labour income leads to an average increase in total tax revenues of 0.074% if the government does not compensate workers for their labour income losses, and of 0.104% if the government fully compensates workers for their labour income losses.

5 Impact of the COVID-19 pandemic on the generational economy

To understand the impact of the COVID-19 pandemic on each generation, is necessary to know how the COVID-19 crisis will affect the evolution of the NTA profiles in the future, while taking into account that populations are not stable, and that economies do not grow at a constant rate. Fortunately, the OLG-NTA model generates NTA cross-sectional and longitudinal age profiles even when the economy is not growing at a constant rate and the population is not stable. Moreover, the NTA profiles generated by the OLG-NTA model are financially consistent because it is assumed that individuals cannot run up an ever-increasing level of debt beyond that which financial institutions would allow, or have an ever-increasing level of wealth that would minimise the consumption of the household. The latter situation may occur in models in which NTA profiles are fixed over time, and only the population age structure is allowed to change.

5.1 Impact on consumption

To capture the long-term effects of the current economic and demographic crises on each generation, it is necessary to use a metric with a longitudinal perspective. To do so, it is convenient to use the concept of lifetime consumption, or, equivalently, the present value of the remaining lifetime of own consumption (public and private). Lifetime consumption captures how consumption evolves over the remaining lifetime given all of the remaining resources people are expected to have (labour income, transfers and assets). Thus, calculating the change in lifetime consumption before and after the COVID-19 pandemic is equivalent to simultaneously calculating the changes in lifetime income, wealth transfers and public debt caused by the economic shock and the demographic shock.[3] Hence, lifetime consumption captures three effects caused by the COVID-19 pandemic:

[3] The lifetime consumption at age x for a generation born in year t, denoted by $C_i(x,t)$, is equal to

$$\sum_{s=x}^{99+}\left(\prod_{z=x}^{s}\frac{p_i(z,t+s)}{1+r}\right)c_i(s,t+s),$$

(i) the decline in labour income, (ii) the changes in public and private transfers, and (iii) the increase in the mortality rate.

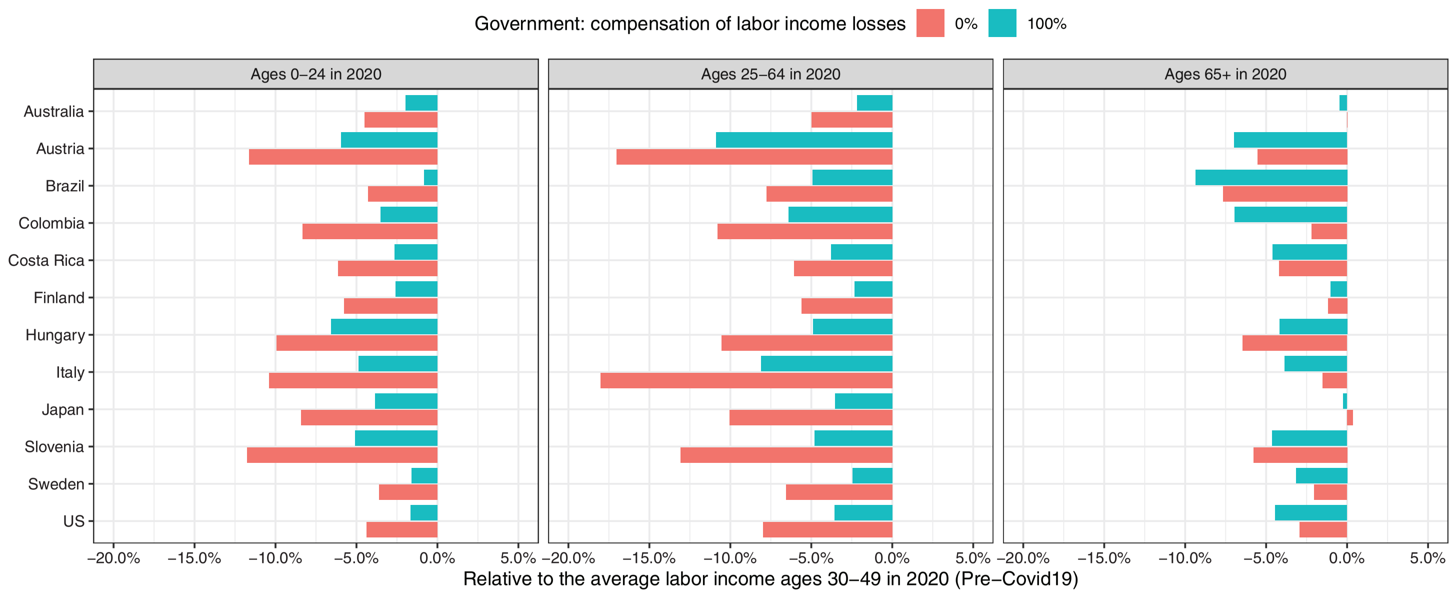
Figure 5 shows the impact of the COVID-19 pandemic on the remaining lifetime consumption relative to the average labour income for three age groups (i.e. 0–24, 25–64 and 65+). The results presented in Figure 5 are robust to changes in the underlying interest rate, which is assumed to be 2.5% (see the sensitivity analysis in Section S4 in the Supplementary Material). This is because individuals react to changes in prices in the OLG-NTA model, and the results are relative to labour income. For each country and age group, Figure 5 contains two bars that reflect the degree of government support to households. The red bars in Figure 5 show that without government support, the negative impact of the COVID-19 pandemic on lifetime consumption is larger for the 0–24 and 25–64 age groups than for the 65+ age group. Among the 12 NTA countries analysed, the 0–24 and 25–64 age groups are the worst hit in Italy, Austria and Slovenia; while the 65+ age group is the worst hit in Brazil, Hungary and Slovenia. These different effects across countries and age groups reflect the cross-country variation in the decrease in economic activity; the fraction of people infected in 2020; and the generosity of the public transfer system, which is well captured by the NTA profiles.

We start the analysis by focusing on the working age group. We then look at the 0–24 age group, followed by the 65+ age group. The results of the OLG-NTA model indicate that the decline in the remaining lifetime consumption for the 20–64 age group is driven by the fall in labour income and the negative impact of the COVID-19 pandemic on the survival probability. For the 0–24 age group, the decline is explained by the reduction in the transfers they receive from their parents (private transfers) and the increase in future taxes needed to pay for the additional debt generated during the crisis (see Figure 4). The decline in lifetime consumption for the 65+ age group is caused by the loss of pension benefits and the increase in the mortality rate. When we compare the labour income losses to the decrease in lifetime consumption, we find that a 1% decline in labour income leads to an average decline in lifetime consumption of 0.73% for the 0–24 age group, of 0.94% for the 25–64 age group and of 0.32% for the 65+ age group.

The turquoise bars in Figure 5 show that when the government fully compensates workers in the 25–64 age group for their labour income losses, the negative impact of the pandemic is more evenly distributed across all age groups. Indeed, when we compare the turquoise bars to the red bars we see that the negative impact of the pandemic on lifetime consumption is reduced on average by 56% for the 0–24 age group, and by 52% for the 25–64 age group. Hence, despite the future increase in taxes caused by the government support (see Figure 4), people in the 0–24 age group

where r is the market interest rate, $p_i(x,t)$ is the conditional probability of surviving to age x in year t and $c_i(x,t)$ is the total consumption (public and private) at age x in year t. We define the difference in lifetime consumption at age x for a generation born in year t as $\Delta C(x,t) = C_1(x,t) - C_0(x.t)$. Subscript i denotes whether the NTA-based model results are pre COVID-19 ($i = 0$) or post COVID-19 ($i = 1$).

Figure 5:
Impact of the COVID-19 pandemic on the remaining lifetime consumption in 2020 by age group and level of government support



Source: Own calculations.

benefit the most from this policy, because they receive more transfers from the 25–64 age group. This result should be interpreted with caution, given that the positive effect of this policy on the 0–24 age group may be lower if the debt-to-GDP ratio is reduced more slowly than 10% per year, as this scenario implies that younger generations will have to pay more taxes when they enter the labour market. If we compare the labour income losses to the fall in lifetime consumption, we find that if the government fully compensates households for their labour income losses, a 1% decline in labour income leads to an average decline in lifetime consumption of 0.24% for the 0–24 age group, of 0.46% for the 25–64 age group and of 0.40% for the 65+ age group.

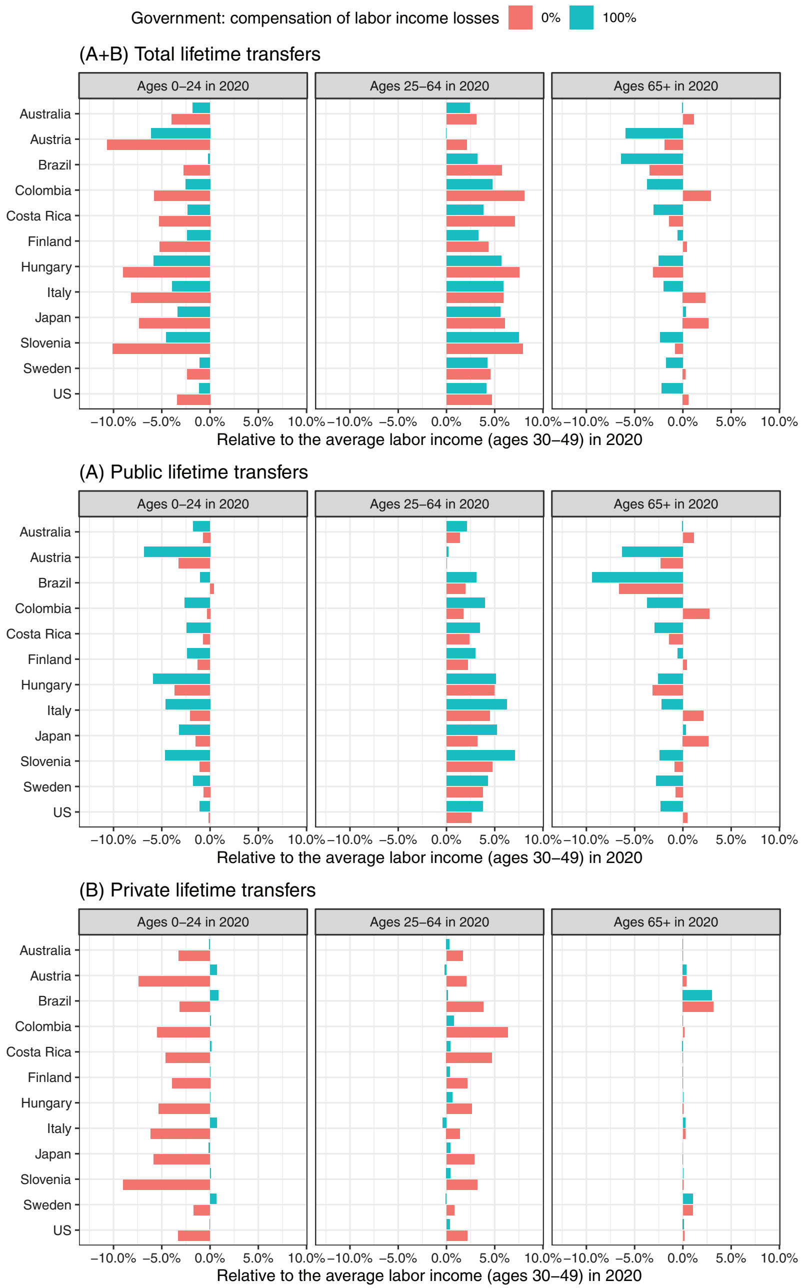
It is also important to note that when the government fully compensates workers for their labour income losses, not all age groups benefit similarly in all countries. For instance, under this scenario, the 0–24 age group is the worst hit in Hungary, Austria and Slovenia; the 25–64 age group is the worst hit in Austria, Italy and Colombia; while the 65+ age group suffers the greatest losses in Brazil, Colombia and Austria. The differences in the ranking of countries with respect to the level of government support stem from the different transfer systems implemented in each country.

5.2 Impact on public and private transfers

To understand how the transfer system in each country shapes the impact of the COVID-19 pandemic, Figure 6 shows the impact of the crisis on lifetime transfers in 2020 by age group and level of government support. Like in Figure 5, the results are robust to changes in the interest rate (see the sensitivity analysis in Section S4 in the Supplementary Material). Figure 6 is divided into three panels. The top panel shows total lifetime transfers (i.e. the sum of public and private lifetime transfers), the middle panel A displays public lifetime transfers and the bottom panel B shows private lifetime transfers. The main difference between Figure 6 and all previous figures is that not all age groups are negatively affected by the COVID-19 pandemic. Specifically, Figure 6 shows that the impact of the COVID-19 pandemic on lifetime transfers is negative for the 0–24 age group, is positive for the 25–64 age group and is mixed for the 65+ age group.

A comparison of the turquoise bars and the red bars in the top panel of Figure 6 shows that the negative impact of the COVID-19 pandemic on the 0–24 age group is more pronounced without additional support from the government. For instance, a 1% decline in labour income leads to an average decrease in total lifetime transfers of 0.61% with no additional support from the government, and of 0.29% with additional support from the government. However, contrary to our intuition, we find that the positive effect of compensating workers for their labour income losses is due to the increase in private lifetime transfers, and not to the increase in public lifetime transfers (c.f. panels A and B). Panel B (red bar in the bottom of the figure) shows that without additional public transfers, the 25–64 age group transfers

Figure 6:
Impact of the COVID-19 pandemic on the remaining lifetime transfers in 2020 by age group and level of government support



Source: Own calculations.

fewer resources to the 0–24 age group (see panel A). Specifically, a 1% decline in labour income reduces the private lifetime transfers of the 0–24 age group by 0.48%. In contrast, with 100% additional support from the government, a 1% decline in labour income increases the private lifetime transfers of the 0–24 age group by 0.03%. Moreover, the red bars show that when there is no compensation for labour income losses, the impact of the COVID-19 pandemic on private lifetime transfers becomes positive for the 25–64 age group and negative for the 0–24 age group. By contrast, the turquoise bars show that if the government fully compensates workers for their labour income losses, the negative effect on the children's private lifetime transfers disappears. Therefore, we can conclude that the additional support of the government has an indirect positive effect on the private lifetime transfers received by the 0–24 age group.

The direct impact of the additional government support on public lifetime transfers is shown in panel A (middle of the figure). The red bars in panel A illustrate how the economic crisis increases public lifetime transfers for the 25–64 age group. This effect is due to the lower taxes and social contributions paid by the 25–64 age group. The turquoise bars show that if the government compensates workers for their labour income losses during the crisis, the 25–64 age group receives more public transfers. The additional debt that this policy generates is paid back through future taxes by all age groups. As a consequence, the impact of the COVID-19 pandemic on public lifetime transfers for the 65+ age group is mixed without the additional government support, and is negative when the government compensates workers for their labour income losses. The degree of the decline in public lifetime transfers for the 65+ age group is directly related to the amount of transfers received at older ages. Thus, for instance, given that Brazil has the most generous pension system among the 12 NTA countries analysed, the greatest decline in the public lifetime transfers can be observed in this country.

In sum, Figures 5 and 6 show that there is no one-size-fits-all policy that can be applied in all countries. Instead, when analysing the potential effects of policy approaches, we must account for each country's transfer system and demographic characteristics, which the NTA project and the OLG-NTA model allow us to do.

6 Discussion

Many economic models analysing the impact of the COVID-19 pandemic have assumed that all generations are equally affected by the crisis. These models do not include realistic demography, and some assume that the population can be modelled using a representative household. Moreover, they do not account for the negative impact that the COVID-19 pandemic is having on different age groups. In addition, these models fail to recognise that different generations are tightly linked to other generations through familial and public transfers. To complement these models, we have shown how to build and use an OLG-NTA model for assessing the economic impact of the COVID-19 crisis across generations.

The OLG-NTA results show that a pandemic, like COVID-19, affects the financial situations of individuals aged 25 to 64 and their children more than those of other age groups. However, not all socioeconomic groups are equally affected. People in lower socioeconomic groups have a higher probability of losing their jobs and being infected with COVID-19. The simulation results suggest that providing workers with financial support will reduce household consumption declines, as well as poverty and inequality levels. In the less developed countries, remittances could also alleviate the decrease in income due to economic inactivity. However, given that the pandemic is affecting all countries, including the most developed countries, the decrease in remittances may be greater than the decline in labour income. Since we have estimated that the decrease in labour income across the 12 countries analysed is close to 10%, the decline in remittances could exceed that figure.

This article has shown that an OLG-NTA model can be used for studying the impact of the COVID-19 pandemic on the generational economy, as well as for analysing the evolution of macroeconomic aggregates (i.e. total taxes, total public and private consumption, national income, debt, etc.). It is worth remembering, however, that a model is always a simplified representation of reality. All models are subject to limitations (assumptions), and knowing a model's limitations is always as informative as knowing its results. For instance, the current version of the OLG-NTA model cannot be used to understand how a pandemic, like COVID-19, affects different population subgroups that differ by socioeconomic status. Existing OLG models that include three generations who differ by education and health status have shown that after a pandemic, the proportion of low socioeconomic groups may increase in the medium term (Boucekkine and Laffargue, 2010), which leads to an increase in inequality. To include these characteristics, it is necessary to have NTA profiles distinguished by socioeconomic status, many of which are still not publicly available, and to endogenise the education decision. The static and dynamic general equilibrium (GE) models that incorporate a social accounting matrix, such as those developed by the NTA teams in Bangladesh and Moldova, are, in principle, preferable for analysing the short-run impact of the COVID-19 pandemic on specific socioeconomic groups. However, these models are not suitable for studying the medium- and long-term effects of the COVID-19 crisis on the economy and the population.

The current version of the OLG-NTA model assumes that the COVID-19 pandemic will not have a permanent impact on public and private education. This possibility can be accounted for by using an alternative scenario from the WIC database or directly endogenising the educational decision. Another limitation of our model is that the decline in working hours is assumed to be proportionally distributed across all ages. In additional simulations that took into account that the labour income of young workers declined 50% more than that of prime-age workers, the results did not significantly change (see the sensitivity analysis in Section S4 in the Supplementary Material). A fourth limitation is the lack of information on the decline in individual utility after the contraction caused by the COVID-19 pandemic. Yet another limitation is the modelling of the various waves of the virus. To include a second or a third wave of the virus in the model, we would need to introduce a trade-off between lockdowns and the probability of the return of the virus in a subsequent wave. These options can be considered as potential extensions of the model.

Some assumptions have been introduced for the sake of computational simplicity. For instance, the OLG-NTA model assumes an open economy with a fixed interest rate. A sensitivity analysis of the model to different interest rates showed that the results were robust to changes in the underlying interest rate (see Section S4 in the Supplementary Material). Although most countries operate with open capital markets, studying a closed economy could be interesting for understanding the total impact of changes in the population age structure on the economy through changes in the interest rate. Second, the model contains one sector only, and does not include trade (i.e. exports and imports). A two-sectors model in which the workers of one sector provide necessary goods and services and the workers of the second sector can work from home could help us better understand the economic impact of COVID-19 crisis. However, given the available NTA data, creating such a model is not yet feasible. Third, the households in our analysis are only comprised of parents (household heads) and their dependent children. While this household structure clearly reflects conditions in modern western societies, it might not fully represent the household composition of less developed countries, Asian countries and African countries. However, it is also true that most OLG models do not properly account for the changes in household structure over the lifecycle, which is an advantage of our OLG-NTA model. Fourth, the model is unisex. A two-sexes model could use all of the available NTA and NTTA data. However, a dynamic two-sexes OLG model is extremely complex, since the number of potential household heads varies stochastically over time. To implement this type of model, more stringent assumptions should be introduced.

Despite the major limitations of the OLG-NTA model presented here, it has a number of advantages, including that it is simple, and can be easily adapted to other ideas and extensions. Moreover, since the model is mainly data driven, the modeller can study many alternative policies by building alternative scenarios for countries in which all of the standard NTA profiles have been constructed.

Supplementary material

Available online at https://doi.org/10.1553/populationyearbook2022.res1.2

Supplementary file 1. List of abbreviations (S1), estimated GDP losses due to Covid-19 (S2), additional figures (S3), and sensitivity analysis (S4).
Supplementary file 2. Summary of publicly available NTA country profiles (S5).

Acknowledgements

I acknowledge the financial support provided by UNFPA, and the helpful comments of two anonymous reviewers, of Anne Goujon (editor) and of many NTA members and colleagues, in building this model. In particular, I appreciate the comments and suggestions received from Gretchen Donehower, Michael Herrmann, Michael Kuhn, Ronald Lee, Sang-Hyop Lee, Andrew Mason, Marcel Merette, Tim Miller and Alexia Prskawetz. I am also grateful for the excellent discussions and feedback from participants at the session on generational perspectives on economic crisis at the 13th Global NTA Meeting, and to Latif Dramani, Bazlul Khondker, Olanrewaju Olaniyan and Valeriu Prohnitchi.

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Appendix

A Demography

The OLG-NTA based model relies on two alternative populations: (i) one population, denoted by 0, that never experienced the COVID-19 pandemic (UN Pop Projections before COVID-19); and (ii) another population, denoted by 1, that experienced the COVID-19 pandemic from the year 2020 until the vaccine was introduced. The duration of the influence of the COVID-19 pandemic and the proportion of infected people can be chosen by the modeller.

A.1 Survival probabilities

The COVID-19 pandemic is assumed to have a negative impact on the mortality rate of those infected, and, because 20% of the symptomatic people report permanent symptoms, we assume that 10% (symptomatic plus asymptomatic) of the infected individuals end up having long-term health effects that may increase their mortality risk (Marshall, 2020). Thus, we assume that the conditional probability of surviving to age x after t(=COVID-19) is

$$p_1(x+n, t+n) = p_0(x+n, t+n) - \gamma(t+n)\delta_C(x+n) \quad \text{if } n = 0$$

and

$$p_1(x+n, t+n) = p_0(x+n, t+n) - \gamma(t)\frac{\delta_C(x+n)}{10} \quad \text{if } n > 0$$

where $p_i(x, t)$ is the conditional probability of surviving to age x in year t, $\gamma(t)$ is the fraction of people infected in year t and $\delta_C(x)$ is the infection fatality rate at age x.

The fertility, mortality, sex ratios at birth, net migration rates and population data are taken from the UN Population Division. The UN only reports population data by single years of age until 2020, while the NTA data are only available by single years of age. For the sake of consistency, we interpolate the UN data by five-year age groups to single years of age by using B-splines. Migration by single years of age is introduced using a net migration standardised age profile for Australia taken from Wilson (2020).

A.2 Population projections

Backward population projection. For our projection, we need individuals who are not affected by the COVID-19 pandemic over their whole lifetimes. Thus, we assume that before the year 1950, the mortality and fertility levels are the same as those observed in 1950. We then project backwards by using the initial $L_x(1950)$ values, and we calculate the population growth rate (Lotka's r) of the Leslie matrix in 1950.

Forward population projection. We use a female-dominant population projection strategy based on Leslie (L) matrices (Preston et al., 2001). We assume an open population, and that the Leslie matrix is filled with the UN's data and assumptions.

$$Pop(t+1) = L(t)(Pop(t) + 0.5I(t)) + 0.5I(t),$$

where $L(t)$ is the Leslie matrix in year t, $Pop(t)$ is a vector with the population size at each age in year t and $I(t)$ is a vector with the total (net) migrants at each age in year t.

B Economy/National Transfer Accounts (NTA)

The economic problem (household problem) is first solved for all generations using the population 0 (pre COVID-19). This exercise will give us the consumption path and the asset holdings for all generations at all ages. Second, using the population 1 (post COVID-19), the household problem is solved for all generations born after 2020. For those generations who are alive in 2020, the household problem should be solved from the age they reach in 2020, using as an initial condition the capital profile obtained with the model without the COVID-19 pandemic.

B.1 Per capita profiles

In constructing the OLG-NTA model, we distinguish three sets of profiles: (i) raw NTA profiles; (ii) exogenously constructed NTA profiles; and (iii) endogenously calculated NTA profiles.

B.1.1 Raw NTA profiles

All raw NTA profiles are standardised each year by the average labour income between ages 30–49. We use this measure of standardisation in order to reduce the importance of individuals' educational and retirement decisions in the simulation results. Thus, the per capita raw NTA profile of individuals with age x at time t is given by

$$NTA\ Profile(x,t) = \frac{\underline{YL}(t)}{\underline{YL}(s)} NTA\ Profile(x,s),$$

where $\underline{YL}(t)$ is the average labour income between ages 30–49 in year t and s is the last year in which the NTA profile has been calculated. Table 1 shows the raw NTA profiles used in the OLG-NTA model.

B.1.2 Exogenously constructed NTA profiles: Household problem

In this category, we have four profiles: (i) labour income (YL); (ii) public transfers, health (TGH/CGH); (iii) social protection, unemployment; and (iv) inter-household transfers from retirees to adult children.

Labour income (YL)

The labour income profile of a cohort is assumed to be driven by three components: (i) the wage per efficient unit of labour per hour worked w; (ii) cohort and age-specific productivity, which depends on the experience and on the mean years of schooling $h(x, Ed)$; and (iii) the number of hours worked l. The wage per efficient unit of labour rate per hour worked is solved in the firm subsection (See the Appendix). The cohort and age-specific productivity profile is given by a standard

Mincerian equation

$$h(x, Ed) = \exp\left\{\rho(Ed)Ed + \beta_0(x - 7 - Ed) - \beta_1(x - 7 - Ed)^2\right\},$$

where $\rho\,(Ed)$ is the rate of return to Ed mean years of schooling, and (β_0, β_1) account for the return of experience on the age-specific productivity of each cohort. Following a strategy similar to that in Sánchez-Romero et al. (2020), we model the rate of return to education with the following simplified Ben-Porath (1967) technology

$$\rho(Ed) = \frac{1}{(1 - \gamma_E)Ed}\log(1 + \theta_E(1 - \gamma_E)Ed),$$

in which we have assumed for the sake of simplicity no depreciation of human capital. The terms γ_E and θ_E are, respectively, the returns to scale of education and the learning ability level. Thus, throughout the cohort and age-specific productivity profile, the cross-sectional labour income profiles reflect the heterogeneity across generations in the mean years of schooling. We follow the literature and assume that $\gamma_E = 0.6$ and $\theta_E = 0.20$, which yields an average return to finishing secondary education of 9.5%. The mean years of schooling by birth cohort are taken from the WIC Human Capital Explorer database. We use this database because it provides the mean years spent in school, classified by sex and by five-year age groups from 1950 to 2100, which coincide in time with the data reported by the UN Population Division. Moreover, the data are available in all scenarios and at all geographical scales.

Given that countries have different labour market settings and institutions, which would imply that a complex labour supply model is needed for each country, we take from the AGENTA project the average number of hours worked (see the National Time Transfer Accounts tab). As a result, the average labour income received by individuals of age x in year t is given by

$$YL(x, t) = w(t)h(x, Ed(t - x))l(x).$$

This function should be able to replicate well the labour income profile for each country, especially when the average number of hours worked for the country is used. See Lee and Ogawa (2011) for a comparison of alternative labour income profiles across NTA countries.

Public Transfers, Health, Inflows (TGHI)

We assume that public transfers, health, inflows (TGHI) at age x in year t in a country vary with the average labour income between ages 30 and 49 in that country, which we denote by $\underline{YL}(t)$, and with the probability of dying at the same age x in year t as follows:

$$TGHI(x, t) = \left(\frac{q(x, t)}{q(x, s)}\right)^{\gamma_q}\left(\frac{\underline{YL}(t)}{\underline{YL}(s)}\right)^{\gamma_y} TGHI(x, s),$$

where $q(x,t)$ is the probability of dying between x and $x+1$ in year t and s is the year of the selected NTA profile. The terms γ_q and γ_y capture how sensitive the public health care expenditure is to changes in the probability of dying and labour income, respectively.

Social protection (due to the COVID-19 pandemic)

To incorporate policies that protect workers from labour income losses due to the lockdown measures, it is assumed that a fraction ϕ_U of the labour income lost is paid by the public sector

$$U(x,t) = \phi_U \epsilon(t)\, YL(x,t),$$

where $\epsilon(t)$ is the percentage decrease in the number of working-hours in year t. This profile is added to the other cash public transfers.

Interhousehold transfers from retirees to adult children: NTA profiles show that recipients of public pensions use them to assist their adult children when public pensions are sufficiently high. To account for this fact, when benefits are higher than a fraction ξ_1 of the average labour income of a prime-age worker $\underline{YL}$, we assume that a fraction ξ_2 is transferred to the adult children. Thus, the interhousehold transfer, outflow of individuals of age x in year t is

$$TFBO(x,t) = \xi_2 \max(0, TGSOAI_0(x,t) - \xi_1 \underline{YL}(t))$$

where ξ_1 sets the pension benefit threshold from which retirees start making transfers to their adult children, and ξ_2 is the fraction of the excess pension that is transferred to the adult children.

Following Sánchez-Romero et al. (2018b), we calculate the amount of transfers received by children at age x in year t using the following expression:

$$TFBI(x,t) = \sum_{s=x+12}^{\min(99+,x+52)} \psi_{t-x}(s,t)\zeta(s,t)TFBO(s,t)$$

where the first term $\psi_{t-x}(s,t)$ is the probability that an individual born in year $t-x$ has a living parent of age s in year t; and the second term $\zeta(s,t)$ represents the fraction of *TFBO* that is received from a parent of age s in year t, which is a function of the expected number of siblings.

Both $TFBO(x,t)$ and $TFBI(x,t)$ are added to TFB.

B.1.3 Endogenously constructed NTA profiles (Household problem)

We implement a standard lifecycle problem for each birth cohort in which household heads optimally decide their consumption and the consumption of their children. The solution to this problem is used to construct the following profiles: (a) private consumption (other than health and education), (b) intra-household transfers and

(c) the private asset-based reallocation. For the sake of notational simplicity, in this section, we remove the variables age and time, and represent the variables in the next period with a prime symbol ($'$).

— **Pre COVID-19:** This will determine the consumption path of private goods and services (other than health and education) of the household (c^F) and the assets held (a) over the lifecycle without the COVID-19 pandemic.

$$\max_c V(a_0) = U({c_0}^F, \eta_0) + \frac{1}{1+\rho} {p_0}' V({a_0}')$$
$$s.t.\ \ {a_0}' = R_0 a_0 + whl - {c_0}^F + {\tau_0}^F + {\tau_0}^{G,\,in\text{-}Cash} - {\tau_0}^{G,-}$$

— **Post COVID-19:** In this regime, both the economy and the population changes. Household heads solve the following economic problem:

$$\max{}_c V(a_1) = U({c_1}^F, \eta_1) + \frac{1}{1+\rho} {p_1}' V({a_1}')$$
$$s.t.\ \ {a_1}' = R_1 a_1 + whl(1-\epsilon) - (1+\theta){c_1}^F + \Theta + {\tau_1}^F + {\tau_1}^{G,\,in\text{-}Cash} - {\tau_1}^{G,-}$$

where ρ is the subjective discount factor; $R_i = (1+r)/p_i$ is the compound interest rate that is gained by individuals in case of surviving; a are the assets held, which can be comprised of investments in firms, national debt and internationally traded bonds; and ϵ denotes the decline in labour income caused by the COVID-19 pandemic. The term θ is the tax rate on consumption, which is a proxy for containment measures aimed at encouraging social distancing (Eichenbaum et al., 2020); and $\Theta = \theta c^F$ are the lump sum transfers from the government. τ^F denotes the sum of the private consumption of health and education and the interhousehold transfers, $\tau^{G,\,in\text{-}Cash}$ denotes all of the public cash transfers received and $\tau^{G,-}$ denotes all of the taxes and social contributions paid. The following NTA profiles are included in each variable:

- ${\tau_i}^F = (\eta_{Ei} + CFE_i) + (\eta_{Hi} + CFH_i) + TFB_i$
- ${\tau_i}^{G,\,in\text{-}Cash} = TGSOAI_0 - \alpha_{SOA} \cdot TGSOAO_i + TGXCI_0 - \alpha_{XC} \cdot TGXCO_i$
- ${\tau_i}^{G,-} = TGEO_i + TGHO_i + TGXO_i$

where η_{Xi} is the cost of children on the good/service X.

Solution

Assuming, similar to Lee et al. (2000) Braun et al. (2009) and Sánchez-Romero et al. (2018a), that $U(c^F, \eta_i) = (1+\eta_i)\log\left(\frac{c^F}{1+\eta_i} - C\right)$, where C is the minimum consumption level, the household problem can be recursively solved using the following system of dynamic equations

$${a_i}' = R_i a_i + whl(1-\epsilon) - (1+\eta_i)\left(C + \frac{1}{1+\theta}\frac{R_i}{\lambda_i}\right) + {\tau_i}^F + {\tau_i}^{G,\,in\text{-}Cash} - {\tau_i}^{G,-},$$
$${\lambda_i}' = \lambda_i(1+\rho)/(R_i {p_i}'),$$

where the private consumption of the household is $(1+\eta_i)\left(C + \frac{1}{1+\theta}\frac{R_i}{\lambda_i}\right)$ and the private consumption of the household head is $C + \frac{1}{1+\theta}\frac{R_i}{\lambda_i}$. Thus, conditional on an initial value for the assets held a, the household problem is solved when the initial guess of λ indicates that the assets held at the maximum age is zero. The initial value of λ can be obtained using a root-finding algorithm (e.g. Bisection method, Regular farsi, Newton-Raphson method, etc.).

B.1.4 Interhousehold transfers

The number of children: The average number of children below age A per adult is given by the following formula (see Sánchez-Romero et al., 2018b):

$$\eta_X(x,t) = \sum_{s=12}^{x} \frac{L(s,t-s)F_x(s,t-s)}{L(x,t)} \frac{L(x-s,t)}{1+SRB(t-s)} X(x-s) 1_{\{x-s \le A\}},$$

where $L(x,t)$ is the person-years lived at age x in year t, $SRB(t)$ is the sex ratio at birth in year t, X denotes the consumption profile and A is the age of leaving the parental home.

Fraction of interhousehold transfers received: If parents leave one monetary unit that is equally split between all surviving offspring, Sánchez-Romero et al. (2018b) show in Eq. (47) that this fraction is given by the following expression:

$$\zeta(s,t) = \frac{1-e^{-\eta(s,t)}}{\eta(s,t)}$$

where $\eta(s,t)$ is the total number of offspring from an individual of age s in year t, which can be calculated by removing the last two components in $\eta_X(s,t)$.

Allocation child consumption: The consumption of a child of age x in year t is proportional to the consumption of her/his parents. Since we do not know with certainty the age of the parent, we calculate the probable age of the parent by using the first row of the Leslie matrix when the individual was born. Thus, we have that the consumption of a child of age $x \in (x, A)$ in year t is given by

$$c^F(x,t) = \theta(x) \sum_{s=x+12}^{x+52} \psi_{t-x}(s,t) c^F(s,t)$$

where $\psi_{t-x}(s,t)$ is the probability that an individual born in year $t-x$ has a living parent of age s in year t

$$\psi_{t-x}(s,t) = \frac{F_p(s-x,t-x)Pop(s,t)}{\sum_{s=x+12}^{x+52} F_p(s-x,t-x)Pop(s-x,t-x)}$$

$F_p(s-x,t-x)$ is the probability that a child was born of a mother of age $s-x$ in year $t-x$, which is obtained by multiplying the first row of the Leslie matrix by the population size and dividing by the total number of births in year $t-x$.

B.2 Aggregate profiles

The macro dimension of the OLG-NTA model is described by aggregate profiles that are obtained by multiplying the per capita profiles by the population size at each age. The sum across ages of the aggregate profiles gives the macro totals from National Accounts. This is an important step, because the aggregate totals affect the inflows and/or the outflows of public transfers due to the constraints imposed by public budgets. To simplify the calculation, we assume that governments run a balanced budget in all years except for those affected by the COVID-19 pandemic; that is, all public inflows are equal to all public outflows.

To adjust all public NTA profiles forwards and backwards in time, we introduce a temporal adjustment factor, which is denoted by α_j for $j \in \{SOA, XC, H, E, X\}$. In particular, we assume that in-cash public transfer outflows and health care public transfer outflows (i.e. social contributions and taxes) are adjusted to finance all the in-cash public transfer inflows (i.e. pensions, social benefits, unemployment, etc.) and health care public transfer inflows (TGHI). Since in-cash transfers and health care spending are mostly received by elderly people, this adjustment implies that social contributions and taxes that pay for social benefits and health care will increase in the future, and were lower in the past. In contrast, since in-kind public transfers inflows for education and other in-kind benefits are mostly received during childhood, we adjust the level of in-kind public transfer outflows (i.e. taxes). Therefore, in-kind public transfer outflows will either decrease or remain the same relative to labour income in the future, and were higher in the past. Thus, we have

Public Transfers, in-cash

- Pensions:

$$\sum_{x=0}^{99+} TGSOAI_0(x,t)Pop_0(x,t) = \alpha_{SOA}(t) \sum_{x=0}^{99+} TGSOAO_0(x,t)Pop_0(x,t)$$

- Other than pensions:

$$\sum_{x=0}^{99+} TGXCI_0(x,t)Pop_0(x,t) = \alpha_{XC}(t) \sum_{x=0}^{99+} TGSXCO_0(x,t)Pop_0(x,t)$$

Public Transfers, in-kind

- Health:

$$\sum_{x=0}^{99+} TGHCI_0(x,t)Pop_0(x,t) = \alpha_{H}(t) \sum_{x=0}^{99+} TGHO_0(x,t)Pop_0(x,t)$$

- Education:

$$\alpha_E(t) \sum_{x=0}^{99+} TGEI_0(x,t)Pop_0(x,t) = \sum_{x=0}^{99+} TGEO_0(x,t)Pop_0(x,t)$$

- Other in-kind:

$$\alpha_X(t)\sum_{x=0}^{99+} TGXI_0(x,t)Pop_0(x,t) = \sum_{x=0}^{99+} TGXO_0(x,t)Pop_0(x,t)$$

where $Pop_0\,(x,t)$ is the population size of age x in year t.

To isolate the economic impact of the COVID-19 pandemic, the balanced budget assumption is relaxed from 2020 until the vaccine for COVID-19 is introduced. We use two alternative populations: one population that is based on the UN Population Division data, labelled with subscript 0; and a second population that is affected by the COVID-19 pandemic, which is labelled with subscript 1. Given that most countries have chosen to implement expansionary fiscal policies to reduce the economic burden of the COVID-19 pandemic, the NTA-based model assumes that public transfer inflows remain unchanged during the period in which the COVID-19 pandemic is affecting the population, and that only the public transfer outflows are adjusted because of labour income losses. Consequently, governments will run deficits and their debt levels will increase. We further assume that after the vaccine is introduced, additional taxes are collected in a way that reduces the debt at a proportional rate. To allow the NTA-based model to have a temporary imbalance in the public budget, we use the same temporal adjustment factors $\alpha_j(t)$ for $j \in \{SOA, XC, E, X\}$ calculated without the COVID-19 pandemic.

B.3 Firms

We assume there is a single good, which can be consumed or saved, and which is produced with a combination of capital and labour, using a Cobb-Douglas production function. Both the labour market and the capital market are assumed to be competitive. Under an open economy with a fixed (real) interest rate r and depreciation of capital δ_K, the wage rate in year t is given by

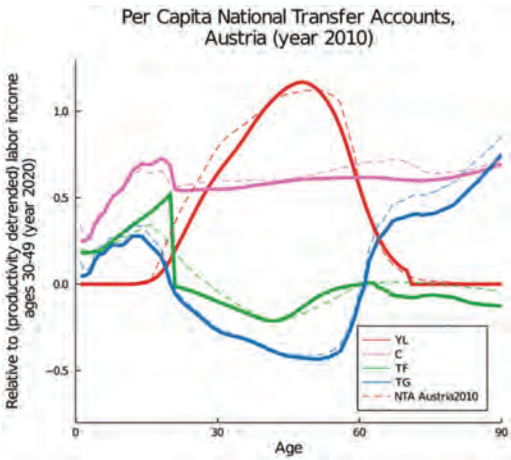
$$w(t) = \Gamma(t)\left(\frac{\alpha_Y}{r+\delta_K}\right)^{\frac{\alpha_Y}{1-\alpha_Y}},$$

where $\Gamma(t)$ is the level of technology, which is assumed to increase at a rate g_Γ annually; $\Gamma(t+1) = (1+g_\Gamma)\Gamma(t)$, and α_Y is the capital share. The total output is

$$Y(t) = \frac{1}{1-\alpha_Y}\sum_{x=0}^{\Omega} YL(x,t)Pop(x,t),$$

where the labour income at age x in year t, $YL(x,t)$, is given by $w(t)h(x,t)l(x)$.

Figure B.1:
In sample performance of the model fitting the NTA profiles of Austria in the year 2010



Notes: The dashed lines depict the NTA data, while the solid lines depict the per capita age profiles obtained with the OLG-NTA model.

B.4 Government

We assume that all public transfer inflows are financed by all transfer outflows in the scenario with no COVID-19 pandemic. However, in the scenario with the COVID-19 pandemic, each country has an imbalance in its public budget

$$B(t+1) = (1+r)B(t) + \tau^{G,+}(t) - \tau^{G,-}(t),$$

which is financed through additional taxes, such that the evolution of debt satisfies the following rule:

$$B(t+1) = B(t) + \phi_B(bY(t) - B(t)).$$

The term ϕ_B is the rate of convergence of public debt to the targeted debt-to-output ratio b.

B.5 Exogenous parameters

Figure B.1 shows the fit of the model to the per capita national transfer accounts for Austria in the year 2010 using the exogenous parameters provided in Table B.1.

Table B.1:
Exogenous parameters

Parameters	Symbol	Value
Productivity growth rate	g_Γ	1.5%
Return to experience	β_0	0.070
	β_1	0.0009
Subjective discount factor	ρ	0
Capital share	α_Y	0.33
Depreciation of capital	α_K	0.05
(Real) interest rate	r	2.5%
Maximum age	Ω	99+
Age at leaving home	A	21
Interhousehold transfers	ξ_1	50%
	ξ_2	50%
Health care elasticities	γ_q	0.20
	γ_y	1.00

Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 143–166

The mathematics of the reproduction number *R* for Covid-19: A primer for demographers

***Luis Rosero-Bixby*[1,*] and *Tim Miller*[2]**

Abstract

The reproduction number R is a key indicator used to monitor the dynamics of Covid-19 and to assess the effects of infection control strategies that frequently have high social and economic costs. Despite having an analog in demography's "net reproduction rate" that has been routinely computed for a century, demographers may not be familiar with the concept and measurement of R in the context of Covid-19. This article is intended to be a primer for understanding and estimating R in demography. We show that R can be estimated as a ratio between the numbers of new cases today divided by the weighted average of cases in previous days. We present two alternative derivations for these weights based on how risks have changed over time: constant vs. exponential decay. We then provide estimates of these weights, and demonstrate their use in calculating R to trace the course of the first pandemic year in 53 countries.

Keywords: Covid-19; reproductive number R; demographic methods; net reproduction rate

1 Introduction

Health professionals and world leaders are talking more and more about the numbers R and R_0 (R-naught), the basic reproduction number.

Angela Merkel, a rare head of state with a scientific background, explained the trajectory of the Covid-19 pandemic on April 16, 2020, as follows:

> "*We are now at about a reproduction number of 1, so one person is infecting another one. . . . If we get to the point where everybody infects*

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The views expressed in this paper are those of the authors and do not necessarily reflect the views of the United Nations and the University of Costa Rica.

DOI: 10.1553/populationyearbook2022.res1.3

1.1 people, then by October we will reach the capacity of our health care system with the assumed number of hospital beds. If we get to 1.2, so that everyone is infecting 20% more – out of five people, one infects two and the rest one. Then, we will reach the limits of our health care system in July. And if it is up to 1.3 people, then in June we will reach the limits of our health care system. So that's where we can see how little the margin is". (The Guardian News, 2020).

The R was explicitly defined for the first time by the epidemiologist Klaus Dietz in 1975[1] (Dietz, 1975) as the expected number of infections (secondary cases) generated by a typical infected individual. If this occurs in a population in which everyone is susceptible (that is, at the beginning of an epidemic; hence the subscript zero), this number is R_0, or the basic reproduction number. In later stages of an epidemic, epidemiologists usually call the R the "effective" reproductive number, which is often represented as $R(t)$. This number can, in turn, be a cohort (longitudinal) R, which is called in some texts the "*case* reproductive number;" or a period (cross-sectional) indicator, which is sometimes called the "*instantaneous R*" (Gostic et al., 2020). This article focuses on the instantaneous, effective reproductive number, the $R(t)$, which we usually refer to simply as R.

R is considered to be an important indicator for monitoring the Covid-19 pandemic, and particularly for assessing the effects of infection control measures that frequently have high social and economic costs. R is also an important input for projecting future scenarios of disease spread. Moreover, knowing R_0 allows us to identify the threshold for *herd immunity*: i.e., the proportion of individuals in a completely susceptible population who need to become immune (naturally or by vaccination) in order to stop the growth of the epidemic curve. This threshold occurs at $(R_0 - 1)/R_0$ in homogeneous populations (Fine et al., 2011).

The demand for information about R for Covid-19 is so great that several websites provide estimates of R at the national and subnational levels, as well as the tools for producing estimates with user-provided data. The website https://shiny.dide.imperial.ac.uk/epiestim/ is an example of the latter (Cori et al., 2013). A systematic review of the Covid-19 literature up to September 2020 found 524 studies that reported R estimates, including 49 that explained the method and the data they used (Billah et al., 2020).

Although the concept of R is clear, the logic for its calculation in epidemiology is not easy to follow, as it usually requires the use of mathematical models and complex algorithms (Bettencourt and Ribeiro, 2008; Dietz, 1993; Nikbakht et al., 2019; Wallinga and Lipsitch, 2007). In addition, the results may vary substantially depending on the method used in the estimate (Billah et al., 2020). Hence, there is a demand for transparent and reasonable estimates of R.

[1] Earlier epidemiology in the field of malaria transmission used the concept of R in an effort to identify critical thresholds of population densities of mosquitos per human for stopping the spread of infection (Heesterbeek, 2002).

The purpose of this article is to use the toolbox of demographers to understand R, and to provide a straightforward procedure for estimating it. We seek to demystify the complexities of estimating this important indicator by following well-known procedures in demography, a discipline in which an analog of R – the net reproduction rate (NRR) – has been routinely computed for more than a century. The approach to estimating R we present in this article is similar to an approach that was recently developed in epidemiology by Cori and colleagues (Cori et al., 2013).

2 Simple (but not useful) formulas

In an ideal world in which we had access to perfect data, the reproduction number R could be calculated for each generation of infected individuals as the simple average of the number of infections generated by each member of the cohort. For example, the cohort of the first two infected persons in Costa Rica (March 6, 2020) had an $R = 4.5$, since, according to press reports, one case was a tourist who infected his spouse and the other was a doctor who infected eight people: $R = (1 + 8)/2 = 4.5$. However, this type of information is not available for the subsequent cohorts of individuals who were infected in the days that followed. Moreover, this information is not perfect, as it is possible that there were additional people who were infected by these two initial cases, but whose infections were not reported.

Another way to estimate R is the approach that has been used in demography since around 1880 (Lewes, 1984), and that was formally developed by Alfred Lotka, the father of mathematical demography (Dublin and Lotka, 1925). Lotka defined the NRR as the ratio of total births of daughters[2] in two successive generations, expressed as:

$$NRR = R = \int_u^v b(a)p(a)\,da \tag{1}$$

Where $b(a)$ is the fertility rate of women at age a and $p(a)$ is the probability of reaching this age alive (both variables refer only to females and female offspring), and the limits of the integral include the reproductive age range of women, which is, in practice, from $u = 15$ to $v = 49$ years.

If instead of applying the formula to population growth, we apply it to the reproduction of an outbreak – that is, to a cohort of individuals infected on the same date – the number of days elapsed since each cohort member was infected would be represented by a (the "age", defined as the days since infected); $b(a)$ would become the transmission rate of the infection at that "age" of a days, or the average number of people infected on day a; and $p(a)$ would become the probability of still being able to spread the disease after a days. The limits of the integral would be from u, or the first day when an individual achieves a sufficiently high viral load to become

[2] Lotka originally defined the NRR for generations of men and sons. However, for practical reasons, demographers compute it for women and daughters.

infectious; to the maximum number of days v that an infected person can still be infectious. Hence, R becomes the NRR of infected individuals or the reproduction number R in the lexicon of epidemiologists.

However, to use this formula as is customary in demography, it would be necessary to have data on daily counts of new cases of infected persons tabulated by the time-since-infection (duration of infection) of the person who infected them. The newly recovered cases,[3] as well as the deceased cases, should also be tabulated by the duration of the infection. Given that these data usually do not exist, it is necessary to make assumptions about the functional form of $b(a)$ and $p(a)$ to be able to estimate the reproduction number R indirectly given the lack of data disaggregated by duration a.

In the following sections, we present two approaches or models for estimating the reproduction number R using widely available data. To simplify the presentation, we assume no demographic change; i.e., a process with no births, deaths or migrants. In the discussion section, we address the robustness of the method to violations of these and other assumptions.[4]

3 A simple model with constant rates

Two heroic assumptions that can be used to simplify the estimation process are that the effective transmission rates and the recovery rates (or, more broadly to include deaths, the "removal rates") are constant throughout a person's infectious period; that is, that the rates are invariant with respect to a, days since infection.

If $b(a)$ is invariant with respect to a over the interval from u to v, then $b(a) = b$, which can be placed outside of the integral:

$$R = b \int_u^v p(a)\, da \tag{2}$$

Where b is the daily rate of effective transmission or the average number of people infected per day.

The probability of continuing to be infectious – or survival function $p(a)$ – is driven by the removal rate $g(a)$. In survival time analysis, this is the "hazard", "failure" or "mortality" rate. The following identity relates the survival function to the failure rate, which, in turn, nicely simplifies into a negative-exponential function

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3 Recovered cases are those of individuals who are no longer able to produce replication-competent virus.

4 The acquired immunity of recovered individuals means that R declines over time because the pool of susceptible individuals is depleted. This dynamic of epidemics does not occur in the NRR of demography, as giving birth is a renewable process. The effect of a naturally declining R is, however, nil on the few days that individuals are sick with Covid-19, and can thus be omitted from the models used to estimate R in this article.

when the recovery rate $g(a)$ is invariant with respect to a (Keyfitz, 1968):

$$p(a) = e^{-\int_0^a g(x)\,d(x)} = e^{-ga} \qquad (3)$$

The integral of $p(a)$ is well-known in demography and in survival time analysis: it is the area under the survival curve, which defines life expectancy; or, in this case, the number of days lived while infectious during the interval between u and v, which we call E.[5] Here, "surviving" means to continue in the infectious state.

Recalling Equation (2), the equation for the reproduction number R therefore simplifies into:

$$R = b \cdot E \qquad (4)$$

b is the daily effective transmission rate of the infection (new infections per day), and

E is the mean number of days infectious.

This simple identity is useful to show that the reproduction number R has two components: the rate at which the infection is transmitted from one person to another and the mean duration of the infectious period. For example, if the daily transmission rate is $b = 0.2$ and the mean duration of the infectious period is $E = 10$ days, the reproduction number of the epidemic would be $R = 2.0$. Each case would produce two infections on average, under the two assumptions of invariance noted above.

4 Estimation of the effective transmission rate in a real population

The expected length of the infectious period E, and the recovery rate from the disease g that determines it, can reasonably be considered universal parameters determined by the biology of the infectious agent, which, in practice, vary little over time and from one population to another, at least as long as there is no treatment to speed recovery. Early data for Covid-19 suggest that the virus has an average infectious period of between eight and 15 days (Anastassopoulou et al., 2020; WHO, 2020; You et al., 2020). If an exogenous value of E is used, estimating R is a question of determining the specific transmission rate b of the population at each time t. The average transmission rate (under the aforementioned assumption of constancy over the infectious period) can be estimated as:

$$b(t) = c(t)/A(t) \qquad (5)$$

$c(t)$ is the number of new cases on day t, and

[5] Solving the definite integral of $p(a)$ in Equation (3) yields the expected number of days a person remains infectious on average: $E = [p(u) - p(v)]/g$. If a person is infectious over the entire disease period, E is simply the inverse of g.

$A(t)$ is the number of currently active cases (infected people who are still spreading the disease) as of day t.

The number of new cases each day is a widely available statistic that is usually published in a timely fashion. However, the number of currently active cases needs to be estimated, which can be done using the data series of new cases in the previous days. Borrowing a basic relationship in demography (Lotka, 1998), which defines the size of a population based on the number of past births and the survival function, the number of active cases in the infective period u to v can be estimated with:

$$A(t) = \int_u^v c(t-a)p(a)\,da \tag{6}$$

Recalling from (2) that $R = b\int_u^v p(a)\,da$, the reproduction number R at time t is:

$$R(t) = \frac{c(t)}{\int_u^v c(t-a)p(a)\,da} \cdot \int_u^v p(a)\,da$$

Dividing both the numerator and the denominator by $\int_u^v p(a)\,da$ gives an expression with a clearer interpretation,

$$R(t) = \frac{c(t)}{\int_u^v c(t-a)\left[\frac{p(a)}{\int_u^v p(a)\,da}\right] da} \tag{7}$$

The numerator of this quotient is the number of new cases counted on day t, while the denominator is the weighted average of the cases reported during the previous u to v days. The weights used to obtain this average are represented by the term in square brackets, which we will call $w(a)$.[6] The weighting term is none other than the distribution of the "survival" function for the infectious state; that is, the proportion of people who continue to be infectious $(t-a)$ days after they first became infected. As previously shown in Equation (3), this is a simple negative exponential distribution under the assumption that the recovery rate is independent of the time elapsed since infected.

Moving on to the discrete version in which we solve the integral and simplify the fraction, we arrive at the following handy formula for estimating $R(t)$, which also assumes a fixed lag of six days between the date the infection occurs and the date the case is reported:

$$R(t-6) = c(t) \Big/ \sum_{a=u}^{a=v} c(t-a)w(a) \tag{8}$$

The weights $w(a)$ are the aforementioned distribution of the survival function $p(a)$ evaluated over the interval u to v, which is determined by the following formula

[6] A quick and rough estimate of the denominator can be obtained by calculating the simple average – without weighting – of the cases in a period of at least 14 previous days.

(see Footnote 5):

$$w(a) = ge^{-ga}/(e^{-gu} - e^{-gv}) \tag{9}$$

Plausible parameters for estimating these factors are:

- Infectious interval: $u = 2$ and $v = 30$ days, and
- Daily recovery rate $g = 1/10$, which implies:
  - Mean duration of illness = 10 days and
  - Mean duration of infectiousness $E = 6$ days.

We took these parameters from early reports of the epidemiology of Covid-19 as observed mostly in the Hubei province in China (Anastassopoulou et al., 2020; Park et al., 2020; WHO, 2020). As knowledge of this disease progresses, different parameters may be favored in the future.

5 A (more realistic) model with exponential rates

Although epidemiology models of Covid-19 often assume that transmission and recovery rates are constant during the illness period, it is useful to explore alternative specifications of these two functions to better approximate the rates that have been observed during the first few months of the pandemic.

Regarding the transmission rate $b(a)$, initial data on the outbreak and measurements of the viral load while infected with the disease suggest a distribution with an early peak at two or three days followed by a sharp decline (He et al., 2020; Prakash, 2020). To keep the math simple, we assume a negative exponential function that declines quickly from the peak day of infection, which is also assumed to be the first day of infectiousness u:

$$b(a) = B_0 e^{-B_1(a-u)} \tag{10}$$

B_0 parameter representing the peak transmission rate on the initial day u, and
B_1 parameter indicating the speed of the decline in the transmission rate.

Regarding the removal rate $g(a)$, we did not find any estimates of its distribution for the novel Covid-19 disease in the literature. However, it seems reasonable to assume that the chance of recovery of an infected individual increases with time. The Gompertz model is a well-known function (and is convenient for integration purposes) for representing this behavior. It assumes that the rate of interest increases with duration time at a constant speed, which is a pattern observed for failure rates in most biological and mechanical entities (Keyfitz, 1968; Pollard, 1991):

$$g(a) = G_0 e^{G_1 a} \tag{11}$$

G_0 parameter representing the recovery at the beginning of the disease, and
G_1 parameter measuring the speed of increase in the recovery rate per unit of a.

The proportion of individuals who are still infectious after a days, or the survival function, is obtained by solving the integral in the formula below, which results in a double exponential function:

$$p(a) = e^{-\int_0^a g(x)\,d(x)} = e^{[(G_0/G_1)(1-e^{G_1 a})]} \tag{12}$$

Determining the effective reproduction number $R(t)$ with the functions $b(a)$ and $p(a)$ would entail estimation at each time t of the parameters defining these functions; most importantly, those of the transmission rate $b(a)$. The data required to do this are not available. Instead, we propose following a procedure that is well-known in demographic analysis: indirect standardization (Shryock and Siegel, 1976). In the first step of the procedure, we estimate the expected number of cases consistent with a reproductive number $R = 1$ with plausible distributions of $b(a)$ and $p(a)$, given the composition by duration a of active (currently infected) cases at time t.

The following relation estimates the expected number of cases given that $R = 1$:

$$c(t, R = 1) = \int_u^v c(t-a)[b(a)p(a)]\,da \tag{13}$$

In a second step, the $R(t)$ factor is estimated as a quotient between the observed and the expected cases:

$$R(t) \approx \frac{c(t)}{\int_u^v c(t-a)[b(a)p(a)]\,da} \tag{14}$$

Note that the denominator is, like in the model of constant rates (Equation (7)), a weighted average of the series of cases in the previous days, with the term in rectangular brackets as the weighting factor we have called $w(a)$.

Given the assumed functions for $b(a)$ and $p(a)$, and with the aforementioned lag of six days between infection and diagnosis, we arrive at the following formula in discrete terms for computing an estimate of the effective reproduction number $R(t)$ under the model we call "exponential rates":

$$R(t-6) = c(t) \Big/ \sum_{a=u}^{a=v} c(t-a)w(a) \tag{15}$$

This is the same formula as the one with the constant rates model (Equation (8)), but with a different set of weighting factors $w(a)$:

$$w(a) = B_0 e^{[-B_1(a-u)+(G_0/G_1)(1-e^{G_1 a})]} \tag{16}$$

These weighting factors $w(a)$ are the distributions derived by multiplying $b(a)$ times $p(a)$, starting with the day $a = u$ when infectiousness begins, which we are also assuming is the peak day of Covid-19 infectiousness.

Plausible parameters for estimating the set of weighting factors are:

- Infectious interval: $u = 2$ and $v = 30$ days (however, the upper limit is irrelevant, since the weighting factors reach zero by day 22);

- Parameters for the survival function $p(a)$ chosen to conveniently reproduce a 10-day mean duration of illness:
  $G_0 = 0.0169$ and
  $G_1 = 0.220$;
- Parameters for the effective transmission function $b(a)$ chosen to reproduce, in conjunction with $p(a)$, a convenient reproduction number $R = 1$:
  $B_0 = 0.157$ and
  $B_1 = 0.0508$.

As before, we chose the parameters on the basis of early knowledge of the Covid-19 epidemiology, mostly from the Chinese province of Hubei (Anastassopoulou et al., 2020; He et al., 2020; Park et al., 2020; Prakash, 2020; WHO, 2020).

6 Weighting factors, generation time and growth

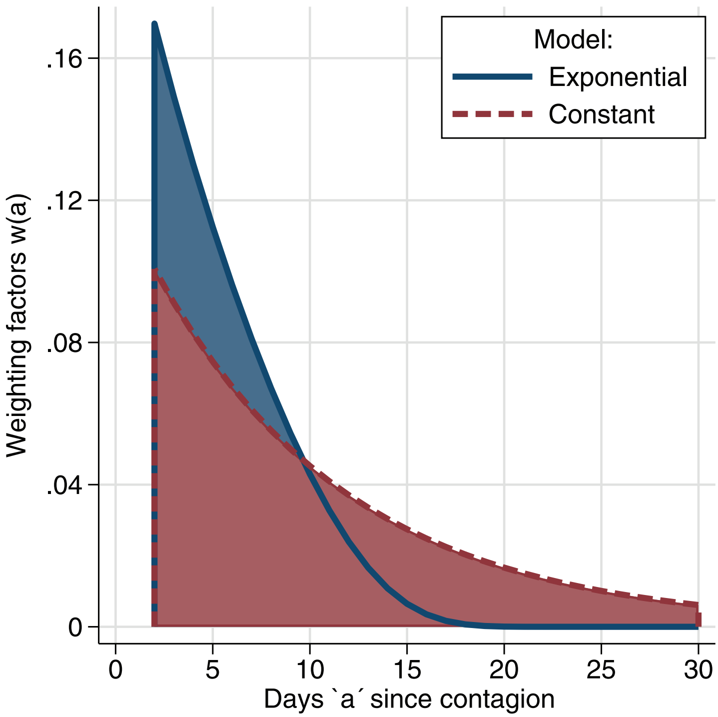
With two different sets of assumptions, we have arrived at the same relationship for estimating $R(t)$ as the quotient between the numbers of new cases in day t divided by the weighted average of cases in the previous days. Therefore, the choice of the correct set of weighting factors $w(a)$ becomes a key issue in estimating R. Figure 1 compares the $w(a)$ distributions in the previously presented constant and exponential models (the functions $b(a)$ and $p(a)$ behind the weighting factors are shown in Figure A.1 in the Appendix).

The constant rates model gives more weight to cases that occurred farther back in the past, while the exponential rates model gives more importance to more recent cases. If the number of new cases has changed little in the past, the $R(t)$ estimated with the two models will be similar. Remembering that these factors are in the denominator of the $R(t)$ formula, the constant rates model will result in higher $R(t)$ when the number of daily cases is increasing. The reverse will happen in later stages of the epidemic, when the number of daily cases is declining: i.e., the $R(t)$ estimates with the constant model will be lower. Therefore, the constant rates model and, in general, wider distributions will exaggerate extreme values of $R(t)$ estimates.

The two models can be considered archetypes for the choice of a weighting distribution for the indirect estimation of the reproduction number $R(t)$. Choosing a narrow distribution, as in the exponential model, gives more weight to recent cases, while a wider distribution, as in the constant model, gives more weight to older cases.

The shape of the $w(a)$ distribution is mostly driven by the shape of the transmission rate curve $b(a)$. To understand the transmission pattern of Covid-19, it is useful to look to evidence from recent outbreaks of other respiratory infections, such as: (1) the seasonal influenza curve with a high and narrow concentration in the first few days of illness; and (2) the SARS-2003 coronavirus outbreak with a wider and later distribution, which is somewhat similar to our rectangle of constant $b(a)$ (see Figure A.1 in the Appendix). Emerging data and estimates for the novel Covid-19 virus suggest that its transmission pattern resembles that of seasonal influenza,

Figure 1:
Weighting factors distributions



rather than of SARS, with a high concentration in days two to four (He et al., 2020); as in our exponential model.

The *generation time*[7] or length is an important indicator that epidemiologists often use to summarize the time it takes for an infected person to pass on the infection to others. It is a key input element in many epidemiological models that estimate the reproduction number R. This indicator is the mean duration a in our $w(a)$ distribution of weighting factors, which we call T:

$$T = \int_u^v a w(a)\, da \tag{17}$$

[7] The epidemiologic literature often uses the “serial interval”İ as an estimate of the “generation time”. The generation time is the interval between the onset of infection for the “parent-child” cases. The serial interval is the observed period of the onset of symptoms between the infector and the infectee. The onset of infection and the onset of symptoms are separated by the “incubation period”.

Since the integral in the exponential model does not have a simple analytical solution, we use numerical integration to derive the generation time (see Table A.1 in the Appendix) with:

$T = 10.20$ days in the model of constant rates, and

$T = 6.06$ days in the model of exponential rates.

Four review papers have identified nearly 40 articles on Covid-19 with estimates of T ranging from four to eight days (Billah et al., 2020; Griffin et al., 2020; Hussein et al., 2021; Park et al., 2020; Rai et al., 2021). As the estimates of our exponential model fall in the middle of this range, it appears that this model better represents the current state of knowledge about Covid-19 transmission than our constant model. An example of a set of $R(t)$ estimates with a shorter generation time of 3.6 days is from the Centre for the Mathematical Modeling of Infectious Diseases (CMMID) at the London School of Hygiene and Tropical Medicine (Abbott et al., 2020). As expected, these estimates result in smaller extreme figures; or, in other words, the estimates are very close to $R(t) = 1$ at all times.

The equivalent of the generation time in demographic analysis is the "mean interval between two consecutive generations," which Alfred Lotka, in his 1934 book *Analytical Theory of Biological Associations,* used to identify a relationship between the net reproduction rate R and a key indicator of the multiplication capacity of a population: the "intrinsic rate of growth" (Lotka, 1969). The relationship is:

$$R = e^{\rho T} \quad \text{or} \quad \rho = \ln(R)/T \tag{18}$$

In the context of Covid-19, ρ is the "intrinsic" or underlying rate of growth of the number of infectious individuals. Note that this growth rate may differ from the observed or real rate usually represented by lowercase r. In Lotka's words: "the ρ exposes the fundamental capacity of multiplication . . . while the r does not give us the true measure of that capacity since it is influenced by past factors we could call adventitious. The ρ is an asymptotic value to which the observed r will approach when those fundamental conditions remain the same" (Lotka, 1969, pp. 126–127). The observed growth r of Covid-19 cases is determined by both the fundamental conditions of its infectiousness and the momentum in the pool of individuals who are the source of infection. The intrinsic ρ is a rate free of momentum effects.

It is worth noting that several epidemiological studies have developed estimation procedures of R that start from this relationship and use observed growth rates as input and borrow T from models.[8] However, those studies usually do not make the distinction between the observed little r and the intrinsic ρ.

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[8] Indeed, estimating the intrinsic growth rate directly from observed population data is a well-known approach in demography. In stable populations, births, deaths and population numbers are all growing at the intrinsic growth rate. In non-stable populations, Preston has shown that the growth rate of the population segment below the mean length of a generation is a good approximation of the intrinsic growth rate (Preston, 1986). Ediev, in generalizing the work of Fisher on reproductive value, has provided a method for estimating the intrinsic growth rate based on the dynamics of the population age structure (Ediev, 2007).

7 Estimates of $R(t)$ for Covid-19 in the real world

In this section, we analyze our estimates of $R(t)$ during the first year of the pandemic for 53 European and Latin American countries.[9] Figure 2 shows the results for Chile and Costa Rica, two Latin American countries known for maintaining good-quality health statistics. The figure illustrates the effect on R estimates of using the two different weighting distributions $w(a)$ corresponding to our constant and exponential assumptions. The figure also shows the relationship between the behavior of $R(t)$ and the epidemic curve of incidence over time.

The two proposed models produce approximately similar time-trend curves. They tell similar stories about when the reproduction number in each country is ascending, declining and crossing the $R = 1$ threshold; and about the speed of change in this indicator. However, at specific points in time, the level of the estimate may differ substantially, especially at extremely high or low levels. As expected, the model assuming constant rates exaggerates extreme values, tending toward higher values at high levels and lower values at low levels. This is in part because the mean generation time in the constant model is wider (10 days vs. six days). However, it is also because new cases tend to be increasing when $R > 1$ and to be decreasing when $R < 1$ (see the epidemic curves in the lower part of the figure), which, as we explained above, pulls the estimate up or down due to the greater weight assigned to older cases in the constant rates model.

As we noted in the previous section, our model of choice is the one that assumes exponential rates of removal and transmission of the Covid-19 disease. The "constant model" was developed for didactic purposes only.

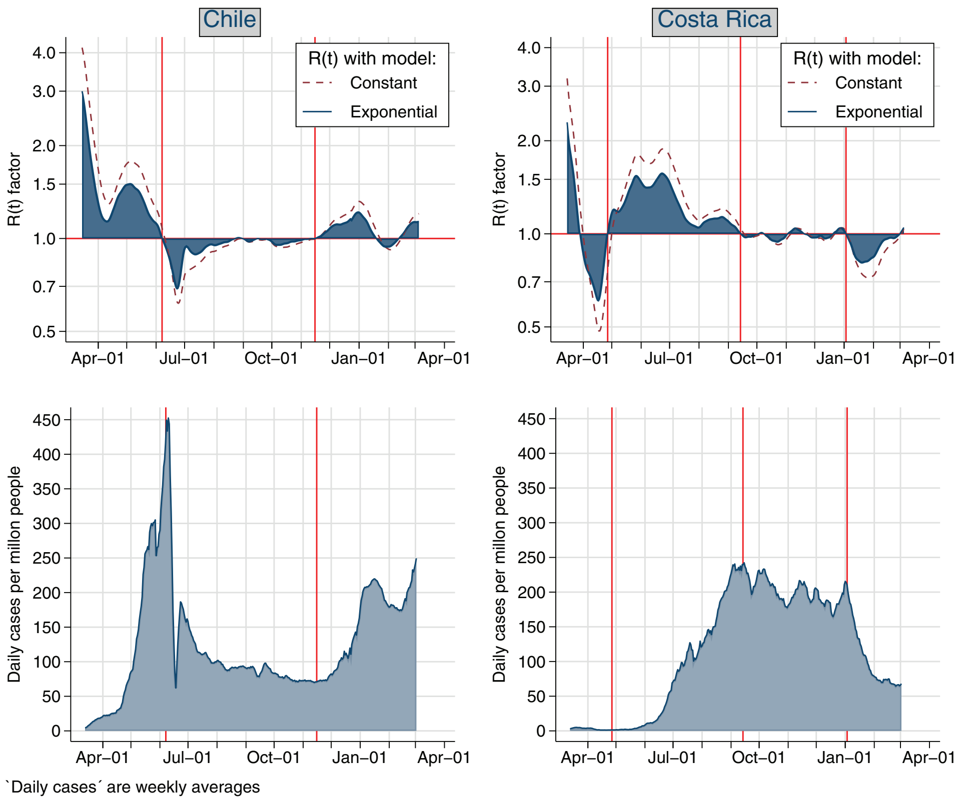
Figure 2 also illustrates the relationship between $R(t)$ and the epidemic curve of incidence. In periods when $R > 1$, the epidemic curve increases; and in periods when $R < 1$, the curve declines. When R is hovering around one, the number of new cases plateaus. This can occur at high levels, such as in Costa Rica from September to December; or at moderate levels, such as in Chile from August to November.

The points in time when $R(t)$ falls below the threshold of one are approximately the peak times of the pandemic waves: i.e., early July and early January in Chile and mid-September and January 1, 2021, in Costa Rica. $R(t)$ also shows the distinct phases or waves of the epidemic, delimited by the red vertical lines of Figure 2.

The $R(t)$ curves observed in these countries demonstrate the importance of taking aggressive action to contain the pandemic in its very early stages. Costa Rica

[9] We used the daily national series of confirmed Covid-19 cases from the "Our World in Data" website (Ritchie, 2020), accessed on March 10, 2021. The raw curves of cumulative cases were first smoothed out with local regression as implemented in the Stata software, command "lowess" (StataCorp, 2017). Clean daily numbers of cases were obtained by the difference in the smoothed cumulative curve, and were used as the input data in the estimation. Countries with populations of less than one million or unreliable data were excluded, along with the period before there were 100 accumulated cases. Our final analytical data file for Figures 2 and 3 is included as supplementary material in Excel and Stata-17 formats (available at https://doi.org/10.1553/populationyearbook2022.res1.3).

Figure 2:
***R*(*t*) and the incidence curve during the first year of the Covid-19 pandemic in Chile and Costa Rica**



Source: Daily national series of confirmed Covid-19 cases from the website "Our World in Data" (Ritchie, 2020), accessed on March 10, 2021.

employed that strategy by implementing aggressive contact tracing and testing programs, as well as drastic lockdown measures that essentially paralyzed the country from March 15 to April 15 (Rosero-Bixby and Jiménez-Fontana, 2021). Consequently, in Costa Rica, the $R(t)$ factor fell well below one, and the number of infections was contained at levels close to zero. In contrast, Chile did not reduce its R to the threshold of one or lower in April, and paid dearly for this failure with a devastating surge in infections in the following period. After the first month of the pandemic, both countries had rising R, but because the increase started at very different baselines, the results were vastly different. By June 15, the pandemic was exploding in Chile, at 260 daily cases per million population; whereas in Costa Rica, just 20 daily cases per million population were being reported.

The effects of Costa Rica's initial success in containing the virus were still apparent as long as one year after the start of the pandemic. As of March 10, 2021, the cumulative mortality caused by Covid-19 was 561 deaths per million residents in Costa Rica, compared to 1,117 deaths per million residents in Chile.

In general, subtle differences in the trajectory of the $R(t)$ resulted in two substantially different epidemic curves of incidence in Chile and Costa Rica. This is an obvious point from a demographic perspective: the absolute increase in population size is driven by both the reproduction rate and the initial population size. By the same token, both the R factor and the number of actively contagious individuals drive the incidence curve.

Broadening the scope of our analysis to 18 countries in Latin America and 35 countries in Europe, Figure 3 shows the results of our R estimates (exponential model), with weekly boxes displaying the distribution of countries by R. The box's hinges indicate the interquartile interval, and each box's central line indicates the median value of R for that week.

Epidemiologists pay special attention to the R_0 factor – the basic reproduction number – to characterize and model epidemic outbreaks. The level of $R(t)$ – the effective reproduction number – in the first days of an outbreak is an approximation of this basic R_0. The first boxes in the figure thus suggest that Covid-19 R_0 was in the interquartile range of 1.9 to 2.8 in European populations, whereas it was in the range of 2.3 to 2.5 in Latin American populations.

On both continents, the initial R declined sharply in the first few weeks, though more so in Europe than in America. In the European countries, R leveled out at around $R = 0.8$ in May, while in the Latin American countries, R leveled out at around $R = 1.15$. This means that in Europe, the first pandemic wave peaked (R crossed one) in early April, with the incidence of Covid-19 falling sharply thereafter. By contrast, in Latin America as a whole, the peak ($R = 1$) of the first pandemic wave seems to have occurred much later, in early August.

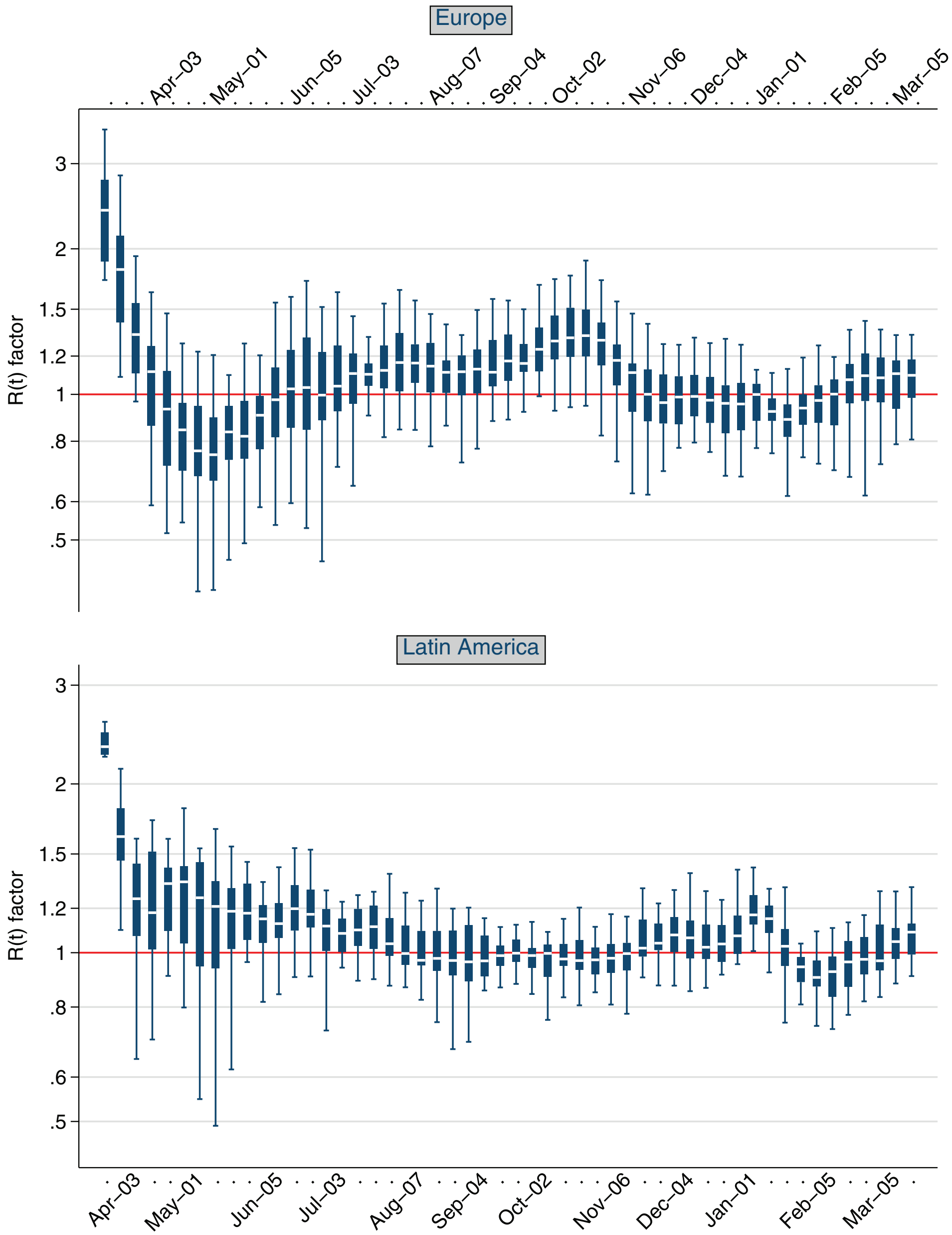
In Latin America, R hovered around $R = 1$ from August to December. Thus, the first wave did not really end, but instead plateaued at high levels of incidence.

In Europe, the Covid-19 pandemic has followed a trajectory of three well-defined waves: the initial wave peaked in April 2020; the second wave peaked in November 2020; and the third wave had not yet peaked by March 5, 2021.

One year after the start of the pandemic, the described trajectories of $R(t)$ resulted in a mortality toll that was 16% higher in Latin America, with 1,325 deaths per million people, than it was in Europe, with 1,139 deaths per million people.

The data from the 18 Latin American countries confirm our previous observation that the very early containment of R correlates with a less severe pandemic in the following months. In these countries, the correlation coefficient between the national level of R two weeks after case 100 was diagnosed and the death toll in the first year of the pandemic is strong, at 81%. However, this association is not observed in Europe, where the correlation coefficient is weak, at 5%. Figure A.2 in the Appendix shows the scatter plots behind these correlations.

Figure 3:
Weekly distribution by $R(t)$ of countries in Europe and Latin America



Source: Daily national series of confirmed Covid-19 cases from the website "Our World in Data" (Ritchie, 2020), accessed on March 10, 2021.

8 Discussion

The reproduction number R is a key indicator that has been used to characterize the dynamics of the Covid-19 pandemic, and to assess the effects of pandemic-related policy interventions. Unfortunately, the available statistics do not allow us to calculate this factor unequivocally. Instead, R must be estimated using indirect methods based on theoretical models and assumptions about the behavior of this novel disease. This article provides an approach for estimating R using methods and models developed a century ago in demography. The strengths of the proposed approach are the transparency of the assumptions from the point of view of demographers and the simplicity of the procedure.

The simple relationship used to estimate $R(t)$ on a daily basis is a quotient between the current number of new cases divided by a weighted average of the number of cases in the previous 20 or 30 days. We suggest using a set of weighting factors derived from assuming that: (1) the transmission rate of an infected individual declines sharply from a peak at day 2 of the illness following a negative exponential function; and (2) the recovery rate from the disease follows the Gompertz law of exponential growth with disease duration. A mean generation time of six days summarizes this suggested set of weighting factors. Early estimates of this interval, mostly for outbreaks in China's provinces, range from four to eight days. A weighting factors distribution with shorter generation times will result in $R(t)$ values that are closer to one; i.e., with less extreme values. We have shown that during stages of the outbreak when the number of new cases is increasing, shorter generation times (narrower distributions) result in lower $R(t)$ estimates; whereas during stages of the outbreak when the number of new cases is decreasing, shorter generation times result in higher (closer to one) estimates. In spite of these differences, the general time trend in $R(t)$ does not change meaningfully when different distributions are chosen. As our knowledge about this novel coronavirus improves, researchers will have more information that will enable them to make better informed choices about the distribution of the weighting factors used to estimate $R(t)$.

The strategy proposed in this article for estimating R is not new in epidemiology. A similar equation was proposed by Wallinga and Lipsitch (2007, Equation 4.2), and was implemented through web-based tools by Cori et al. (2013). The distribution $w(a)$, or the set of weighting factors of cases that occurred in previous days $t - a$, is called the "*infectivity profile*" by these authors, which is also the distribution of the generation time. Epidemiology studies assume a mathematical function for the $w(a)$ distribution, with the gamma function being the most commonly used (Knight and Mishra, 2020).

Using the computer tool provided by Cori et al. (2013), we were able to reproduce very closely our R estimates with the gamma function for a mean generation time of six days and a standard deviation of three. One study has recommended using the Cori et al. approach to estimate R after comparing it with two other epidemiological methods applied to a simulated Covid-19 epidemic in which the true *R* is known (Gostic et al., 2020).

The main contribution of this article is that we demonstrated how the problem of estimating *R* can be approached with demographic thinking. The key set of weighting factors $w(a)$ is seen here not as a black box of a mathematical function, but as the product of two well-known demographic concepts: a survival function and a birth function, which could be defined analytically or with discrete observed distributions.

Our model assumes the absence of demographic change, meaning that births, deaths and migrations do not exist. Given that the time horizon involved in $R(t)$ estimates is short (30 days or less), including or excluding demographic change is unlikely to change the results in a meaningful way. Potential exceptions to this general observation are the arrival of imported cases of Covid-19 and mortality caused by Covid-19 itself.

Imported cases should not be counted in the numerator if the information is available, even though they must be included in the denominator. However, imported cases are statistically important only when the outbreak is at very low levels, and is in its initial stages.

Covid-19 deaths can be included by broadening the concept of the recovery rate $g(a)$ to a "removal rate" that would include both recovery and death as means of exiting the population of the infected. However, this correction would change the estimates very little, since the case fatality rate of Covid-19 has an order of magnitude of 0.01 (Worldometer, 2020), which, along with a mean period of illness of 15 days, is equivalent to a daily mortality rate of less than 0.001. Given that the mean daily recovery rate of Covid-19 is around 0.1, the correction would thus be about 1%. Such a small correction may well be omitted.

A weakness in all of the estimates on the numbers of reported cases is that this statistic is just the tip of the iceberg of all Covid-19 infections. But this does not necessarily invalidate the estimate. The estimated *R* would be valid insofar as these known observations are representative of the whole. Regardless of what proportion of cases is known and what proportion of cases is unknown, the important thing is that the known cases reflect the characteristics of the whole, and that this proportion does not change rapidly on the scale we are using to measure *R*. It is worth noting that given this weakness in the available input data, it might be pointless to use more intricate models to estimate *R*, which would seem to support the use of the simple approach this article proposes.

The *R* number is probably the best indicator for monitoring the dynamics in the propagation of an epidemic, and for taking action to contain it. It is like the speedometer in a car that tells us how quickly an epidemic is moving, and it does so in a more timely manner and with less contamination than its cousins; i.e., the rates of variation in the curves of incidence, hospitalizations or deaths. For example, in late January and early February 2021 in Costa Rica, the epidemic curve of incidence was declining, whereas *R* was clearly increasing (Figure 2). Thus, the former indicator was misleading, while the *R* estimates reinforced the need to keep public health restrictions in place.

However, the *R* number tells only a partial story of an epidemic and its drivers. It does not, for example, tell us about the severity of an outbreak, which is better described by the incidence of diagnoses, the prevalence of hospitalizations or the mortality rate. In addition, because it is just an average, *R* can miss several important dimensions of reproduction, particularly in heterogeneous populations. For example, the existence of super-spreader individuals or clusters, which can be crucial in an outbreak, is totally hidden in this average. As a long tradition of demographic research has shown us, estimating the reproduction rate and assessing its meaning is just a first step in an ongoing quest to grasp the complexities of human behavior and the conditions that drive it.

Supplementary material

Available online at https://doi.org/10.1553/populationyearbook2022.res1.3

Supplementary file 1. Data in Excel format
Supplementary file 2. Data in Stata 17 format

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Appendix

Figure A.1:
Transmission rate $b(a)$ and "survival" function $p(a)$ in the constant and exponential rates models

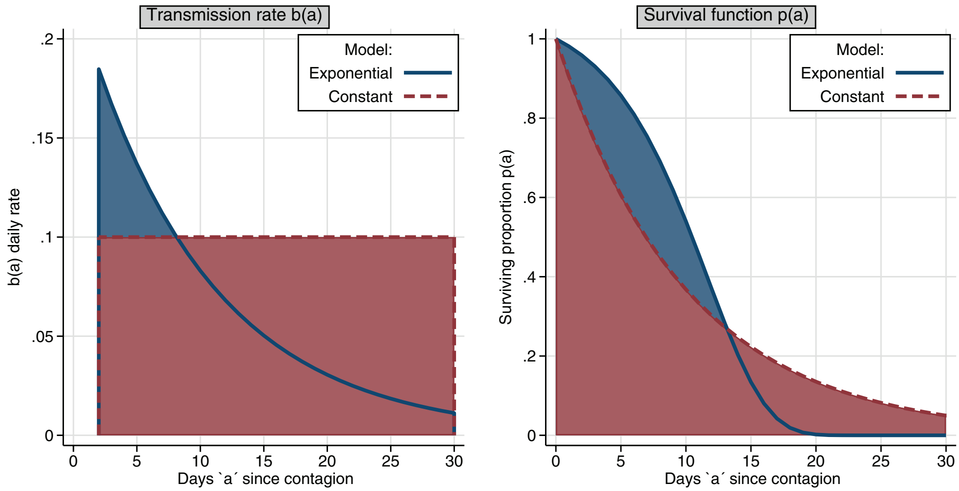
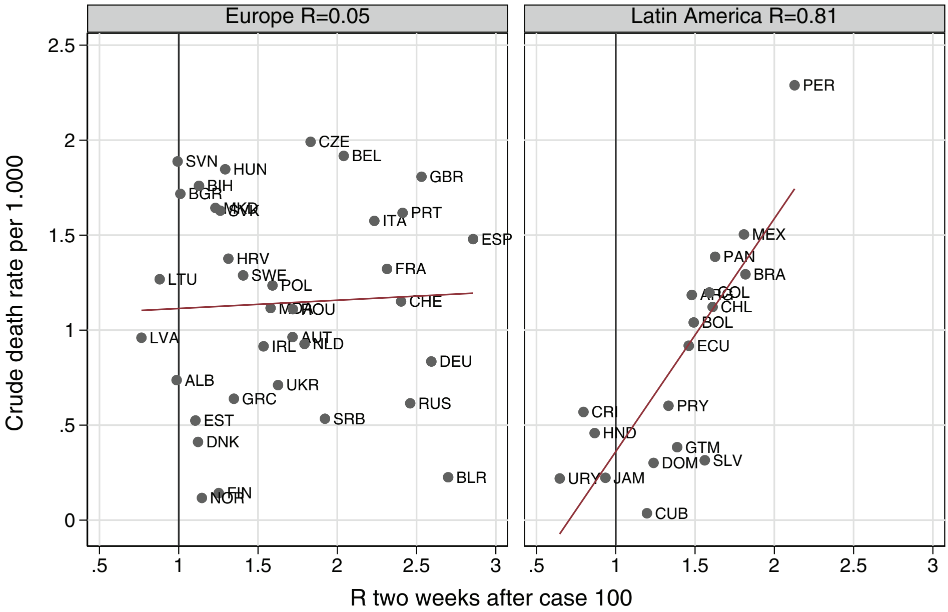


Figure A.2:
Correlation between the early level of *R* and the Covid-19 crude death rate in the first year



Note: Countries are identified by their ISO alpha-3 codes. United Nations Statistics Division, "*Standard Country or Area Codes for Statistical Use*" (M49 standard) https://unstats.un.org/unsd/methodology/m49/ Accessed on March 15, 2021.
Source: Daily national series of confirmed Covid-19 cases and deaths from the website "Our World in Data" (Ritchie, 2020), accessed on March 10, 2021.

Table A.1:
Weighting factors $w(a)$ to estimate $R(t)$ with two models

Days	Constant rates model			Exponential rates model			
a	$g(a)$	$p(a)$	$w(a)$	$g(a)$	$p(a)$	$b(a)$	$w(a)$
0.5	0	0.9512	0	0.0189	0.9911	0	0
1.5	0	0.8607	0	0.0235	0.9704	0	0
2.5	0.10	0.7788	0.1013	0.0293	0.9452	0.1531	0.1746
3.5	0.10	0.7047	0.0917	0.0365	0.9147	0.1455	0.1529
4.5	0.10	0.6376	0.0830	0.0455	0.8781	0.1383	0.1328
5.5	0.10	0.5769	0.0751	0.0568	0.8345	0.1315	0.1142
6.5	0.10	0.5220	0.0679	0.0708	0.7831	0.1249	0.0970
7.5	0.10	0.4724	0.0615	0.0882	0.7235	0.1188	0.0811
8.5	0.10	0.4274	0.0556	0.1099	0.6555	0.1129	0.0665
9.5	0.10	0.3867	0.0503	0.1370	0.5797	0.1073	0.0532
10.5	0.10	0.3499	0.0455	0.1708	0.4973	0.1020	0.0413
11.5	0.10	0.3166	0.0412	0.2129	0.4108	0.0969	0.0309
12.5	0.10	0.2865	0.0373	0.2654	0.3237	0.0921	0.0220
13.5	0.10	0.2592	0.0337	0.3308	0.2406	0.0876	0.0148
14.5	0.10	0.2346	0.0305	0.4123	0.1662	0.0832	0.0092
15.5	0.10	0.2122	0.0276	0.5139	0.1048	0.0791	0.0053
16.5	0.10	0.1920	0.0250	0.6405	0.0590	0.0752	0.0027
17.5	0.10	0.1738	0.0226	0.7984	0.0288	0.0715	0.0012
18.5	0.10	0.1572	0.0205	0.9951	0.0118	0.0679	0.0004
19.5	0.10	0.1423	0.0185	1.2404	0.0039	0.0645	0.0001
20.5	0.10	0.1287	0.0167	1.5461	0.0010	0.0614	0.0000
21.5	0.10	0.1165	0.0152	1.9271	0.0002	0.0583	0.0000
22.5	0.10	0.1054	0.0137	2.4020	0.0000	0.0554	0.0000
23.5	0.10	0.0954	0.0124	2.9940	0.0000	0.0527	0.0000
24.5	0.10	0.0863	0.0112	3.7319	0.0000	0.0501	0.0000
25.5	0.10	0.0781	0.0102	4.6516	0.0000	0.0476	0.0000
26.5	0.10	0.0707	0.0092	5.7980	0.0000	0.0452	0.0000
27.5	0.10	0.0639	0.0083	7.2269	0.0000	0.0430	0.0000
28.5	0.10	0.0578	0.0075	9.0080	0.0000	0.0409	0.0000
29.5	0.10	0.0523	0.0068	11.2280	0.0000	0.0388	0.0000
Sum			1.0000				1.0000
T			10.20				6.06

Pitfalls and solutions in case fatality risk estimation – A multi-country analysis on the effects of demographics, surveillance, time lags between case reports and deaths and healthcare system capacity on COVID-19 CFR estimates

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Abstract

Across European countries, there have been large differences in COVID-19 case fatality risk (CFR) estimates, and considerable variation in these estimates over time. CFR estimates vary depending on both the method used for estimation and country-specific characteristics. While crude methods simply use cumulative total numbers of cases and deaths, the CFR can be influenced by the demographic characteristics of the cases, the case detection rates, the time lags between the reporting of infections and deaths and infrastructure characteristics, such as healthcare capacities. We use publicly available weekly data for 11 European countries on the COVID-19 case and death numbers by age group for the year 2020. Moreover, we use data on national weekly test rates to adjust the case numbers, and to investigate the effects of different time lags between the reporting of cases and deaths on the estimation of CFRs. Finally, we describe the association between case fatality

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DOI: 10.1553/populationyearbook2022.res1.4

rates and the demand for hospital and intensive care unit beds for COVID-19 cases, while taking into account national bed capacities. The crude CFR estimates differ considerably across the investigated countries. In the crude international CFR time series, the differences are smaller when adjusting for the demographics of the cases. Differences in testing policies significantly affect the CFR estimates as well. However, the question of precisely how these testing procedures should be adjusted requires further investigation. Lag adjustments of CFRs do not lead to improvements in estimates of COVID-19 CFRs, and no connection between hospital capacities and CFRs can be found for the countries included in our study.

Keywords: COVID-19 pandemic; epidemiological surveillance; case fatality risk; demographics; vulnerable populations; testing policy; healthcare; public health

1 Introduction and background

Countries' COVID-19 case fatality risk (CFR) estimates vary considerably. Crude CFR estimates – i.e., the cumulative number of deaths divided by the cumulative number of cases – are known to be biased (Lipsitch et al., 2015). The main sources of bias are shown in Table 1. A distinction must be made between factors that might influence actual lethality, such as healthcare capacity, and those that bias the estimates of the CFR, such as an underassessment of the number of cases. One asterisk denotes factors that may affect the actual CFR, whereas two asterisks refer to factors that simply bias the CFR estimate.

Differences in CFRs across countries might be explained by differences in the demographic characteristics of infected cases, such as age, comorbidities or underlying risk factors; as well as differences in the underlying population structures of the respective countries (Dudel et al., 2020). There is evidence that being older and having comorbidities – such as hypertension, diabetes, cardiovascular disease or chronic lung disease – are major risk factors for severe COVID-19 infection outcomes (Fernández Villalobos et al., 2021; Jordan et al., 2020; Wu et al., 2020; Zhou et al., 2020). The higher susceptibility to disease and the higher prevalence of comorbidities among the elderly (Fernández Villalobos et al., 2021; Vanella et al., 2020) have an impact on the morbidity and mortality of this subpopulation (Gornyk et al., 2021). Thus, CFRs tend to be higher in countries with an older population than in countries with a younger age structure, including during the COVID-19 pandemic (Cai, 2020; Dudel et al., 2020; European Centre for Disease Prevention and Control, 2020a; Shim et al., 2020; Wu et al., 2020; Wu and McGoogan, 2020; Xie et al., 2020; Yang et al., 2020; Zhang et al., 2020).

Differences in the surveillance systems and testing capacities of countries lead to huge variations across countries in the numbers of tests performed (European Centre for Disease Prevention and Control, 2020b, 2021b; Fang et al., 2020; Pan et al., 2020; Rajgor et al., 2020; World Health Organization, 2020b). Thus, the degree of underassessment of infections differs between countries (Lau et al., 2020; Li et al., 2020). Furthermore, surveillance and testing capacities influence the probability of

Table 1:
Sources of bias of case fatality risk estimates

Factor	Description	Impact on CFR estimates	Literature
Population structure*	Age, comorbidities and underlying risk factors	Higher CFRs due to an older population with a higher load of comorbidities	Cai (2020); European Centre for Disease Prevention and Control (2020a); Gianicolo et al. (2020); Shim et al. (2020); Wu et al. (2020); Wu and McGoogan (2020); Xie et al. (2020); Yang et al. (2020); Zhang et al. (2020)
Surveillance and testing**	Surveillance system and different testing capacities	Overestimation of CFRs due to a poor surveillance system and low testing capacities, as fewer currently infected persons in relation to deaths are counted	European Centre for Disease Prevention and Control (2020b); Lau et al. (2020); Li et al. (2020); Lipsitch et al. (2015); Rajgor et al. (2020); Reich et al. (2012); World Health Organization (2020a)
	Methods and capacities for recording deaths	Underestimation of CFRs due to low capacities and poor quality methods for recording deaths from the disease, resulting in a smaller numerator of deaths to current reported infections	Gordis (2014)
		Overestimation of CFRs if all deaths are counted regardless of whether the patient died of the target disease or another cause given the same number of infections	Gordis (2014)
Time lag**	Deaths occur with a time delay after infections	Underestimation of CFRs due to a time lag of several days between case registrations and deaths, resulting in a smaller numerator of current deaths to current infections	Gianicolo et al. (2020); Wilson et al. (2020)
Healthcare system*	Healthcare system capacity measured as the number of intensive care beds per 100,000 inhabitants	Higher CFRs due to low healthcare capacities and excessive demand for intensive care beds during the pandemic, resulting in more deaths, and, therefore, a higher numerator of deaths to current infections	Eriksson et al. (2017); European Centre for Disease Prevention and Control (2020a); Eurostat (2019); Ji et al. (2020); Legido-Quigley et al. (2020); Rajgor et al. (2020); Rhodes et al. (2012)

Note: *Factors that may influence the actual CFR; **factors that bias the CFR estimates.

detecting infections early, and of applying countermeasures in response. Countries may also differ in their capacities and methods for recording deaths caused by COVID-19. While some countries perform post-mortem screening of all deaths, other countries only perform post-mortem screening in cases considered clinically suspicious (Onder et al., 2020). Moreover, during the pandemic, countries have changed their testing strategies and the number of tests they perform multiple times (European Centre for Disease Prevention and Control, 2021b; Robert Koch Institut, 2020a, 2020b), which limits the representativeness of case time series on the country level.

There is a time lag between the reporting of an infection in an individual and his or her eventual death. The distribution of such time lags may differ between countries. These delays are not reflected in crude CFR estimates (Wilson et al., 2020). More robust estimates could be obtained by dividing cumulative deaths by cumulative recoveries. However, even these estimates are not reliable due to the low numbers of recoveries during the early stages of the pandemic, when a large relative increase in infection numbers and the incomplete reporting of recoveries were observed (Lipsitch, 2020). Therefore, some authors have proposed investigating the cumulative deaths in relation to lags of varying numbers of days for the cumulative infection numbers (Lipsitch, 2020; Wilson et al., 2020). However, due to the high transmission rates of the virus in the early stages of an epidemic, the estimates depend strongly on the lags, and both an underestimation and an overestimation of the true CFR can occur (Spychalski et al., 2020).

Furthermore, CFRs may be influenced by the healthcare system capacities of the affected countries. Previous studies have shown that healthcare capacities differ substantially across countries, and even between regions within countries (Eriksson et al., 2017; European Centre for Disease Prevention and Control, 2020a; Eurostat, 2019; Ji et al., 2020; Legido-Quigley et al., 2020; OECD, 2021a; Rajgor et al., 2020; Rhodes et al., 2012). When a country's healthcare system is overwhelmed by the pandemic, it may have higher CFRs.

While all of the factors mentioned above may help to explain the differences in the CFRs in the affected countries at different time points during the COVID-19 pandemic, how much of the differences in CFR estimates during the pandemic are explained by each of these factors is unclear. This paper aims to quantify the effects of demographics, testing levels, delays in death after infection and demand for hospital beds on weekly COVID-19 CFR estimates. The countries were selected for the study based on whether they have a population of over eight million, and provide age-specific data on COVID-associated deaths and infections, either on their national health services web pages or in the COVerAGE database provided by the Max Planck Institute for Demographic Research. This selection process resulted in a sample of 11 European Union (EU) and Schengen area countries,[1] which are examined during the year 2020 using a comparative perspective. The study shows

[1] Belgium, France, Germany, Greece, Italy, the Netherlands, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

that these countries had different levels in the COVID-19 CFR time series, and, as we will see in the next section, that they accounted for a large share of the COVID-19 disease burden in Europe over the study period.

In the following, we will show the time series of the crude CFRs for all study countries over the year 2020. We will then present the data used in our study and our methodological approach. In a sequential approach, we will check whether adjustments of the crude CFRs to account for differences in demographics, testing, delays and the burden on the national health system as represented by hospitalisations can provide a more realistic picture of the actual fatality risks across countries and over time. We will consider the cross-national and intertemporal variations of the CFRs as a goodness-of-fit measure. In the following section, we will present the results of our investigation. We will end our contribution with a discussion and an outlook.

2 Data and methods

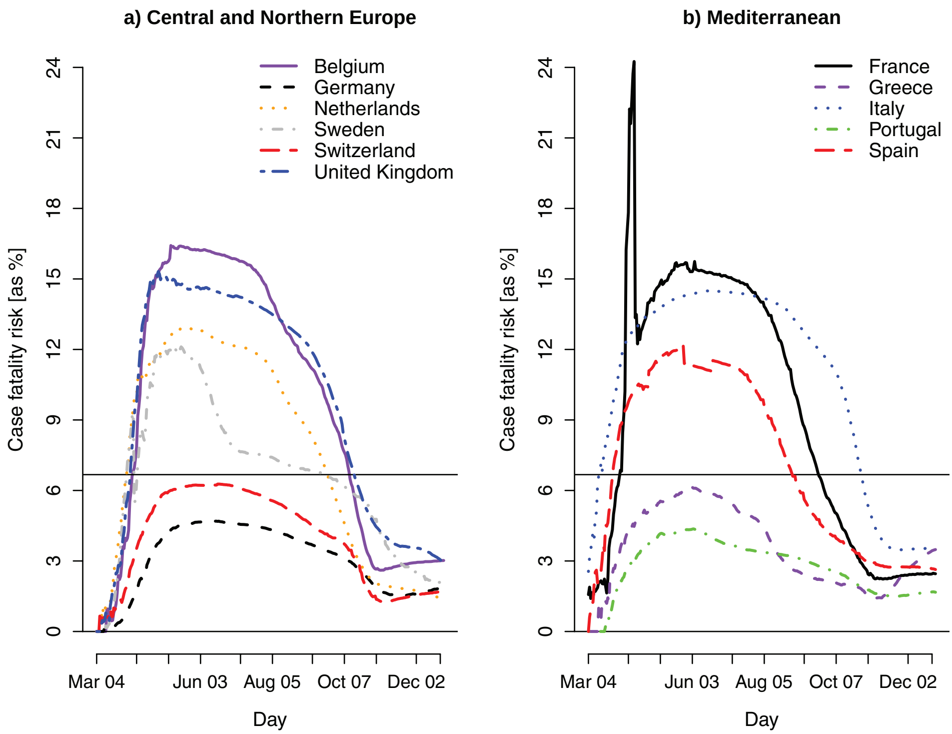
The crude CFR of country j on day δ is estimated by dividing the cumulative number of official COVID-19 deaths $D_{ij\delta}$ for each age group i by the cumulative number of COVID-19 cases $\hat{N}_{ij\delta}$, both until day δ and for each age group i:

$$\widehat{CFR}_{.j\delta} = \frac{D_{.j\delta}}{\hat{N}_{.j\delta}}. \tag{1}$$

The hat underlines that the cases are the reported COVID-19 infections, which are a subset of all infections $N_{.j\delta}$. The crude CFR ignores all of the factors presented in the previous section. Figure 1 shows the development of the crude CFR estimates of the 11 study countries as percentages between 2 March and 31 December 2020, as provided by Dong et al. (2020). Figure 1(a) displays the estimates for the countries of central and northern Europe, whereas Figure 1(b) provides the estimates for the Mediterranean countries. The horizontal line marks the mean of the daily CFR estimates over the study period and all 11 study countries (6.67%). The peak for the French data illustrates the data inconsistencies, which will be explained below.

All curves increase until late spring or early summer 2020, and then decrease again until the end of the study period, with some countries, such as Belgium and Greece, experiencing slight increases in their crude CFRs during the last weeks of the year. We observe significant differences between the curves. Our study aims to help explain these geographical and temporal differences, and to develop adjusted case fatality measures. The French and the Spanish lines in the right panel follow a rather jagged course. For France in particular, a sharp increase until early April can be observed, followed by a sharp decrease on 12 April, which is due to an almost doubling of the case numbers in the Johns Hopkins University (JHU) data on that date following the addition of French Ehpad data on cases reported for nursing homes (Johns Hopkins University, 2021; Ministère des Solidarités et de la Santé, 2021). Therefore, we find that there was a significant undercounting of

Figure 1:
Crude case fatality risk estimates due to COVID-19 between 2 March and 31 December 2020 (the horizontal line represents the mean of the daily CFR estimates over all dates and countries)



Source: Johns Hopkins University (2021); Own computation.

cases in France before that date that resulted in an overestimation of CFRs during that period. The tub-shaped line for Spain between mid-May and mid-June may be explained by a change in the reporting of the Spanish COVID-19 data during that time. Between mid-May and early July, Spanish authorities developed a new strategy for tracking and reporting COVID-19 data (Instituto de Salud Carlos III, 2020b) that resulted in less detailed reports, which may, in turn, have led to the case data during that period being unrepresentative. While the crude CFR estimates had largely converged by the end of the year, there were still differences between the study countries. Sequentially, we will investigate how the cross-country and temporal variations can be explained by the abovementioned factors and mitigated by adjustments to the crude CFR. Since the variance is not an appropriate measure for comparing our different models, as it depends on the level of the variables, we compare our adjustments using the coefficient of variation (cv) of the different iterations, which is defined as the ratio of the standard deviation and the mean of a certain variable (Brown, 1998):

$$cv(X) = \frac{sd(X)}{E(X)}. \tag{2}$$

2.1 Step I: Adjustment to demographics

In a first step, we investigate the effect of demographics on the CFR estimates. To do so, we gathered weekly data on cumulative age-specific case and death numbers from various sources for the study countries between early March and the end of 2020. The data for Germany have been downloaded from the Robert Koch Institute (RKI)'s Github database (Robert Koch Institut, 2021). For Italy, the data have been collected from early press releases and then regular reports published by the Istituto Superiore di Sanità (ISS) (2020a, 2020b, 2020c, 2020d). For the United Kingdom (UK), we downloaded data as provided from the website of the UK's national health authority (Public Health England, 2021a). For France, we found, after comparing different sources, that a combination of national reports from Santé publique France (2020a, 2020b) until calendar week 32 and data from the new COVerAGE database (Riffe et al., 2021a, 2021b) for the following period provided the best coverage of the age-specific case and death data, as we have observed significant irregularities and missing data for France. All of the data for the remaining seven countries came from the latter database. In our comparison of crude and age-adjusted CFRs, we use the European Standard Population (European Union, 2013) for standardisation. We use the following notation: for each country j, $d_{.jk}$ is the number of deaths over all age groups observed during week k. Similarly, $\hat{n}_{.jk}$ is the number of observed new cases over all age groups during week k. Summing up the deaths up to week w, we obtain the total cumulative number of deaths in country j over all ages $D_{.jw} = \sum_{k=1}^{w} d_{.jk}$. Similarly, summing up the cumulative number of cases up to week w, we obtain $\hat{N}_{.jk} = \sum_{k=1}^{w} \hat{n}_{.jk}$, the total cumulative number of cases for country j and up to week w.

While the numbers of cases and deaths in week k, for each country j and age group i, are observed (respectively, $\hat{N}_{ijk}$ and D_{ijk}), the number of new infections in age group i, country j and week k (denoted by n_{ijk}) is latent (unknown). The number of cumulative infections in this group up to week w is $N_{ijk} = \sum_{k=1}^{w} n_{ijk}$. Our first aim is to identify the role of the age structure of the cases in the overall CFRs, and to derive age-specific and age-standardised CFR estimates for all study countries. Based on the cumulative age-specific case numbers $\hat{N}_{ijk}$ of the 11 European countries, we calculate age-specific CFR estimates

$$CFR_{ijk} = \frac{D_{ijk}}{\hat{N}_{ijk}}. \tag{3}$$

Multiplying these estimates with population weights derived from the European Standard Population, we obtain age-adjusted CFR estimates

$$CFR_{jk}^{age} = \sum_{i} w_i \times CFR_{ijk}. \tag{4}$$

2.2 Step II: Adjustment of age-specific cases to the level of surveillance

In the second step, we investigate the impact of the surveillance of cases, as represented by time series data of weekly national tests provided by the European Centre for Disease Prevention and Control (ECDC) (2021b). As the ECDC does not provide corresponding test data for Switzerland and the UK, we obtained these data for these two countries from their respective national health services (Federal Office of Public Health, 2021; Public Health England, 2021b). However, age-specific data on testing for the first year of the pandemic were not available in time series form. Since symptoms vary by age (Davies et al., 2020), the detection rates of cases are age-specific. We deal with this data restriction indirectly by conducting principal component analysis (PCA). PCA is a data reduction technique that transforms the original, correlated variables into linear combinations that are uncorrelated, and are referred to as principal components (PCs) (Vanella, 2018). Working with PCs allows us to cover indirectly simultaneous trends and sensitivities of the case numbers to the testing strategy. As we lack age-specific data on testing for the first year of the pandemic, we cannot directly estimate the sensitivities of the age-specific case numbers to the testing strategy on a population level. Therefore, our approach is to approximate the different sensitivities of the age-specific case numbers to the testing strategy indirectly by estimating the sensitivity of the country-specific PCs to adjustments in the test numbers (irrespective of the age groups). We assume that the case numbers are influenced by the test numbers, but to differing degrees depending on age, as both the symptoms and the detection rates of infections vary by age (Gornyk et al., 2021). According to that hypothesis, $\hat{n}_{ijk}$ are functions of the weekly test numbers of the corresponding age group and week in the same country t_{ijk}, say $\hat{n}_{ijk} = f(t_{ijk})$. This could be quantified by fitting a generalised linear model. However, since we do not know t_{ijk}, but only the overall test numbers t_{jk}, we cannot derive age-specific models. To approximate the connection between random testing (irrespective of age) and age-specific case numbers, PCA is used. We perform PCA for each country separately on all square root transformed age-specific case time series[2] as follows:

$$P_{zjk} = \sum_{i} \lambda_{zij} \sqrt{\hat{n}_{ijk}}, \tag{5}$$

[2] The root transformation ensures that our model cannot predict negative case numbers, along with a reduction of heteroskedasticity in our data.

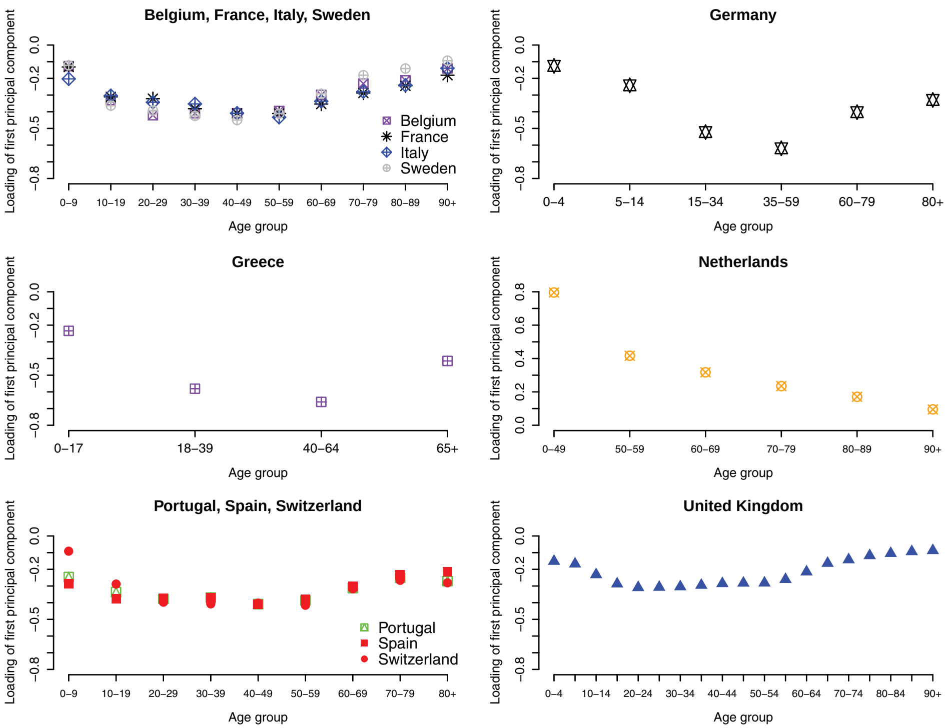
with

- P_{zjk}: z^{th} PC of country j in week k
- λ_{zij}: Loading of transformed weekly new cases in age group i on z^{th} PC of country j.

PCA allows us to cover the common trends in the case numbers across all age groups with a small number of indices that are linear combinations of the original variables.

Figure 2 illustrates the loadings of the first PC for each country. Except in the Netherlands, the loadings have a similar bathtub shape, with smaller loadings, in terms of absolute values, for the children and the elderly age groups and larger loadings for the working-age population. For the Netherlands, we observe a monotonously decreasing trend by age. Large absolute loadings represent a high correlation between the PCs and the corresponding age groups, and vice versa. There is an inverse relationship between the PCs and age-specific case numbers, which is represented by the negative signs of the loadings. Hence, increases in these

Figure 2:
Loadings of first principal components of square roots of age-specific weekly case numbers by country



Source: Own computation.

PCs are associated with decreasing weekly case numbers of the corresponding age groups, and vice versa.[3] For all countries, the respective first PCs[4] explain 93–99% of the variance in the square roots of age-specific weekly new case numbers over the year 2020, and are therefore sufficient to explain the major age-specific trends in case numbers.

We see that decreases in the PCs[5] are associated with increases in case numbers to varying degrees for different age groups. Looking at the example of Greece, we see (absolute) smaller loadings in the 0–17 and 64 and older age groups, and larger loadings for the 18–64 age group. Therefore, a decrease in that PC is associated, ceteris paribus, with more distinct increases in the case numbers among individuals aged 18–64 than among the younger and the elderly populations. As P_{1jk} is a linear combination of the age-specific case numbers according to (5), we can quantify some connection $P_{1jk} = g(t_{jk})$, which is used to investigate the statistical association of P_{1jk} to the overall weekly test numbers in country j. PCs account for the differences in detection rates indirectly, as we first quantify the test number coefficient in a regression of P_{1jk} on the tests. After deriving the coefficient of t_{jk} in $P_{1jk} = g(t_{jk})$ by the maximum likelihood, we can then predict the expected value of P_{1jk} based on a given number of tests. By plugging in the predicted values of all P_{zjk} in (5), while holding all P_{zjk} with $z \neq 1$ fixed, we have a system of linear equations, which, given that we predict all P_{zjk} after test adjustment and know all λ_{zij} from singular value decomposition, we can derive predicted age-specific case numbers $\hat{n}_{ijk}$ from (5) after test adjustment without having access to age-specific test numbers.

The impact of testing on the case numbers and the detection rates of infections is investigated in a causal regression, as described above. However, it is important to separate increases in case numbers due to increases in infection numbers from those caused by more testing, and, hence, higher detection rates. Increases in test rates might be caused by a shift in the political agenda, such as a move to increase the number of random tests in order to detect more asymptomatic infections, or a response to higher numbers of infections that includes more testing of suspected cases (e.g., of individuals who have come into contact with confirmed cases). We investigate this connection through regression analysis as follows: for each country, the first PC is regressed on the first lag of official COVID-19 cases together with the weekly tests:

$$P_{1jk} = \alpha_j + \beta_j \hat{n}_{.jk-1} + \gamma_j t_{jk}, \qquad (6)$$

with

- P_{1jk}: value of PC1 for country j in week k

[3] For the Netherlands, increases of PC1 are associated with increases in case numbers because the loadings are positive.

[4] The total number of PCs for each country equals the number of age groups; e.g., the number of PCs for Belgium, France, Italy and Sweden is 10.

[5] Or increases for the case of the Netherlands.

- $\alpha_j, \beta_j, \gamma_j$: country-specific parameters estimated via ordinary least squares
- t_{jk}: number of tests conducted in country j during week k.

The kth residual from (6) shall be named ε_{jk}.

The model assumes that the observed cases are affected by the number of tests performed in the current week, which is, however, affected by both politically driven decisions and concrete increases in infection activity in the previous week. Therefore, $\hat{n}_{.jk-1}$ serves as a control variable in the analysis that includes increases in both the numbers of infections and the share of positive tests. By using this approach, we mitigate potential bias in our interpretation of the connection between contemporaneous increases in both test and case numbers. After fitting country-specific models following (6), we adjust the observed case numbers for underestimation, and, thus, underdetection, by holding the control variable $\hat{n}_{.jk-1}$ as observed and adjusting the test variable t_{jk} to a specific value. This enables us to predict the number of cases we would, ceteris paribus, have *expected* to find given a fixed number of random tests each week that are not connected to observed positive cases. That value is in essence arbitrary. However, it appears plausible to set country-specific constants to account for the population size of each country. According to the ECDC (European Centre for Disease Prevention and Control, 2021b), among the study countries, the maximum outcome of the tests performed was around 5.7% of the estimated population, found for Portugal in calendar week 47. Therefore, we set our maximum of hypothetical weekly test numbers to $\tilde{t}_j = \max(t_{PT}) \cdot \frac{B_j}{B_{PT}}$, with $\max(t_{PT})$ being the maximum outcome of the weekly tests performed in Portugal, B_{PT} being the population estimate for Portugal and B_j being the population estimate for country j. Let us define $\tilde{P}_{1jk}$ as the hypothetical value we would have observed for P_{1jk} for a test number fixed at $\tilde{t}_j$. The prediction of $\tilde{P}_{1jk}$ is then:

$$\mathbb{E}[\tilde{P}_{1jk}] := \mathbb{E}[P_{1jk}|t_{jk} = \tilde{t}_j] = \hat{\alpha}_j + \hat{\beta}_j\hat{n}_{.jk-1} + \hat{\gamma}_j\tilde{t}_{jk}, \tag{7}$$

where $\hat{\alpha}_j$, $\hat{\beta}_j$ and $\hat{\gamma}_j$ are country-specific parameter estimates derived by OLS regression according to (6). As infection time series are not stationary, but instead move in waves of peaks and troughs, a simple adjustment according to (7) would not include these seasonal patterns in the development of infections. To incorporate this seasonality into our adjustment, we add the residuals extracted from (6), and adjust our prediction from (7) to infection trends above or below expectations caused by the wave-like development of infections. We assume that the observed derivations from the case numbers expected from our model under the observed test and the previous case numbers would carry over, even under a specified number of tests. The adjustment of the PCs is therefore

$$\tilde{P}_{1jk} = \hat{\alpha}_j + \hat{\beta}_j\hat{n}_{.jk-1} + \hat{\gamma}_j\tilde{t}_j + \varepsilon_{jk}, \tag{8}$$

For each country, the remaining PCs are unchanged. Let $\tilde{\boldsymbol{P}}_{\boldsymbol{j}}$ be the matrix of test-adjusted PCs for country j. We then derive the square roots of the test-adjusted weekly case numbers for country j by

$$\tilde{\boldsymbol{M}}_{ij} = \tilde{\boldsymbol{P}}_j \times \boldsymbol{\Lambda}_j^{-1}, \tag{9}$$

with

- $\tilde{\boldsymbol{M}}_{ij}$: the matrix of the square roots[6] of the test-adjusted age-specific weekly case numbers of country j,
- $\boldsymbol{\Lambda}_j^{-1}$: the inverse of the loadings matrix of country j.

Finally, we compute the squares for all elements of (9), which are then test-adjusted case numbers, say $\tilde{n}_{ijk} = (m_{ijk})^2$, with m_{ijk} being the element in the ith row and the kth column of the matrix $\tilde{\boldsymbol{M}}_{ij}$.

We will then compute the test-adjusted age-specific CFRs by

$$\widetilde{CFR}_{ijk} = \frac{D_{ijk}}{\tilde{N}_{ijk}}, \tag{10}$$

with $\tilde{N}_{ijk}$ being the sum of the weekly test-adjusted age-specific case numbers up to week k in country j. Using this, we derive the age- and test-adjusted CFR estimates over time, similar to (3):

$$CFR_{jk}^{age,test} = \sum_i w_i \times \widetilde{CFR}_{ijk}. \tag{11}$$

2.3 Step III: Investigate bias in CFRs due to delays between the reporting of cases and deaths

In the third step, we investigate the effects of different lags between case reports and deaths on the CFR estimates. The unknown distribution of the time lag of Δ weeks between the reporting of a case and death is considered. Verity et al. (2020) estimated the average time from infection to death to be about 14 days. For instance, the age-specific and lag-adjusted CFR of age group i, in country j, in week k, based on a lag of the cases of Δ weeks is

$$\breve{CFR}_{ijk-\Delta} = \frac{D_{ijk}}{\hat{N}_{ijk-\Delta}}. \tag{12}$$

The age- and lag-adjusted CFR[7] is then similar to (4):

$$CFR_{jk,\Delta}^{age,lag} = \sum_i w_i \times \breve{CFR}_{ijk-\Delta}. \tag{13}$$

[6] The initial use of square roots ensures the non-negativity of the predicted case numbers, since we eventually take the squares of the square roots of the cases we predict from PCA.

[7] In the next section, we will explain why we do not include testing here.

We compare this measure for the pandemic over the study period and for all countries with $\Delta = 0, 1, 2, 3$; with $\Delta = 0$ being the case of the age-adjusted CFR, as in (4). We will provide the results in Section 3.3.

2.4 Step IV: Investigation of the effects of healthcare system capacity and occupancy on CFRs

For our investigation of the impact of healthcare system capacity on CFRs, we use estimates of the available intensive care unit (ICU) beds per 1,000 inhabitants provided by the OECD (2021a), and the weekly means of daily ICU bed occupancies $I_{.jk}$ provided by the ECDC (European Centre for Disease Prevention and Control, 2021a) for seven of our study countries. For the countries for which these data are not available, we instead use hospital beds per 1,000 inhabitants together with weekly counts of new cases. Hospital admissions due to COVID-19 for the previous γ weeks are addressed as $h_{.jk,\gamma}$. First, we give a qualitative assessment using graphical analysis of the connection between CFRs and healthcare capacity and occupancy. To compare the hospital bed capacities in the study countries, we adjust the weekly numbers of new hospitalisations, as provided by the ECDC (European Centre for Disease Prevention and Control, 2021a), by the bed capacities per 1,000 inhabitants. These figures are provided as static estimates by the OECD (2021b). As both variables are measured relative to each country's population, dividing them leads to an admission-per-hospital bed measure in percent, defined as

$$h^{adj}_{.jk,\gamma} = \frac{h_{.jk,\gamma}}{\overline{b}_j}, \tag{14}$$

with $\overline{b}_j$ denoting the per 100,000 inhabitant number of available hospital beds in country j. While this measure has its merits, as it is static and thus does not change over time, it should be seen as a rough adjustment parameter that accounts for the differences between national healthcare system capacities. Similarly, the connection between age-adjusted CFRs and ICU occupancies is investigated as

$$\mathcal{I}^{adj}_{.jk} = \frac{I_{.jk}}{\overline{c}_j}, \tag{15}$$

with $\overline{c}_j$ being the estimates of the national ICU beds available. As the latter estimates are not available from the OECD, we use the latest available estimates provided by Our World in Data (2021).

3 Results

We will now present the results from our adjustments of the crude CFR for each step described in Section 2, and provide a measure that is most appropriate for quantifying case fatality risks for the study countries given the available data. Specifically, we will compare the crude CFR without any adjustment (addressed by M1) with the age-standardised CFR, as derived following the approach described in Section 2.1 (M2); the adjusted CFR after age standardisation and test adjustment (M3); and the adjusted CFR after age standardisation and lag adjustment (M4). Finally, we will investigate the impact of hospitalisations on the CFR.

3.1 Impact of age standardisation on CFR estimates

Age-standardised CFRs for the study countries are illustrated in Figure 3, with Figure 3(a) again displaying estimates for the study countries in central and northern Europe, and Figure 3(b) providing estimates for the study countries in the Mediterranean region.

The courses of the age-standardised curves are more stable than those of the crude CFR curves. A large share of the decreases in the crude CFRs observed since spring 2020 vanishes when accounting for the age structure of the cases. In general, the weekly investigation smooths out some of the variations that appear in daily monitoring. In particular, some of the peaks shown in Figure 1 are smoothed out to a large extent. While international differences are still observable, the curves converge to a greater degree than is the case for the crude CFRs. The strong peak for France is a statistical artifact caused by the change in the input data in calendar week 33. The horizontal line again represents the mean of all observations of the CFR with an age structure according to the European Standard Population. The variance between this line and the age-standardised CFR curves has, compared to that of the crude CFR, decreased substantially. We understand that the crude CFR curves between countries are skewed due to the age structure of the cases, especially in the early stages of the pandemic. While $cv(M1)$[8] of the initial crude CFRs is around 72%, the age standardisation decreases this value to $cv(M2)$[9] $\approx 51\%$. Hence, a large share of the international and intertemporal variance in the CFR is explained by the demographics of the cases.

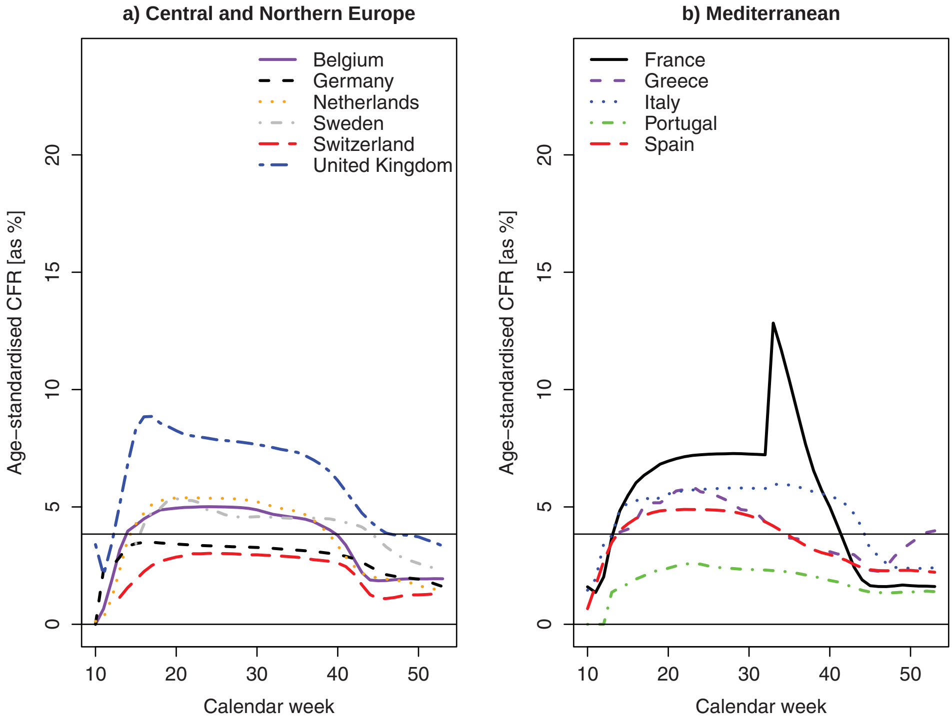
3.2 Impact of test adjustment on CFR estimates

Regarding test adjustment, our regression models estimated following (6) for all countries shows a highly statistically significant effect of testing on the PCs, and thus on the weekly numbers of new cases, even when controlling for the first lag of

[8] Crude CFR without any adjustment.

[9] Age-standardised CFR as derived following the approach described in Section 2.1.

Figure 3:
Age-standardised CFR estimates (the horizontal line represents the mean of the daily age-standardised CFR estimates over all dates and countries)



Source: European Union (2013); Instituto de Salud Carlos III (2020a, 2020b); Istituto Superiore di Sanità (2020a, 2020b, 2020c, 2020d); Johns Hopkins University (2021); Robert Koch Institut (2021); Santé publique France (2020a, 2020b); own computation.

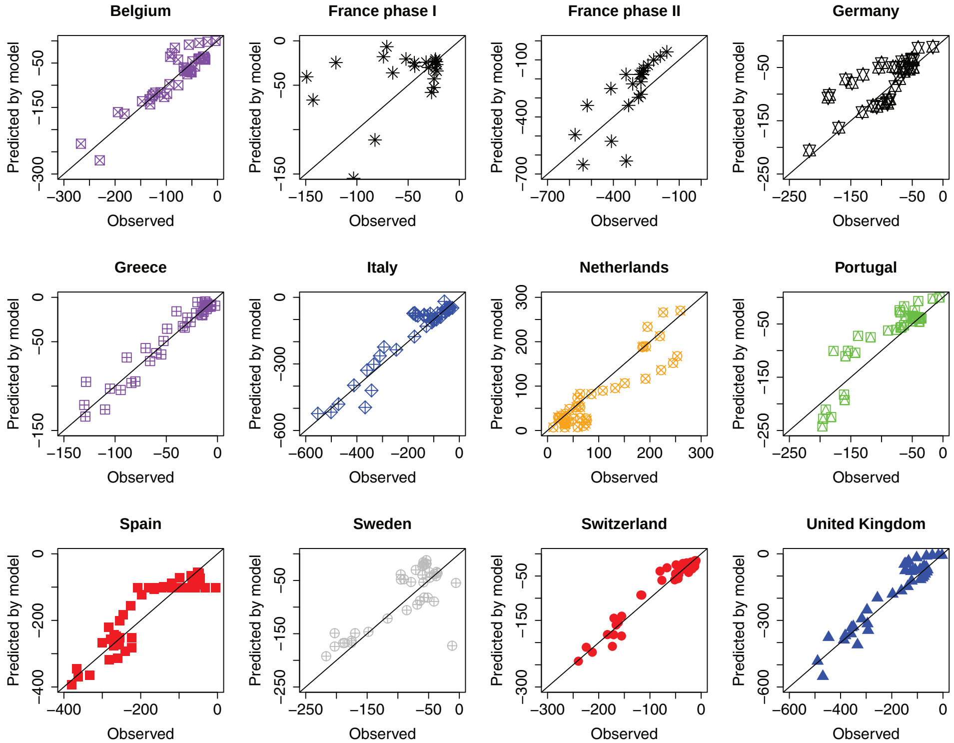
the new case numbers. Figure 4 illustrates this finding via quantile-quantile plots of the model fits for each country.[10]

However, the adjustment of cases to testing leads to a considerable worsening of the CFR model, with $cv(M3)^{11} \approx 124\%$. We conclude that the testing strategy has an effect on the case numbers. However, our approach of including this finding in CFR estimation does not lead to improvements. Therefore, in our further analysis, we proceed without a test adjustment. However, our results imply that the

[10] We checked lin-log models as well. For simplicity, we show here the plots of the lin-lin models only.

[11] Adjusted CFR after age standardisation *and* test adjustment.

Figure 4:
Quantile-quantile plots of testing model fits for first PCs of age-specific case numbers



Source: Own computation.

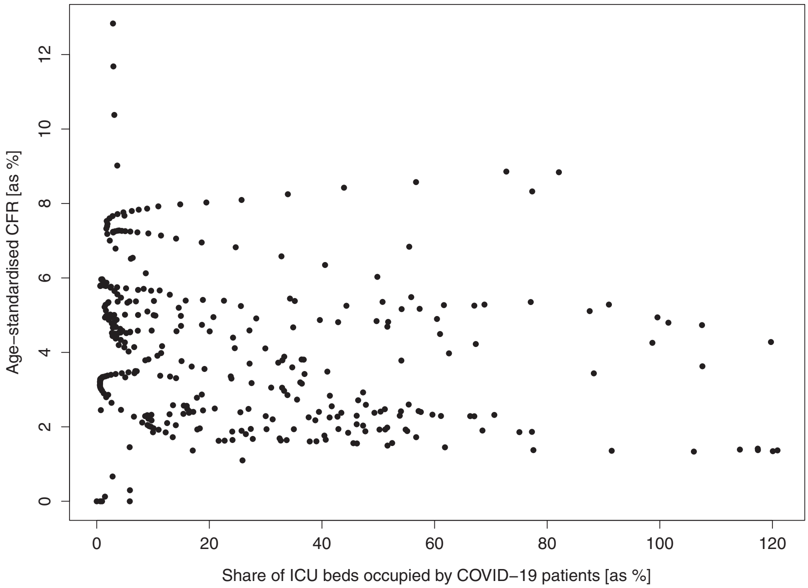
differences found in case fatality estimates stem at least in part from differences between countries in levels of underdetection.

3.3 Impact of lag adjustment on CFR estimates

The lag adjustments according to (12) and (13) do not provide improvements in the CFR estimates, but instead worsen them, with, e.g., a $cv\,(M4)^{12} \approx 107\%$ employing the first weekly lag of cases. This pattern is especially apparent for the early stages of the pandemic, for which the CFRs are highly overestimated. Therefore, pure age standardisation, as done in M2, gives the most stable CFR estimates.

[12] Adjusted CFR after age standardisation *and* lag adjustment.

Figure 5:
Connection between age-standardised CFRs and ICU bed occupancy



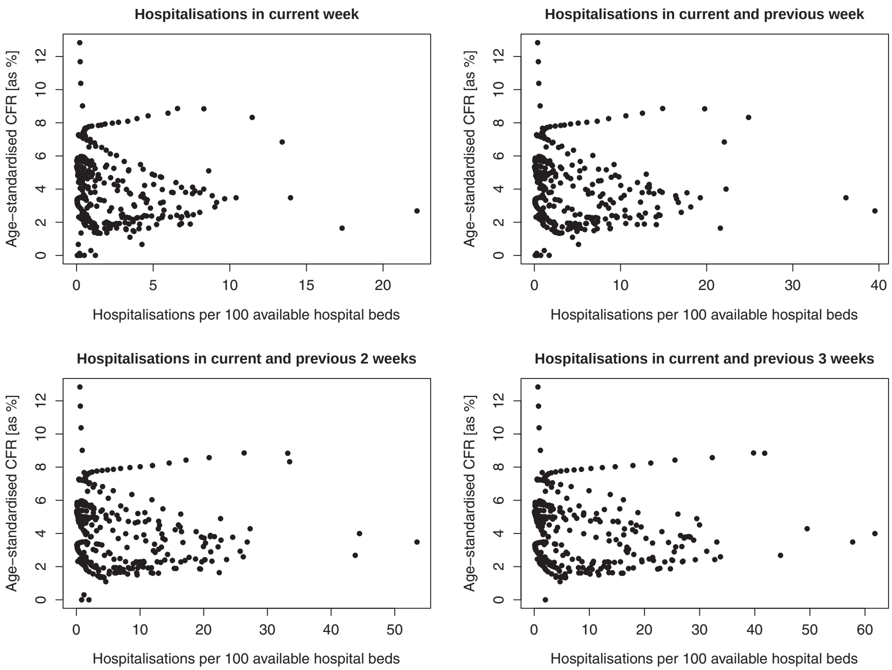
Source: European Centre for Disease Prevention and Control (2021a); Human Mortality Database (2021); Our World in Data (2021); Own computation.

3.4 Impact of hospitalisations on CFR estimates

Figures 5 and 6 display scatterplots of the age-standardised CFRs, regardless of the country[13] against $\mathcal{I}^{adj}_{.jk}$ and $h^{adj}_{.jk,\gamma}$, respectively, over the study period without any lags, with lags of no and one week, with lags of the previous two weeks and with lags of the previous three weeks, respectively. Regardless of which lags are chosen for the COVID-19-related hospitalisations, or of whether we use the daily ICU occupancy, the age-standardised CFRs do not show any statistical correlation between the chosen healthcare hospital burden variable and the age-adjusted COVID-19-specific fatality rates.

[13] We checked this by country as well, but the outcome did not change significantly when individual countries were examined.

Figure 6:
Connection between age-standardised CFRs and new hospitalisations



Source: European Centre for Disease Prevention and Control (2021a); OECD (2021b); Human Mortality Database (2021); Own computation.

4 Discussion and conclusion

The results of our analysis indicate that there are large differences in the reported CFRs of different countries. We discussed factors derived from the literature that may help to explain these differences. We presented evidence that a large proportion of the differences in CFRs between the 11 countries investigated here can be attributed to differences in the countries' age distributions of cases and testing policies. Our analysis also showed, however, that given the available data, employing age-standardised CFRs provides the most stable intertemporal and international CFR estimates for the first year of the pandemic. Although we found that testing had a clear impact on the case numbers, and, in turn, on the CFR estimates, which affected different age groups very differently, with the level of underestimation of infections being especially high in the working-age group, we lacked sufficient information on detection rates to derive better CFR estimates by employing our test adjustment. Future studies may use detection rates derived from population-based studies of infection frequency (either seroprevalence or longitudinal PCR-based surveys) to adjust for the underdetection of infections.

We did not find that a lag adjustment of the case numbers for the computation of CFRs led to improvements in the estimates. Moreover, we did not find a statistical connection between healthcare system capacity and CFRs, which we checked using ICU occupancy as well as hospitalisations. Neither of these approaches identified any connection between the national healthcare systems and the CFR estimates.

However, there were still differences in CFRs between the countries and over the year that could not be explained by the factors investigated here. Future research could address those differences in more detail. We should keep in mind, however, that there are general differences in age-specific mortality rates between the countries investigated here (Vanella, 2017). A more thorough comparative international analysis might take these differences in general mortality into account as well. Certainly, there are other factors that also play into country-specific differences, including environmental factors, such as air pollution or climate conditions (Contini and Costabile, 2020). A limitation of our contribution is related to the latency of infections. We do not know the real number of infections in the population. To account for this gap in our knowledge, we included the weekly test rates in a PC approach, along with age-specific sensitivities to testing. More information on detection rates would improve our test adjustment of cases, and could shed more light on the remaining variation observed here. Regarding the age-standardised CFR, it is important to note that this indicator is not a real CFR, but is, rather, a hypothetical CFR we would expect to observe for the population under a hypothetical age structure.

Another important limitation of our work is that public data on the age structure of infected and deceased individuals were found to be missing in public reports on COVID-19 in many European countries. Even for the included countries, these data are only partly available; e.g., they are available only for specific time points, for roughly aggregated age groups or for a selection of all reported cases or deaths. For other countries, age-specific data are not publicly available at all. Moreover, many countries do not even provide data stratified by sex. This lack of appropriate data biases our understanding of the severity of the disease, as there are significant gender differences in susceptibility to severe disease and general mortality (Fernández Villalobos et al., 2021; Luy and Di Giulio, 2006; Spagnolo et al., 2020; Vanella, 2017; Vanella et al., 2020, 2021). As the age groups in the reported data differ across countries as well, there appears to be a bias in international age standardisation that should be taken into account when considering our results. For the analysis of the association between fatalities and the healthcare load as measured by hospitalisations and individuals in intensive care due to COVID-19, we could not incorporate the age structure or the severity of hospitalised cases into our computations because these data are not available.

Thus, our results suggest that to allow for a more sophisticated statistical analysis, further improvements in age-specific data on cases, deaths and test rates are needed. In particular, more and better data on the connection between infection detection rates and testing rates are required, and could significantly improve our understanding of the underestimation of infections in our case data. This could, in turn, lead to more accurate CFR estimates. For analyses of publicly available data to have an impact on public health, better reporting of data on healthcare capacities on a daily or at least a weekly basis is needed. More detailed data on the demographics of cases and deaths, and age-specific test data with infection numbers derived by population-based sentinels, would improve our understanding of the impact of demographic factors on the CFRs, as these data would allow us to include age-specific detection ratios in our investigations. Even health authorities that provide data on the age structure of cases and deaths do not separate the age groups in the same manner. The most important databases give only the crude case and death numbers, without further disaggregation, which might lead to a misinterpretation of the true mortality differences between countries. Moreover, these data would ideally be merged with comorbidity-specific information.

Our study has shown that further progress towards establishing a better coordinated and more unified public health data reporting system in Europe and worldwide is needed to fight the COVID-19 pandemic, and any other pandemic that may emerge in the future.

List of abbreviations

$\bar{b}_j$	Overall available hospital beds per 1,000 inhabitants in country j
CFR	Case fatality risk
CFR_{jk}^{age}	Age-standardised case fatality risk for country j, in week k
$CFR_{jw,\Delta}^{age,lag}$	Age- and lag-adjusted case fatality risk for country j, in week w, with Δ weekly lags
$CFR_{ijw}^{age,test}$	Age- and test-adjusted case fatality risk for age group i, in country j, up to week w
d_{ijk}	Number of deaths in age group i, in country j, in week k
$d_{.jk}$	Number of deaths over all age groups, in country j, in week k
D_{ijw}	Cumulative number of deaths for age group i, in country j, up to week w
$D_{.jw}$	Cumulative number of deaths over all age groups, in country j, up to week w
Δ	Lag length
$h_{.jk,\gamma}$	number of hospitalisations per 100,000 inhabitants in country j, from weeks k-γ to k
$\max\{t\}$	Global maximum of weekly tests per 100,000 inhabitants
n_{ijk}	Number of infections in age group i, in country j, in week k
N_{ijk}	Cumulative number of infections in age group i, in country j, up to week w
$\hat{N}_{ijw}$	Cumulative number of observed cases for age group i, country j, up to week w

$\hat{N}_{.jw}$	Cumulative number of observed cases for over all age groups, country j, up to week w
$\hat{n}_{ijk}$	Number of observed cases in age group i, in country j, in week k
$\hat{n}_{.jk}$	Number of observed cases over all age groups, in country j, in week k
$\tilde{N}_{ijw}$	Cumulative test-adjusted number of cases in age group i, in country j, up to week w
$\tilde{n}_{ijk}$	Test-adjusted number of cases in age group i, in country j, in week k
$\tilde{n}^*_{ijk}$	Lag-weighted and test-adjusted number of cases in age group i, in country j, in week k
t_{jk}	Rate of tests per 100,000 inhabitants in country j, in week k
w_i	Weight of age group i

Funding

PV, BL and GK received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 101003480 (project CORESMA) and from the Initiative and Networking Fund of the Helmholtz Association.

Authors' contributions

PV, HB, CW and BL developed the methods used in this study. PV, HB and CW researched, organised and structured the data, and conducted the computations. BL, AM, AH, SW, HB and PV did the literature research. PV built the illustrations for the manuscript. All authors wrote the original version of the text. PV revised the manuscript.

Acknowledgments

We appreciate the knowledgeable and timely remarks by the anonymous reviewers. Moreover, we thank Gabriele Doblhammer, Carlo-Giovanni "Giancarlo" Camarda and Yohann "Jon" Anson for their helpful comments on an earlier version of the paper, which helped us make significant improvements. We are also grateful to Fabian Flaßkamp, who strongly supported the revision of the paper by providing additional country-specific case and death data.

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Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 195–221

COVID-19 and relationship quality: Emotional, paid work and organizational spheres

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Abstract

This study contributes to the growing literature on the repercussions of the COVID-19 pandemic for family functioning, with a special focus on couples' relationship quality. We advance an analytical model that emphasizes the role of three main stressors of relationship quality during the pandemic: namely, emotional, paid work-related and organizational stressors. To outline such an approach, we analyze whether the onset of the pandemic – and the home confinement that followed – has reduced relationship quality in France, Italy and Spain using survey data collected in April 2020. We show that relationship quality decreased for a non-negligible part of the population, and that this result was driven mostly by the emotional stressor. These negative effects on relationship quality appeared to be relatively stable across genders, different levels of network support and countries; which suggests that the severity of the lockdown measures outweighed the traditional moderating factors usually accounted for in family research.

Keywords: relationship quality; COVID-19; emotions; paid work; organizational issues

1 Introduction

The coronavirus (COVID-19) pandemic and the subsequent lockdown measures greatly changed the everyday lives of individuals and families across the world. Social distancing measures became obligatory in several countries starting in March or April of 2020. For example, on March 10, 2020, Italy closed all shops other than

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DOI: 10.1553/populationyearbook2022.res1.5

grocery stores and pharmacies. Spain imposed a strict nationwide quarantine on March 14 and extended it to April 25, with only essential workers being allowed to work starting on April 6. France implemented a full lockdown from March 16 to April 15, prohibiting both outdoor walks and public meetings (Koh, 2020). Thus, dimensions related to home life were of increasing relevance for predicting individual well-being during these periods.

Several scholars in the intimate relationship sciences have argued that the pandemic constitutes an extraordinary setting for studying the functioning of relationships given that the majority of couples were “locked inside the same home” (Fernandes et al., 2020), at least in countries that experienced national lockdowns. The direct (e.g., illness, death of loved ones and the fear of one’s own mortality) and indirect (e.g., employment loss) consequences of the pandemic have been closely interconnected with couples’ relationship quality (Pietromonaco and Overall, 2021) and stability (Fallesen, 2021; Manning and Payne, 2021). We believe that understanding whether and how the pandemic and the quarantine measures have affected relationship quality is crucial. Partners’ support represents a fundamental source of both physical and emotional well-being (for those in relationships) that has become even more vital in the current global context.

This paper focuses on the potential short-term negative effects of the pandemic on relationship quality. However, the pandemic may have also generated positive effects. For instance, Schmid et al. (2021) noted that for Germany, a substantial proportion of respondents experienced not only negative (40%) but also positive (20%) changes in relationship satisfaction during the crisis. The focus on the negative effects of the pandemic on relationship quality is justified in light of the ample discussion on its possible consequences for union dissolution (e.g., Prasso, 2020; Ryall, 2020; see Manning and Payne, 2021 for an analysis of divorce counts in five states of the US). We leave to future investigations an analysis of the pandemic’s potential positive effects on relationship quality, especially during the later stages of the crisis.

The nature of the COVID-19 pandemic differs from that of other natural disasters. Nonetheless, it is useful to recall that exogenous stressful shocks tend to challenge unions. Couples facing heightened stress levels (including in the form of mental health issues), employment concerns or organizational problems as a result of a natural disaster are likely to experience fluctuations in their relationship satisfaction levels. On the one hand, individuals experiencing traumatic events (i.e., a terrorist bombing) may seek comfort and security from their loved ones (Pietromonaco and Overall, 2021). There is, for example, evidence that divorce rates declined in affected communities in the immediate aftermath of events like the 1995 Oklahoma City bombing (Nakonezny et al., 2004) or the 2001 September attacks (Cohan et al., 2009). On the other hand, life-threatening events externally generated by sudden shocks may cause chronic stress and relational conflicts, which could contribute to relationship deterioration. For example, divorce rates were shown to increase in the areas affected by Hurricane Hugo in 1989 (Cohan and Cole, 2002).

While the current pandemic partly recalls the settings associated with several previous disasters, its duration and pervasiveness make it unique. A review of 43 studies (Vindegaard and Benros, 2020) has shown that the pandemic has led to increased levels of anxiety and depression. There is also evidence that this phenomenon has occurred across countries (Luo et al., 2020). As people attempt to cope with negative emotions and the sense of being overwhelmed due to the pandemic, substance abuse appears to have increased significantly (Rogers et al., 2020). Thus, a number of scholars have observed that the COVID-19 pandemic has challenged the functioning of couple relationships, generating (in many countries) emotional obstacles that may be chronic or long-lasting, and that may hinder the pursuit of close interactions (e.g., Pietromonaco et al., 2021).

In this study, we advance an analytical model that emphasizes the role of three main stressors of couples' relationship quality during the pandemic, namely, emotional, paid work-related and organizational stressors. Inspired by the main theories on relationships and family stress, this model guides our empirical analyses, which are based on the results of an online survey conducted during the first wave of the COVID-19 pandemic in France, Italy and Spain.

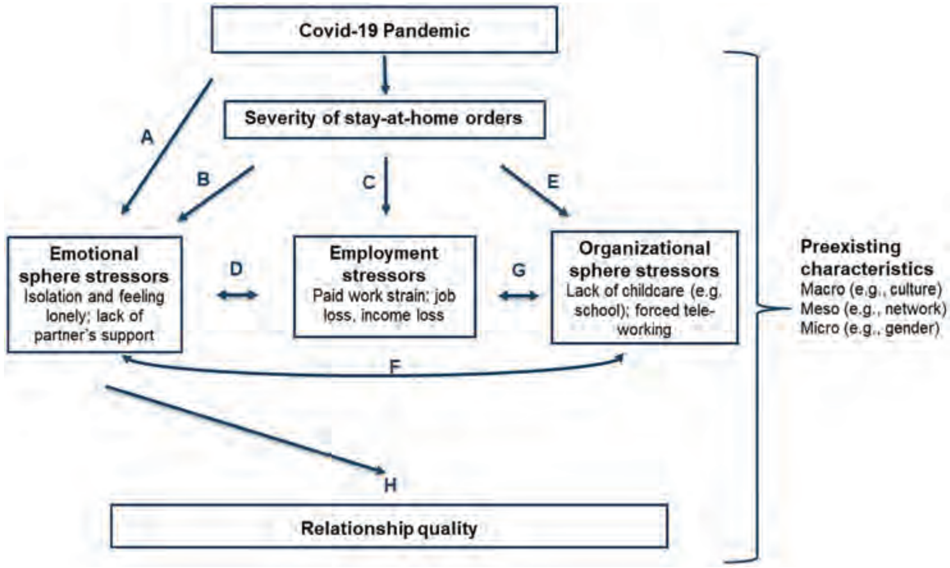
2 How the pandemic can shape relationship quality: Theoretical relations

Figure 1 presents our adaptation of Pietromonaco and Overall's (2021) conceptual model on couples' relationship quality during the pandemic. It suggests that direct and indirect pandemic-related stressors associated with emotions, paid work and organization are likely to impact relationship quality.

First, the pandemic may have directly influenced a couple's emotional sphere (arrow A). In some cases, the partners may have lost loved ones, or be afraid that they or people close to them could die. The uncertainty associated with the pandemic's duration may have frustrated hopes of establishing a time frame for a return to normality, thus generating emotional stress and pain (Holmes et al., 2020). The pandemic might have also influenced the emotional sphere indirectly, through the imposition of lockdown policies (arrow B). The state-imposed physical distance from loved ones (e.g., friends and family members outside the household) may have exacerbated the partners' emotional distress. Generally speaking, isolation and a lack of emotional support within the couple may have harmed relationship quality (arrow H).

Second, couples' pandemic-related stress might have further increased if they had concerns about (paid) work, especially if one or both partners lost their job or (part of) their income. As represented by arrow C, this was typically not a direct consequence of the virus *per se*, but was, rather, the result of lockdown measures. The COVID-19 outbreak has been accompanied by unprecedented disruptions to

Figure 1:
A pandemic stress model for a couple's relationship quality



Source: Own elaboration.

global economies, which has, in turn, led to income losses and high unemployment rates (Dang and Viet Nguyen, 2021). Individuals who experience income or job loss, or reduced working hours, are more likely to experience a decrease in relationship quality (e.g., Blom et al., 2020; Brand, 2015; Kinnunen and Pulkkinen, 1998); see arrow D. A job loss is one of the worst financial shocks a family can face, making it extremely difficult for them to make ends meet, and to avoid distressing downstream effects, such as a foreclosure or an eviction (Gama et al., 2021). In addition, the pandemic has brought with it an enormous increase in economic uncertainty, fueling negative future expectations for all workers, regardless of whether they lost their jobs (Guetto et al., 2021). While the majority of the global population have not been directly exposed to the virus and its economic consequences, most people have been exposed to government restrictions and media-channeled shared narratives of an uncertain future (Guetto et al., 2021; Vignoli et al., 2020). Widespread uncertainty may have increased individuals' concerns about their present and future economic conditions, which may, in turn, have triggered relationship dissatisfaction and conflict.

Third, (strict) stay-at-home orders have likely generated organizational challenges for couples (arrow E). These orders have greatly influenced the organization of domestic life (Ruppanner et al., 2021), with many people being forced to start working or attending school from home. This shift to working from home has led to the blurring of temporal and spatial boundaries between home and work life (Rudolph et al., 2021). Lowman (2021) has observed that in many families during the pandemic home issues have become work issues, and struggles at work have become entangled with home life. For instance, the lack of a commute may have removed the time many people previously used to calm down from or reframe an unpleasant day at work. Thus, remote working has hindered the division between the workplace and the domestic sphere, which may have made it easy for partners to transform their work struggles into marital conversations, instead of turning to their colleagues to complain, seek solidarity or discuss work events. On the other hand, working from home may have fostered relationship quality by increasing the time partners have been spending together. Despite being potentially therapeutic (Benjamin, 1998), the sharing of work-related issues with the other partner may have “invaded” the intimate relationship, thus reducing the couple’s relationship quality. Difficulties in balancing working from home and family life might have been exacerbated by poor housing conditions due to overcrowding.

The organizational consequences of the COVID-19 pandemic might have also led to lower levels of relationship satisfaction by aggravating time stress and negative subjective feelings about the couple’s division of labor (arrow F). Clearly, by definition, employment and organizational stressors interact with one another, as, for instance, a job loss or a reduction in working hours can dramatically change the time a person has available to spend at home (arrow G).

Importantly, our model emphasizes the role of micro, meso and macro characteristics that may represent vulnerabilities – or possibly even strengths – that contribute to important processes that influence couples’ relationship quality. Pre-existing characteristics shape the association between the three life spheres and couples’ relationship satisfaction, which can vary depending on the contexts in which the couples are embedded (e.g., the national culture), their social networks (e.g., the non-physical support offered by family and friends), and their individual characteristics (e.g., gender).

A final element of the model requires clarification. Arrow H may be partly counterbalanced by an adaptive process through which couples learn how to overcome stressors and negative events, which can reinforce their relationship before additional pandemic-related stressful events occur. Even if partners experience negative emotions and high levels of stress that have a detrimental impact on their relationship quality, they might be able to manage these stressful shocks through their own interactions. Couples may also adopt a problem-solving approach for managing changes to their emotional, paid work-related and organizational spheres (Sebri et al., 2021).

3 Literature review

In the following, we present a brief review of the literature on the three specific domains (emotional, paid work-related and organizational) that our theoretical model considers to be crucially associated with relationship quality during the pandemic. It is worth noting that an exhaustive literature review is challenging to provide at the time of writing, as the literature on this topic is growing rapidly. We therefore narrow our review by focusing on studies that have examined the key micro-, meso- and macro-level pre-existing characteristics that might moderate such an association.

3.1 Emotional sphere

There is a considerable amount of evidence suggesting that the pandemic-induced lockdowns have had negative emotional consequences for couples (e.g., Donato et al., 2021). Although individuals in a relationship tend to experience less anxiety and depression than never- or previously-married individuals (e.g., Goldfarb and Trudel, 2019; Waite and Gallagher, 2001), being in relationship during the pandemic has not necessarily represented a safety net (for the Indian case, see Ahmad et al., 2020; for the Austrian, see Pieh et al. (2020).[1]

At the couple level, individual negative feelings triggered by either the pandemic or the forced quarantine measures may have worsened the functioning of a relationship. Stressful events can weaken relationship quality, as the individuals affected by external shocks may be less likely (or able) to provide their partner with emotional support (Reid and Reczek, 2011). This pattern has been observed during the COVID-19 pandemic as well (Settersten et al., 2020). Pieh and colleagues' (2020) cross-sectional study on the Austrian case indicated that during the pandemic, relationship quality has been strongly related to mental health. In their study, they found that poor relationship quality was negatively associated with symptoms of both depression and anxiety.

Relational uncertainty can be defined as (among other aspects) uncertainty about the partner's commitment, and is another crucial factor in this context (Solomon et al., 2016). Bellani and Vignoli (2020) found that "couples held in captivity" were at risk of decreased relationship quality, particularly when the partners reported experiencing stressors related to feeling lonely. It seems reasonable to assume that perceptions of loneliness[2] are negatively associated with relationship quality, given that individuals suffer when they cannot turn to their known support network to help them manage unexpected shocks (Saltzman et al., 2020).

[1] Studies have shown that having a partner is associated with several positive outcomes. However, it also carries a number of risks. If a couple is having difficulties (e.g., related to financial issues or a lack of support from the partner), the partners' satisfaction with their intimate relationship may suffer. This may, in turn, lead to an increase in stress levels (Archuleta et al., 2011). Another crucial risk is the contagion of negative emotions from one partner to another (Roberts and Levenson, 2001).

[2] In psychology, loneliness is defined as the negative effect an individual experiences when she or he perceives a discrepancy between his or her desired and actual relationships (Perlman and Peplau, 1981).

H1: *Couples experience a decrease in relationship quality during the lockdown when a partner(s) experiences an increased sense of loneliness.*

3.2 Paid work sphere

Research on romantic relationships has shown that economic hardship, unemployment and a shortage of jobs can threaten a couple's relationship quality and stability. Navigating economic adversity and job loss can have severe effects on the mental health of partners (Lund et al., 2018), often leading to depression (Llosa et al., 2018). Losing a job generally has a negative impact on a person's well-being (Burgard et al., 2012). Several studies have also identified a causal relationship between job loss and declines in psychological and physical well-being (e.g., De Moortel et al., 2017).

Despite the efforts of European governments to alleviate financial distress during the pandemic by providing massive amounts of welfare support, Mimoun et al. (2020) found that people who were even temporarily underemployed or laid off during the COVID-19 pandemic reported higher levels of distress than those who were unemployed prior to the crisis.

H2: *Couples in which a partner(s) loses a job and/or income are likely to experience a decrease in relationship satisfaction.*

3.3 Organizational sphere

A number of studies have noted the enormous time pressures couples were under during the lockdowns (e.g., Craig and Churchill, 2021), especially if they had children (Collins et al., 2021). The pressures faced by partners who wanted to maintain their attachment to their job while also devoting their time and attention to their children or other family members led to organizational issues.

Craig and Churchill (2021) found that as well as affecting how domestic life was structured, the pandemic also modified couples' time allocation patterns. The primary consequence of these shifts has been the blurring of spatial and temporal boundaries between paid and unpaid work (Craig and Churchill, 2021). A key challenge in the organizational sphere that emerged during the pandemic was the sharp increase in the level of unpaid work (Del Boca et al., 2020; Farre et al., 2020). For example, evidence from Italy has shown that most of the extra unpaid work caused by the crisis fell to women (Meraviglia and Dudka, 2021). In particular, women's child care duties expanded dramatically due to school closures. D'Ambrosio et al. (2020) explored the time allocation and well-being of couples in several countries in the later stages of the pandemic (November 2020). They found that the increase in the time women spent on child care during the pandemic was much greater in Italy than in Spain or Germany, largely because of the longer school closures in Italy.

H3: *Couples in which a partner(s) faces organizational struggles are likely to experience a decrease in relationship satisfaction.*

3.4 Moderation effects: Micro, meso and macro

The risk of experiencing worsening relationship quality is not equally distributed between men and women. A gender gradient in the prevalence of various of mental health disorders, such as depressive symptoms, has often been observed. It has generally been established that women tend to suffer from depressive symptoms more often than men; and that women are more likely than men to experience psychological disorders after traumatic events (e.g., Boerma et al., 2016).

There are also some reasons to expect that the pandemic has hit women more severely than men. Studies on gender inequalities during the pandemic have suggested that even if both men and women have experienced negative psychological consequences, they have been differentially exposed to stressors. On average, women have been more exposed than men to worsening working conditions and increasing work–family conflicts (Rubery and Tavora, 2020). Moreover, there is evidence that the employment declines related to social distancing measures have had a larger impact on sectors with high female employment shares. These gender differences may be especially relevant in Europe, where women are generally less likely than men to work in "essential" or "frontline" sectors; although they are more likely to work in "teleworkable" sectors (Fana et al., 2020, p. 16). Dang and Viet Nguyen's (2021) study on China, South Korea, Japan, Italy, the UK and the four largest states in the US found that women were 24% more likely than men to have permanently lost their job during the pandemic, and that this trend was pronounced in regions heavily affected by the virus.

An even more important factor that may have shaped the gender differences in the consequences of the pandemic relates to the increased needs of children (e.g., in term of child care), but also of other family members (e.g., cohabiting parents). Working women, and especially mothers, had been contributing far more than men to unpaid housework and child care before the pandemic (e.g., Bianchi and Milkie, 2010). The outbreak may have further exacerbated pre-existing gender inequalities in the division of domestic tasks within dual-earner couples. School and day care closures due to the pandemic have likely put even more pressure on women to assume care duties (for a review, see Croda and Grossbard, 2021; as well as Alon et al., 2020). This, in turn, has generated further stress that may have affected relationship quality.

In addition to micro-level moderation effects (gender in particular), meso-level effects also play a pivotal role in relationship quality (Furfaro et al., 2021). For instance, the lack of social support (e.g., by friends or family members, excluding the partner) during the pandemic may have triggered or exacerbated depressive symptoms and feelings of loneliness that could impede positive relationship adaptation after the pandemic is over (Saltzman et al., 2020). As a number of studies have suggested, the presence and the strength of associational solidarity are important to life satisfaction and happiness (e.g., Perry and Pescosolido, 2010). Research has also shown that social networks influence well-being through the provision of social support. This support may, in turn, influence depressive symptoms (Lin et al., 1999), as well as marital quality (e.g., Holman, 1981).

Finally, there are various macro-level forces that may shape the effects of the pandemic on family lives. The first phase of the pandemic affected the three studied countries heterogeneously; e.g., in terms of the timing and the severity of containment strategies. Moreover, the socioeconomic and institutional features that characterize these national contexts might have had different levels of influence on relationship quality. As Luppi et al. (2020) reported, the lockdown restrictions reduced levels of physical intergenerational support. This loss of support might have influenced the quality of couples' relationships, especially that of couples with children in countries such as Italy and Spain, where grandparental child care tends to be more intensive. However, while the Italian government granted parents 30 additional days of parental leave, Spain has introduced the "Plan MECUIDA" to enable flexible employment and reductions in working hours (with corresponding reductions in wages) for employees with care responsibilities. Among the other relevant contextual characteristics are the differences in the three countries' social policy responses to COVID-19 (e.g., Luppi et al., 2021; Moreira et al., 2021). The Italian government was the first of these countries to introduce a temporary suspension of layoffs for economic reasons in order to protect employment, followed by Spain; whereas no such suspension was implemented in France. In both Italy and Spain, firms – including those operating in the many sectors not previously covered – were authorized to use existing temporary layoff and wage support schemes. In France, the main response was the development of short-term or flexible working hours (Moizard, 2020).

4 Data and empirical strategy

Our analyses are based on the results of the online survey Intergen-Covid (Arpino et al., 2020). Respondents were interviewed between April 14 and April 24, 2020, in France, Italy and Spain during periods of strict home confinement. The survey used CAWI (Computer Assisted Web Interviewing), and had a total sample size of 9,186 individuals, with approximately 3,000 respondents per country.

The questionnaire explored the core respondents' experiences and emotions during the first home confinement, including their feelings and social connections. The survey company Lucid collected the data, while imposing representative quotas at the country level by gender, age, region of residence and educational level. Quota sampling ensured that the final sample was virtually distributed according to the country benchmarks based on the statistics on key sociodemographic factors provided by the national statistical offices. Additionally, we used post-stratification weights to adjust for small deviations from the benchmark population statistics.

4.1 Sample

We selected respondents aged between 20 and 60 in a co-residential relationship (marriage or cohabitation).[3] Our final sample was $N = 3{,}587$ ($N = 1{,}197$ for Italy; $N = 1{,}357$ for Spain; and $N = 1{,}033$ for France).

4.2 Dependent variable

The dependent variable was the perceived change in the quality of the relationship at the time of the interview compared to before the lockdown (before January 31, 2020, in Italy and Spain; and before January 24, 2020, in France). More precisely, the respondents were asked the following question: “Since the first nationwide restrictions in response to the coronavirus went into effect in your country (date), have you experienced any of these changes?” A possible response was “worsened relationship with partner.” The dependent variable took the value of [1] if the respondent reported experiencing a worsening of their relationship quality, and the value of [0] otherwise.

4.3 Explanatory and control variables

We were interested in examining the association between the change in relationship quality and the shifts in the emotional, paid work and organizational spheres during the first lockdown. Accordingly, we used the following main explanatory variables. Our indicator for the emotional sphere was having felt more lonely (whether the respondent did or did not feel lonely most of the time or often during the week before the interview). We relied on two indicators for the paid work sphere: namely, having lost one’s job or having lost income.[4] Finally, our indicator for the organizational sphere was whether the respondent reported having more difficulties with organizing work (or school) from home.[5]

[3] We excluded from our analysis those aged 60 or older because if they experienced partnership instability, they would fall into the “gray divorce” category (Brown and Lin, 2012), which is a distinct phenomenon.

[4] The question related to job loss and income loss was as follows: “Since the first nationwide restrictions due to the coronavirus went into effect in your country (date), have you experienced any of these changes? (Tick all that apply).” The potential answers were “suffered income loss” and “job loss.”

[5] The question related to organizational issues was as follows: “Since the first nationwide restrictions due to the coronavirus went into effect in your country (date), have you experienced any of these changes? (Tick all that apply).” The potential answer was “difficulties with organizing work or education from home.”

Table 1:
Descriptive statistics

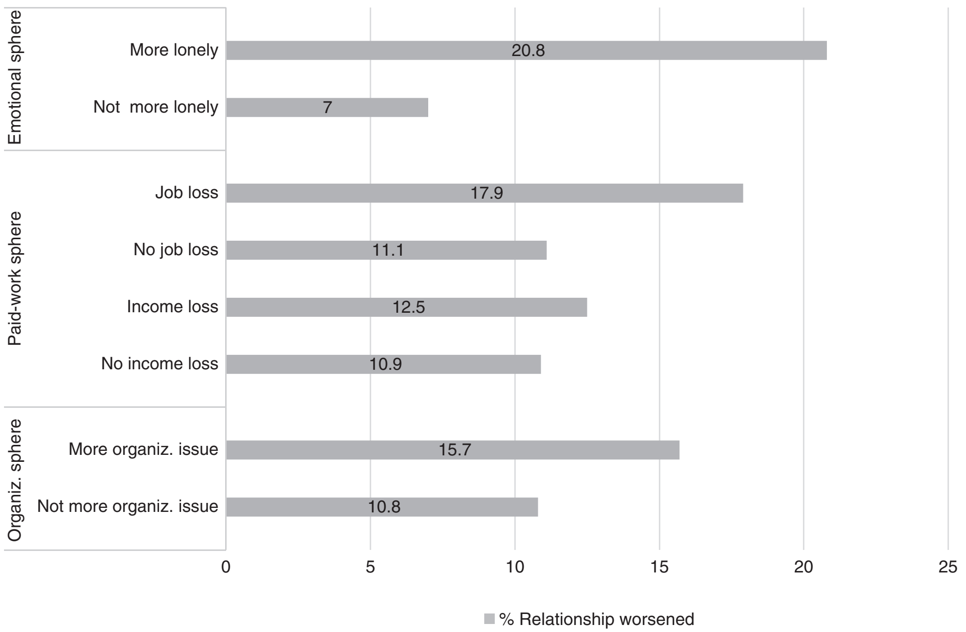
Variable	Mean	Std. Dev.	Min	Max
Gender	.441	.497	0	1
Age	43.5	10.6	20	60
Country				
Italy	.334	.472	0	1
Spain	.378	.485	0	1
France	.288	.453	0	1
Network support	.424	.494	0	1
Educational level:				
Primary or less	.085	.279	0	1
Secondary	.451	.498	0	1
Tertiary	.464	.499	0	1
In cohabitation (not in a marriage)	.297	.457	0	1
Feeling more lonely	.341	.474	0	1
Feeling more depressed	.519	.500	0	1
Income loss	.481	.500	0	1
Job loss	.090	.287	0	1
More organizational issues	.180	.384	0	1
At least one child aged 0–17	.516	.5	0	1

The following variables were also included in the equation: gender; age (in its linear form); country; having received understanding and emotional support from family members and/or friends during the lockdown (this operationalized the meso-level dimension related to the network of support); educational level (low: below upper secondary education, ISCED 0, 1 and 2; medium: up to upper high school, ISCED 3 and 4; and high: tertiary education, ISCED 5 and 6); partnership form (cohabitation or marriage); and having or not having at least one child younger than 17 years old.

The overall composition of the sample is illustrated in Table 1.

First, we present descriptive findings concerning the three spheres of interest. We analyzed the results for the three countries because of their small country-specific samples, and used country-specific weights to offer estimates adjusted according to the sampling quota scheme. Second, we report the average marginal effects (AMEs) of the emotional, paid work and organizational domains on relationship quality by using logistic regression models. Finally, we present moderation models by segmenting the analysis by gender, emotional support from social networks (family and/or friends) and country.

Figure 2:
Percentages of couples with a decline in relationship quality during the lockdown, by emotional, paid work and organizational spheres



5 Results

The overall share of respondents who reported a decline in partnership quality was 11.86%. Broken down by country, this share was 12.51% in Italy, 11.31% in Spain and 11.83% in France. Figure 2 reports the weighted percentage of respondents who said they experienced a decrease in relationship quality according to the three domains. As expected, the respondents who experienced more frequent feelings of loneliness during the lockdown reported the highest rate of reduction in relationship quality (approximately 21%). For those who lost a job, the corresponding percentage was roughly 18%. The relationship between the decrease in relationship quality and the variable of feeling lonely more often was statistically significant at the .01 confidence level. This was also the case for those who had experienced both a job loss and organizational difficulties.

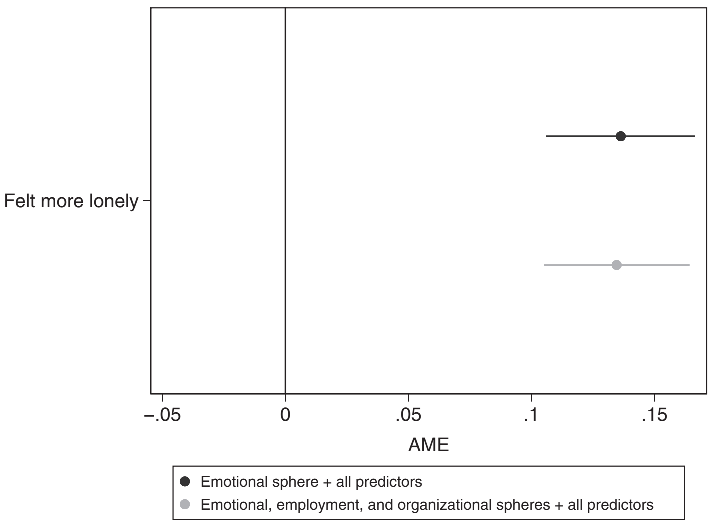
Moving on to the multivariable logistic regression models, Table 2 displays the coefficients of the association between the emotional sphere and relationship quality in their log-odds form. Model 1 represents the baseline, controlling for gender, age, country, the level of emotional support received from social networks during the lockdown, educational level, partnership form and having a child younger than

Table 2:
Estimates from a series of logistic regression models for worsening relationship quality as a function of variables related to the "emotional sphere" and individual characteristics. Log odds

	(M1) Baseline + predictors	(M2) With all spheres predictors	(M3) Only women	(M4) Only men	(M5) Italy	(M6) Spain	(M7) France	(M8) Without support network	(M9) With support network
Feeling more lonely	1.391***	1.391***	1.538***	1.217***	.989***	2.128***	1.302***	1.499***	1.290***
	(.221)	(.216)	(.241)	(.39)	(.291)	(.606)	(.254)	(.265)	(.356)
Gender (Ref. = woman)	−.345*	−.346*			−.615**	.31	−.699***	−.548**	−.127
	(.205)	(.207)			(.306)	(.448)	(.271)	(.26)	(.304)
Age	.007	.006	.001	.012	.006	.026	−.013	−.001	.018
	(.011)	(.01)	(.015)	(.016)	(.017)	(.019)	(.014)	(.014)	(.015)
Country (Ref. = Italy)									
Spain	.006	−.006	−.297	.415				−.144	.215
	(.284)	(.286)	(.356)	(.419)				(.362)	(.431)
France	−.034	.066	.055	−.164				−.371	.379
	(.185)	(.196)	(.223)	(.352)				(.267)	(.267)
Network support	−.228	−.271	−.428*	.012	−.488	−.451	.196		
(Ref. = No network support)	(.214)	(.208)	(.243)	(.370)	(.303)	(.59)	(.227)		
Education (Ref. = Primary)									
Secondary	−.084	−.168	−.065	−.215	−.433	.412	−.113	−.328	.330
	(.251)	(.245)	(.29)	(.419)	(.351)	(.484)	(.429)	(.303)	(.452)
Tertiary	.022	−.103	−.099	.065	−.205	.471	−.198	−.158	.369
	(.284)	(.279)	(.333)	(.432)	(.392)	(.516)	(.445)	(.343)	(.492)
In cohabitation (Ref. = in marriage)	.539**	.553**	.005	1.369***	.376	1.272**	.215	.628**	.475
	(.214)	(.220)	(.271)	(.325)	(.317)	(.522)	(.264)	(.256)	(.361)
Having a child < 17	.487**	.466**	.208	.925***	.772***	.169	.506*	.468*	.566*
	(.199)	(.199)	(.237)	(.337)	(.290)	(.459)	(.274)	(.243)	(.322)
Observations	3587	3587	2005	1582	1197	1357	1033	2065	1522
Pseudo R^2	.079	.091	.083	.108	.062	.157	.093	.1	.072

Note: Standard errors are in parentheses. $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$.

Figure 3:
Average marginal effects of the variables related to the "emotional sphere" on relationship satisfaction – computed from Table 2



17 years old.[6] In Model 2, we added the other spheres' indicators to the baseline model in order to compare the results both with and without the controls related to other spheres.

Figure 3 graphically reports the AMEs of the indicators of the emotional sphere for two models (i.e., M1 and M2 of Table 2). As expected, we found that the respondents who had experienced an increase in feelings of loneliness were more likely to report a decrease in relationship quality during the lockdown compared to those who had not experienced such feelings. The AMEs were statistically significant, at between 13 and 14 percentage points ($p < .01$). Thus, our findings (partly) support H1.

We then explored the relationship between the paid work indicators and relationship quality. Table 3 displays the results of logistic regression models when testing to determine whether there was an association between job/income loss and a worsening of relationship quality. Again, the table first reports the coefficients related to the basic model (M1), and then adds the indicators of the other spheres of interest (M2).

Figure 4 reports the AMEs of having experienced a worsening of relationship quality due to paid work-related variables such as income and job loss.

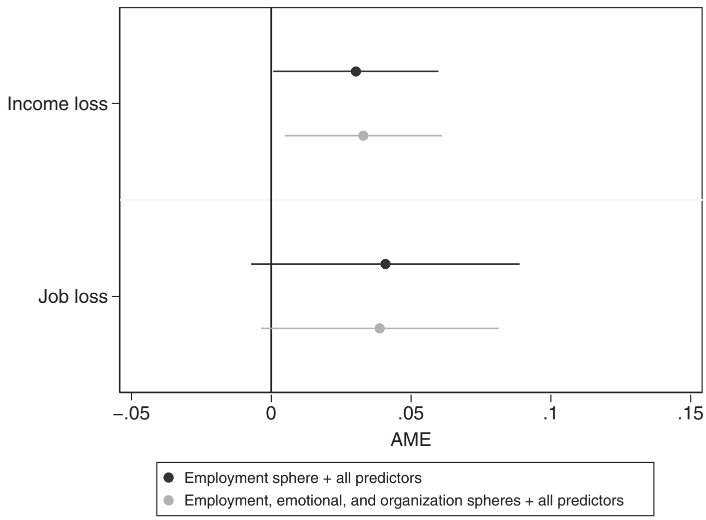
6 We ran robustness checks in which we included in the model the age of the youngest child and the number of children. The results did not change (results are available upon request).

Table 3:
Estimates from a series of logistic regression models for worsening relationship quality as a function of variables related to the "employment sphere" and individual characteristics. Log odds

	(M1) Baseline + predictors	(M2) With all spheres predictors	(M3) Only women	(M4) Only men	(M5) Italy	(M6) Spain	(M7) France	(M8) Without support network	(M9) With support network
Income loss	.295	.340*	.179	.474	.114	.933*	.005	.621**	−.002
	(.204)	(.207)	(.238)	(.341)	(.281)	(.541)	(.243)	(.260)	(.308)
Job loss	.398	.401	.476	.287	−.342	.396	1.116*	.645	.018
	(.339)	(.321)	(.383)	(.611)	(.407)	(.573)	(.61)	(.450)	(.481)
Gender (Ref. = woman)	−.390*	−.346*			−.650**	.195	−.675***	−.639**	−.182
	(.202)	(.207)			(.306)	(.452)	(.241)	(.250)	(.300)
Age	.004	.006	−.001	.008	.004	.011	−.013	−.002	.016
	(.010)	(.010)	(.014)	(.015)	(.017)	(.021)	(.013)	(.013)	(.015)
Country (Ref. = Italy)									
Spain	−.095	−.006	−.360	.269				−.179	.108
	(.277)	(.286)	(.346)	(.444)				(.361)	(.431)
France	−.007	.066	.018	−.085				−.253	.290
	(.185)	(.196)	(.218)	(.338)				(.265)	(.263)
Education (Ref. = Primary)									
Secondary	−.047	−.168	.013	−.227	−.316	.181	.038	−.292	.380
	(.237)	(.245)	(.281)	(.402)	(.350)	(.482)	(.401)	(.290)	(.432)
Tertiary	.039	−.103	−.085	.113	−.118	.158	−.047	−.215	.412
	(.271)	(.279)	(.318)	(.440)	(.394)	(.528)	(.389)	(.333)	(.471)
In cohabitation (Ref. = in marriage)	.505**	.553**	−.057	1.408***	.324	1.207**	.180	.548**	.486
	(.211)	(.220)	(.242)	(.375)	(.314)	(.524)	(.251)	(.249)	(.366)
Having a child <17	.470**	.466**	.225	.906**	.724**	.140	.519**	.387	.552*
	(.198)	(.199)	(.232)	(.357)	(.284)	(.504)	(.254)	(.239)	(.320)
Network support	.093	−.271	−.079	.319	−.238	.053	.459**		
(Ref. = No network support)	(.204)	(.208)	(.236)	(.338)	(.299)	(.508)	(.222)		
Observations	3587	3587	2005	1582	1197	1357	1033	2065	1522
Pseudo R^2	.024	.091	.011	.074	.033	.063	.049	.052	.018

Note: Standard errors are in parentheses. $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$.

Figure 4:
Average marginal effects of the variables related to the "employment sphere" on relationship satisfaction – computed from Table 3



The respondents who said they had these experiences were more likely to report a decrease in relationship quality than those who did not. The AMEs were positive – with a magnitude of approximately 3–4 percentage points – but not statistically significant in the case of job loss (even if they were very close to a 10% level of significance).[7] Accordingly, H2 is not supported by the data.

Finally, Table 4 displays the log-odds related to the association between the organizational sphere and the dependent variable. As above, Model 1 contains the coefficients related to the basic model, whereas Model 2 also includes the indicators related to the other spheres.

In Figure 5, we can observe that the AMEs were positive (between five and six percentage points) and statistically significant at the 5% (M1) and 10% (M2) levels. This suggests that having more organizational burdens was associated with decreased relationship quality. Thus, our findings support H3.

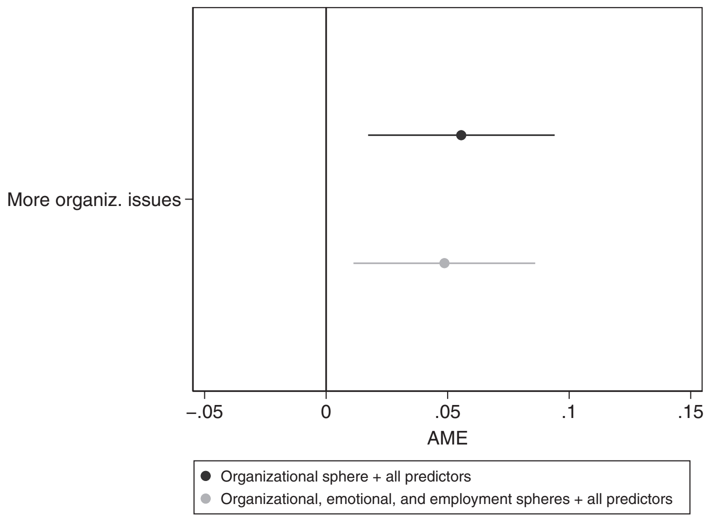
[7] At the onset of the analysis, we included all control variables in a stepwise fashion (the results are available upon request for all models from Tables 2–4). The only difference we noted was that in Table 3, the variable "income loss" was significant once the model excluded the presence of a young (under age 15) child in the household.

Table 4:
Estimates from a series of logistic regression models for worsening relationship quality as a function of a variable related to the "organizational sphere" and individual characteristics. Log odds

	(M1) Baseline + predictors	(M2) With all spheres predictors	(M3) Only women	(M4) Only men	(M5) Italy	(M6) Spain	(M7) France	(M8) Without support network	(M9) With support network
More organizational issues	.542**	.502*	.125	1.088***	.459	.767	.432	.622*	.526
	(.264)	(.272)	(.257)	(.403)	(.310)	(.553)	(.398)	(.359)	(.387)
Gender (Ref. = woman)	−.391*	−.346*			−.647**	.148	−.663***	−.622**	−.155
	(.202)	(.207)			(.308)	(.455)	(.249)	(.248)	(.304)
Age	.004	.006	−.001	.011	.006	.019	−.013	−.002	.015
	(.010)	(.01)	(.014)	(.015)	(.016)	(.020)	(.013)	(.013)	(.015)
Country (Ref. = Italy)									
Spain	−.065	−.006	−.351	.303				−.219	.144
	(.276)	(.286)	(.343)	(.434)				(.365)	(.412)
France	−.012	.066	−.020	−.082				−.308	.359
	−.065	−.006	−.351	.303				−.219	.144
Education (Ref. = Primary)									
Secondary	−.064	−.168	.020	−.277	−.339	.304	−.059	−.267	.334
	(.237)	(.245)	(.281)	(.385)	(.350)	(.472)	(.407)	(.286)	(.431)
Tertiary	−.104	−.103	−.133	−.129	−.185	.044	−.262	−.310	.248
	(.276)	(.279)	(.323)	(.428)	(.388)	(.549)	(.448)	(.329)	(.489)
In cohabitation (Ref. = in marriage)	.512**	.553**	−.045	1.516***	.349	1.109**	.207	.570**	.462
	(.212)	(.22)	(.245)	(.374)	(.314)	(.532)	(.249)	(.247)	(.386)
Having a child < 17	.453**	.466**	.210	.946***	.719**	.149	.535**	.413*	.524
	(.198)	(.199)	(.231)	(.363)	(.289)	(.496)	(.260)	(.241)	(.327)
Network support	.081	−.271	−.057	.311	−.291	.170	.430*		
(Ref. = No network support)	(.205)	(.208)	(.235)	(.342)	(.289)	(.485)	(.228)		
Observations	3587	3587	2005	1582	1197	1357	1033	2065	1522
Pseudo R^2	.024	.091	.007	.093	.036	.043	.041	.037	.025

Note: Standard errors are in parentheses. $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$.

Figure 5:
Average marginal effects of the variables related to the "organizational sphere" on relationship satisfaction – computed from Table 4



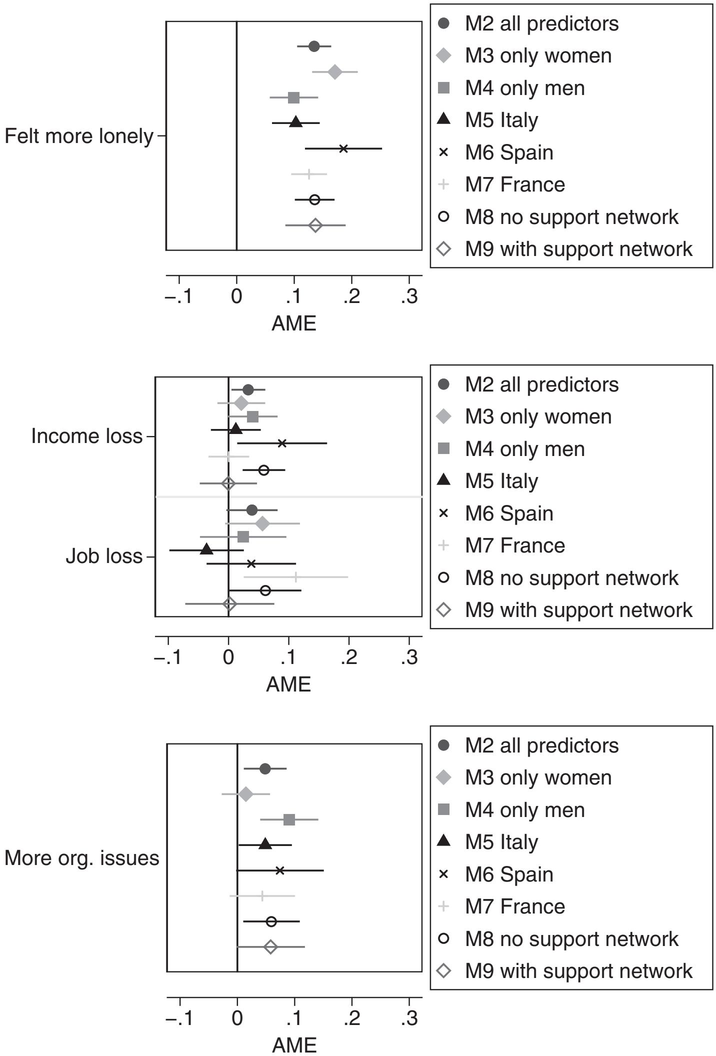
5.1 Pre-Existing Characteristics

Models 3 and 4 of Tables 2–4 display the results of the logistic regression models with the sample segmented by gender (M3 for women and M4 for men). Models 5, 6 and 7 of Tables 2–4 report the log odds for the three countries separately (M5 for Italy, M6 for Spain and M7 for France). Finally, Models 7 and 8 display the coefficients of two population groups, namely, those who did and did not receive emotional support from social networks.

In Figure 6, we report the AMEs corresponding to M2 of Table 2, as well as those that are related to M3 to M9, for each sphere of interest (Panel a: emotional, Panel b: employment and Panel c: organizational). The figure suggests that there were no differences by gender, support network or country for the "felt more lonely" indicator.

Focusing on the employment sphere, Panel b shows that, compared to the general M2 of Table 3, there were no significant differences by gender in the association between income/job loss and relationship quality (M3 and M4). However, when we consider each country individually, we see that in Spain, there was a positive and significant (at the .1 level) association between income loss and worsening relationship quality. In France, but not in Italy and Spain, we observed a positive association (significant at the .1 level) between job loss and worsening relationship quality. Moreover, Panel b shows that the respondents who had experienced income

Figure 6:
Average marginal effects of the variables related to the "emotional sphere," the "paid work sphere" and the "organizational sphere" on relationship satisfaction by gender, country and support network – computed from Tables 2–4



loss and were not receiving emotional support from family/friends were more likely to report worsening relationship quality (AME = .07, significant at the .05 level).

Finally, Panel c graphically presents the results from M2 to M9 of Table 4. The panel suggests that men in particular reported experiencing a more severe decline in relationship quality when they were facing organizational issues. We observed no national differences or dissimilarities according to the level of network support.

6 Conclusions and discussion

As part of the "circuit breaker" policies designed to halt the spread of COVID-19, the governments of Italy, Spain and France (among many others) decided to impose highly restrictive lockdown measures from March to May 2020. "Non-essential" services were either severely limited or completely shut down, and the majority of workplaces, schools and universities closed. Home confinement measures, imposed as part of nationwide movement restrictions, forced household members to live together at home for several weeks. Our study looked at whether and how relationship quality declined during this strict lockdown period based on the changes survey respondents reported experiencing in their emotional, paid work and organizational spheres.

We found that relationship quality decreased for a non-negligible part of the population in all three countries. Moreover, our results provide evidence that this decline in relationship quality was mostly driven by emotional stressors. We also observed a somewhat limited effect for the organizational sphere: i.e., more difficulties in organizing working from home resulted in higher levels of anxiety, stress and depression; and, in turn, higher levels of relationship conflict.

These negative effects on relationship quality appeared to be relatively similar regardless of the respondents' gender, level of network support or country. What seemed to be most striking about the characteristics associated with declines in relationship quality was their regularity across countries with distinctive cultures and different welfare arrangements. This may have been due to the severity of the lockdown measures in the three societies. Future research should examine whether our findings are transferable to countries where the responses to the COVID-19 pandemic were milder.

This study has several limitations. First, as a self-reported measure of worsening relationship quality during the lockdown, our dependent variable may have been subject to several sources of bias, such as social desirability bias and ex-post rationalization. However, the collection of data while the pandemic was at a peak was also a strength, as it minimized potential recall bias, which will likely affect future studies based on surveys employing a retrospective approach. Second, the results may not be entirely generalizable because the data were based on an online survey, which could only target the population with an internet connection. However, online data collection was the only possible option during the lockdown. Moreover, using quota sampling and post-stratification weights, we made the sample representative of the national populations with respect to key sociodemographic variables. Performing quota sampling ensured that the final sample was virtually distributed according to the country benchmark statistics on key sociodemographic factors provided by the national statistical offices. Additionally, we used post-stratification weights to adjust for small deviations in the sample from the benchmark population statistics. Finally, because we needed to keep the questionnaire of our online survey as short as possible (Revilla and Ochoa, 2017), our data did not include more suitable markers of the three spheres of interests. This was especially the case for the organizational sphere. Future studies using new surveys with retrospective designs may be able to overcome these limitations.

We conclude by highlighting the importance of conducting follow-up studies. Our analysis was confined to the examination of the short-term consequences of the pandemic, and only scrutinized the potential negative consequences of the lockdown experience. This is because even if a decrease in relationship quality does not lead to union dissolution, it increases the risk of instability. Studies based on the insights of marriage practitioners and family life educators have stressed that early interventions can prevent couples who are experiencing relationship stress from allowing the stress to become chronic, and, eventually, to cause them to separate (e.g., Cordova et al., 2001, 2005). Indeed, certain precautionary actions have been shown to lessen the negative impact of the pandemic on the psychological sphere, and to reduce levels of stress, anxiety and depression. Intervention approaches that provide emotional support and promote social cohesion would be useful for improving couples' well-being both during and immediately after a lockdown or a new pandemic wave (Wang et al., 2020). Future investigations, in line with other recent studies (e.g., Schmid et al., 2021), should also examine the potential positive effects of the pandemic on relationship quality, especially during the most advanced stages of the COVID-19 crisis. It will be crucial to determine what happened to couples' relationships after some time has passed since the initial emergency; as couples may have found ways to adapt to a new form of family life organization, with implications for their relationship quality.

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Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 223–260

Narratives of the future and fertility decision-making in uncertain times. An application to the COVID-19 pandemic

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Abstract

The sociological and demographic literatures have widely demonstrated that fertility decisions are shaped by individuals' previous life experiences and socioeconomic status – i.e., the "shadow of the past." However, rising uncertainty in contemporary societies necessitates an analytical framework that acknowledges the influence of the future in the fertility decision-making process. Based on the Narrative Framework, we argue that personal narratives of the future, and their constitutive elements of expectations and imaginaries – i.e., the "shadow of the future" – represent crucial drivers of fertility intentions under conditions of uncertainty. Our arguments are tested empirically by exploiting the exogenous uncertainty shock provided by the COVID-19 pandemic, and unique data we collected during the Italian lockdown. Results suggest that, because of COVID-induced uncertainty, subjective perceptions and personal narratives of the future – also shaped by media "shared narratives" – gained the upper hand over the shadow of the past in influencing fertility intentions. In addition, we provide evidence of a causal impact of shared narratives of the future on fertility intentions through an online experiment simulating a "real" exposure of the respondents to a new media narrative on the expected length of the emergency.

Keywords: uncertainty; fertility; COVID-19; narratives

1 Introduction

Uncertainty – a condition with unknown probability distributions of future outcomes – represents an intrinsic characteristic of contemporary societies. The ideas of "risk

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DOI: 10.1553/populationyearbook2022.res1.6

society," "reflexive modernity," or "liquid modernity" describe a historical trend of the last decades in which uncertainty is a new feature of social change (Bauman, 2000; Beck, 1992; Giddens, 1991). More than a century ago, Karl Marx designated modernity itself as a novel era in which "all that is solid melts into air" (1848/2020, p. 475), but the increasing speed of technological change, the constant flows of financial capital across the globe, labor market reforms and, more recently, climate change and its social consequences have expanded the sources of uncertainty. These conditions of uncertainty affect private lives (Sennett, 1998) and family life courses (Kreyenfeld et al., 2012; Mills and Blossfeld, 2013). Embedded in such a contemporary scenario, the COVID-19 pandemic of 2020, and the responses to the outbreak, escalated the uncertainty at the core of the public debate and personal lives. Policy-makers, but also scientists, have no clear answers to the questions of how long the pandemic will last, and what the real consequences will be for public health, as well as for other social and economic outcomes. Especially in countries that implemented nationwide lockdowns, people started to feel insecure in their daily lives due to the risk of contagion, which also depended on others' "safe" behavior. The possibility of losing one's job and/or having a reduced standard of living is a widespread renewed source of concern in response to a looming economic future that nobody can forecast, even in the short term. This additional condition of uncertainty can be seen as an ancillary outcome of globalization, as the rapid diffusion of the pandemic is also related to the large volume of exchanges and global interdependencies (Kaufmann, 2009).

Thus, while media reports speculated about a surge in "corona-babies" conceived during the pandemic and its related lockdowns, it seems plausible to expect an additional negative impact on family formation due to the increasing uncertainty about the future, at least in high-income countries (Aassve et al., 2020). In this article, we explore the consequences that the rising uncertainty induced by the COVID-19 pandemic may have for fertility intentions. The latter reflect the combined effects of desired fertility and situational constraints (Billari et al., 2009), and have been generally regarded as a fairly reliable predictor of behavior, provided that a time frame for their realization is set (Schoen et al., 1999; Westoff and Ryder, 1977).

The pandemic occurred within a context of demographic change in which fertility rates in many countries in Europe and the US had been declining during much of the 2010s. The underlying nature of this decline is still a conundrum for demographers and sociologists. Fertility decreased dramatically both in already low-fertility countries of Southern Europe that were severely affected by the economic and social consequences of the Great Recession; and in Nordic countries such as Norway and Finland, which experienced an almost immediate recovery of economic growth, and where the institutional context continued to provide a more favorable environment for childbearing. There have been several empirical attempts to understand the reasons underlying the fertility decline after 2008, but even studies that simultaneously included several indicators of economic conditions, such as the unemployment rate, foreclosure rates and the cost of public debt, were not able to fully explain the relatively homogeneous fertility contractions that Western societies are currently facing (e.g., Comolli, 2017; Goldstein et al., 2013; Matysiak et al., 2020; Schneider, 2015). This is because, we posit here, objective indicators of individuals' employment and economic conditions subsume the "statistical shadow of the past" (Davidson, 2010, p. 17), which tells us little about the uncertain future that people experienced during the crisis.

We argue that research on fertility decisions in uncertain times needs to partly shift its perspective, recognizing that uncertainty is a forward-looking notion. The study of the influence of the future in decision-making processes has a long tradition in the social sciences, and there has been renewed interest in this topic in recent years. We rely on the Narrative Framework for the analysis of fertility intentions (Vignoli et al., 2020a, 2020b), which is based on recent developments in economic sociology on decision-making under conditions of uncertainty (Beckert, 2016; Beckert and Bronk, 2018). This future-oriented framework represents a novelty in the study of fertility decision-making processes, and it is obviously applicable to the analysis of the consequences of the COVID-19 emergency. The pandemic, and the related lockdowns, indeed represent a situation in which the ordinary temporal orientation is suspended: the degree of "clarity" with which the future is imagined is reduced, and the future horizon is "contracting" because forecasting is more difficult than it was before (Mische, 2009, p. 700). During the pandemic, the expected future has been shaped by individuals' direct exposure to the SARS-CoV-2 virus – i.e. by their own or their close relatives' exposure to contagion and subsequent social isolation, hospitalization, or even death – and the economic consequences of the pandemic, such as job loss or temporary inactivity due to a lockdown. However, for the majority of the population who have not experienced severe health and economic consequences due to the pandemic, expectations are shaped by the spread of *shared narratives* of an uncertain future (Vignoli et al., 2020b), especially those channeled by the media and related to the diffusion of the virus, government restrictions and the scientific debate about when the pandemic will be over (Egidi and Manfredi, 2021).

In Italy, our case study, the COVID-19 disaster has created an enormous uncertainty shock, which, without operationalizing the whole Narrative Framework, allows us to make a first explorative attempt to test empirically the influence of the "shadow of the future" (Bernardi et al., 2019, p. 4; Huinink and Kohli, 2014, p. 1303) on fertility intentions under conditions of uncertainty. Italy was affected more strongly by the 2008 recession and by the public debt crisis than many other industrialized countries. While Italy had a total fertility rate of 1.46 in 2010, it reverted to a *lowest-low* fertility regime in 2019, with a total fertility rate of 1.29, which was the lowest in Europe. On top of that, Italy was the first country in the Western world to be severely hit by the COVID-19 pandemic, with Italians experiencing the longest complete and nationwide lockdown, which started on March 9 and ended on May 4, 2020. Because of COVID-induced uncertainty, subjective perceptions and personal narratives of the future – which are also influenced by media-channeled shared narratives – may gain the upper hand over the "shadow of the past" for fertility intentions. What has happened to childbearing plans during this unexpected period of uncertainty about the future? Have fertility intentions been negatively affected by the pandemic? Can the impact of the pandemic be explained by people's objective exposure to the virus and its related socioeconomic consequences, or is it better grasped by exploring people's rising uncertainty about the future, which has also been spread by the media?

To address these questions, we make use of unique data that we collected during the spring 2020 lockdown on a sample of Italians of reproductive ages. We measured individuals' expectations concerning the duration of the pandemic emergency and family imaginaries, contrasting their effects on fertility intentions during the lockdown with those of past experiences, and the individuals' objective levels of exposure to the pandemic and its socioeconomic consequences. In addition, we provide empirical evidence of a causal impact of shared narratives of the future on fertility intentions by making use of online experimentation, an innovative approach to the study of the impact of the future in decision-making processes. Our experiment simulates a "real" exposure of respondents to a new media narrative. Respondents were randomly assigned to read different mock news bulletins concerning the expected end of the pandemic emergency in Italy, each of which presented a different expected duration of the crisis before a return to normality. We then compared their post-treatment and pre-treatment fertility intentions.

2 Uncertainty and fertility: The Narrative Framework

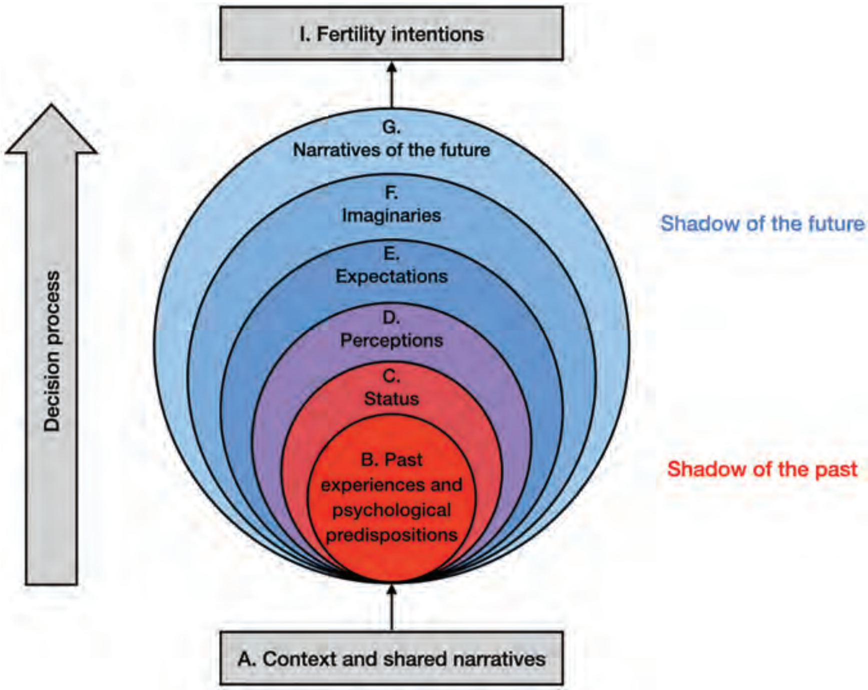
Much of the literature on fertility is based on the study of the social determinants of fertility, which mainly accounts for the influence of what already happened in previous stages of the life course, and thus considers factors such as educational attainment, previous (un)employment episodes and partnership histories (Barbieri et al., 2015; Busetta et al., 2019; Kreyenfeld et al., 2012; Vignoli et al., 2020c). These experiences are shaped during socialization and by personal predispositions, like risk aversion or time discounting preferences, which may also have a direct influence on fertility choices (Bellani et al., 2021; Schmidt, 2008). Psychological predispositions, cumulative past experiences over the life course and the present socioeconomic status are the standard elements usually identified as determinants of fertility intentions and behaviors (Busetta et al., 2019; Dantis and Rizzi, 2020; Mills and Blossfeld, 2013; Vignoli et al., 2012), and are aspects that need to be controlled for in any empirical model of fertility intentions. However, this "driven-by-the-past framework" (Seligman et al., 2013, p. 127) makes agency and choice difficult to understand, as fertility decision-making is a complex process that is influenced, but not determined, by past experiences.

The influence of the future on the course of action is difficult to conceptualize and operationalize in empirical research. The pragmatist philosophical tradition devoted special attention to the role of the future in the course of action. Following this approach, we can posit that future expectations are not just determined by pre-existing cognitive schemas or typification (Schütz, 1962), but are deeply imbued with imaginative capacity (Dewey, 1922/1930; Mead, 1932/2002). Of course, not all human actions are the result of deliberative thinking. According to Dewey, the ordinary course of action is an unreflective flow of activities in which "habits do all the perceiving, recalling, judging, conceiving and reasoning that is done" (1922/1930, p. 177). However, the ordinary, unconscious course of action can be interrupted by the emergence of conflict between "different habits, or by the release of impulses," or when the actor is confronted with a "new and surprising situation" (Beckert, 2016, p. 54) in which the expected outcome of the ordinary routine no longer seems to apply. At this point, people experience uncertainty about the future, and the deliberative process emerges, as the situation requires a (new) judgement. In a situation of uncertainty, past experiences and expectations come into play in an imaginative "dialogue" in which "competing possible lines of action" are considered because "deliberation is an experiment in finding out what the various lines of possible action are really like" (Dewey, 1922/1930, p. 190). The influence of the future in fertility plans has previously been considered in the New Home Economics approach (Becker, 1981) and the psychological Theory of Planned Behavior (Ajzen, 1991; Ajzen and Klobas, 2013). However, these approaches undermined the role of human agency, and failed to provide a systematic framework to account for its importance in explaining fertility dynamics.[1] The Narrative Framework – presented in Figure 1 – identifies the key elements that are involved in this future-oriented deliberative process: expectations, imaginaries and personal narratives of the future, which define what can be referred to as the "shadow of the future" that influences the decision-making process.

The figure represents the different steps of a stylized decision-making process. Each element of the framework stems from the previous ones, but can also exceed them and have an independent effect on fertility decision-making. Although these

[1] From a microeconomic perspective, Becker (1981) and the New Home Economics consider fertility behavior as an individual action oriented toward utility maximization. Expected utility is a forward-looking concept, even though the concept of *utility* remains largely undefined (Strandbakken, 2017). The application of a strict economic approach to fertility behavior may create an unrealistic type of family agency, in which individuals *calculate* and *discount* the actual cost of a child in the light of future utility (Caldwell, 1982). Usually, human actions are a mix of different types of agency (Emirbayer and Mische, 1998; Weber, 1922/1978). Fertility decisions are particularly complex decisions in which interests, values, opportunities and social ties interact (Vignoli et al., 2020a, p. 30). According to the Theory of Planned Behavior (TPB) (Ajzen, 1991), an action is the result of actors' *attitudes toward the behavior*, *subjective norms* (dependent on the relevant others' perceptions of the behavior) and *perceived behavioral control* (self-efficacy) (Ajzen and Klobas, 2013). Perceived behavioral control is clearly a forward-looking concept. However, the TPB set of elements still relies on a deterministic approach to fertility behavior, disregarding an individual's capacity to deviate from the expected course of action. Hence, from our perspective, the TPB misses one crucial element in its forward-looking approach: namely, the imaginative capacity of human agency. Moreover, the empirical validation of the TPB is highly problematic and much debated (Schoen et al., 1999), especially in terms of the role of background factors and structural constraints (Mencarini et al., 2015).

Figure 1:
The Narrative Framework for the analysis of the fertility decision-making process



elements are not meant to follow any strict order in actual decision-making, from an analytical point of view, it is useful to start considering psychological predispositions, past experiences (B) and current (socioeconomic) status (C), which represent a set of opportunities and constraints for childbearing plans. A recent stream of literature has introduced personal *perceptions* (D) of past and current experiences as a way to introduce agency into empirical models of fertility intentions and behavior, and they account for the fact that people may react very differently to the same objective experiences and economic conditions (Kreyenfeld, 2010, 2015). Individuals' perceptions have been found to play an independent role net of objective indicators of individuals' past and current labor market situations (e.g., Bhaumik and Nugent, 2011; Fahlén and Oláh, 2018), and to moderate the impact of these indicators on fertility intentions (Vignoli et al., 2020d) and behavior (Kreyenfeld, 2015). This approach is in line with the Thomas theorem, which posits that the interpretation of a situation causes the action (Thomas and Thomas, 1928). While perceptions of insecurity are related to individuals' current circumstances, they obviously refer to possible future events or threats. However, individuals' subjective evaluations of the (in)security of their current conditions only implicitly entail a reference to the future. In this sense, perceptions are somewhat "in between" the shadow of the past and the shadow of the future. To address theoretically and empirically the role of uncertainty in fertility decisions, a conceptualization that explicitly acknowledges its *forward-looking nature* is needed.

In Figure 1, *expectations* (E) are the first step into the shadow of the future, as they represent what people expect will happen in the future based on the available information. Although expectations may arise from past experiences, they are often connected to a shadow of the future, and, thus, become an independent source of agency. For instance, working with a fixed-term contract may not negatively affect an individual's fertility intentions if he/she believes that economic growth will be strong or that permanent employment opportunities will increase.

However, expectations do not account for the full influence of the future on the course of action, as *imaginaries* (F) may shape and deviate from an expected future. Imagination is the capacity to place oneself in one or more imagined situations, while also hypothesizing alternative courses of action and their effects. But imagination, more radically, also allows individuals to imagine a possible future that cannot be deduced from their present circumstances. Personal imaginaries may be easily influenced by social norms and relevant others' opinions, but may also deviate from them, and can thus move the decision-making process in a different direction. For instance, while the two-child norm is widespread in wealthy countries (Sobotka and Beaujouan, 2014), a personal family imaginary may revolve around a one-child or even a childless family. Imaginaries constitute a less abstract point of reference than social norms because they represent wishful (or fearful) projections into the future, which arise from the capacity of human agency to shift away from the expected course of action (Emirbayer and Mische, 1998). Imaginaries may play a crucial role in decision-making, and especially when making decisions that are likely to have complex and long-term outcomes, as in the case of fertility decisions. Long-term outcomes cannot be forecast, and/or each possible future may involve both positive and negative expectations. A normative orientation related to personal imaginaries ("How I would (not) like the future to be") may come into play and orient deliberation, shedding a special light on the different pros and cons implied by the available options, and thus help to orient the decision. A psychological mechanism compatible with the importance of imaginaries can be found in the "affective forecasting theory," which posits that people base their decisions on affective forecasts; i.e., on their predictions about their own emotional reactions to future events (Wilson and Gilbert, 2003). Demographic research has shown that the happiness of parents-to-be increases before childbirth (Myrskylä and Margolis, 2014), and that the anticipation of an increase (or a decrease) in one's own happiness from having a(nother) child may influence the decision to have the child at all (Billari, 2009). According to the Narrative Framework, family imaginaries represent the source of the "expected happiness" from childbearing, and, thus, have a dual effect on the cognitive process of deliberation. First, they provide a frame in which the current status (C) and the perception of the current status (D) are interpreted and evaluated, and which cannot be reduced to expectations (E), such as whether or not the (un)employment situation influences childbearing plans. Second, they represent an independent source of a conscious desire for a change in the future; i.e. they may provide a life goal, irrespective of the shadow of the past and (more or less plausible) expectations.

Personal narratives of the future (G) reflect the contingent plan for reaching the goals set by the imaginaries. As Figure 1 suggests, narratives do not just add an additional element to the framework; rather, they represent the less abstract level of the decision-making process, in which the shadow of the past, expectations and imaginaries find their proper places, and, at this level, influence fertility intentions (Vignoli et al., 2020a). All previous elements in the framework are selected, interpreted and included in a personal narrative of the future, which also entails a hypothetical course of action and the causal interconnection of these elements.

Life course decisions like fertility decisions necessarily involve a conscious narrative of the future, which embodies the causal path that people deem necessary to reach their imagined goal. Expectations, imaginaries and narratives of the future might facilitate or inhibit fertility in conditions of uncertainty. They might foster fertility in line with the socio-psychological uncertainty reduction framework from Friedman et al. (1994), who argued that more economically vulnerable women may respond to uncertain life prospects by choosing to become a mother, which gives meaning and stability to their lives. However, empirical evidence suggests that people, and especially young people, usually build their personal narratives to act in accordance with a condition of economic uncertainty in order to avert risk (McDonald, 2002; Schmidt, 2008). Young adults tend to postpone making long-term, binding decisions, such as decisions about marriage and childbearing, until they become more settled in the labor market (Mills and Blossfeld, 2013), and such tendencies may be particularly strong in a country like Italy, which is characterized by the "postponement syndrome" (Livi Bacci, 2001), and where the perceived economic preconditions for family formation seem very high (Vignoli et al., 2020b). Moreover, a family imaginary may revolve around the desire to remain childless. For these individuals, all of the previous elements of the Narrative Framework play only a marginal role in defining the personal narrative that influences their fertility decisions.

Individual actors are not the only "authors" of their own narratives of the future, as they are influenced by factors external to them, in the form of *context and shared narratives* (A). The "context" usually considered in comparative analyses of fertility is related to the institutional setting, prevailing values and long-term cultural continuities (Balbo et al., 2013). However, above and beyond the influence of these contextual factors, a last element of our Narrative Framework is represented by *shared narratives* (A): i.e. narratives of the future adopted by relevant others such as parents and peers, or conveyed by the media (Vignoli et al., 2020b). Parental pressure is likely to influence young people's family plans, especially in a "strong family" setting in which young adults tend to leave their family of origin relatively late, such as in Southern European countries (Billari, 2004). This is a situation that may not apply to other Western European countries, where the influence of peers may be more relevant (Di Giulio and Rosina, 2007; Guetto et al., 2016). However, in recent years, a major source of influence in globalized societies is the unprecedented access to press and new (social) media, which may shape individuals' perceptions, expectations and imaginaries.

Media-channeled shared narratives have started to play a major role in spreading feelings of uncertainty about the future in recent decades, and the media coverage of economic issues has increased substantially, especially after the 2008 crisis, in both Europe and the US (Baker et al., 2016). This constant (over-)flow of information, which was further intensified after the start of the pandemic (Altig et al., 2020), is likely to exacerbate individuals' feelings of uncertainty about the future because of the prevailing tone and angles of media reports (Alsem et al., 2008; Dräger, 2015). Schneider (2015) suggested that press coverage comes closer to measuring the sentiments that shape economic uncertainty and that affect fertility decisions than actual economic constraints. More recently, the European sovereign debt crisis has received considerable attention in the media, and the simplified narratives presented in the press have served as a multiplier of uncertainty, contributing to shrinking birth rates (Comolli and Vignoli, 2021).[2]

3 Adapting the Narrative Framework to the COVID-19 pandemic

In this paper, we propose an application of the Narrative Framework outlined above to the study of fertility intentions during the COVID-19 pandemic outbreak, with an empirical focus on the first nationwide lockdown implemented in Italy. Although this empirical exercise does not aim to operationalize the whole theoretical scheme presented so far, two sets of hypotheses refer to the "shadow of the past" of COVID-induced uncertainty (Hypotheses **H1a**, **H1b**) and to the "shadow of the future" of pandemic uncertainty and personal family imaginaries (Hypotheses **H3a**, **H3b**). Given their liminal positioning at the intersection between the two "shadows" (Figure 1), a specific hypothesis (**H2**) refers to the role of perceptions related to personal and general situations. We also take into account the role of media shared narratives during the pandemic, and their possible *causal* impact, through an *ad hoc* experiment (Hypothesis **H4**).

The pandemic has exogenously exposed people of reproductive ages to a new environment characterized by a high level of uncertainty. This new, uncertain situation affects individuals through two main mechanisms: the health and economic consequences of the pandemic and related government restrictions (*context*) on the one hand, and exposure to the (social) media coverage of the pandemic (*shared narratives*) on the other.

[2] A more detailed discussion of the functions of personal narratives and the interconnections between the different elements of the Narrative Framework would be beyond the scope of the paper, but can be found in Vignoli et al. (2020a).

The pandemic context has led to important changes in individuals' objective status, first and foremost in terms of the potential health consequences of direct exposure to the SARS-CoV-2 virus. Apart from those individuals who needed hospitalization because they had more severe symptoms, people who tested positive for the virus had to face quarantine and social isolation, and even many untested people were put in quarantine because of a suspicion that they or their close relatives or acquaintances had been infected. The uncertainty created by this unexpected situation is likely to hinder childbearing plans, both directly and indirectly due to induced perceptions of insecurity, which leads to our first hypothesis:

Hypothesis 1a. Personal, close relatives' or acquaintances' exposure to the SARS-CoV-2 virus negatively affects pre-pandemic fertility intentions.

The economic consequences of the pandemic have been even more widespread. During the first lockdown, which started on March 9, 2020, Italians were prohibited from leaving their homes, except to engage in work activities deemed "essential," to buy food, or in cases of utter emergency. The most fortunate workers – usually highly educated individuals employed in skilled jobs and in regular forms of dependent employment – shifted to working from home, and did not face a serious risk of being laid off or suffering earning losses, especially if they were public sector employees. However, the Italian National Institute of Statistics (ISTAT) estimated that approximately one-third of the total labor force were employed in economic sectors whose activities were suspended, especially in the private sector, in which almost half of firms were affected by government restrictions (ISTAT, 2020). This meant that millions of suspended employees had to rely on wage guarantee funds, which entailed a 35% average reduction of the usual salary; whereas many self-employed individuals, especially in the consumer services sector, had to temporarily interrupt their activities with limited or no earnings, apart from discretionary lump-sum transfers provided by the government to help them weather the emergency. Finally, many workers lost their jobs, although the exact numbers of such workers are difficult to estimate, especially if they were employed with temporary contracts or in the black economy. Restrictions were gradually loosened by the government up to the end of the lockdown on May 4, 2020. Many businesses, such as bars and restaurants, did not re-open until the beginning of June, and travel between Italian regions (NUTS-2) without any certified urgent reason was not allowed until June 3, 2020. In light of the available empirical evidence concerning the negative effects of unemployment and more unstable labor market conditions on fertility in Italy (Alderotti et al., 2021; Busetta et al., 2019), this objective situation of economic uncertainty leads to the next hypothesis:

Hypothesis 1b. The experiences of work suspension and/or job loss because of government restrictions negatively affect pre-pandemic fertility intentions.

The new context created by the pandemic and government restrictions influenced many aspects of individuals' objective status, which, together with their past experiences and psychological predispositions, are part of the shadow of the past in the fertility decision-making process during the COVID-19 pandemic. However, the pandemic context also influenced more subjective states through exposure to media shared narratives. Indeed, during the lockdown, most people were informed about the diffusion of the pandemic and government decisions only by the (social) media, which focused heavily on trends in the diffusion of coronavirus infections. During this period, Italians gathered in front of their TVs every day at 6 p.m. to get the official updates concerning the daily numbers of hospitalized individuals and deaths from the Civil Protection's press conference. The daily news of coronavirus deaths and infections was a major source of concern for the population in this period. In the first half of April 2020, at the peak of the pandemic and in the middle of the lockdown period, Italy recorded an average of 700 COVID-related deaths per day. As of April 15, Italy had approximately 150,000 positive cases and 20,000 official deaths, which were the highest numbers in Europe at that time. It is important to note that these figures are difficult to compare across countries due to various kinds of biases in the identification of the exact cause of death (Odone et al., 2020).[3] Nonetheless, the awareness of these official numbers is likely to have shaped individuals' perceptions of the seriousness of the emergency, and to have added a generalized feeling of insecurity to individuals' baseline psychological predispositions to risk aversion, even among those who were not directly exposed to the objective socioeconomic consequences of the pandemic. This leads to our next hypothesis:

Hypothesis 2. Perceptions of insecurity across several life domains due to the pandemic negatively affect pre-pandemic fertility intentions.

The public media discourse in Italy was filled with heated debates among virologists, politicians and opinion leaders on issues such as "the exponential growth of infections," the need for "measures to flatten the curve" and whether (and which types of) masks are useful to slow down the pandemic, often with contradictory messages (Ruiu, 2020). In line with our Narrative Framework, people were thus exposed to a high degree of uncertainty about their future, and had to form their own expectations about when the return to pre-pandemic conditions would occur. Expectations are the first element of the shadow of the future that have influenced fertility intentions during the pandemic:

Hypothesis 3a. The expectation that the return to pre-pandemic conditions will take a long time negatively affects pre-pandemic fertility intentions.

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[3] The very high apparent mortality rate associated with COVID-19 in Italy was most likely attributable to a combination of several factors, above all Italy's age population structure. In addition, the elderly have been particularly hard hit by the pandemic because of the spread of Sars-CoV-2 in nursing homes (Bernardi et al., 2021; Trabucchi and Diego De Leo, 2020). Finally, especially in the early stages of the pandemic and in Lombardy, the most severely affected Italian region, only people with serious symptoms were tested. Thus, the actual numbers of asymptomatic or paucisymptomatic infected individuals were underestimated in the official numbers (Odone et al., 2020).

Taken together, people's current status, perceptions and expectations about the length of the emergency – all of which are influenced by the new, uncertain context created by the pandemic and the related media shared narratives – are expected to influence people's fertility intentions during the pandemic, net of past experiences and psychological predispositions. Personal family imaginaries related to the joy of parenthood are also expected to influence changes in fertility intentions, although they should be only marginally affected by the pandemic. Imaginaries do change during the life course, but since they usually incorporate a normative orientation toward the future, they are not likely to be modified in the short term (Kiley and Vaisey, 2020). The presence of family imaginaries and their influence on fertility intentions leads to our next hypothesis:

Hypothesis 3b. Individuals with a positive family imaginary are less negatively influenced by the pandemic, and are less likely to change their pre-pandemic childbearing plans.

For people who were not directly exposed to the health and economic consequences of the pandemic, the shared narratives spread by the media were the major sources of uncertainty. However, to effectively grasp the media effects, indicators of the media coverage of the pandemic, combined with measures of individuals' exposure to those specific media contents, would be needed. Moreover, even if all of the necessary information was available, causality would remain difficult to ascertain. For these reasons, we adopted an experimental approach in which respondents were exogenously exposed to different scenarios regarding the expected end of the pandemic, mimicking a news report. We then asked the respondents about their (renewed) fertility intentions, in light of the expected duration of the emergency. Using this approach, we both provide additional evidence on the importance of media shared narratives and reinforce the claims about the causal role of the shadow of the future in fertility intentions. This experiment allows us to test our last hypothesis:

Hypothesis 4. Exposure to a new shared narrative that the return to pre-pandemic conditions will take a long time negatively influences fertility intentions; whereas exposure to a new shared narrative that the return to pre-pandemic conditions will happen quickly positively influences fertility intentions.

To sum up, if fertility decisions have been negatively influenced by the pandemic, we hypothesize that this effect cannot be explained by the objective exposure to the pandemic's health and economic consequences alone (Hypotheses **H1a** and **H1b**). In a context of amplified uncertainty about the future, perceptions (Hypotheses **H2**), and, in particular, expectations and imaginaries, may gain the upper hand (Hypotheses **H3a** and **H3b**). Expectations about the length of the pandemic spread by the media, which are simulated through our experiment, may also have a specific influence on fertility intentions (Hypothesis **H4**).

This first application of the Narrative Framework to the empirical analysis of changes in fertility intentions during the pandemic is carried out by means of survey data that we collected during the lockdown in Italy. These data operationalize all of the elements included in Figure 1, but do not include personal narratives of the future, which are more easily explored through qualitative interviewing. However, if relevant information regarding all of the elements involved is available in the survey data, it may be used as a proxy to grasp the effects of personal narratives (Vignoli et al., 2020b).

4 Data, variables and methods

4.1 Sampling and data collection

The data come from an online survey carried out between April 25 and May 1, 2020; that is, during the final week of the Italian lockdown. A well-known issue of online sampling is that of coverage bias, which may undermine the survey's ability to represent the target population. Indeed, online surveys can only reach people who are online, and who have agreed to become part of a panel and to participate in the specific survey (Duffy et al., 2005). These limitations notwithstanding, we had no real alternative to the use of this method of data collection. Given our aim to exploit the lockdown as an exogenous uncertainty shock, we needed to collect all the relevant information for a reasonably large sample size in a very short time period. Face-to-face interviewing was, of course, not an option during the lockdown. The sampling was carried out by the international survey company Lucid, which is well-known in academic circles for its high-quality and rigorous data collection (Coppock and McClellan, 2019), and we followed several strategies to ensure both data representativeness and quality.

First, given our focus on fertility intentions, we targeted Italian men and women aged 20–43 and 20–41, respectively, regardless of their living arrangements and partnership status. For Italians in this age group, the incidence of regular internet use is close to 90% (ISTAT, 2018). Second, based on data from ISTAT, we set quotas for gender, age and area of residence that reflected the characteristics of the target group. Given the heterogeneous impact of COVID-19 across Italian areas – i.e. northern regions were hit harder by the pandemic in terms of the numbers of infections and official deaths – we set quotas for provinces (NUTS-3) in the northern part of Italy (including the Marche region), and for regions (NUTS-2) in the central and southern parts of the country (including Sicily and Sardinia). Third, respondents who provided deliberately fatuous answers had their answers filtered out. We also discarded interviews that were shorter than three minutes; the average duration of the interviews in the final sample was approximately eight minutes. After eliminating a few respondents who were expecting a child in January and/or at the interview date, the final sample consists of 3,934 individuals.

4.2 Variables

Among the sociodemographic factors related to past experiences and psychological predispositions, we collected information on each respondent's level of risk aversion

("Do you feel inclined to take risks or rather to avoid them?"), number of siblings, living arrangement (no partner, married, cohabiting, living apart together), number of children and educational attainment. These are standard predictors of fertility intentions that were largely unaffected by the pandemic context, at least in the short term. Descriptive statistics for all variables are shown in Table 1.

To assess the influence of the shadow-of-the-past elements of the Narrative Framework that may have been affected by the exogenous uncertainty shock of the pandemic, we asked the respondents about their exposure, either direct or indirect, to SARS-CoV-2, and about changes in their socioeconomic status. While the majority of the respondents in our sample reported no personal exposure (60%), 5% said they had either tested positive for the virus or had been put in isolation due to a suspected infection, 24% reported having a close relative or acquaintance who had tested positive, and 10% reported having a close relative or acquaintance who had been put in isolation due to a suspected infection. To capture the respondents' socioeconomic status, we asked them several questions referring to both their pre-pandemic (January) and current circumstances: i.e. employment status (employed, not employed, student); for the employed, the level of qualification of the occupation (high or low, with the former including managerial, professional and technical occupations) and the professional status (employee or self-employed); and for employees, the presence and the type of job contract (permanent, temporary, irregular work). We merged all of the pre-pandemic information in a "labor market status" variable. To measure more directly the impact of the lockdown and government restrictions, we compared pre-pandemic and current information, and created three binary variables concerning changes in employment status, as the other dimensions of the labor market status were less likely to be influenced by the new pandemic context, at least in the short term. As shown in Table 1, 8% of respondents who were workers or students in January were not employed at the time of the interview. In addition, 13% of respondents who were employed in January reported being temporarily inactive, while 21% indicated that they had shifted to remote work. Finally, we measured respondents' net monthly household income at the time of the interview. We asked each and exposure to the (socialtegories, which were subsequently recoded as a continuous variable ranging from €300 to €5,000. The average in our sample was close to €2,000 (median of €1,800), with a substantial number of missing values (17%), which had been imputed with the median value (missing values are concentrated among the students and the not employed).[4] According to ISTAT, the median net monthly household income in Italy in 2017 was approximately €2,100. Thus, considering the negative impact of the lockdown, our sample average appears

[4] Based on ISTAT data (2018), approximately 89% of students under age 40 live with at least one parent, which suggests that parental income should be considered. For this reason, imputing missing cases with the median household income should not have important consequences for our results.

Table 1:
Descriptive statistics (N = 3,934)

	Mean	Std. Dev
B. Past experiences and psychological predispositions		
Risk aversion (0–10)	4.83	2.79
Number of siblings (0–3+)	1.22	0.84
Living arrangement		
No partner	.25	
Living Apart Together	.27	
Cohabiting	.16	
Legally married	.33	
Number of children (0–2+)	.42	.72
Educational attainment		
Lower-secondary	.12	
Upper-secondary	.47	
Tertiary	.41	
C. Status		
Exposure to SARS-CoV-2		
No exposure	.60	
Indirect (suspected)	.10	
Indirect (positive)	.24	
Direct (suspected or positive)	.05	
Labor market status (January)		
Permanent employment (low)	.29	
Permanent employment (high)	.07	
Temporary employment (low)	.13	
Temporary employment (high)	.05	
Irregular employment	.02	
Self-employed (low)	.05	
Self-employed (high)	.05	
Not employed	.18	
Student	.16	
Labor market transitions due to the lockdown		
Toward not employment (from all other statuses)	.08	
Toward temporary inactivity (from employment)	.13	
Toward smart work (from employment)	.21	
Net monthly household income (in €)	1940.51	967.22
Missing on income	.17	

Continued

Table 1:
Continued

	Mean	**Std. Dev**
A. Media shared narratives		
Media exposure (politics and latest news)		
Hours of TV (January)	.93	1.01
Diff. in hours of TV (Now-January)	.67	1.15
Hours of internet (January)	1	1.09
Diff. in hours of internet (Now-January)	.61	1.03
D. Perceptions *(insecurity due to)*		
Own work (0–10)	5.90	3.09
Own health (0–10)	3.95	2.31
Diffusion of the pandemic (0–10)	6.87	2.50
General economic situation (0–10)	6.39	2.57
General political situation (0–10)	6.98	2.50
E. Expectations		
Before the return to pre-pandemic condition (own)		
My condition did not change	.07	
3 months	.12	
6 months	.25	
12 months	.39	
2 years	.12	
More than 2 years	.05	
Before the return to pre-pandemic condition (Italy)		
3 months	.03	
6 months	.08	
12 months	.25	
2 years	.28	
More than 2 years	.36	
F. Imaginaries		
How much would having a(nother) child make you happy? (0–10)	5.89	3.74
I. Fertility intentions in the next 3 years		
In January, were you planning to have a child? (0–10)	3.29	3.78
Today, do you plan to have a child? (0–10)	3.21	3.62
$\Delta Fertility\_intentions_{t1-t}$	−0.08	2.19

to be in line with the "true" population average, notwithstanding the high number of missing values.

While each respondent's objective status was likely influenced by the pandemic-related health and socioeconomic consequences and government restrictions, his/her perceptions and shadow-of-the-future elements were likely influenced by media shared narratives as well. To grasp the effects of these narratives, we asked respondents about how much time they spent each day watching TV and surfing the internet to get information about politics and the latest news. To isolate possible changes during the lockdown, we measured media exposure in January and at the time of the interview. While the respondents spent, on average, one hour per day watching TV and surfing the internet in January, their use of both types of media had increased by approximately 40 minutes per day during the lockdown.

To capture perceptions, we measured the respondents' feelings of insecurity due to their work, health, the diffusion of the pandemic and the general economic and political conditions, on a scale from zero to 10. On average, the respondents reported that they were not too worried about their health status (3.95), but they expressed a high level of insecurity because of the pandemic (6.87), and, potentially, because of its negative effects on their work (5.90) and on the general economic (6.39) and political (6.89) conditions.

To capture the shadow of the future, the role of pandemic uncertainty in expectations was measured through two questions regarding the expected length of time before the pre-pandemic conditions would return, with respect to the respondent's own situation and the country's social and economic conditions. The respondents indicated that they were much more pessimistic about the state of the country than about their own situation. While more than half of the respondents said that it would take at least two years for the pre-pandemic conditions to return throughout the country, a large majority of respondents said that they expected their own situation to return to normal within one year. However, 17% of respondents indicated that they expected that their own situation would not to return to normal for at least two years.

Exploring individuals' family imaginaries through online survey questions is complicated by social desirability and cognitive dissonance biases, as well as by the fact that imaginaries may differ depending on the stage of the life course, such as before and after the birth of the first child (Vignoli et al., 2020b). Following the literature on expected happiness (Billari, 2009) and affective forecasts (Wilson and Gilbert, 2003), we asked the respondents how much having a(nother) child would make them happy, on a scale from zero to 10. *Ceteris paribus*, higher values on this variable can be interpreted as the ultimate outcome of a positive family imaginary.

Finally, following recommendations to measure individual differences in psychological constructs with acceptable levels of precision (MacCallum et al., 2002), we asked the respondents to report their fertility intentions in the following three years, on a scale from zero ("definitely not") to 10 ("definitely yes"), both before (in January) and after the start of the pandemic (at the time of the interview). As shown in Table 1, the average values of the answers to the two questions – 3.29 and 3.21, respectively – point to only a minor reduction in fertility intentions. Thus, these descriptive statistics do not suggest that there was a substantial and generalized drop in pre-pandemic fertility intentions during the lockdown. However, three factors should be taken into account when interpreting these results. First, responses to retrospective questions about fertility intentions may be adjusted *ex post* to accord with current intentions, and they may be affected by recall bias; although the short time window (3/4 months) should limit this risk. Second, temporary postponements of reproductive plans may not be captured in our results, as we asked about fertility intentions in the following three years, which likely include a post-pandemic period. Third, and most important, 41% of the sample answered zero ("definitely not") to questions on fertility intentions both in January and at the time of the interview, which means that, regardless of the abovementioned measurement issues, for a substantial share of the respondents there simply was no room to observe a decline in fertility intentions due to the pandemic. Considering only individuals with non-zero intentions in January (N = 2,068), the average fertility intention in January was 6.25, and had declined to 5.56 at the time of the interview, with 34% of the respondents reporting lower intentions, and just 15% reporting higher intentions at the time of the interview. Irrespective of the actual magnitude of the absolute decline in fertility intentions, our aim is to understand which individual characteristics are associated with a decline (or an increase) in fertility intentions after the onset of the pandemic.

4.3 The experimental design

The survey included an experiment that presented the respondents with a mock news bulletin concerning the expected end of the pandemic emergency, according to a task force made up of leading coronavirus experts in Italy. We opted for this treatment because a few days before data collection the Italian prime minister had announced the formation of a task force of academics and other prominent experts to address the COVID-19 emergency, and to provide guidelines for the return to normality; thus, the treatment should have sounded realistic. Respondents were randomly assigned one of five treatments, each presenting a different expected duration before the return to normality: three months, six months, one year, two years, or more than two years. As a check for the validity of the treatment, respondents were asked which type of scenario they were exposed to. The percentage of respondents who could not recall the exact expected length of the pandemic included in the scenario accounted for 13% in our analytical sample, but dropped to approximately 5% if we excluded people who confused "more than two years" with "two years." After being exposed to the treatment, respondents were asked about their fertility intentions in the next three years in light of the expected duration of the emergency. Finally, the respondents were informed of the fictitious nature of the information about the evolution of the pandemic they had received. The experimental protocol received formal approval from the Ethical Committee of the University of Florence. The full text of the treatment is reported in Appendix A.

4.4 Methods

The analytical strategy is twofold. For the analysis of changes in fertility intentions due to the pandemic, we implemented the following stepwise OLS regression models:

$$M1\colon \Delta Fertility_{t1-t} = Status + Past + Fertility_t$$
$$M2\colon \Delta Fertility_{t1-t} = Perceptions + Media\ shared\ narratives + M1$$
$$M3\colon \Delta Fertility_{t1-t} = Imaginaries + Expectations + M2$$

Where $\Delta Fertility_{t1-t}$ is the difference between fertility intentions at the interview and fertility intentions in January ($Fertility_t$), with the latter being included in all models together with basic sociodemographic variables and risk aversion (*Past*). All elements of the stylized equations include the related variables, as shown in Table 1. Model 1 only adds individuals' objective socioeconomic status and direct and indirect exposure to SARS-CoV-2, thus allowing us to test Hypotheses **H1a** and **H1b**. Models 2 and 3 cumulatively add additional variables to test whether perceptions, including perceptions influenced by media shared narratives (Hypothesis **H2**), expectations and imaginaries (Hypotheses **H3a** and **H3b**), exert an additional influence on changes in fertility intentions. As a robustness check, Model 3 is also estimated on a subsample of respondents with non-zero fertility intentions in January. Finally, to disentangle the different mechanisms that potentially underlie declines and increases in fertility intentions during the lockdown, and to offer a different evaluation of our effect sizes, Model 3 is also estimated through a multinomial logistic regression analyzing the probability of fertility intentions decreasing, increasing or remaining the same as in January.

In a second step, we analyzed the causal impact of a new shared narrative of the future (Hypothesis **H4**) by means of our survey experiment. We compared respondents' post-treatment and pre-treatment fertility intentions by means of the following OLS regression model:

$$M4\colon \Delta Fertility_{t2-t1} = Treatment + Recall + Fertility_{t1}$$

Where $\Delta Fertility_{t2-t1}$ is the difference between post- and pre-treatment fertility intentions ($Fertility_{t1}$). *Treatment* represents a set of dummies for the different scenarios, with the "three months" scenario as the reference category. *Recall* is a dummy variable taking a value of one for the respondents who were not able to recall exactly which type of scenario they have been exposed to. In order to check for the exogeneity of our treatment, Model 4 has also been estimated with the addition of all variables included in Model 3 of the previous analytical step. To provide additional insights, we performed an analysis of possible heterogeneity in treatment effects.

5 Results

5.1 Determinants of changes in fertility intentions during the lockdown

Table 2 presents the results of our stepwise OLS models, with the exclusion of coefficients related to basic sociodemographic factors, past experiences and psychological predispositions (*Past*) not directly affected by the pandemic and government restrictions. Model 1 shows that individuals' adaptations of their fertility intentions after the pandemic outbreak were moderated by their labor market status in January: the respondents who were temporarily employed in a low-skilled occupation or in the underground economy, or who were not employed, had lower fertility intentions than low-skilled employees with a permanent contract. Similar patterns can be observed for the highly skilled self-employed and students. However, the effects of variables that capture the impact of the lockdown more directly were virtually null. Neither a (temporary) job loss, a transition to remote work after the start of the pandemic, the degree of exposure to the virus nor household income was associated with changes in fertility intentions. Indeed, having tested positive for the virus was even associated with higher post-pandemic fertility intentions, especially compared to an indirect experience (we will come back to this point later on). Thus, the empirical evidence provides very limited support for Hypotheses **H1a** and **H1b**. Moreover, as the stepwise inclusion of perceptions and shadow-of-the-future factors further reduced the impact of labor market status in January, the only shadow-of-the-past factors that had a *direct* effect on changes in fertility intentions (Model 3) were those of being a student and a highly skilled self-employed individual.

Model 2 includes perceptions, and shows that individuals' levels of insecurity concerning their own health and work, as well as the general economic situation, were significantly associated with a contraction in fertility intentions; whereas their levels of insecurity concerning the political situation and the pandemic were not. Thus, the results are partially in line with our Hypothesis **H2**, as insecurity concerning the pandemic was not directly associated with fertility intentions once insecurity concerning the respondent's personal situation was accounted for. The effects of the statistically significant variables were not trivial: on the 0–10 scale, the regression coefficients indicate that the most insecure respondents reported an approximately half-point decrease in fertility intentions. Interestingly, in this model, the effects of the respondent's labor market status in January turned non-significant. This result suggests that perceptions mediated the (limited) influence of objective socioeconomic factors on post-pandemic changes in fertility intentions. Model 2 also includes the variable for media exposure, which suggests that the respondents who increased their TV consumption during the lockdown adjusted their fertility intentions downward, although the coefficient was statistically significant only in Model 3. Notwithstanding the abovementioned difficulties involved in capturing their (causal) effects with such a rough measure, this result provides a first indication of the role of media-channeled shared narratives.

Model 3 adds our two measures of expectations concerning the evolution of the pandemic, and our proxy of the imaginary associated with childbearing. In line with our Hypothesis **H3a**, expectations about the length of time before the respondent's own personal situation would return to pre-pandemic conditions were negatively associated with post-pandemic fertility intentions, but were statistically

Table 2:
Determinants of changes in fertility intentions after the lockdown. OLS models

	M1		M2		M3	
	Coeff.	**Std. Err.**	**Coeff.**	**Std. Err.**	**Coeff.**	**Std. Err.**
C. Status						
Labor status in January (ref. Permanent-low)						
Permanent-high	0.016	(0.145)	0.025	(0.143)	0.010	(0.134)
Temporary-low	−0.257**	(0.122)	−0.170	(0.121)	−0.191	(0.116)
Temporary-high	−0.150	(0.183)	−0.069	(0.183)	−0.087	(0.176)
Black job	−0.525*	(0.270)	−0.399	(0.268)	−0.359	(0.263)
Self-low	−0.187	(0.180)	−0.108	(0.180)	−0.042	(0.171)
Self-high	−0.373**	(0.162)	−0.304*	(0.161)	−0.290*	(0.153)
Not employed	−0.223*	(0.117)	−0.016	(0.121)	0.005	(0.118)
Student	−0.550***	(0.126)	−0.479***	(0.127)	−0.393***	(0.124)
HH income (1€)	5.53e-05	(3.46e-05)	7.20e-06	(3.45e-05)	1.30e-05	(3.36e-05)
Labor market transitions due to the lockdown						
To not emp.	−0.002	(0.152)	0.168	(0.152)	0.171	(0.147)
Temp. not emp.	−0.054	(0.109)	0.078	(0.109)	0.055	(0.104)
To smart work	0.069	(0.099)	0.050	(0.097)	0.090	(0.094)
Exposure to SARS-CoV-2 (ref. No exposure)						
Indirect (susp.)	−0.105	(0.100)	−0.077	(0.098)	−0.131	(0.095)
Indirect (pos.)	0.050	(0.079)	0.093	(0.079)	0.071	(0.077)
Direct	0.215	(0.154)	0.222	(0.156)	0.228	(0.149)
A. Media shared narratives						
Media exposure (politics and latest news)						
TV hours (Jan.)			0.035	(0.043)	0.026	(0.042)
TV hours (Today-Jan.)			−0.063	(0.044)	−0.083**	(0.042)
Web hours (Jan.)			0.055	(0.039)	0.068*	(0.038)
Web hours (Today-Jan.)			−0.013	(0.049)	−0.021	(0.047)
D. Perceptions *(insecurity due to)*						
Own health			−0.047***	(0.016)	−0.034**	(0.016)
Own work			−0.046***	(0.014)	−0.036***	(0.014)
General economic situation			−0.059***	(0.018)	−0.044**	(0.017)
General political situation			−0.011	(0.017)	−0.011	(0.017)
Diffusion of the pandemic			−0.001	(0.017)	−0.009	(0.017)

Continued

Table 2:
Continued

	M1		M2		M3	
	Coeff.	**Std. Err.**	**Coeff.**	**Std. Err.**	**Coeff.**	**Std. Err.**
E. Expectations						
Return to pre-pandemic own condition (ref. It did not change)						
3 months					–0.010	(0.139)
6 months					–0.044	(0.120)
12 months					–0.130	(0.114)
2 years					–0.178	(0.142)
More than 2 years					–0.686***	(0.196)
Return to pre-pandemic condition in Italy (ref. 3 months)						
6 months					0.191	(0.238)
12 months					0.139	(0.216)
2 years					–0.014	(0.219)
More than 2 years					0.057	(0.218)
F. Imaginaries						
Happiness from childbirth					0.179***	(0.012)
Constant	0.624***	(0.174)	1.588***	(0.231)	0.881***	(0.298)
Observations	3,934		3,934		3,934	
R-squared	0.162		0.184		0.247	

Notes: Robust standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. All models control for fertility intentions in January, risk aversion, number of children, siblings, education, area of residence, sex, age and age^2.

significant only for the most pessimistic forecasts.[5] Interestingly, expectations about the general situation in Italy did not exert any direct effects once expectations concerning the respondent's personal situation were controlled for. The variable for the expected level of happiness from having a(nother) child exerted both a statistically and substantively significant positive effect, while also contributing to a substantial rise in the model's R-squared. That is, respondents with a more positive imaginary related to childbearing had been less negatively influenced by the lockdown, and had higher post-pandemic fertility intentions, in line with our Hypothesis **H3b**.[6]

All in all, the results of Model 3 suggest that the most relevant individual characteristics needed to understand fertility decision-making under conditions of

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5 Results do not change if the family imaginary is not simultaneously included in the model.

6 Additional analyses revealed that the effect of the expected level of happiness from having a(nother) child is larger for individuals with zero or only one child (0.19 and 0.21, respectively), whereas it is substantially smaller for individuals with at least two children (0.10), signaling lower perceived gains from higher-order childbirths.

COVID-induced uncertainty were perceptions and the shadow of the future, whereas objective measures of the respondents' socioeconomic situations and exposure to SARS-CoV-2 did not play a significant role.[7] Notwithstanding an obvious increase in the uncertainty surrounding our estimates, this overall conclusion held even after implementing separate models by sex. This is not to say, however, that the shadow of the past was not at all relevant. Age, sex, the number of children and the area of residence were significantly associated with changes in fertility intentions: i.e. childless women, people living in southern regions, and people in their mid-thirties had higher post-pandemic intentions.[8]

In Table B.1 in Appendix B, Model 3 was implemented selecting only individuals with non-zero fertility intentions in January, before the onset of the pandemic in Italy. The most important changes to highlight are the substantial increases in the magnitude of the coefficients associated with media exposure, expectations and imaginary. This is not surprising, as the individuals who had at least some positive fertility intentions were those who were more likely to have been negatively affected by the sudden uncertainty shock, and for whom the media coverage of the pandemic and pessimistic expectations about the future would have been particularly salient. On the other hand, people with a more positive family imaginary were expected not only to keep their higher pre-pandemic fertility intentions, but also potentially to increase their fertility intentions as they aimed for their imagined goal, regardless of their COVID-induced uncertainty.

Table 3 provides additional insights by distinguishing between the effects of covariates on the probability of decreasing or increasing fertility intentions during the lockdown, through a multinomial logistic regression implemented on the whole sample. Consistent with our arguments, the respondents' perceptions of insecurity concerning their own health and work were associated with a higher relative risk of having reduced fertility intentions during the lockdown, whereas their perceptions of insecurity about the general economic situation reduced the relative risk of increasing vs. holding the same fertility intentions. The respondents' expectations about their personal situation were strongly, positively and monotonically associated only with the relative risk of decreasing vs. holding the same fertility intentions. The predicted probabilities calculated after the multinomial logistic regression indicate that those respondents who thought that it would take more than two years for their personal situation to return to pre-pandemic conditions had a 25% probability of having decreased their fertility intentions, compared to 10% for those who did not perceive any changes. For the increasing fertility outcome, the differences in the predicted probabilities were, by contrast, small and statistically insignificant.

[7] We checked that the model does not suffer from major multicollinearity issues, as the mean variance inflation factor (VIF), as well as the single VIFs associated with each regression coefficient of Model 3, are lower than 2.5.

[8] Full models are available from the authors upon request.

Conversely, and as expected, a more positive family imaginary was associated with both lower risks of having decreased fertility intentions and higher risks of having increased fertility intentions, with the latter effect being stronger than the former: i.e. a one-point increase in the expected happiness from childbirth was associated with a lower predicted probability of having decreased fertility intentions of

Table 3:
Determinants of changes in fertility intentions after the lockdown. Multinomial logit model

	Decrease vs. Same		**Increase vs. Same**	
	RRR	**Std. Err.**	**RRR**	**Std. Err.**
C. Status				
Labor status in January (ref. Permanent-low)				
Permanent-high	1.009	(0.215)	0.971	(0.200)
Temporary-low	1.380*	(0.235)	1.183	(0.199)
Temporary-high	0.772	(0.204)	0.756	(0.200)
Black job	0.876	(0.303)	1.009	(0.389)
Self-low	1.079	(0.239)	0.984	(0.230)
Self-high	1.113	(0.261)	0.520**	(0.157)
Not employed	0.717*	(0.131)	0.959	(0.173)
Student	0.803	(0.176)	0.457***	(0.105)
HH income (1€)	0.999**	(5.99e-05)	0.999**	(5.88e-05)
Labor market transitions due to the lockdown				
To not emp.	0.862	(0.175)	1.045	(0.219)
Temp. not emp.	0.963	(0.148)	1.054	(0.172)
To smart work	1.086	(0.153)	1.134	(0.162)
Exposure to SARS-CoV-2 (ref. No exposure)				
Indirect (suspected)	1.052	(0.168)	0.730*	(0.132)
Indirect (positive)	1.029	(0.126)	0.966	(0.122)
Direct	1.220	(0.280)	1.692**	(0.364)
A. Media shared narratives				
Media exposure (politics and latest news)				
TV hours (Jan.)	1.062	(0.070)	1.149**	(0.066)
TV hours (Today-Jan.)	1.108**	(0.058)	1.011	(0.058)
Web hours (Jan.)	1.027	(0.060)	1.118**	(0.060)
Web hours (Today-Jan.)	1.180***	(0.072)	1.117*	(0.070)
D. Perceptions *(insecurity due to)*				
Own health	1.090***	(0.025)	1.015	(0.025)
Own work	1.112***	(0.026)	1.042*	(0.023)
General economic situation	1.022	(0.029)	0.938**	(0.025)
General political situation	0.999	(0.025)	0.999	(0.026)
Diffusion of the pandemic	1.000	(0.023)	0.963	(0.023)

Continued

Table 3:
Continued

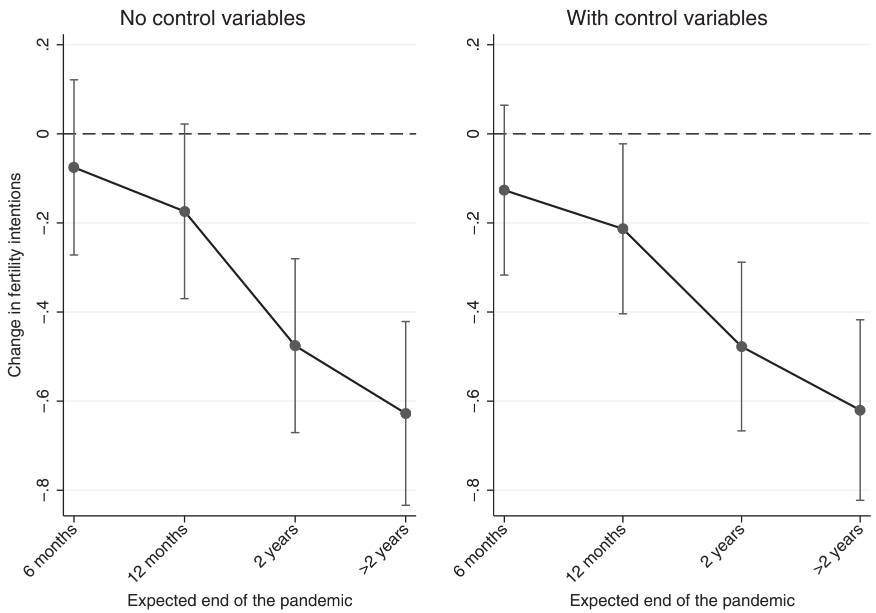
	Decrease vs. Same		Increase vs. Same	
	RRR	**Std. Err.**	**RRR**	**Std. Err.**
E. Expectations				
Return to pre-pandemic own condition (ref. It did not change)				
3 months	1.463	(0.455)	1.138	(0.292)
6 months	2.091***	(0.582)	1.325	(0.299)
12 months	2.530***	(0.677)	1.477*	(0.321)
2 years	2.877***	(0.832)	1.211	(0.310)
More than 2 years	3.768***	(1.231)	0.846	(0.322)
Return to pre-pandemic condition in Italy (ref. 3 months)				
6 months	1.052	(0.383)	1.156	(0.378)
12 months	1.046	(0.350)	0.842	(0.259)
2 years	1.112	(0.376)	0.726	(0.229)
More than 2 years	0.827	(0.281)	0.671	(0.213)
F. Imaginaries				
Expected happiness from child	0.927***	(0.020)	1.278***	(0.020)
Constant	0.012***	(0.006)	0.085***	(0.041)
Observations	3,934			
Pseudo *R*-squared	0.191			

Notes: Relative risk ratios, with robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All models control for fertility intentions in January, risk aversion, number of children, siblings, education, area of residence, sex, age and age^2.

1.3 percentage points, and a higher predicted probability of having increased fertility intentions of 2.7 percentage points. Contrary to our predictions, but in line with the results of Table 2, the model also showed a positive effect of having had direct experience with SARS-CoV-2 on the risk of increasing fertility intentions, whereas the respondents who had only indirect experience of relatives or acquaintances with a suspected infection had a lower risk of increasing fertility intentions than those with no exposure at all. This result held across different model specifications, irrespective of the number of additional variables included. A tentative explanation for this finding is that for respondents who had close acquaintances or relatives who were put in isolation, COVID-19 was an unknown threat casting a shadow over their future; whereas those respondents who actually tested positive, and likely had low to moderate symptoms given their young age, looked to the future with more optimism, possibly also due to their acquired immunity.[9]

[9] It is worth mentioning that during the early stages of the pandemic, there was a widespread belief, fostered by media reports, that young people are very unlikely to get infected, and if so, that they only get cold-like symptoms.

Figure 2:
Changes in fertility intentions after the treatment, by different scenarios regarding the expected end of the pandemic ("3 months" is the reference scenario). OLS models without (left panel) and with (right panel) additional control variables



Notes: Both models control for fertility intentions at the time of the interview and the Recall dummy for respondents who could not recall the exact expected length of the pandemic included in the scenario.

5.2 The causal impact of a new shared narrative of the future

Figure 2 shows the results of our experiment: that is, post-treatment changes in respondents' fertility intentions based on the type of scenario they were exposed to. The left panel plots regression coefficients associated with the different scenarios from an OLS model specified as in Model 4. The dotted zero line represents the reference scenario of a predicted return to normality for Italy within three months. The respondents who were exposed to scenarios in which a return to normality would not occur for at least two years significantly reduced their post-treatment fertility intentions: the intensity of the reduction was of approximately 0.6 points for the more pessimistic scenario, compared to the reference scenario.[10] The right panel shows that the coefficients were virtually identical after the inclusion of a long list

[10] Results remain virtually identical with the exclusion of respondents who could not recall the exact scenario they have been exposed to (a value of one on the Recall dummy).

of controls (all the variables included in Model 3 of Table 2), apart from the slightly smaller confidence intervals. These findings reinforce the causal interpretation of the results, and confirm that the treatment was, indeed, exogenous.

In addition, thanks to the robustness of the main findings and the simplicity of the model, we explored possible heterogeneity in treatment effects, first through combinations of sex and area of residence. These additional models (available from the authors upon request) produced very similar patterns to those of Figure 2 across all combinations, although the treatment effects were somewhat stronger in central and southern Italy, whereas the differences by sex were neither statistically nor substantially significant. The regression coefficients associated with the "more than two years" scenario were −.45 ($p = 0.014$) and −.56 ($p = 0.002$) among women and men in the northern regions, and −.97 ($p = 0.001$) and −.78 ($p = 0.001$) among their counterparts in the central and southern regions. A potential explanation for these differences is that in the northern regions, which were more severely affected by the pandemic, the pre-treatment expectations about the return to normality were already more pessimistic. Indeed, our data indicate that 39% of the northerners, compared to 30% of the southerners, thought that conditions would not return to normal for more than two years.

More generally, it seems plausible for the treatment to have had stronger negative effects among the respondents who had more optimistic expectations and who were exposed to more pessimistic scenarios. We analyzed different treatment effects by the respondents' pre-treatment expectations about the length of time it would take for Italy to return to pre-pandemic conditions, distinguishing between those respondents who expected it to occur within 12 months, two years, and more than two years (the modal category, see Table 1). The regression coefficients associated with the "more than two years" scenario were −.35 ($p = 0.031$), −.64 ($p = 0.000$) and −.92 ($p = 0.000$), respectively.

6 Discussion

In this article, we argued that the explanation for individual decision-making in conditions of uncertainty – especially for long-term, binding decisions, such as fertility decisions – needs to provide a complex account of different temporal orientations. While the sociological and demographic literatures have widely demonstrated that fertility decisions are shaped by individuals' previous life experiences and socioeconomic status – which we refer to as the "shadow of the past" – rising uncertainty about the future necessitates an analytical framework that explicitly acknowledges its forward-looking nature. Building on recent developments from economic sociology (Beckert, 2016; Beckert and Bronk, 2018), we relied on the Narrative Framework (Vignoli et al., 2020a, 2020b), which argues that personal narratives of the future, and their constitutive elements of expectations and imaginaries – which we refer to as the "shadow of the future" – represent crucial drivers for decision-making under conditions of uncertainty. Personal narratives of the future are not merely the result of psychological predispositions or idiosyncratic preferences, but are socially constructed in that they are shaped by "shared narratives" in the form of public images produced by the media and other powerful opinion formers.

We exploited the exogenous shock provided by the COVID-19 pandemic as a crucial occasion to test empirically some of the predictions of the Narrative Framework, without having any explicit aim to operationalize the whole theoretical schema. We argued that narratives of the future have become particularly important for fertility decision-making in contemporary societies, but also that the recent COVID-19 pandemic represented an enormous uncertainty shock that could have made the role of the shadow of the future particularly salient, over and above the effects of the shadow of the past. For instance, even scientists found it difficult to forecast the length and the consequences of the pandemic. Meanwhile, people needed to cope with leading a different daily life; form their own expectations about when conditions would return to "normal;" and, on that basis, formulate their life plans, including about family formation. Government restrictions that were imposed following the start of the pandemic may not have negatively influenced people's intentions to have a(nother) child if they anticipated a rapid return to pre-pandemic conditions, whereas these restrictions might have inhibited fertility if people had a darker view, and thus expected uncertainty to persist, irrespective of their current socioeconomic status and perceptions of it. At the same time, in such an unprecedented situation, in which expectations could not be based on any firm grounds, imaginaries may have played an additional, independent role.

Using unique data collected during the spring 2020 lockdown in Italy, the first Western country to experience widespread diffusion of the SARS-CoV-2 virus, we showed that objective indicators of individuals' exposure to the health and economic consequences of the pandemic played a very limited role in re-shaping individuals' fertility plans during the lockdown. This is not to say that the shadow of the past was not at all relevant: traditional predictors, such as age, sex, the number of children and the area of residence were significantly associated with changes in fertility intentions. However, people's subjective perceptions, also supported by media-channeled shared narratives, and especially their expectations and imaginaries, were found to be crucial moderators of their adaptation to a new context characterized by overwhelming uncertainty. Hence, taking the shadow of the future into account is a more effective way to understand the mechanisms through which the pandemic affected fertility intentions than simply measuring people's objective exposure to the virus and its related socioeconomic consequences. Our results suggest that when respondents expected that it would take a long time for their pre-pandemic life to return to normal, their pre-pandemic fertility intentions were reduced.

Importantly, having a higher level of expected happiness from childbirth, which is a proxy for a positive family imaginary, not only helped respondents to remain faithful to their plans, it even encouraged them to increase their fertility intentions, COVID-induced uncertainty notwithstanding. Even if Italy, like other Western countries (Sobotka et al., 2021), is already showing the first signs of fertility decline, our results suggest that a homogenous reaction in terms of a downward revision of childbearing plans is unlikely as well. In a situation in which rational decision-making was rendered difficult by mounting uncertainty about the future state of the world, those individuals who strongly valued parenthood may have reconsidered their life goals in favor of plans to form a family.

The claim that narratives of the future play a causal role has been reinforced by our experimental analysis, through which we were able to assess the causal impact of a shared narrative of the future on fertility intentions. Indeed, respondents were randomly exposed to different future scenarios regarding the expected length of the pandemic, and we found their pre-treatment fertility intentions decreased monotonically as the expected length of the pandemic increased. Both experimental and survey data converge in supporting the hypothesis that the shadow of the future had a clear impact on shaping fertility intentions during the pandemic emergency.

Of course, our work is not without limitations. First, the retrospective analysis of intentions may be influenced by the reduction of cognitive dissonance between current and pre-pandemic fertility intentions. While the use of panel data would, of course, have been preferable, the exceptional and unexpected situation of the pandemic did not allow us to plan pre- and post-pandemic waves of a panel survey. Second, even if the Narrative Framework is built on top of the established pragmatist tradition, which has recently been reappraised by Beckert and colleagues, its operationalization within a survey is a novelty. While there are well-known and validated indicators available in the literature for "traditional" variables related to past experiences and psychological predispositions, status, and perceptions; for expectations, and especially for imaginaries, there are just a few examples of their operationalization (Vignoli et al., 2020b). For imaginaries, we relied on the literature on the "expected happiness" (Billari, 2009); however, the common finding that couples are already happier before the birth of a child (see, e.g. Myrskylä and Margolis, 2014) may be attributable to more than the perception of an increase in happiness from the arrival of a future child – e.g. it may be the result of having a happy relationship and high life satisfaction, which are positively associated with fertility (Mencarini et al., 2018). A more in-depth exploration of personal imaginaries of parenthood, together with their relationship to childbearing desires (Mynarska and Rytel, 2018, 2020), should be developed in future research. In addition, future studies should attempt to capture more directly the role of personal narratives of the future and their functions in the fertility decision-making process through the use of both quantitative and qualitative methods.

In this paper, we showed that when studying changes in fertility intentions after the onset of a pandemic, it is important to take shadow-of-the-future factors into account. However, our conclusion that the shadow of the past is substantially less relevant than the shadow of the future for understanding the adaptation of the fertility decision-making process in a situation of increasing uncertainty may be traced back, at least in part, to the fact that our empirical analyses focused on the short-term effects of an unprecedented uncertainty shock. It is possible that long-lasting economic hardship due to subsequent waves of the pandemic and the responses to it may become increasingly important, and thus influence potential reductions in fertility. In addition, the shadow of the past already played an important role in shaping pre-pandemic fertility intentions. However, we argue that our results are suggestive of the factors that drive fertility decision-making in contemporary societies, even beyond the pandemic emergency. Long-term societal changes driven by globalization, and the "harsh new world of economic insecurity" (Hacker, 2019, p. xvi) that have accompanied them, are likely to have made narratives of the future more salient for fertility decisions in contemporary Western societies, in part due to the increasing pervasiveness of the media coverage of the economy. The Great Recession, for instance, fueled general perceptions of uncertainty about future economic conditions that may have hampered fertility even in countries and social groups that were only marginally affected by mass lay-offs or company bankruptcies (Sobotka et al., 2021; Hofmann et al., 2017). Preliminary empirical evidence corroborating this argument has been provided for the US, where it has been shown that fertility rates at the state level have been influenced by unemployment rates at the national level, and the press coverage of the economy, net of state-level economic conditions (Schneider, 2015). Future research should clarify whether the spreading of narratives of an uncertain future is responsible for the homogeneous decline in fertility that the US and European countries have been facing since 2010.

Acknowledgements

The members of the University of Florence Population and Society Unit (UPS), in particular Bruno Arpino and Gustavo De Santis, are gratefully acknowledged for their useful comments on a preliminary version of the study. The Editors and Reviewers of the Vienna Yearbook of Population Research also offered insightful suggestions. This work was supported by the Italian Ministry of University and Research under the FARE grant 'Narratives' (PI: Daniele Vignoli).

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Appendix A. Wording of the treatment

In the next screen we will provide you with up-to-date forecasts concerning the evolution of the coronavirus pandemic.

Within the last few days there haven't been substantial variations in the number of infections, hospitalizations and deaths. The task force composed of leading experts on the coronavirus pandemic eventually obtained reliable predictions about the future of the pandemic in Italy.

The experts predict that the coronavirus pandemic emergency will last **X** before a return to normality.

(5 randomized scenarios for **X**: 3 months, 6 months, 12 months, 2 years, more than 2 years.)

Appendix B. Determinants of changes in fertility intentions after the lockdown

Table B.1:
Determinants of changes in fertility intentions after the lockdown, only individuals with non-zero fertility intentions in January. OLS models

	Coeff.	Std.Err
C. Status		
Labor status in January (ref. Permanent-low)		
Permanent-high	−0.078	(0.175)
Temporary-low	−0.296*	(0.157)
Temporary-high	0.052	(0.222)
Black job	−0.144	(0.400)
Self-low	−0.221	(0.248)
Self-high	−0.470**	(0.190)
Not employed	0.097	(0.179)
Student	−0.266	(0.192)
HH income (1€)	1.27e-04**	(5.00e-05)
Labor market transitions due to the lockdown		
To not emp.	0.249	(0.209)
Temp. not emp.	0.139	(0.141)
To smart work	−0.013	(0.122)
Exposure to SARS-CoV-2 (ref. No exposure)		
Indirect (suspected)	−0.071	(0.137)
Indirect (positive)	0.148	(0.111)
Direct	0.261	(0.204)
A. Media shared narratives		
Media exposure (politics and latest news)		
TV hours (Jan.)	0.025	(0.063)
TV hours (Today-Jan.)	−0.136**	(0.060)
Web hours (Jan.)	0.093	(0.059)
Web hours (Today-Jan.)	−0.088	(0.065)
D. Perceptions *(insecurity due to)*		
Own health	−0.044	(0.027)
Own work	−0.084***	(0.024)
General economic situation	−0.033	(0.028)
General political situation	−0.046*	(0.026)
Diffusion of the pandemic	−0.010	(0.027)

Continued

Table B.1: Continued

	Coeff.	Std.Err
E. Expectations		
Return to pre-pandemic own condition (ref. It did not change)		
3 months	−0.122	(0.213)
6 months	−0.271	(0.181)
12 months	−0.367**	(0.173)
2 years	−0.564***	(0.204)
More than 2 years	−1.144***	(0.329)
Return to pre-pandemic condition in Italy (ref. 3 months)		
6 months	0.144	(0.397)
12 months	0.184	(0.377)
2 years	−0.108	(0.385)
More than 2 years	0.151	(0.385)
F. Imaginaries		
Expected happiness from child	0.255***	(0.024)
Constant	0.918*	(0.480)
Observations	2,068	
R-squared	0.227	

Notes: Robust standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Model controls for fertility intentions in January, risk aversion, number of children, siblings, education, area of residence, sex, age, and age^2.

Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 261–284

Cognitive schemas and fertility motivations in the U.S. during the COVID-19 pandemic

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Abstract

While current evidence indicates that the United States did not experience a baby boom during the pandemic, few empirical studies have considered the underlying rationale for the American baby bust. Relying on data collected during the pandemic (n = 574), we find that pandemic-related subjective assessments (e.g., self-reported stress, fear of COVID-19 and relationship struggles) and not economic indicators (e.g., employment status, income level) were related to levels of fertility motivations among individuals in relationships. Analysis of within-person changes in fertility motivations shows that shifts in the number of children, increases in mental health issues and increases in relationship uncertainty, rather than changes in economic circumstances, were associated with short-term assessments of the importance of avoiding a pregnancy. We argue for broadening conceptual frameworks of fertility motivations by moving beyond a focus on economic factors to include a cognitive schema that takes subjective concerns into account.

Keywords: pandemic; fertility expectations; subjective appraisals

1 Introduction

Prior to the COVID-19 pandemic, the United States had been facing record declines in fertility levels (Hamilton et al., 2020); and current trends suggest that further declines are likely, as women have made downward adjustments in their fertility goals (Kahn et al., 2021; Lindberg et al., 2020; Luppi et al., 2020). Given the uncertain social and economic climate associated with this unprecedented pandemic,

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DOI: 10.1553/populationyearbook2022.res1.7

it appears that women and men may be adjusting their motivations, or schemas, regarding future childbearing and family life. Thus, the pandemic provides a critical opportunity to assess people's fertility goals. We draw on the Toledo Adolescent Relationships Study (TARS), a population-based dataset with repeated measures of respondents' fertility motivations prior to the pandemic (2018–2020) and during the pandemic (June–November 2020), to assess the fertility motivations of a sample of U.S. adults during the COVID-19 pandemic. The respondents are in their prime childbearing years, and we focus on those in relationships, for whom childbearing decisions are of more immediate relevance. We assess the respondents' fertility motivations in the short term, and examine whether pandemic-related changes in their economic circumstances, relationships, health or stress levels have affected their fertility motivations. While building on prior demographic research on fertility, these key independent variables are not included in most demographic datasets, including in recent surveys. Furthermore, we examine changes in respondents' fertility motivations both before and during the pandemic, and evaluate how changes in their number of children, health (physical and mental), economic circumstances and social ties have influenced their fertility motivations. These findings will help guide future research on the ways in which the pandemic has affected the lives of Americans, including their fertility behavior.

2 Background

It is well-documented that fertility levels in the United States are low, and concerns that the current low fertility levels may not rebound have been widely expressed in the media and in academic circles. Individual fertility preferences are responsive to societal shifts and pressures, including economic pressures (Hartnett and Gemmill, 2020). For example, fertility began falling around the time of the Great Recession (2007–2009), partly due to the disproportionate impact that this economic downturn had on individuals of childbearing ages (Cherlin et al., 2013; Percheski and Kimbro, 2017; Schneider, 2015; Su, 2019). Importantly, rates have continued to decline (Allred and Guzzo, 2018; Hamilton et al., 2020) despite an upturn in the economy after the recession. Generally, fertility falls during economic downturns. However, in the past, such fertility declines have tended to be brief, as postponed births are recouped after the economy has rebounded (Cherlin et al., 2013; Örsal and Goldstein, 2018; Sobotka et al., 2011). It appears, however, that the young adults who came of age during the Great Recession may not just be delaying, but may ultimately be reducing their fertility in response to the uneven economic recovery.

The U.S. total fertility rate (TFR) reached a decade low of 1.70 in 2019 (Hamilton et al., 2020), putting the United States on track to follow the path of many European countries. The factors that are associated with the extremely low fertility rates in European countries include the weak economic positions of young adults, low levels of economic and subjective well-being, and struggles to combine work and family obligations (Billari, 2018). Prior to the Great Recession, the United States had relatively high fertility – at or above 2.0 – compared to other industrialized nations. Now, however, the TFR in the United States is on par with that of nations with TFRs closer to 1.0, rather than with the pre-recession level of 2.0 (Billari, 2018). It is critical to understand how these downward changes occurred, especially as the COVID-19 pandemic continues to have social, economic and health impacts.

Examining fertility motivations can provide important insights into the processes that undergird aggregate fertility rates. At the most basic level, aggregate fertility trends are comprised of individual fertility decisions, and, on average, individuals' fertility preferences tend to be strong predictors of aggregate fertility levels (Beaujouan and Berghammer, 2019; Morgan and Rackin, 2010). Unlike many other studies, we focus on short-term fertility motivations, as these are most likely to be directly affected by the changes that occurred during the pandemic. Men's and women's longer-term fertility goals may be relatively unaffected, given that both the modal category for the ideal family size and the average total intended parity in the U.S. has remained at two since before the Great Recession (Gemmill and Hartnett, 2020; Saad, 2018). Thus, people's fertility behavior in the immediate future is more likely to be affected by the pandemic than their intentions to have children at some point over the longer term.[1] Our focus on fertility motivations, and on how they are linked to various domains that reflect the context in which people make fertility decisions, will provide key insights into the factors that may be driving the fertility baby bust observed during the pandemic.

The societal implications of the pandemic are unlikely to represent a short-term *blip*. It is more likely that they will have an enduring impact, accelerating and exacerbating the declining fertility trends ushered in by the Great Recession. However, a unique feature that distinguishes the COVID-19 pandemic from prior economic downturns is the heightened sense of uncertainty brought on by the lack of a clear timeline regarding when, and if, American family life will return to *normal;* uncertainty regarding the potential long-term health effects of the pandemic beyond the risks of the disease itself; and uncertainty regarding employment and other changes in the economy (Calarco, 2021; Carlson, 2021; Landivar, 2021). This pervasive sense of uncertainty is not unwarranted. Rather, it is driven by individuals' concerns about health care and medical treatments, skyrocketing unemployment levels, shifting workplace demands and increases in parenting obligations in the face of child care and school closures, among other factors. Cumulatively, these concerns are challenges for couples in intimate relationships, and constrain individuals' social lives in new ways. Americans of childbearing age have not previously faced so many forms of sustained uncertainty, and at such high levels, in their lifetimes. Thus, it seems quite likely that the current climate characterized by pervasive uncertainty will further dampen fertility motivations. Indeed, in Europe, about 70%

[1] At the time of the survey, the TARS cohort studied here was aged 29–36, and many its members were already parents. Thus, it is likely that they believed they had sufficient time to reach overall fertility goals, if they had not met them already.

of respondents who planned to have a child during 2020 reported either postponing or abandoning their plans during the pandemic (Luppi et al., 2020). However, no consistent pattern tying fertility decisions to perceived income declines or the spread of COVID-19 has been observed.

Claims that there have been pandemic-related changes in people's life circumstances are often based on limited, but compelling survey evidence. People's economic concerns are evident based on their responses to the recession and skyrocketing unemployment rates (BLS, 2021), as well as their expressions of pessimism about their financial future (Parker et al., 2021). It certainly appears that the pandemic has caused people to pay increased attention to their health, both currently, and over the long term (Dayton et al., 2021). There is evidence indicating that the pandemic has led to changes in Americans' social and psychological well-being, including increases depressive symptoms and anxiety over time (Ettman et al., 2021; Manning et al., 2021). Similar findings have been reported in cross-sectional population-based surveys (Jia et al., 2021). The empirical literature on stress related to COVID-19 has shown that nearly 40% of individuals have reported experiencing some distress during the pandemic (Taylor et al., 2020). On the relationship front, it appears that there have been challenges to relationship functioning during the pandemic. There is, for example, evidence suggesting that there have been short-term changes in the prevalence of relationship conflicts, but limited shifts in the numbers of physical fights over a one-month period (Lee et al., 2021). While such findings are not conclusive, it appears that there have been substantial shifts in key dimensions of well-being during the pandemic, which may have affected fertility decision-making.

We argue that traditional theoretical approaches focusing on planned behaviors may not be relevant during periods characterized by substantial uncertainty. With regard to the formation of childbearing decisions, greater conceptual attention to the link between plans and outcomes is needed. To better understand how the confluence of pandemic-related changes and stressors have affected fertility, we draw on insights from the Theory of Conjunctural Action, or TCA (Johnson-Hanks et al., 2011). Central to the TCA is the assumption that individuals' "schemas" – i.e., their ideas, values, beliefs, scripts and patterns of thinking – inform and guide their behavioral intentions and actions. The TCA provides a framework for conceptualizing the new reality in the United States, which is characterized by the lack of a clearly outlined and predictable future, by drawing attention to the schemas that people use to make sense of a situation, and to inform their decision-making, including their fertility decisions. During the pandemic, the heightened sense of uncertainty surrounding health, economic, relational and childrearing decision-making has meant that individuals can no longer rely on their past experiences (typically thought of as the best predictor of future behavior) (Ferrante et al., 2013; Ouellette and Wood, 1998) or pre-existing attitudes to guide their decisions. In brief, what was previously "true" or "right" may no longer be applicable. Women and men facing such high levels of uncertainty are likely to hold off on making any new commitments, including having a child, until they have a better grasp on their lives, and on the situations that they will face in the future.

The TCA has been applied to empirical research on fertility in Africa and Europe that focuses on the context of uncertainty (e.g., Hayford and Agadjanian, 2011; Trinitapoli and Yeatman, 2011). Moreover, consistent with this theoretical approach, scholars focused on Europe have also have called for theoretical developments (e.g., Narratives of the Future) that address how uncertain economic contexts influence fertility decisions (Vignoli et al., 2020a). Vignoli and colleagues found that employment uncertainty influenced fertility intentions through indicators of well-being (Vignoli et al., 2020b); and that perceived uncertainty at the macro level due to the debt crisis influenced fertility (Comolli and Vignoli, 2021). We extend this focus on uncertainty to the current situation in the United States by including indicators that reflect economic, health and relational uncertainties; and by assessing whether such uncertainties affect fertility schemas. For example, in the United States, a normative schema surrounding the decision to have a child is that childrearing requires major economic, emotional and social investments, which directly affect children's development, and, ultimately, their life success (see e.g., Blair-Loy, 2009; Bock, 2000; Calarco, 2018; Hays, 1998; Lareau, 2011; Myers, 2017). As a consequence of the uncertainties caused by the pandemic, the strength or certitude of this schema has likely been amplified. Furthermore, during certain phases of the pandemic, the burdens of parenting were shouldered almost entirely by parents, as child care centers and schools remained closed, or opened only intermittently (Landivar, 2021). Moreover, due to social distancing mandates, parents could no longer rely on their social networks for child care, emotional support and social activities. Earlier research drawing on the TCA has found that fertility preferences are responsive to "contingencies, inputs and shifts that occur in micro and macro levels" (Trinitapoli and Yeatman, 2018, p. 87), and this conclusion has been supported by recent empirical evidence (e.g., Hartnett and Gemmill, 2020). Building on these prior studies, we expect to find that indicators of uncertainty are associated with decreased fertility plans. However, unlike prior studies, our data permit us to focus on multiple domains of uncertainty, including health, relationship and economic concerns associated with the COVID-19 pandemic.

In addition, we move beyond prior work by focusing on pregnancy avoidance, rather than on wanting/planning to get pregnant. This approach reflects the hypothesized theoretical links: i.e., that the pandemic affected people in ways that made childbearing less desirable over the short term. While it could be argued that changes during the pandemic might have made it less necessary to avoid a pregnancy (for instance, working from home may have alleviated parental leave or child care concerns, thus reducing work-family conflict), it is harder to make the case that the pandemic increased the sense of urgency about having a child. Again, given that most Americans want small families, there is generally little or no urgency to have a child at a particular point in time to achieve their fertility goals; indeed, most people of reproductive age spend the majority of their fertile years actively avoiding a pregnancy. Pregnancy avoidance measures have been widely used in studies of fertility and reproductive behavior to capture pregnancy intentions and desires (e.g., Barber et al., 2019; Hayford and Guzzo, 2013; Higgins et al., 2012).

The overarching goal of the current study is to provide theoretically-informed insights into fertility more broadly. Although there is early evidence of a decline in fertility during the pandemic (e.g., Cohen, 2021; Sobotka et al., 2021), full vital statistics data on fertility in the United States during this period will not be available until 2022. Early data for the first quarter of 2021 are available for two states, and suggest that there was a decline in "pandemic babies" (Cohen, 2021). However, the evidence regarding births in the rest of the nation, and into the summer and fall, is inconclusive. In addition to vital statistics data, another major source of data on fertility goals and behaviors in the United States is the National Survey of Family Growth, which also will not release its data covering this period until roughly 2022. While some organizations have fielded surveys to investigate fertility preferences and behaviors, there is a pressing need for more timely research. Still, the limited data that are available have demonstrated that the pandemic has indeed led to shifts in fertility decision-making. For example, the Guttmacher Survey of Reproductive Health Experiences found that two-fifths of women of reproductive age have changed their fertility plans in response to the pandemic (Lindberg et al., 2020). Extending existing descriptive profiles, this study uses population-based data that cover periods before and during the pandemic to assess how people's fertility motivations developed and changed during these critical periods.

3 Current study

Despite speculation in the media about a COVID-19 baby boom, it is fairly clear now that there was no such baby boom, and that there was instead a baby bust. We add to this straightforward conclusion by providing empirical evidence on the mechanisms underlying this fertility decline, and thus seek to shed light on the question of why the United States did not experience a baby boom. In our first research question, we hypothesize that economic, relational and health uncertainties dampened fertility motivations during the pandemic. Specifically, we focus on a measure of pregnancy avoidance, because it reflects whether childbearing became less desirable over the short term, and because it is consistent with the observation that most of adulthood is spent avoiding having children (Barber et al., 2019; Hayford and Guzzo, 2013; Higgins et al., 2012). Unlike some demographic research that has relied on unmeasured indicators that are implied based on behaviors or contextual measures, our analyses include direct measures of uncertainty. The data include pandemic-related subjective assessments (e.g., self-reported stress, fear of COVID-19, relationship struggles) as well as behavioral indicators (e.g., employment status, income level). Importantly, because Americans' responses to the pandemic may have been colored by political ideology, we consider whether respondents expressed approval of the government's handling of the pandemic, and whether they agreed with the statement that the media are overreacting to the pandemic. The second research question utilizes the longitudinal TARS data to assess changes in the importance placed on avoiding a pregnancy. We hypothesize that the number of children, health status, economic circumstances, parental attachment and relationship certainty/uncertainty were associated with the importance placed on avoiding a pregnancy. We expect to find that parents were especially likely to report that they consider avoiding having another child to be important.

4 Data

The TARS is a study of the lives of a diverse sample of adolescents (n = 1,316) who were interviewed seven times as they transitioned to adulthood (2001, 2002, 2004, 2006, 2011, 2019, 2020). The sixth wave of data collection was conducted April 2018–March 2020, and included 990 respondents who were aged 29–36 (mean age of 32). Although the sample, which was devised by NORC (National Opinion Research Center), was initially based on school rosters, school attendance was not a requirement for inclusion. Thus, the sample included young adult women and men who represented a broad range of socioeconomic circumstances. The population-based sample was regional; nevertheless, the respondents were demographically similar to 30–34-year-olds at the national level when compared to the American Community Survey data (e.g., in the TARS sample, 38% of respondents were racial/ethnic minorities, compared to 35% of the U.S. population; and 36% of respondents were college graduates, compared to 40% of the U.S. population). In response to the pandemic, new data, wave 7, were collected with a brief (25-minute) online survey that afforded a unique opportunity to assess behaviors and attitudes during the pandemic. High response rates have been maintained; for example, between waves 6 and 7, we retained 82% of the sample. Overall, the characteristics of the wave 7 sample differed somewhat from those of the wave 1 sample due to attrition, with attrition being greater among men and racial and ethnic minorities in the wave 7 sample. The interviews were conducted between June and November 2020. During this time period, which was prior to the release of vaccines, Americans were experiencing a high degree of uncertainty about the course of the pandemic. While the respondents in the sample were spread across 41 states and U.S. overseas territories, the majority were living in Ohio. During this time period, Ohio was experiencing elevated COVID-19 infection rates and hospitalizations, but the state had not yet reached peak COVID-19 mortality levels.

To ensure consistency across our analyses, the analytic sample included women and men who answered both surveys (n = 815) and reported valid data on fertility expectations (n = 756). The results are focused on a sample of 574 respondents who were in dating, cohabiting or married relationships at wave 7. This restriction excluded respondents who were most motivated to avoid having children because they were not in a relationship, and may not have been exposed to the risk of having a child (as they may have had no sexual relationships). Supplemental analyses were conducted that included respondents who were single at wave 7 (n = 756), and separate analyses were conducted among respondents who reported being with the same partner at both waves 6 and 7 (n = 494). Sensitivity checks indicated that restricting the sample to respondents with valid wave 6 data on their fertility motivations did not influence the levels of fertility motivations observed in wave 7.

Dependent Variable. The dependent variable was based on data on the fertility motivations reported at wave 7, with some preliminary analyses of data on the levels reported at wave 6. In wave 6 and in the wave 7 COVID-19 module, respondents' *fertility motivations* were measured using the following question: "How important it is to avoid becoming pregnant right now?" The responses were provided on a five-point scale ranging from "not at all important" to "very important." Respondents were asked about their immediate motivations because the aim of the item was to assess the impact of the pandemic on their current circumstances, and not at an unspecified time in the future.

*Pandemic-Related Independent Variable*s. The key independent variables for the analyses of fertility motivations during the pandemic were based on pandemic-related indicators. The *fear of COVID-19* variable was based on two items that assessed the frequency of the following worries: (1) "Worried that you might contract the virus" and (2) "Worried that one or more members of your family might contract COVID-19" (alpha = .86). Responses were provided on a five-point scale ranging from "never" to "often."

Conservative political beliefs were measured as the level of agreement with the following two items: (1) "Politicians, the news and other social media have exaggerated the risk" and (2) "The government should not tell me what to do" (alpha = .74). The possible responses ranged from (1) "strongly disagree" to (5) "strongly agree."

Among the potential sources of support during the pandemic were the respondents' own parents. The *parental arguments* variable was based on a single question: "How often do you and your parents have arguments about issues related to social distancing or COVID-19?" The response options ranged from "never" to "very often." The aim of this question was to assess respondents' levels of agreement or disagreement with significant others regarding compliance with health mandates that may be perceived as challenging.

The variable on *relationship uncertainty* – i.e., uncertainty about the relationship with the current partner – was based on a single item. Respondents were asked about the extent of their agreement with the following statement: "Our relationship feels more uncertain than ever." The possible responses ranged on a five-point scale from "strongly disagree" to "strongly agree."

The *work from home* variable was based on responses to the question of whether the respondent or his/her partner had started working from home during the pandemic. The response categories were "yes" and "no."

The variable on *loss of income* due to the pandemic was based in part on affirmative responses to the item: "Since the COVID-19 pandemic occurred how much has your income from all sources been affected?" The response options included "much less income" or "somewhat less income." The variable was also based or affirmative responses to the question of whether the respondent or his/her partner "experienced a cut in pay as the result of the COVID-19 pandemic." An additional variable measuring *employment change* was based on responses to questions about whether the respondent or his/her partner was employed at the time of the interview, and whether s/he had been employed prior to the pandemic. Affirmative responses indicated that the respondent had been "laid off" or "furloughed." We also logged the respondents' *household income* at wave 6. (These latter two measures were not included in the final models, as they were not associated with fertility motivations). *Stress* was measured based on a single item: "*Since COVID-19 how stressed have you been due to your future?*" Responses were provided on a five-point scale ranging from "not at all stressed" to "very stressed."

Independent Variables Included in Models of Changes in Fertility Motivations. The independent variables in the analyses of changes in fertility motivations were aligned with the pandemic-related factors (presented above), including changes in fertility, economic, health and social ties that occurred before and during the pandemic. These indicators were measured in the same way at both interview waves. The variable on the *change in number of children* was based on questions about the number of biological children, and ranged from zero to four, with 73% of respondents reporting no change.

The variable on changes in *economic hardship* was based on six questions with "yes" and "no" responses, including items that asked respondents whether they "didn't pay the full amount of the mortgage or rent because there wasn't enough money" or "couldn't see a doctor or go to hospital because there wasn't enough money." The possible responses ranged from "strongly disagree" to "strongly agree." The changes in the hardship indicator ranged from −5 to five, with 61.7% reporting no change, 25.3% reporting fewer hardships and 13.1% reporting more hardships. *Economic stress* was measured based on two items posed at each interview wave: "How stressed have you been about money/finances?" and "How stressed have you been about work/employment?" Responses were given on a five-point scale. The indicator ranged from −4 to three, with 22.5% of respondents reporting no change in their economic stress, 44.4% reporting less stress and 33.1% reporting increased stress.

The self-reported *physical health* indicator was based on a question that asked respondents about potential changes in their health. Responses were provided a five-point scale ranging from "poor" to "excellent." The indicator ranged from −2 to three, with 54.5% of respondents reporting no change in health, 21.9% reporting declining health and 23.6% reporting improved health.

The *mental health* of respondents was measured based on their self-reported depressive symptoms using an eight-item version of the CES-D scale (Radloff, 1977). The respondents were asked how often each of the following statements had been true over the past week: (1) "You felt you just couldn't get going;" (2) "You felt that you could not shake off the blues;" (3) "You had trouble keeping your mind on what you were doing;" (4) "You felt lonely;" (5) "You felt sad;" (6) "You had trouble getting to sleep or staying asleep;" (7) "You felt that everything was an effort;" and (8) "You felt depressed." Higher scores indicated higher levels of depressive symptoms, and ranged from one ("never") to eight ("every day"). The summed scale ranged from eight to 64. The indicator on changes in depression ranged from −56 to 47, with 11.7% of respondents reporting that there was no change in their depressive symptoms, 28.6% indicating that their depressive symptoms had decreased and 59.7% reporting that their depressive symptoms had increased.

Closeness to parents was assessed based on the level of agreement ("strongly disagree" to "strongly agree") with a single item: "I feel close to my parents." While 65.3% of respondents indicated that their closeness to their parents had not changed, 16.7% reported experiencing less closeness and 18.0% reported experiencing more closeness.

Relationship uncertainty was measured with two items: "I feel uncertain about our prospects to make this relationship work for a lifetime" and "I would leave my partner if it was not so difficult to do so." The potential responses ranged from "strongly disagree" to "strongly agree." The alpha on this indicator was 0.82 before the pandemic and was 0.79 during the pandemic. The indicator on changes in relationship uncertainty ranged from −8 to seven, with 46.7% of respondents reporting no change, 36.8% reporting less uncertainty and 17.5% reporting greater uncertainty.

Sociodemographic Characteristics. Six sociodemographic indicators were included in the analysis of fertility motivations during the pandemic. *Parenthood* was a dichotomous measure indicating whether the respondent had biological children at wave 7. *Gender* was coded as 1 = female and 0 = male. *Race/ethnicity* was recoded into four categories: non-Hispanic white (reference category), non-Hispanic Black, Hispanic and "other." *Education* was measured at wave 6, and was based on the respondents' highest level of education: high school (or less) (reference category), some college and college or more. Union status at wave 7 was measured using three categories: dating (reference), cohabiting and married. *Age* was measured in years using a continuous variable based on the respondents' reported age at wave 7. To account for the rapid changes in the pandemic over time, a series of dummy variables indicating the *month of interview* (June-October/November) were included, but were not shown in the models.

5 Analytic strategy

For the first research question, we analyzed how pandemic-related indicators were associated with respondents' fertility motivations during the pandemic. We used OLS regression modeling to estimate the association between pandemic-related measures and sociodemographic characteristics, and to assess how these indicators influenced the desire to avoid pregnancy.

The second research question analyzed changes in respondents' fertility desires across interview waves; i.e., before and after the start of the pandemic. Using fixed-effects regression models (Allison, 2009), we examined how changes in fertility, economic factors, health, social ties (parents and partner) and levels of depression were associated with changes in motivations to avoid pregnancy before and during the pandemic. We pooled pre-pandemic and pandemic data from the TARS, and estimated fixed-effects models by examining how changes in economic, relationship and health stressors; uncertainty about the future; and fertility were associated with changes in fertility expectations. One advantage of fixed-effects modeling is that it uses each individual as his/her own control, and thus statistically removes unobserved, time-invariant variables that may confound the association between key predictors and fertility motivations (i.e., reducing endogeneity).

6 Results

6.1 Fertility motivations during the pandemic

Table 1 presents the distribution of the analytic sample. The mean response for the question on the importance placed on avoiding a pregnancy was 3.14, or "somewhat important." During the pandemic, about two-fifths of respondents reported that they considered avoiding a pregnancy to be very important; while 30.5% of respondents reported that they viewed avoiding a pregnancy as not important at all.

The multivariate ordinary least squares regression results estimating the importance placed on avoiding a pregnancy during the pandemic are presented in Table 2. (Given the skewed distribution of the dependent variable, a logistic regression estimating the importance placed on avoiding a pregnancy was also tested, and similar results were obtained.) The sociodemographic characteristics of respondents were not strongly associated with how important they considered avoiding a pregnancy to be. On average, parents reported a stronger desire to avoid a pregnancy than respondents who were not yet parents. Men and women were roughly equally likely to want to avoid a pregnancy. Latinx or Hispanic respondents were less likely to want to avoid a pregnancy. The remaining measures of education, union status and age were not associated with the desire to avoid a pregnancy.

The next set of indicators addressed pandemic-specific factors. Respondents who were worried about themselves or their family members getting COVID-19 reported having a stronger desire to avoid a pregnancy. The pandemic-related political views of respondents were not associated with their fertility motivations. With regard to social ties, whether respondents were arguing with their parents about social distancing was not significantly associated with their fertility motivations. In contrast, the respondents' relationship context was associated with the importance they placed on avoiding a pregnancy; i.e., respondents who were more uncertain about their relationship since the start of the pandemic had a greater desire to avoid a pregnancy. Contrary to expectations, respondents' economic indicators were not associated with their pregnancy motivations. Working from home was associated with a stronger desire to avoid a pregnancy at the bivariate level (not shown), but not in the multivariate model. Having experienced a loss of income was not associated with the importance placed on avoiding a pregnancy. In an effort to determine whether our economic indicators were or were not capturing the respondents' economic stresses and strains, we conducted supplemental analyses that included changes in employment (not working, laid off or furloughed) as well as household income; and the results showed that neither were associated with the importance placed on avoiding a pregnancy (results not shown). Finally, respondents who

Table 1:
Distribution of dependent and independent indicators

Avoiding pregnancy (1–5)	3.14 (1.74)
Not at all important	30.49%
Not too important	13.24%
Somewhat important	7.32%
Pretty important	9.41%
Very important	39.55%
Sociodemographic	
Parent	
No	28.57%
Yes	71.43%
Gender	
Male	40.07%
Female	59.93%
Race/ethnicity	
NH White	72.82%
NH Black	13.94%
Hispanic	11.32%
Other	1.92%
Education	
HS or less	15.85%
Some college	39.72%
College degree	44.43%
Union status	
Dating	12.20%
Cohabiting	25.09%
Married	62.72%
Age (31–38)	34.11 (1.70)

Continued

Table 1:
Continued

Pandemic indicators	
Conservative beliefs	2.97 (1.05)
Fear COVID (1–5)	3.10 (1.01)
Parental disagreements	1.54 (0.77)
Relationship uncertainty (1–5)	1.75 (1.00)
Loss of income	
No	67.49%
Yes	32.51%
Work from home	
No	45.60%
Yes	54.40%
Stress future (1–5)	2.14 (1.02)
Month	
June	37.80%
July	26.48%
August	17.07%
September	12.37%
October/November	6.30%

Data source: Toledo Adolescent Relationships Study (*n* = 574).

reported feeling more stressed about their future tended to place greater importance on avoiding a pregnancy. In sum, the results showed that having relationship-based problems and feeling stressed about the future were more strongly related to fertility motivations than to economic factors.

It is, of course, possible that economic factors drove the respondents' feelings of stress about their relationship or the future. To delve further into the role of economic factors, we conducted supplemental analyses to determine how economic indicators influenced the respondents' levels of stress, fear of COVID-19 and relationship uncertainty (results not shown). The results suggest there may have been an indirect pathway through which economic indicators influenced the respondents' fertility motivations during the pandemic.

Finally, as the analytic sample was limited to individuals who were in a relationship at wave 7, we conducted supplemental analyses that included respondents who were single (not dating, cohabiting or married) at wave 7. Respondents who were in a relationship reported placing less importance on avoiding a pregnancy than single respondents did. The multivariable results on single respondents' views on pandemic-related measures (relationship uncertainty was excluded from the model) were similar to those of the partnered respondents, with one exception. In this model, concerns about COVID-19 were not associated with fertility motivations,

Table 2:
OLS regression: Importance of avoiding a pregnancy during the pandemic

Sociodemographic	
Parent	
(No)	
Yes	0.40*
Gender	
(Male)	
Female	0.11
Race/ethnicity	
(NH White)	
NH Black	–0.09
Hispanic	–0.50*
Other	–1.36*
Education	
(HS or less)	
Some college	0.02
College degree	–0.03
Union status	
(Dating)	
Cohabiting	–0.09
Married	–0.33
Age (31–38)	–0.02
Pandemic indicators	
Conservative beliefs (1–5)	–0.02
Fear COVID (1–5)	0.17*
Parental disagreements (1–5)	0.004
Relationship uncertainty (1–5)	0.22**
Loss of income	
(No)	
Yes	–0.24
Work from home	
(No)	
Yes	0.18
Stress future (1–5)	0.17*

Source: Toledo Adolescent Relationships Study (n = 574). $^{*}p < .05$; $^{**}p < .01$.

which could be partly because single respondents were less worried than partnered respondents about COVID-19.

6.2 Changing fertility motivations

The next research question assessed changes in the importance placed on avoiding a pregnancy. Figure 1 presents the changes in responses from the period before to the period during the pandemic. To simplify the figure, the measures of importance were categorized into three groups: not too important or not important; somewhat or fairly important; and very important. It is clear that there were both continuities and changes in the importance placed on avoiding a pregnancy. While there were flows in both directions, there was a significant (p = .000) increase in the percentage of respondents who reported that they considered avoiding a pregnancy to be very important, from 29% before the pandemic to 40% during the pandemic. Notably, about one-quarter of respondents ported that they viewed avoiding a pregnancy as not important at both time points.

Table 3 presents the distribution of the indicators used in the fixed-effects models of changes in fertility motivations. On average, respondents' fertility motivations

Figure 1:
Continuities and changes in the importance placed on avoiding a pregnancy before and during the pandemic

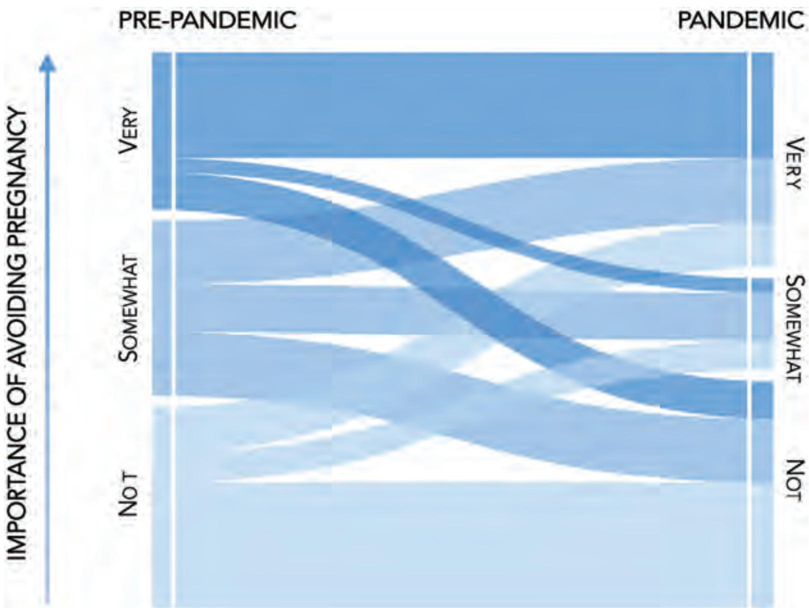

Table 3:
Distribution of indicators in fixed-effects

	Mean (SD)
Dependent variable change	
Change in fertility expectation (−4–4)	0.06 (1.79)
Independent variable change measures	
Number of children (0–4)	0.25 (0.59)
Economic hardship (−5–5)	−0.28 (1.26)
Economic stress (−4–3)	−0.16 (1.11)
Physical health (−2–3)	0.03 (0.77)
Mental health symptoms (−56–47)	3.47 (10.54)
Parental closeness (−4–4)	0.01 (0.80)
Relationship uncertainty	−0.63 (2.15)

Data source: Toledo Adolescent Relationships Study (n = 574).

underwent only modest changes across the interview waves. As expected, respondents had, on average, more children across the interview waves. Moreover, between the interview waves, economic hardship declined, but economic stress increased, on average. The changes in physical health were minimal, but mental health issues increased across the interview waves. The mean level of parental closeness did not change between the interview waves, and the mean level of relationship uncertainty declined.

The coefficients in the fixed-effects models estimating changes in fertility motivations were quite similar to those estimating the levels at wave 7 (Table 4). These models required indicators that were identically measured at both interview

Table 4:
Fixed-effects of changes in importance to avoid pregnancy

Change	
Number of children	0.65**
Economic hardship	0.06
Economic stress	−0.07
Physical health	−0.07
Mental health symptoms	0.02**
Parental closeness	0.02
Relationship uncertainty	0.14**

Source: Toledo Adolescent Relationships Study (n = 574). $^{*}p < .05$; $^{**}p < .01$.

waves, and were linked to the pandemic-based indicators. The model indicated that an increase in the number of children was associated with placing greater importance on avoiding a pregnancy. Shifts in levels of economic well-being, economic hardship and stress about work or money were not associated with changes in fertility motivations. Moreover, changes in self-rated health were not linked to changes in fertility motivations. With regard to social ties, changes in levels of closeness to parents were not associated with shifts in fertility motivations. Respondents who indicated that they were more uncertain about their relationship also reported an increased desire to avoid a pregnancy. Finally, an increase in self-reported depressive symptoms was associated with a greater desire to avoid a pregnancy. Supplemental analyses indicated that when the analytic sample was limited to individuals who were in the same relationship at both waves (n = 494), the results were similar (results not shown).

7 Discussion

The pandemic has fundamentally changed how individuals live their lives. Although it remains to be seen which of these changes become permanent as society slowly, and fitfully, recovers from the pandemic, there is little doubt that these changes have introduced new stressors and sources of uncertainty to wide swaths of the population, and have had ripple effects that go well beyond those related to health. In this paper, we considered how the pandemic, and the shifts in personal, relational and economic well-being that accompanied it, influenced the fertility motivations of individuals in their childbearing years using longitudinal data that are uniquely suitable for comparing individuals' fertility plans – as well as their status and overall well-being– before and after the start of the COVID-19 pandemic.

Our approach was grounded in the Theory of Conjunctural Action, which argues that individuals draw on established mental schemas to make sense of, and to respond to, events and situations. Among Americans, the normative cognitive schema regarding childbearing centers around the notion of what children need from parents to succeed. In this schema, parents and would-be parents consider whether they have the resources – e.g., economic and relational stability, social support from personal networks, stable housing and employment and safe and reliable child care – to provide for children, and to maximize their chances of success (e.g., Blair-Loy, 2009; Bock, 2000; Calarco, 2018; Hays, 1998; Lareau, 2011; Myers, 2017). Furthermore, there is an ongoing dialogue not just about the direct costs of childrearing and its impact on employment (especially for mothers); but also, via social media, about the opportunity costs of childrearing in terms of leisure time, and the challenges of parenting (Orton-Johnson, 2017). Given that levels of uncertainty have increased across multiple domains, even as levels of concern about how the challenges associated with raising a child could affect the well-being of both the parents and the child have grown, finding a schema for making sense of the pandemic is likely to be a problem for many men and women of childbearing age.

As such, we anticipate that pandemic-related fears and uncertainty will lead many people to avoid childbearing in the near future.

Although there is emerging evidence that fertility rates have indeed declined during the first quarter of 2021, the specific mechanisms that drove these lower birth rates are unclear. In particular, given the cascading sets of changes across domains, identifying which factors – for instance, economic concerns or stress within intimate partnerships, or health-related fears – is challenging. However, to design interventions aimed at stemming, if not reversing, ongoing fertility declines, it is necessary to identify these factors. In this paper, we explored the desire to avoid having a child among a longitudinal sample of men and women. The results showed that in summer or fall of 2020, about four in 10 adults aged 31–38 (mean age of 34) in a relationship reported that they considered avoiding a pregnancy to be important, up from about three in 10 prior to the pandemic.

We had expected to observe that experiencing uncertainty and stress increased the likelihood of wanting to avoid a pregnancy, and our results largely supported this expectation. Specifically, we found that partnered men and women who reported being more afraid of COVID-19, more stressed about the future and more uncertain about their relationship also reported a stronger desire to avoid a pregnancy. There was, however, one interesting exception to this general pattern. Unexpectedly, and inconsistent with the cognitive schema of needing to feel financially settled before having children, we did not find that economic factors directly influenced the desire to avoid a pregnancy. This finding held true even when we tested a fuller range of economic measures. Initially, we thought that this finding could be explained by our analytic sampling frame, as partnered men and women may be better able than single people to weather economic stressors because they have a partner to rely on. However, we obtained the same results when we included individuals who were not in a relationship. Another potential explanation for this finding is that there were other factors that offset these economic factors; i.e., income losses due to changes in employment may have been offset by increases in unemployment assistance, policy changes such as the moratorium on evictions or the suspension of student loan payments, or cost savings stemming from lower child care costs or less commuting. Similarly, given the paucity of parental leave in United States, some individuals may have found that job furloughs or greater flexibility in their working conditions provided them with an opportunity to have a child that was otherwise unavailable. Our results are consistent with those of Luppi et al. (2020), who found that the share of respondents in six countries who maintained their fertility plans during the pandemic was not sensitive to their views of the economic implications of the pandemic. Future work should delve more deeply into the economic and employment changes – both good and bad – that have affected the work-family nexus. Further analysis suggested that economic factors were linked to measures of the respondents' cognitive schema (uncertainty about their relationship, fear of COVID-19 and stress about the future), but were not directly linked to their fertility motivations. Investigating whether economic factors have indirect effects on fertility motivations is an important avenue for future work.

Similarly, the analysis of within-person changes in the desire to avoid a pregnancy showed that these changes were associated with increases in the number of children, lower levels of mental health and higher levels of relationship uncertainty. As in our other analyses, increases in economic stress or in economic hardship were not found to be associated with changes in fertility motivations. These findings highlight that people's relationships and psychological well-being influence their fertility intentions more than economic factors do. To the extent that the pandemic has led to relationships becoming more uncertain and to increases in depressive symptoms, it is likely that the pandemic will have a negative effect on fertility.

Furthermore, we found evidence that parents were more likely than childless individuals to report an elevated desire to avoid a pregnancy. Given the relatively young age of the analytical sample (in their early to mid-thirties), it may be assumed most of the parents in the sample had school-aged children. This finding likely taps into the stressors that parents faced during the pandemic, as child care centers and schools shut down. For instance, Calarco and colleagues (2020) reported that the increased parenting demands in response to virtual schooling have negatively impacted mothers' well-being. Although we lacked a sufficient sample size to do so, future work should consider how fertility decision-making during times of uncertainty varies depending on parenthood status, parity and children's ages.

While this paper has provided new insights into changes in fertility motivations and the underlying factors associated with declines in fertility during the pandemic, it also has a number of limitations. First, most of the respondents in the sample grew up in northwestern Ohio, and their circumstances may not reflect those of the national population. Even though the sample's demographic characteristics mirror those of a similar cohort at the national level, further analysis of national-level data is warranted. Second, the data were collected before both the major spikes in pandemic-related deaths and the widespread release of vaccines in the U.S. During this period, there were widespread concerns about how best to manage the health and social threats posed by the pandemic. Third, we were unable to determine to what extent fertility would have declined for Americans in this age group in the absence of the pandemic. The decreases we observed may simply reflect the declines that would have otherwise occurred for people in these age groups; however, we lacked the within-person data that we would need to determine whether this was the case. Nonetheless, we were able to account for pandemic-specific factors, and the associations we found between them indicated that the pandemic played some role in these declines. Fourth, the data do not reflect the experiences of a broad age range of adults, as they cover only individuals in their early to mid-thirties. It is possible that younger respondents would have been more responsive to pandemic economic stressors, as they had more time to achieve their fertility goals. Future work should consider more carefully how the pandemic has been experienced by people at different stages of the life course.

While much has been made of changes in the economic realm during the pandemic, it appears that the more proximal influences of the pandemic on fertility motivations were driven by cognitive factors that were linked to worries about falling prey to the coronavirus, relationship strains and stress about the future. These results are in line with the Narrative Framework (Vignoli et al., 2020b,c), which directly assesses how economic constraints frame fertility intentions in Europe. While our results and those of Luppi et al. (2020) hint that economic factors may not be direct drivers of fertility motivations, other studies focusing on the pandemic should further investigate this issue. We argue that our field's traditional theoretical frameworks may not apply in the same way during the pandemic as they have during other crises, such as the Great Recession. Future work should delve further into the underlying reasons for the changes in fertility motivations by moving beyond established approaches and disciplinary boundaries.

Acknowledgements

This paper was presented at the annual meeting of the Population Association of America in May 2021. This project was supported by Award Nos. 1558755 and 2028429, awarded by the National Science Foundation; and Award No. 2016-IJ-CX-0012, awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice. The Eunice Kennedy Shriver National Institute of Child Health and Human Development of the National Institutes of Health provided support R03HD105848 and infrastructure support to the Center for Family and Demographic Research (P2CHD050959). The opinions expressed in this publication are those of the authors, and do not necessarily reflect the official views of the NSF, the NIJ or the NIH.

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Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 285–316

Human costs of the first wave of the COVID-19 pandemic in the major epicentres in Italy

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Abstract

Deaths from COVID-19 can be miscounted due to under-reporting and inaccurate death registration. Mortality is often reported at the national level, which can result in the underestimation of the true scale of the impact of the pandemic since outbreaks tend to be localised. This study exploits all-cause daily death registration data provided by the Italian Statistical Office (ISTAT) from 1 January to 31 October to estimate the excess mortality and the corresponding changes in life expectancy during the first wave of the COVID-19 pandemic. Focusing on the five most severely hit provinces in Italy (Bergamo, Brescia, Cremona, Lodi and Piacenza), we calculate the excess mortality in 2020 compared to the average mortality of the years 2015 to 2019. Moreover, we estimate the excess mortality in the first quadrimester of 2020, and the annual life expectancy at birth. The estimated excess deaths show that during this period, mortality was significantly higher than the official mortality statistics for COVID-19. According to our estimates for the first quadrimester, life expectancy in the five provinces declined by 5.4 to 8.1 for men and by 4.1 to 5.8 years for women. In addition, we find that annual life expectancy decreased by 2.4 to 4.1 years for men and by 1.9 to 2.8 years for women compared to the 2015–2019 average. Thus, we conclude that the first wave of the COVID-19 pandemic had a substantial impact on population health in the hardest hit areas in Italy.

Keywords: COVID-19; death registration; excess mortality; first wave; Italy; life expectancy; pandemic

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DOI: 10.1553/populationyearbook2022.res2.1

1 Introduction

As European countries are struggling to contain the third wave of the coronavirus disease 2019 (COVID-19) pandemic and limit the spread of the more infectious and deadlier new variants of the virus, governments face a difficult trade-off between supporting the economy and protecting public health. Therefore, it is crucial that officials understand the direct and indirect health effects of the pandemic when making policy decisions.

COVID-19-related mortality is one key indicator that is widely used to track the severity and the public health effects of the pandemic. When the pandemic began in early 2020, most of the existing literature on the impact of the pandemic relied on case-fatality rates (CFR) as a measure of mortality (CDC COVID-19 Response Team, 2020; Giangreco, 2020; Khafaie and Rahim, 2020; Onder et al., 2020). However, CFR are not informative for international and historical comparisons. Since they are calculated as the number of deaths divided by the number of confirmed cases, the absence of an accurate estimation of the infection rates in a reference population makes the denominator in the CFR reliant on testing strategies and capacities.

There is no uniform way of classifying, recording and reporting COVID-19 deaths (Garcia-Basteiro et al., 2020). Moreover, when the epidemic worsens, the counting of fatalities becomes more difficult. People who die at home or in long-term care facilities might not be tested at all simply because resource allocation prioritises emergency operations (Iacobucci, 2020; O'Dowd, 2020). Likewise, there may be indirect mortality effects due to congestion in healthcare services (The Lancet Oncology, 2020), or to patients with chronic conditions avoiding visiting health facilities because they are concerned about the risk of COVID-19 infection (Weinberger et al., 2020). Therefore, COVID-19 mortality reports that rely on data on COVID-19-attributed deaths are likely to undercount the pandemic's death toll.

With the release of mortality surveillance data, such as all-cause mortality data from vital statistics systems for various countries, recent studies have used the "excess deaths" approach to estimate the mortality burden of the COVID-19 pandemic (Rivera et al., 2020; Rossen, 2020; Stang et al., 2020; Vandoros, 2020). Excess mortality counts the total number of persons who have died, regardless of the cause of death, relative to the number of deaths that would have normally been expected for a given place and time. For instance, Modi et al. (2020) compared excess mortality data for Lombardy with the official fatality statistics for Italy, and found that the estimated excess mortality in Lombardy between January and April 2020 was about three times higher than the COVID-19 death rate reported in the official data. Thus, this measure allowed the authors to capture both under-reported COVID-19-related deaths and fatalities that could be indirectly attributed to a lack of health care access, economic deprivation or other causes.

While excess mortality is a useful measure of the health impact of the COVID-19 pandemic, using overall crude death rates or the proportion of deaths for cross-national or historical comparisons is not very informative, because these indicators are affected by the age distribution of the populations studied. By contrast, life expectancy, which is calculated based on human mortality data aggregated in life tables, is insensitive to the age structure of the population, and can therefore reflect differences in mortality reasonably well. Against this background, this study aims to measure the impact of the first wave of COVID-19 on life expectancy at birth by focusing on the hardest hit areas in Italy. As Italy was the first western country severely affected by a large COVID-19 outbreak, this approach allows us to reasonably capture the human cost of the first wave of the COVID-19 pandemic, especially in a context in which non-pharmaceutical interventions were delayed.

In particular, this study focuses on specific geographical areas in Italy that were the most severely affected by the early stages of the COVID-19 pandemic: four provinces in Lombardy (Bergamo, Lodi, Cremona, Brescia) and one province in Emilia Romagna (Piacenza). In modelling the spread of COVID-19 in Italy, Gatto et al. (2020) highlighted the importance of considering the spatial nature of the progress of the wave of infections. The selected provinces experienced the highest numbers of excess deaths in Italy in the observation period compared to the average mortality levels in the years 2015–2019. The highly clustered nature of local transmission resulted in a high concentration of severe illnesses and deaths in one area (Jia et al., 2020). Therefore, the direct impact of COVID-19 on mortality and average life expectancy was likely felt at the sub-national level, rather than at the national level. Indeed, our results suggest that even in Lombardy – which was the hardest hit region in Italy during the first wave of the pandemic (Sebastiani et al., 2020) – the reduction in life expectancy due to COVID-19 was significantly lower than in Bergamo, the province that contributed one-third of the total excess mortality in the Lombardy region. Thus, spatial granularity is needed to assess the full scale of the impact of the pandemic on human life.

Drawing on daily death registration data published by the Italian Statistical Office (ISTAT) for the period of 1 January to 31 October 2020, the present study compares the mortality rates in 2015–2019 and in 2020 across age and gender categories, and provides estimates of the changes in life expectancy following the first wave of the COVID-19 pandemic. While measures such as mortality rates are no doubt useful, they need to be collapsed in an index that is universal enough to provide a reliable measure of all of the human lives lost. By contrast, life expectancy is significantly related to the overall wellbeing of the population, and can therefore provide a simple, objective and immediate measure of the human casualties associated with unprecedented shocks, such as the COVID-19 pandemic (Aburto et al., 2020; Ghislandi et al., 2019; Sen, 1998). Furthermore, as reliable measures of life expectancy are available for some countries from the 19th century onwards, we can use life expectancy for historical comparisons of the human costs associated with major events.

2 Institutional and geographical contexts of the hardest hit areas

In the early hours of 21 February 2020, the first severe case of local transmission of COVID-19 was diagnosed in Europe at a small hospital in Codogno, a municipality in the province of Lodi, south-east of Milan (Paterlini, 2020). Initially, authorities reacted by tracing the connections of *patient one,* but ultimately failed to identify a *patient zero*. As early as 24 February 2020, 11 municipalities in the province of Lodi were placed under strict measures to contain the spread of the disease, and were declared a quarantine “red zone”. Meanwhile, another cluster of COVID-19 cases emerged in Alzano Lombardo and Nembro, two municipalities in the province of Bergamo, north-east of Milan. In response to the rapid rise in the number of detected cases, especially in the municipalities surrounding these two epicentres, the Italian government announced on 8 March 2020 that it was imposing a (partial) nationwide lockdown starting on 9 March, followed by a total lockdown of all non-essential activities starting on 23 March (Galizzi and Ghislandi, 2020). While the Italian government was praised by the World Health Organization (WHO) for implementing such drastic measures (i.e., restrictions that had not been employed in modern democratic nations since World War II), the virus had already been spreading undetected in the northern part of the country since December 2019 (La Rosa et al., 2021). Thus, it appears that these containment measures were imposed a little too late (Signorelli et al., 2020). During this first wave of the pandemic, the outbreak put an unprecedented burden on the Italian healthcare system, resulting in an exceptionally high number of coronavirus deaths.

Geographically, Lodi and Codogno – two of the 12 provinces in Lombardy – are close to the other two provinces included in our sample: Cremona and Piacenza (see Figures A.1 and A.2 in the Appendix for the geographical location of the provinces being studied). The epidemic wave involving these provinces is thus considered as part of the Lodi-Codogno cluster. Bergamo and Brescia are located north-east of Milan, and, even though the first severe cases of COVID-19 were detected in these provinces just one day after *patient one* was identified in Lodi, they experienced a week-long delay in the arrival of the first epidemic wave (Galizzi and Ghislandi, 2020).

Of the regions in Italy, Lombardy is the most populated, and it has the highest Gross Domestic Product (GDP). Overall, one-sixth of the Italian population live in Lombardy, and the region produces one-fifth of the country’s GDP. Lombardy is relevant for our analysis, because it was the region in Italy that was hardest hit by the COVID-19 pandemic during the first wave, accounting for almost 50% of the human casualties in the entire country (Odone et al., 2020). Indeed, with the exception of Piacenza (located in the Emilia Romagna region), a province that borders the Lombardy region, all of the other four hardest hit provinces included in the analysis are located in Lombardy. Thus, in the following, we will also present statistics for the region of Lombardy.

3 Materials and methods

3.1 Data

We rely on a compendium of administrative data provided by the Italian National Institute of Statistics (ISTAT) that covers all municipalities in Italy (7,903 as of 2020). Specifically, we combine three main datasets. First, we compile daily death counts for all causes at the municipality level, disaggregated by sex and five-year age classes, between 2015 and 2020. For the calendar year 2020, they cover the period between 1 January and 31 October; while for the calendar years 2015–2019, they cover the period between 1 January and 31 December. Second, we obtain data on the resident population at the municipality level, disaggregated by sex and single-year age classes, on 1 January of the years 2015–2020. We reclassify the age classes to five-year age groups to match those used by ISTAT for daily death counts, and aggregate the data accordingly. Third, we use data on monthly (live) births and deaths, disaggregated by sex, at the municipality level from January 2015 to December 2019.

3.2 Estimation procedure for excess mortality

Excess mortality is measured in any day t of 2020 as the difference between the observed and the expected number of deaths in 2020 in t. The expected number of deaths in t is defined as the average number of deaths observed in t over the period 2015–2019:

$$ {}_nD_x^{excess}(t_{2020}) = {}_nD_x^{observed}(t_{2020}) - {}_nD_x^{expected}(t_{2020}) \tag{1} $$

with

$$ {}_nD_x^{expected}(t_{2020}) = \frac{1}{5} \sum {}_nD_x(t_{2015\text{–}2019}) \tag{2} $$

where the number of deaths in the age interval x to $x + n$ at time t is defined as ${}_nD_x(t)$.

3.3 Estimate procedures for life expectancy

Life expectancy is calculated for two different reference periods: the life expectancy for the first quadrimester (i.e., life expectancy for the first four months of the year), and the period (annual) life expectancy (i.e., life expectancy for the entire calendar year).

Since the excess mortality wave was over by the end of April in all of the provinces (Blangiardo et al., 2020), we calculate the first quadrimester life expectancy for the period of 1 January to 30 April for the years 2015–2020 (for men and women separately). To do so, we calculate the first quadrimester age- and sex-specific mortality rates for each year. We aggregate the daily death counts (the numerators) over the period of 1 January to 30 April at the provincial level (and at the regional level for Lombardy). The corresponding exposures (i.e., the denominators) are estimated as follows. Starting from the estimated resident population on 1 January, we count the age-specific person-days up to 30 April of each year. Theoretically, these counts are a function of four demographic events: namely, births, ageing, migration and deaths. The daily inflow of births is estimated by using monthly birth data, and assuming that these births are uniformly distributed throughout the month. Since the monthly births for 2020 are not available, we estimate monthly births over 2020 in each province by sex by means of linear extrapolation using province-specific data on monthly live births by sex between January 2015 and December 2019. The effect of ageing – i.e., individuals might be in transition into and out of a given age interval – is modelled by giving each individual the probability of 1/365 of turning one year older during the observation period. The outflows due to deaths are straightforward, as the age-specific death counts are known on a daily basis. We assume no migration.[1] Formally, the exposed population at day t in age group x in province p is given by the population alive at day $t - 1$ in age group x in province p plus those who age into age group x at day t minus those who either die in age group x or age out of the age group x in day t in province p:

$$ {}_nE_x^p(t) = P_x^p(t-1) + {}_nAge_{in_x}^p(t) - D_x^p(t) - {}_nAge_{out_x}^p(t) \tag{3} $$

We express the obtained daily exposure values in terms of person-years by multiplying them by 1/365 (1/366 for leap years). Then, we derive age-specific mortality rates for the period of 1 January to 30 April by dividing $D_x^p(t)$ by $E_x^p(t)$. Finally, life tables are built following the standard procedures outlined by the Human Mortality Database protocol (Wilmoth et al., 2019).

While first quadrimester life expectancy does not require any assumptions and relies entirely on observed data, annual life expectancy needs assumptions on mortality trends for the rest of the year 2020 after 31 October when the available ISTAT data on all-cause mortality at the municipality level end. Given the timing of the second wave, which hit Italy in mid-October 2020, harvesting (i.e., the reduction in mortality rates following peak mortality associated with shock events) can be excluded. Thus, we assume that in November and December 2020, mortality returned to the average levels recorded in 2015–2019. It should be noted that this is a conservative approach, since the mortality levels in November and December are expected to be higher than in 2015–2019 due to the unfolding of the second epidemic wave. As we do not know the daily distribution of deaths after 31

[1] The no-migration assumption is fairly realistic. Due to the travel restrictions to and from Italy, and also within the country, it may be expected that migration flows declined. Indeed, the existing data suggest that labour migration as well as refugee admissions were far lower in 2020 than in 2019 (EASO, 2020; EMN/OECD, 2020; OECD, 2020).

October, we assume that the deaths were distributed uniformly across November and December 2020.

We then proceed with the estimation of population exposure for each day between 1 January and 31 December 2020 following the same procedure detailed above (sex- and age-specific population estimates by province are reported in Table A.1). Finally, we aggregate the death counts and population exposure values over the entire year to derive the age-specific mortality rates and life expectancies under both scenarios. For the calendar years 2015–2019, we compute the age-specific mortality rates by dividing the total annual death counts over the mid-year population, and derive the life expectancies accordingly.

We estimate confidence intervals for both the first quadrimester and the annual life expectancies by bootstrapping using Monte Carlo simulation methods, assuming the death counts follow a binomial distribution (Andreev and Shkolnikov, 2010; Chiang, 1984).

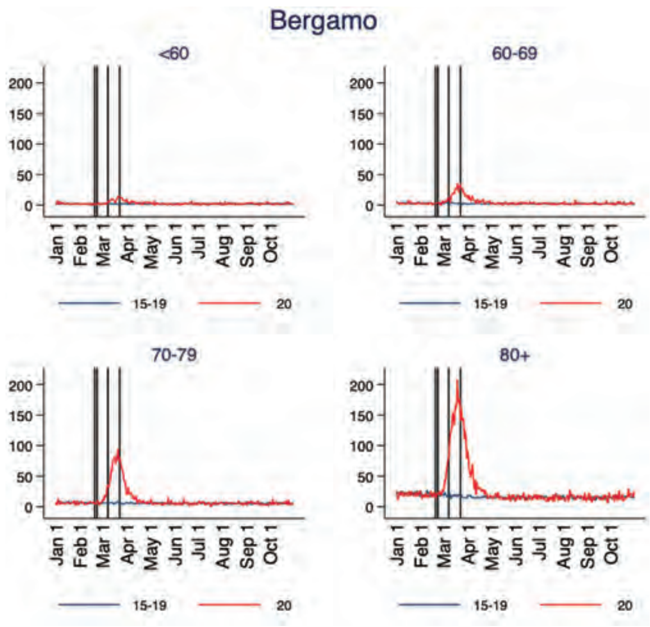
4 Results

Figures 1(a)–1(f) show the trends in daily mortality for the five provinces with the highest numbers of declared cases in Italy and in the whole Lombardy region.[2] Plotting the mortality distribution by age groups allows us to fully capture the progression of the first epidemic wave. It is evident that the epidemic curve inflated with age across all provinces. It is also clear that by 30 April, the daily mortality in all selected provinces approached the pre-pandemic values (i.e., no excess mortality). Hence, the wavelength of the epidemic in these provinces was between six and eight weeks, with the peak happening around two weeks after the onset of the outbreak.

The vertical lines show four relevant dates for the evolution of the first epidemic wave. After the case of *patient one* was first identified in Codogno, located in the province of Lodi, the authorities quickly locked down 11 municipalities in the area on 24 February 2020. The containment measures associated with the lockdown were not implemented in other provinces until after 8 March. Although the earlier lockdown enabled Lodi to flatten the curve more effectively than other severely affected provinces (Figure 1), the province still experienced a notable increase in excess mortality. Considering that the incubation period – i.e., the time between the exposure and the onset of symptoms – can be up to 24 days, it is evident that the lockdown was imposed too late in these provinces. While political reasons prevented the authorities from implementing the lockdown earlier in the provinces where the number of cases had been rising rapidly, like in Bergamo, there is recent evidence showing that COVID-19 had already been circulating undetected in northern Italy

[2] All figures for the Lombardy region cover all 12 provinces in the region.

Figure 1(a):
Trends in total daily death counts in the province of Bergamo January 1 and October 31 2020 vs. 2015–2019 average



Note: The vertical lines show relevant dates for the evolution of the epidemic. The vertical lines indicate the following relevant days: 20 February = patient one found in Codogno; 23 February = red zones in Codogno. Schools and Universities in affected regions are closed; 8 March = orange zones were established in Lombardy and Piacenza; 23 March = all non-essential economic activities were closed.

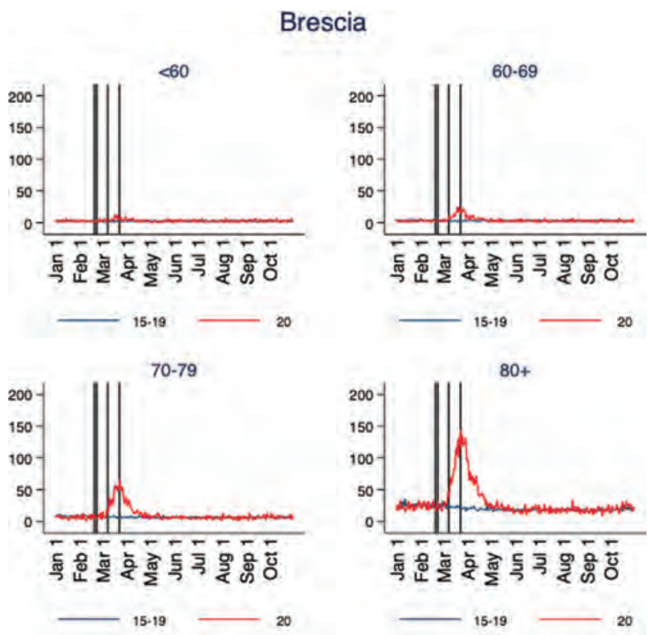
since December 2019 (La Rosa et al., 2021). Thus, our study proxies the impact of the COVID-19 outbreak in the absence of containment interventions.

The geographical distribution of excess deaths in the first quadrimester across Italy (Figure 2) matches the distribution of confirmed cases (which comprise the deceased, the recovered individuals and the active cases) provided by the Italian Civil Protection Department, which publishes the official surveillance data on COVID-19.[3] This geographical pattern indicates that the excess mortality observed in our data represents mortality directly and indirectly related to COVID-19.

Note that in Figure 2, we focus on the 1 January-30 April period only in order to better capture the impact of the first wave of the COVID-19 pandemic. Compared to the average number of people who died in the same period in the previous five years (2015–2019), the excess number of deaths (for those aged 40 or older)

[3] Official statistics on COVID-19 cases and deaths provided by the Italian Civil Protection Department are available at http://www.protezionecivile.gov.it/home (Situation Map).

Figure 1(b):
Trends in total daily death counts in the province of Brescia January 1 and October 31 2020 vs 2015–2019 average

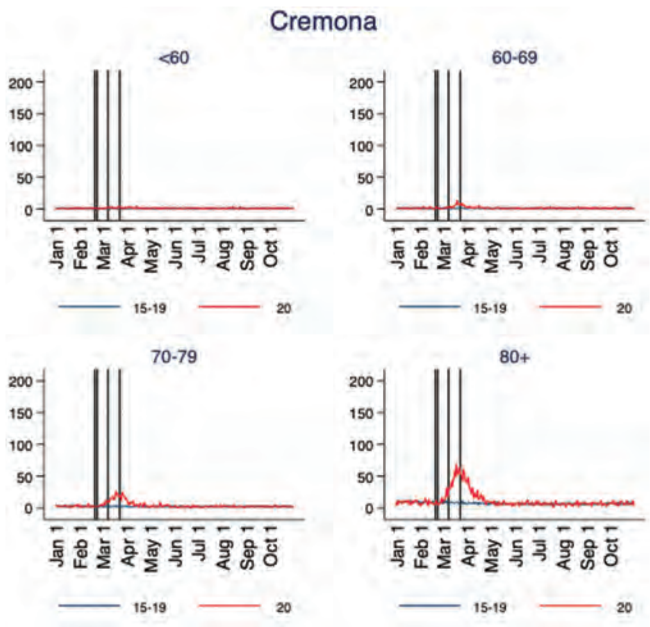


Notes: The vertical lines show relevant dates for the evolution of the epidemic. The vertical lines indicate the following relevant days: 20 February = patient one found in Codogno; 23 February = red zones in Codogno. Schools and Universities in affected regions are closed; 8 March = orange zones were established in Lombardy and Piacenza; 23 March = all non-essential economic activities were closed.

between 1 January and 30 April 2020 sums to 6,084 in Bergamo, 3,969 in Brescia, 2,030 in Cremona, 905 in Lodi and 1,170 in Piacenza. For the entire region of Lombardy, the excess number of deaths is approximately 23,649 (Table 1). The total number of COVID-19 deaths reported by the Italian Civil Protection Department for Lombardy as of 30 April 2020 is 13,772. This implies that the overall death toll of the first epidemic wave was about 70% higher than that suggested by official statistics on COVID-19 deaths. The mortality rate in the first quadrimester of 2020 increased substantially in all provinces and for all age groups, with the largest increase being observed for men aged 70–79 in Bergamo (a 347% increase). Age clearly represented a risk factor for excess mortality, in line with the age gradient in COVID-19 CFR observed in Italy and elsewhere. For instance, among the excess deaths observed in Bergamo, the mortality rate was much higher among older men aged ≥70 years. A similar ratio is found in the other provinces.

When we only consider the distribution of excess mortality without adjusting for population size in each age-sex category, we observe slightly more excess mortality

Figure 1(c):
Trends in total daily death counts in the province of Cremona January 1 and October 31 2020 vs. 2015–2019 average

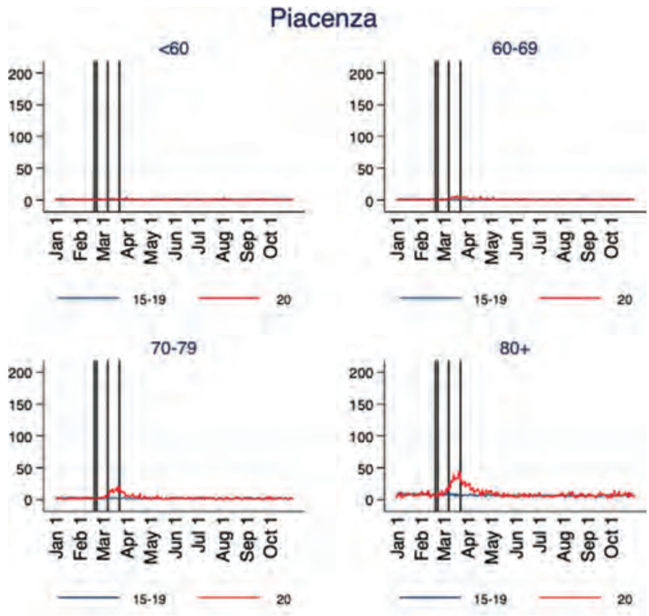


Notes: The vertical lines show relevant dates for the evolution of the epidemic. The vertical lines indicate the following relevant days: 20 February = patient one found in Codogno; 23 February = red zones in Codogno. Schools and Universities in affected regions are closed; 8 March = orange zones were established in Lombardy and Piacenza; 23 March = all non-essential economic activities were closed.

in men than in women (53% of excess deaths involved male subjects). However, when we consider the mortality risk ratio between the sexes, we find that the excess mortality for males was consistently higher than that for females across all age groups and provinces (relative risk ≥1).

The trends in the first quadrimester and the annual life expectancies are illustrated in Figures 3 and 4. When we look at the trends in the first quadrimester of 2020, it is evident that the drop in life expectancy was significant for both men and women in all provinces. Compared to the average life expectancy of the 2015–2019 period, the reduction for men ranged from 5.5 years in Brescia to 8.1 years in Bergamo, and the reduction for women ranged from 4.1 years in Piacenza to 5.8 years in Bergamo. The larger reduction in the first quadrimester life expectancy for men was due to sex differentials in the COVID-19 mortality risk, as both the official case fatality data and our death registration data consistently show. Indeed, when we decompose the loss in life expectancy to identify which age groups contributed the most to the reduction in life expectancy (Figure A.3 in Appendix), it becomes clear

Figure 1(d):
Trends in total daily death counts in the province of Piacenza January 1 and October 31 2020 vs 2015–2019 average



Notes: The vertical lines show relevant dates for the evolution of the epidemic. The vertical lines indicate the following relevant days: 20 February = patient one found in Codogno; 23 February = red zones in Codogno. Schools and Universities in affected regions are closed; 8 March = orange zones were established in Lombardy and Piacenza; 23 March = all non-essential economic activities were closed.

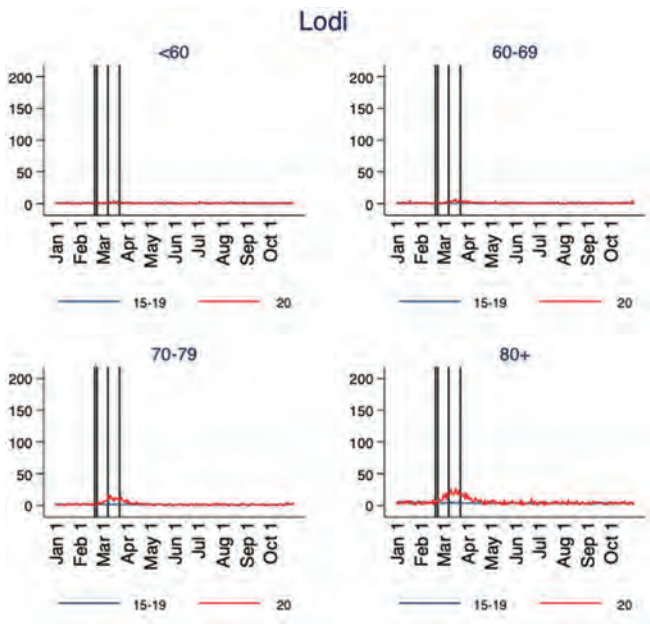
that the older populations, and especially men aged 60–79 years, played a major role.

When life expectancy is extrapolated for the whole year, the loss in life expectancy is diluted over a longer period. Thus, the drop in life expectancy due to COVID-19-related excess mortality was less steep than that observed in the first quadrimester life expectancy.

In the most severely hit province of Bergamo, life expectancy dropped by 4.1 years for men and 2.8 years for women when compared to life expectancy for the years 2015–2019. In the slightly less affected provinces of Brescia, Cremona, Lodi and Piacenza, the reduction in life expectancy ranged between 2.4 in Brescia and 3.8 in Cremona for men, and between 1.9 in Piacenza and 2.6 in Cremona for women. As expected, the reduction in life expectancy was smaller in Lombardy, at 1.9 years for males and 1.5 years for females.

When we turn to the national level, we see that the results are extremely heterogeneous (Figure 5). It is evident that the higher excess mortality experienced in the northern part of Italy, particularly in Lombardy, was not experienced in most

Figure 1(e):
Trends in total daily death counts in the province of Lodi January 1 and October 31 2020 vs. 2015–2019 average



Notes: The vertical lines show relevant dates for the evolution of the epidemic. The vertical lines indicate the following relevant days: 20 February = patient one found in Codogno; 23 February = red zones in Codogno. Schools and Universities in affected regions are closed; 8 March = orange zones were established in Lombardy and Piacenza; 23 March = all non-essential economic activities were closed.

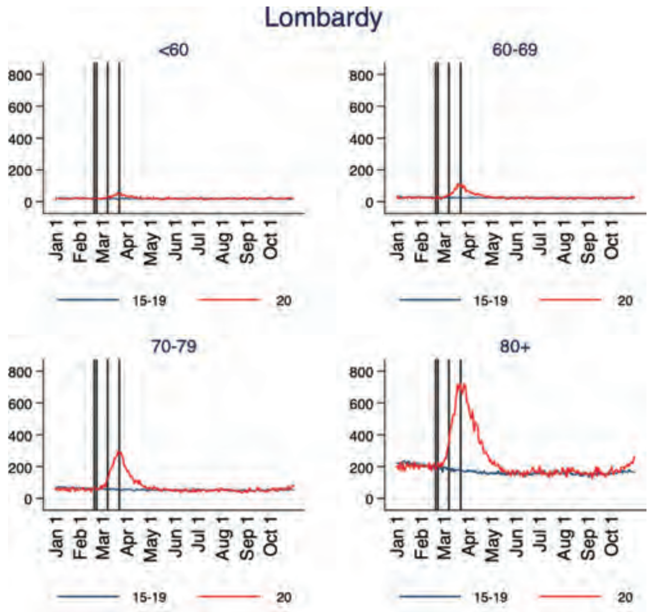
of the provinces of the central part and the south of the country. For example, in provinces like Sassari and Nuoro in Sardegna and Cosenza in Calabria, the lockdown *reduced* mortality in the first four months of the year, resulting in an estimated increase in life expectancy up to two years for both men and women.

5 Discussion

By avoiding the inconsistencies in the classification of causes of death and in testing practices, and by focusing on the five areas in Italy that were most severely affected by the first wave of the pandemic, this study provided an assessment of the full impact of the first wave of the COVID-19 pandemic on human life.

Two empirical regularities clearly emerged when we looked at demographic differentials. First, the age gradient in excess mortality was steep, and age was the most evident risk factor for COVID-19 mortality. In Lombardy, men and women

Figure 1(f):
Trends in total daily death counts in the region of Lombardy January 1 and October 31 2020 vs. 2015–2019 average



Notes: The vertical lines show relevant dates for the evolution of the epidemic. The vertical lines indicate the following relevant days: 20 February = patient one found in Codogno; 23 February = red zones in Codogno. Schools and Universities in affected regions are closed; 8 March = orange zones were established in Lombardy and Piacenza; 23 March = all non-essential economic activities were closed.

over age 70 were 23 times more likely to die than their counterparts under age 70. These patterns were replicated in all five provinces. Therefore, areas where older people made up a high proportion of the population (e.g., 17% of the population were over age 70 in the Lombardy region in 2019) had a higher burden of COVID-19 mortality (Dowd et al., 2020). Second, within each province, the risk of dying was consistently higher for men than for women for all age classes and provinces considered. Evidence that men are more likely than women to suffer from COVID-19, as measured by hospitalisations, admissions to intensive care units and fatality rates, has been consistently reported for other countries across different studies and subsamples (Gebhard et al., 2020; Peckham et al., 2020; Scully et al., 2020). Higher mortality rates for men than for women translate into a larger reduction in life expectancy for men than for women.

Although these data provided evidence of the severity of the first wave of the COVID-19 pandemic in Europe, a further measurement effort was needed, particularly for geographical and historical comparability purposes. In terms of life expectancy, we showed that for the period of 1 January to 30 April 2020, the reduction in the first quadrimester life expectancy, compared with the average of the years 2015–2019, was as high as 8.1 years for men and 5.8 years for women in Bergamo.

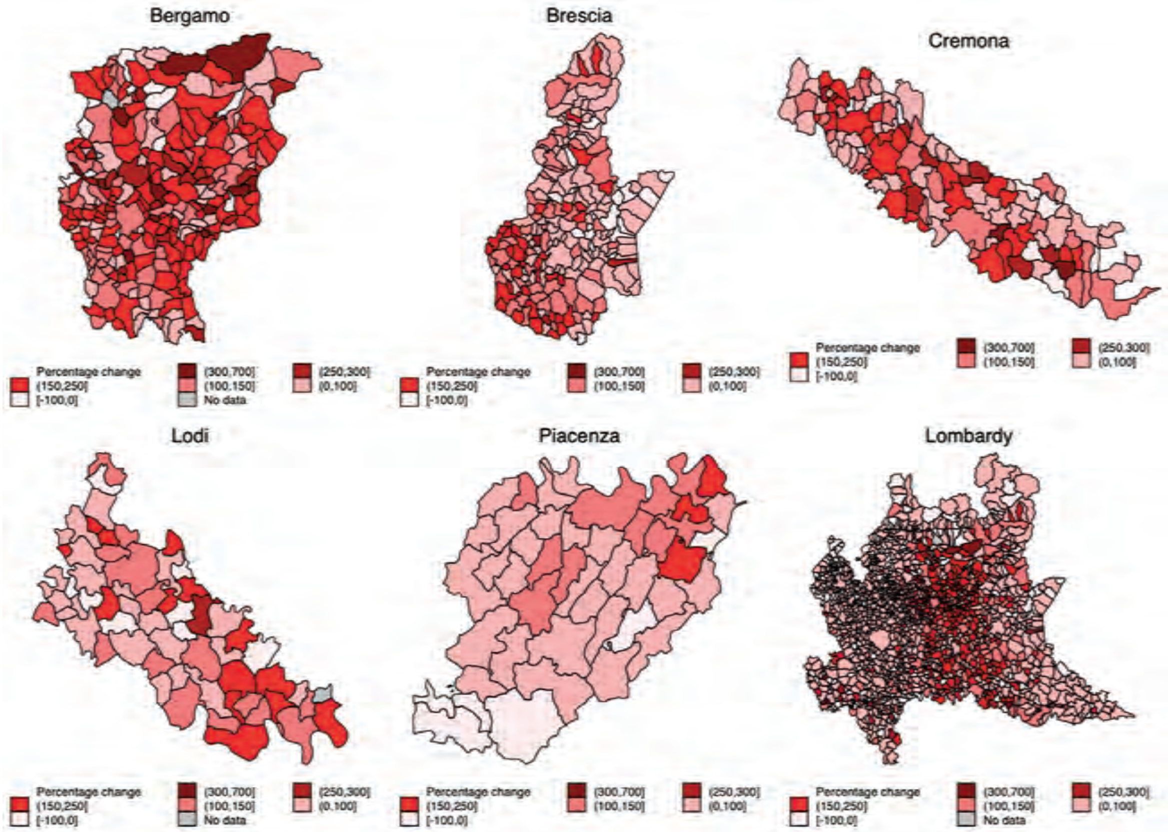
When the analysis was extended to the whole year, under the assumption that the mortality rates from November onwards were back to "normal", life expectancy was reduced by up to four years (for men in Bergamo). However, significant uncertainties remain about the longer-term effects of the pandemic on health conditions among, for instance, patients who recovered from COVID-19 with major co-morbidities and mental health issues, and pregnant women. It is also possible that indirect physical and mental health consequences of changing socio-economic conditions affected the mortality patterns in 2020.

What can we say regarding the validity of the no harvesting assumption? Figure 1 provides evidence that after the end of the first wave, the mortality patterns in all age-provinces groups were largely similar to those in the previous years. This result is not consistent with harvesting, which would require negative excess mortality to compensate for the high levels of mortality registered in the first quadrimester. It should also be noted that since November 2020, Italy has been experiencing a severe second wave of infections that has not fully finished. Moreover, since March 2021, the country has been bracing for a third wave. Therefore, mortality in Italy is likely to increase even further. Thus, the figures provided can be considered estimates of the human life lost only *for the first wave* of the COVID-19 epidemic in the affected provinces.

It should also be noted that in the first quadrimester, some provinces in Italy experienced an improvement in life expectancy thanks to a reduction in mortality compared to the average of the previous years. There may have been spill-over benefits of the lockdown measures that contributed to a decline in premature deaths, such as from road traffic fatalities, alcohol consumption, violence and injuries at work (Qi et al., 2020; Qureshi et al., 2020). Moreover, our observation that the epidemic had a differential impact across different regions within Italy shows the importance of considering specific geographic areas when estimating the effect of the COVID-19 pandemic on human life. Indeed, focusing on national-level statistics only would further bias downward the estimation of the impact of the virus. Thus, our explicit focus on a local context can be considered the main strength of this analysis. Because the COVID-19 outbreaks have been geographically concentrated, looking at country-level life expectancy is misleading, and underestimates the actual impact of the pandemic.

Along with Italy, other European countries have been experiencing sharp declines in life expectancy due to the COVID-19 pandemic. Estimating weekly life expectancy for Spain, Trias-Llimós et al. (2020) found a particularly large drop at the beginning of April 2020, with a decline of up to 7.6 years at the national level. At the regional level, the authors reported an even more pronounced drop in life expectancy, with Madrid in particular experiencing a large reduction, ranging from 11.2 years in week 13 to 14.8 years in week 14 for both men and women. Moreover, the findings of a study for Sweden based on mortality data for the first 33 weeks

Figure 2:
Excess mortality between January 1 and April 30 2020 by municipalities in selected provinces and in Lombardy



Notes: The maps plot the percentages change in total number of deaths recorded between 1 January and 30 April 2020 with respect to the 2015–2019 average.

Table 1:
Total population as of January 1 2020, excess mortality and male to female relative risk (RR) for selected provinces and Lombardy region, by age and sex (1 January–30 April 2020)

Age	Population males	Population females	Excess deaths males	Excess deaths females	Increase MR Males	Increase MR Females	RR
				BERGAMO			
40–49	87798	83447	18	11	1.419	1.418	1.555
50–59	90465	87550	130	41	2.230	1.586	3.069
60–69	65932	67646	456	123	2.910	1.967	3.804
70–79	48938	55601	1109	473	3.399	2.465	2.664
80–89	23213	35807	1398	1088	2.936	2.329	1.982
90+	2878	8995	391	846	2.623	2.233	1.444
				BRESCIA			
40–49	100560	96071	6	2	1.148	1.104	2.866
50–59	100949	98976	81	31	1.748	1.427	2.562
60–69	72690	76000	241	76	1.909	1.558	3.315
70–79	56544	64688	728	304	2.364	1.858	2.740
80–89	27054	42900	934	757	2.085	1.800	1.956
90+	3575	11875	277	809	1.804	1.926	1.137
				CREMONA			
40–49	27269	26207	7	6	1.539	1.906	1.121
50–59	28706	28163	42	5	2.241	1.192	8.241
60–69	22333	23107	109	27	2.349	1.569	4.177
70–79	17463	19921	336	136	2.804	2.092	2.818
80–89	8941	14449	388	411	2.346	2.162	1.526
90+	1278	4068	168	395	2.475	2.249	1.354

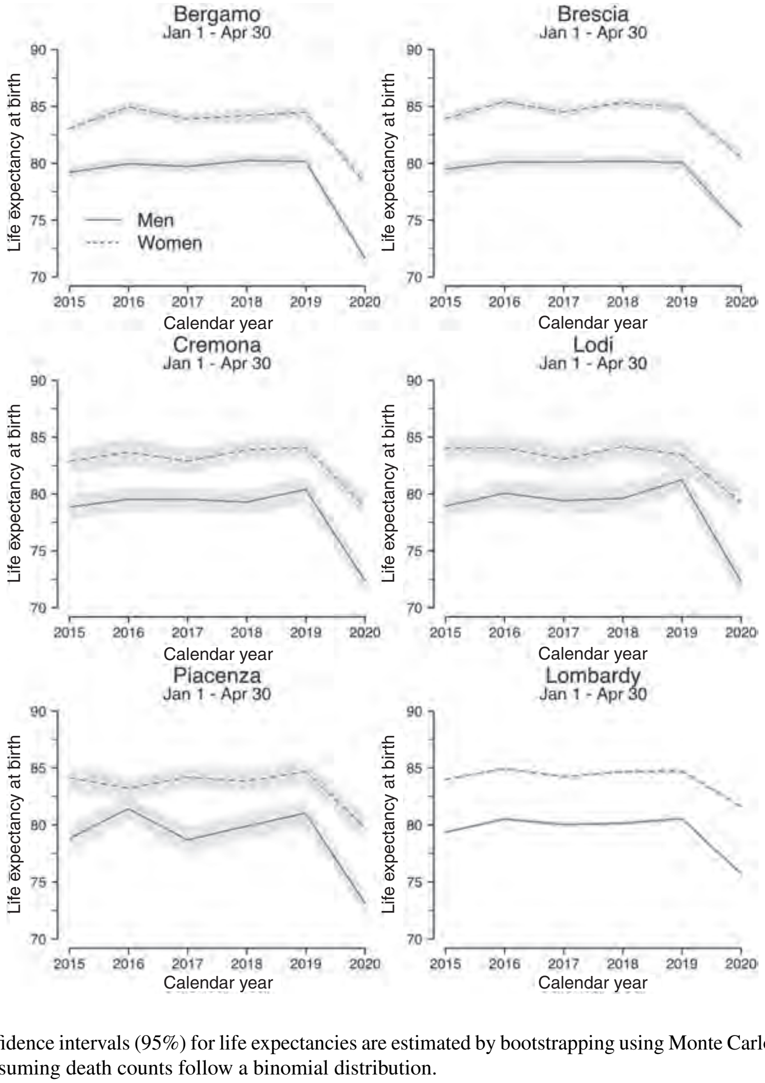
Continued

Table 1:
Continued

Age	Population males	Population females	Excess deaths males	Excess deaths females	Increase MR Males	Increase MR Females	RR
				LODI			
40–49	18554	17694	4	1	1.431	1.232	3.815
50–59	18757	18214	20	0	1.837	0.974	
60–69	13548	14073	73	23	2.485	1.859	3.297
70–79	10264	11802	215	76	2.967	1.983	3.253
80–89	4770	7890	184	131	2.128	1.667	2.323
90+	587	1940	34	148	1.549	1.988	0.759
				PIACENZA			
40–49	21381	21089	3	−5	1.363	0.293	−0.592
50–59	22926	22790	29	7	2.001	1.370	4.118
60–69	17373	18099	83	16	2.377	1.416	5.404
70-79	14041	16290	207	99	2.367	2.093	2.426
80–89	7945	12234	275	185	2.063	1.595	2.289
90+	1258	3598	78	193	1.656	1.695	1.156
				LOMBARDY			
40–49	734989	715954	69	34	1.200	1.167	1.977
50–59	711601	716834	440	94	1.535	1.176	4.715
60–69	518652	560324	1312	400	1.705	1.377	3.544
70-79	414020	494374	3609	1560	1.906	1.565	2.762
80–89	205659	331869	5338	4592	1.891	1.652	1.876
90+	27458	85968	1835	4366	1.814	1.718	1.316

Notes: Excess deaths: (Number of deaths 1 January-30 April 2020) – (Average number of deaths 1 January 1–30 April 2015–2019). RR(M/F): Risk Ratio (Male/Female) = (excess deaths males/pop males)/(excess deaths females/pop females).

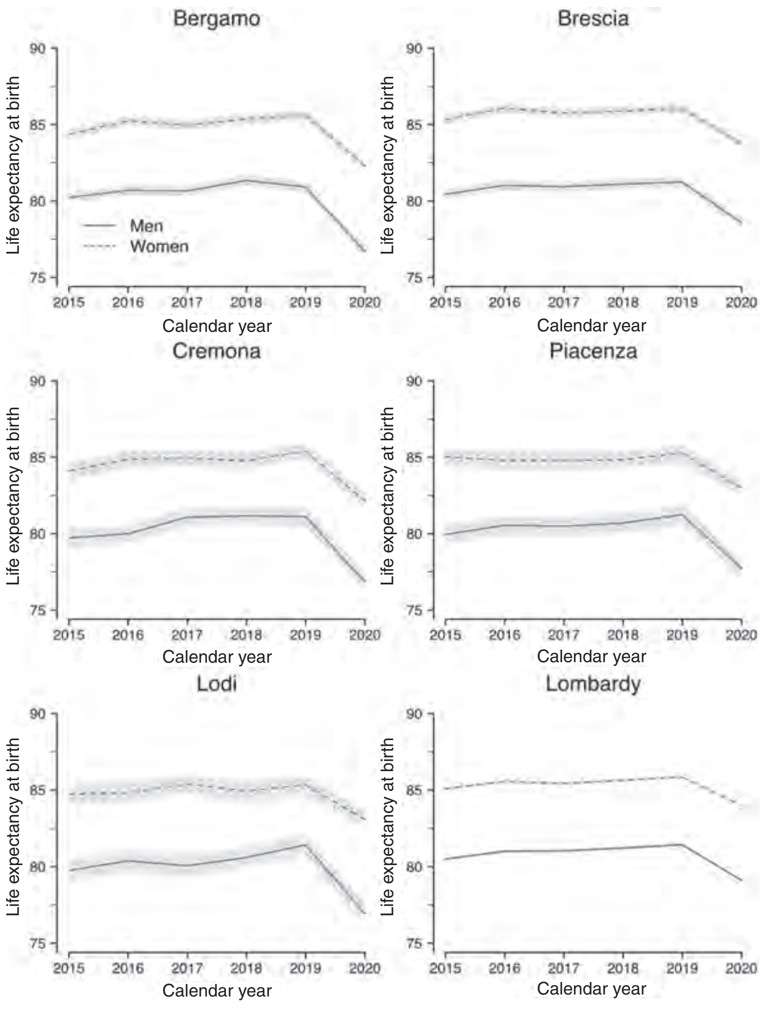
Figure 3:
Estimates of the first quadrimester (1 January–April 30) by sex in selected provinces and in Lombardy (95% confidence intervals in grey)



Notes: Confidence intervals (95%) for life expectancies are estimated by bootstrapping using Monte Carlo simulation methods, assuming death counts follow a binomial distribution.

of the pandemic suggest that life expectancy at age 50 in Stockholm decreased by about two years for men and about 1.5 years for women (Modig et al., 2021). At the national level, the reduction in annual life expectancy during the COVID-19 pandemic is expected to be smaller. Similarly, a study that calculated life expectancy at birth in England and Wales on the basis of data for the first 47 weeks of the

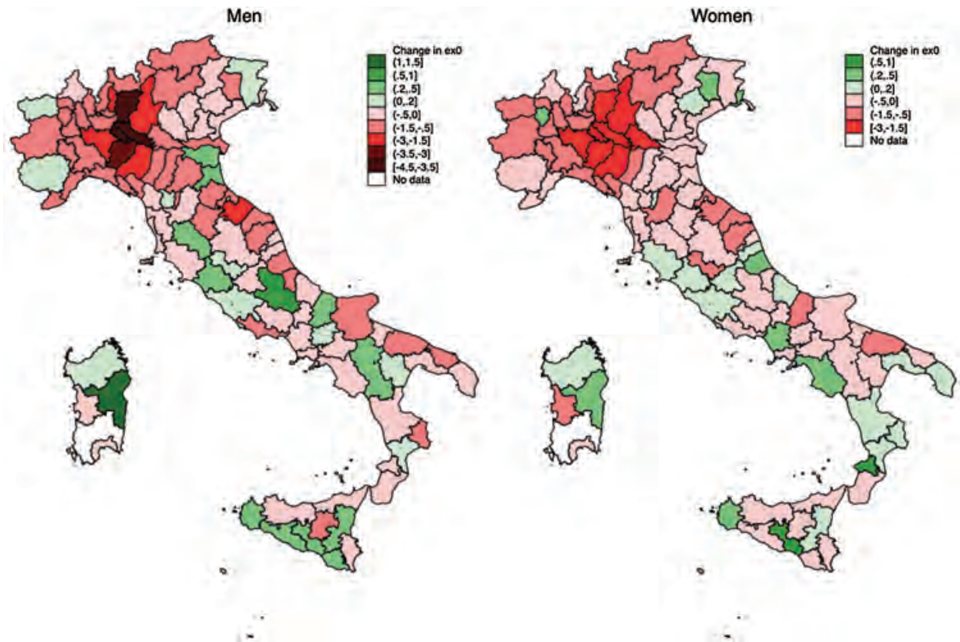
Figure 4:
Estimates of the annual life expectancies by sex in selected provinces of Lombardy and in the Lombardy region as a whole (95% confidence intervals in grey)



Notes: Confidence intervals (95%) for life expectancies are estimated by bootstrapping using Monte Carlo simulation methods, assuming death counts follow a binomial distribution.

pandemic found that it declined by 0.9 years for women and 1.2 years for men between 2019 and 2020 (Aburto et al., 2021). Our results are in line with those of these previous studies, as we also found the largest declines in life expectancy at a local level; in our case, in the north of Italy.

Figure 5:
Differences between life expectancy at birth (ex0) in 2020 in Italian provinces and 2015–2019 average, by sex



Under normal conditions, life expectancy at birth is calculated with mortality data for one calendar year, and provides an estimate of mean longevity for a hypothetical group of individuals who experience the mortality regime of a given period over their entire life course. Obviously, in reality, no group of people will be exposed over their life course to the mortality regime of the worst hit regions in Italy during the first wave of the COVID-19 pandemic. With the development, approval and rollout of several vaccines and the implementation of protective measures, it is highly likely that in the future, mortality in these regions will bounce back to lower levels. Still, life expectancy is a powerful tool for summarising and comparing mortality rates between regions and over time, especially because it accounts for differences in age-specific mortality (Marois et al., 2020; Trias-Llimós et al., 2020).

As the results of this study show, the cost in terms of human life of the delays in public interventions to reduce the transmission of the virus was disturbingly high. As European countries struggle to manage the successive waves of the coronavirus by striking a balance between protecting public health and reducing the economic effects of restriction measures, it is important to keep in mind the potential risk of viral reintroduction, and the direct and indirect dangers it poses to human life. Well-planned government measures aimed at flattening the epidemic curve while preventing a new wave of infections, along with public cooperation in maintaining physical distancing, wearing a face mask and practicing proper hygiene until there is widespread access to vaccination for the novel coronavirus, are key to achieving a balance between protecting public health and sustaining the economy.

Author contributions

SG and BS designed the research; BS acquired data, performed the analysis and created the display items with the help of MS. SG, RM, MS and BS contributed to the writing of the manuscript.

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Appendix

Figure A.1:
Distribution of excess mortality in March–April 2020 across Italian provinces. The provinces in Lombardy are highlighted by the bold black line. The province of Piacenza is indicated by the blue arrow. Excess mortality is calculated as the percentage difference with respect to baseline mortality (2015–2019 average)

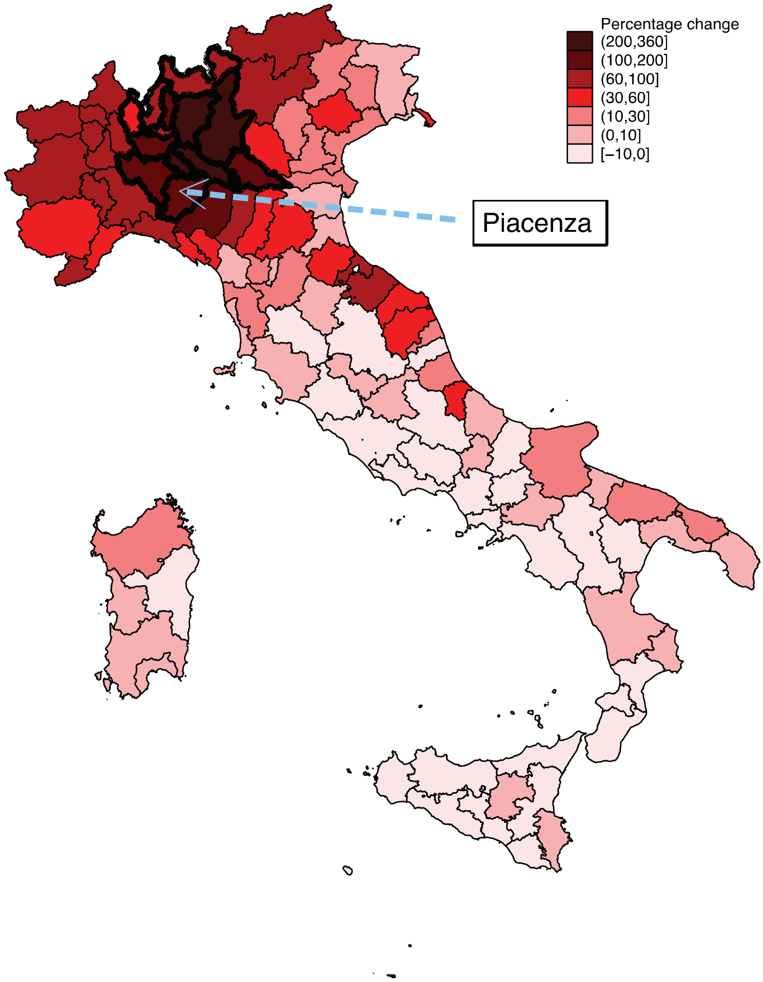


Figure A.2:
Distribution of excess mortality in March–April 2020 across municipalities in Lombardy and in the province of Piacenza

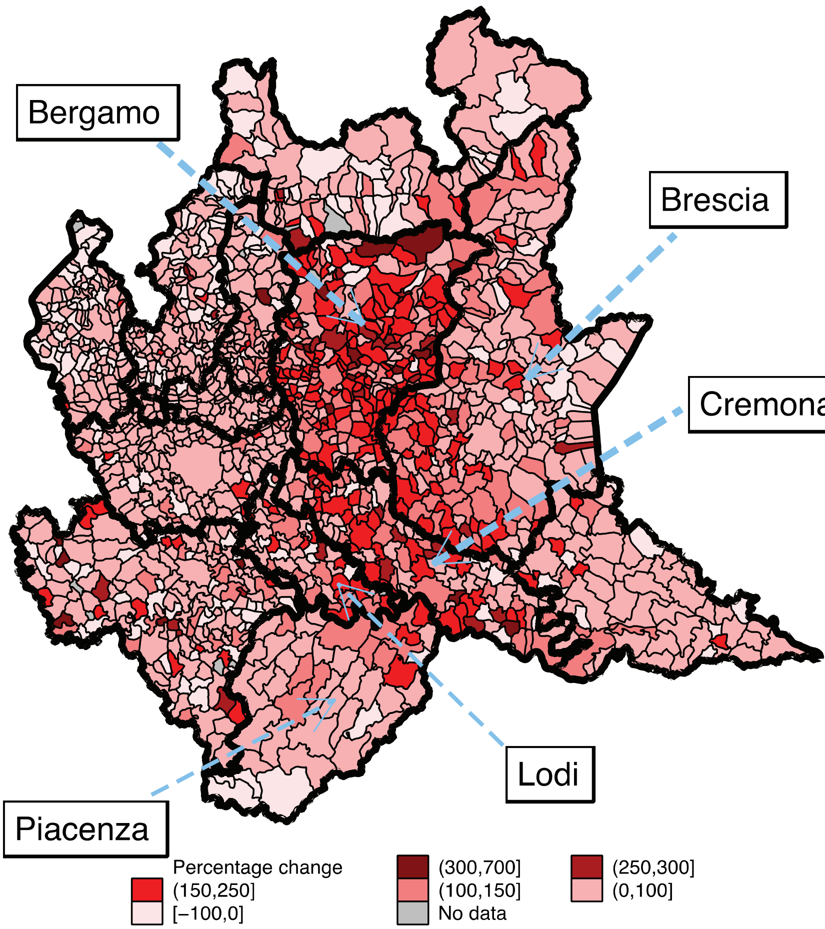
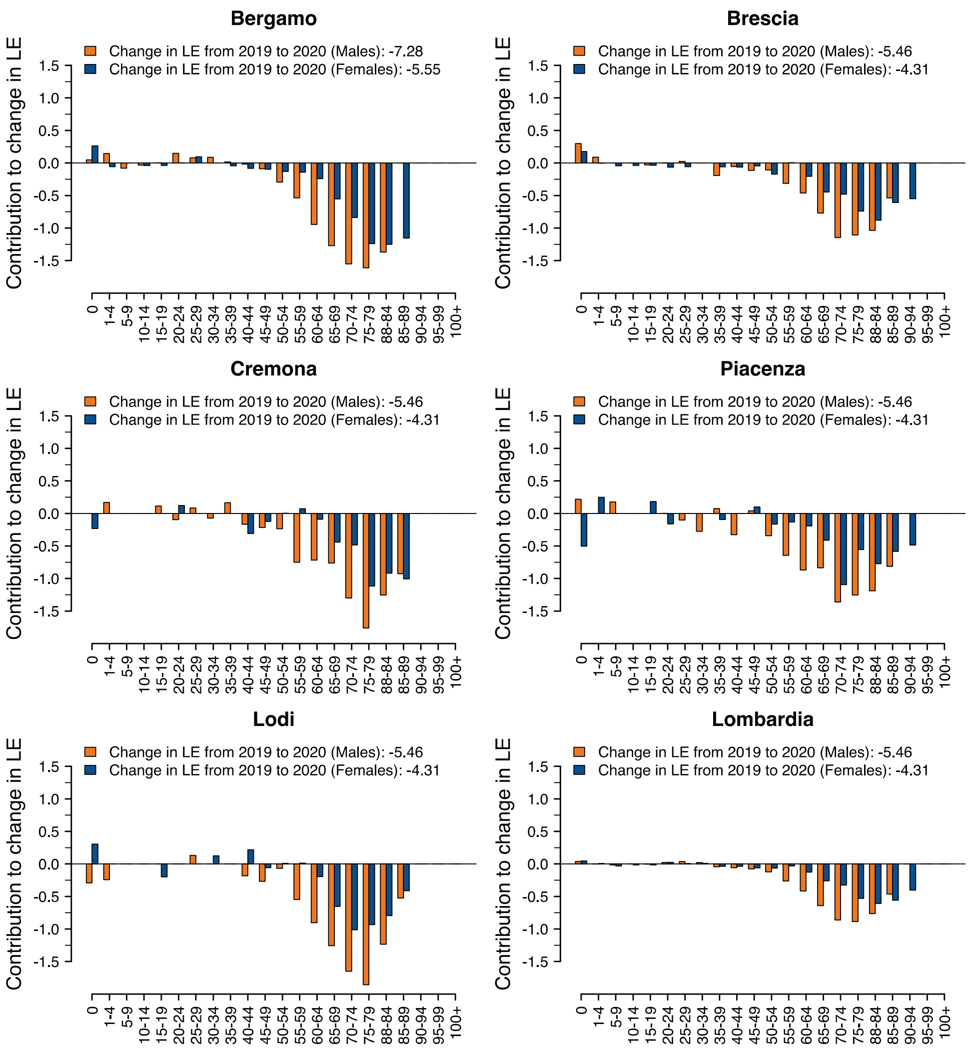


Figure A.3:
Decomposition of the loss of life expectancy in the first quadrimester, by age and sex and province



Note: For decomposing changes in life expectancy into age-specific contributions, the method proposed by Arriaga (1984)[3] is applied. This approach is used to assess which age-groups have primary contributed to the change in the first quadrimester life expectancy between 2019 and 2020

[3] Arriaga, E.E. (1984). Measuring and Explaining the Change in Life Expectancies. Demography 21(1):83–96. doi: 10.2307/2061029.

Table A.1:
Population exposure by province, year 2020

Age class	Pop 2020 males (beginning)	Pop 2020 males (end)	Exposure males (person-years)	Pop 2020 females (beginning)	Pop 2020 females (end)	Exposure females (person-years)
			BERGAMO			
0	4140	4127	4133	4112	4100	4106
1–4	19110	19109	19110	17998	17995	17997
5–9	28054	28051	28052	26278	26277	26277
10–14	30073	30068	30070	28448	28445	28446
15–19	29875	29866	29871	27856	27854	27855
20–24	29701	29687	29694	27304	27300	27302
25–29	29134	29124	29129	27849	27845	27847
30–34	30332	30315	30323	30035	30029	30032
35–39	34293	34272	34283	33522	33512	33517
40–44	41078	41036	41057	39572	39537	39554
45–49	46720	46623	46671	43875	43822	43848
50–54	47710	47547	47628	45497	45399	45448
55–59	42755	42490	42622	42053	41917	41985
60–64	35011	34594	34802	35498	35304	35401
65–69	30921	30258	30589	32148	31859	32003
70–74	27929	26875	27402	30184	29695	29939
75–79	21009	19661	20335	25417	24570	24994
80–84	15480	13775	14627	21472	20105	20789
85–89	7733	6227	6980	14335	12483	13409
90–94	2463	1696	2080	6901	5272	6087
95–99	396	212	304	1918	1189	1554
100+	19	2	10	176	62	119

Continued

Table A.1:
Continued

Age class	Pop 2020 males (beginning)	Pop 2020 males (end)	Exposure males (person-years)	Pop 2020 females (beginning)	Pop 2020 females (end)	Exposure females (person-years)
			BRESCIA			
0	4823	4810	4816	4504	4496	4500
1–4	21513	21509	21511	20613	20610	20611
5–9	30953	30952	30952	29459	29457	29458
10–14	33484	33483	33483	31670	31669	31669
15–19	32860	32853	32856	30250	30245	30248
20–24	33324	33312	33318	30213	30206	30210
25–29	33204	33192	33198	31884	31878	31881
30–34	34943	34927	34935	34248	34243	34246
35–39	39634	39598	39616	38994	38975	38984
40–44	47140	47093	47116	45568	45537	45552
45–49	53420	53340	53380	50503	50457	50480
50–54	53368	53208	53288	51550	51451	51501
55–59	47581	47314	47447	47426	47295	47360
60–64	38707	38337	38522	39872	39701	39787
65–69	33983	33421	33702	36128	35840	35984
70–74	31695	30752	31223	34845	34372	34608
75–79	24849	23609	24229	29843	29061	29452
80–84	18232	16602	17417	25725	24384	25054
85–89	8822	7382	8102	17175	15335	16255
90–94	3022	2192	2607	9114	7157	8135
95–99	516	292	404	2514	1621	2068
100+	37	10	24	247	107	177

Continued

Table A.1: Continued

Age class	Pop 2020 males (beginning)	Pop 2020 males (end)	Exposure males (person-years)	Pop 2020 females (beginning)	Pop 2020 females (end)	Exposure females (person-years)
			CREMONA			
0	1299	1294	1297	1186	1181	1183
1–4	5567	5567	5567	5185	5185	5185
5–9	8152	8152	8152	7417	7417	7417
10–14	8674	8673	8673	7897	7896	7897
15–19	8414	8411	8412	7685	7684	7684
20–24	9036	9032	9034	8038	8035	8037
25–29	9189	9188	9189	8693	8692	8693
30–34	9684	9674	9679	9321	9320	9320
35–39	10738	10735	10737	10267	10261	10264
40–44	12943	12922	12932	12463	12451	12457
45–49	14326	14298	14312	13744	13730	13737
50–54	15146	15091	15118	14494	14461	14477
55–59	13560	13458	13509	13669	13623	13646
60–64	11665	11537	11601	12120	12058	12089
65–69	10668	10444	10556	10987	10883	10935
70–74	9967	9623	9795	10787	10625	10706
75–79	7496	7015	7256	9134	8821	8977
80–84	5986	5399	5692	8541	8018	8279
85–89	2955	2411	2683	5908	5141	5524
90–94	1065	710	887	3095	2338	2716
95–99	204	104	154	895	536	716
100+	9	3	6	78	33	55

Continued

Table A.1: Continued

Age class	Pop 2020 males (beginning)	Pop 2020 males (end)	Exposure males (person-years)	Pop 2020 females (beginning)	Pop 2020 females (end)	Exposure females (person-years)
			LODI			
0	855	851	853	836	835	836
1–4	3987	3984	3986	3827	3827	3827
5–9	5576	5576	5576	5213	5213	5213
10–14	5973	5973	5973	5470	5470	5470
15–19	5503	5503	5503	5331	5330	5330
20–24	5728	5723	5726	5275	5275	5275
25–29	5908	5906	5907	5742	5742	5742
30–34	6544	6542	6543	6338	6335	6336
35–39	7323	7320	7322	7085	7083	7084
40–44	8678	8671	8675	8410	8405	8407
45–49	9876	9856	9866	9284	9270	9277
50–54	10106	10069	10087	9737	9716	9727
55–59	8651	8604	8627	8477	8459	8468
60–64	7209	7128	7169	7444	7410	7427
65–69	6339	6213	6276	6629	6565	6597
70–74	5958	5737	5847	6429	6324	6377
75–79	4306	4031	4168	5373	5206	5289
80–84	3216	2875	3046	4828	4555	4691
85–89	1554	1284	1419	3062	2710	2886
90–94	501	356	428	1491	1128	1309
95–99	78	42	60	422	254	338
100+	8	5	6	27	9	18

Continued

Table A.1: Continued

Age class	Pop 2020 males (beginning)	Pop 2020 males (end)	Exposure males (person-years)	Pop 2020 females (beginning)	Pop 2020 females (end)	Exposure females (person-years)
			PIACENZA			
0	997	995	996	1058	1055	1056
1–4	4661	4660	4660	4241	4241	4241
5–9	6339	6338	6339	5984	5984	5984
10–14	6579	6579	6579	6273	6273	6273
15–19	6516	6515	6516	6060	6060	6060
20–24	7113	7110	7111	6202	6201	6201
25–29	7584	7580	7582	7059	7057	7058
30–34	7692	7685	7689	7516	7516	7516
35–39	8388	8385	8386	7950	7945	7947
40–44	9921	9908	9914	9596	9590	9593
45–49	11460	11445	11452	11493	11484	11489
50–54	11967	11919	11943	11736	11717	11727
55–59	10959	10893	10926	11054	11012	11033
60–64	9444	9331	9388	9725	9677	9701
65–69	7929	7797	7863	8374	8298	8336
70–74	7605	7358	7481	8583	8427	8505
75–79	6436	6069	6252	7707	7494	7600
80–84	5079	4597	4838	7076	6689	6882
85–89	2866	2397	2631	5158	4562	4860
90–94	1043	753	898	2685	2055	2370
95–99	202	126	164	831	526	678
100+	13	5	9	82	37	59

Note: Population at the beginning of 2020 is provided by ISTAT. Population at the end of 2020 is estimated following the procedure outlined in the Methods section. Exposure (person-years) is given by the rounded average of population at the beginning and at the end of the year.

Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 317–348

Excess mortality and COVID-19 in Sweden in 2020: A demographic account

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Abstract

In this study, we provide an account of mortality levels in Sweden in 2020, focusing on both excess mortality and mortality due to COVID-19 deaths. We present various measures of life expectancy for women and men based on age-specific death rates in 2020. Our measures of excess mortality are based on comparisons with benchmarks derived from a previous mortality forecast for 2020 by Statistics Sweden and observed average mortality rates during 2017–2019. We present data on regional and seasonal variation in excess mortality, as well as estimates of Years of Potential Life Lost due to COVID-19. We decompose excess mortality in 2020 into excess mortality due to COVID-19 and excess mortality attributable to other causes. We also provide some estimates on the impact of excess mortality in 2020 on the remaining life expectancy for different cohorts of women and men in Sweden. We demonstrate that the impact of COVID-19 mortality was concentrated at higher ages, and among men in particular. Conversely, some younger age groups experienced negative excess mortality. The mortality changes during 2020 caused life expectancy levels to revert back to those observed in 2018 for women and in 2017 for men.

Keywords: excess mortality; mortality; life expectancy; COVID-19; Sweden

1 Introduction and background

COVID-19 spread across the globe in early 2020, and reached Sweden in March 2020. For much of the remaining year, Sweden witnessed elevated mortality due

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DOI: 10.1553/populationyearbook2022.res2.2

to mortality associated with COVID-19. Here, we assess the extent of pandemic-induced excess mortality observed in 2020. We provide a comprehensive breakdown of mortality due to COVID-19, as well as of overall excess mortality in Sweden by age, sex, calendar time and region.

In a very short time, the research world has produced an extensive body of work on various aspects of the COVID-19 pandemic and its consequences. Demographers have produced estimates of the impact of COVID-19 on mortality for a number of countries, including the United States (Andrasfay and Goldman, 2021; Goldstein and Lee, 2020), England and Wales (Aburto et al., 2021a) and Spain (Trias-Llimós et al., 2020). A comparative study by Aburto et al. (2021b) presented life expectancy estimates for 2020 for 29 countries, including Sweden, with mortality rates from 2019 used as a benchmark. The results showed that most of these countries experienced excess mortality, with a decline in life expectancy of up to 1.5 years, and with larger declines occurring among men than among women. Based on this benchmark, Sweden had slightly higher excess mortality than the median of the countries in the study, which may be attributable in part to an unusually pronounced mortality reduction in Sweden in 2019. A study by Pifarré i Arolas et al. (2021) calculated years of life lost in 2020 for 81 countries, and found that Sweden, like many other high-income countries, had a high concentration of mortality at older ages, with fewer years of life lost than if deaths had occurred at younger ages. Islam et al. (2021) estimated total excess mortality in 2020 for 29 high-income countries, and found that Sweden ranked in the middle of the 29 countries. Nevertheless, several countries had mortality levels in 2020 that were similar to or lower than their mortality levels in 2019, including the other Nordic countries of Denmark, Finland and Norway.

Some researchers have extolled the advantages of using excess mortality as a summary measure of the pandemic's effects in terms of elevated mortality, observing that it is a simple and objective measure that is particularly appropriate when comparing mortality differentials between countries (Beaney et al., 2020; Modig et al., 2020). Excess mortality is also suitable for measuring the effects of the pandemic in countries that lack high-quality registration of causes of death, which is not the case in Sweden, where death registration is of high quality and is virtually complete. Nonetheless, even for Sweden, using the extent of excess mortality as a summary measure of the impact of the COVID-19 pandemic on mortality patterns is of interest to researchers, not least in order to place the findings of investigations of the effects of the pandemic on mortality in the context of international research and earlier mortality patterns in Sweden.

Several studies conducted in Sweden have examined patterns of COVID-19-related mortality based on individual-level data on observed deaths and causes of deaths during the early months of 2020. These studies found that mortality increased, most notably among socioeconomically disadvantaged groups (Drefahl et al., 2020), people living in crowded and multigenerational households (Brandén et al., 2020) and migrants (Aradhya et al., 2021; Rostila et al., 2021). Similar studies on mortality among foreign-born populations have been conducted in

Norway (Indseth et al., 2020) and Belgium (Vanthomme et al., 2021). Calderón-Larrañaga et al. (2020) showed that mortality in Stockholm was elevated in areas with lower incomes and/or in areas with more foreign-born residents. Modig et al. (2021a) investigated how mortality varied over different weeks throughout the year based on data up to week 33 (early August), and revealed the magnitude of excess mortality during the 2020 spring peak in Swedish mortality. Modig et al. (2021b) went on to report strongly elevated mortality among women and men living in elderly care homes within Sweden.

Throughout 2020, Sweden's COVID-19 response was regularly highlighted as an outlier relative to those of other European countries, as fewer restrictions were imposed on everyday life in Sweden than elsewhere. This issue was covered widely, and often critically, in international media (Simons, 2020). Among the crucial differences between Sweden and many other European countries were that in Sweden, primary schools, restaurants and shops were never closed; and mask-wearing was uncommon and was not mandated throughout 2020. However, working from home was very common for white-collar workers (Baral et al., 2021; Ludvigsson, 2020). In general, social distancing was encouraged through public-oriented guidelines rather than through policy-enforced mandates (Baral et al., 2021). Here, we also provide a regional comparison of mortality patterns within Sweden. However, there were no important regional differences in policy responses to COVID-19. While regional travel was discouraged during some periods, no travel restrictions were enforced (Ludvigsson, 2020).

There was a decrease in life expectancy for men and women in Sweden in 2020 that was, of course, due to the impact of COVID-19. In the remainder of our study, we demonstrate how this decrease (Section 3.1) was reflected by mortality changes in different age groups of women and men (Section 3.2), different months of the year (Section 3.3) and different regions of Sweden (Section 3.4). Furthermore, we show the extent to which the changes in life expectancy can be attributed to registered COVID-19 deaths, and to any remaining excess or reduced mortality from other causes of death in different age groups (Section 3.5). We conclude by estimating how excess mortality in 2020 affected measures of cohort life expectancy (Section 3.6). To our knowledge, such a comprehensive review of excess mortality for a country in 2020 has not previously been produced, although similar reviews for other countries will likely be available in the future.

Our study differs from previous studies on the levels and patterns of excess mortality in several ways. In particular, we compare the observed mortality in 2020 with the predictions from a pre-pandemic mortality forecast for 2020 produced by Statistics Sweden. Moreover, we primarily use the forecasted mortality rates for 2020 as our baseline, instead of the observed mortality during one or several pre-pandemic years, which can also be used as a baseline to which we compare any mortality deviations during the pandemic (e.g., Aburto et al., 2021b; Islam et al., 2021). Our approach has two advantages. First, it accounts for the secular trend of falling mortality that has been observed in most developed countries, including in Sweden (Drefahl et al., 2014). Simply using a pre-pandemic average of mortality rates as a benchmark could overestimate the mortality that would have occurred in the absence of COVID-19, and produce levels of excess mortality during 2020 that are unrealistically low. Second, the forecasted mortality values are based on the Lee-Carter method for extrapolation (described in Statistics Sweden, 2018) based on data for a longer time period that runs up to the time just before the outbreak of the pandemic, which produces more stable rates than those derived from shorter extrapolation windows. However, the use of this approach could also turn into a disadvantage if a new trend needs to be given more weight than it is given in the Lee-Carter design. Thus, we also compare the observed mortality patterns during 2020 with those of an observed average for the years 2017–2019, as this approach has been standard in much of the previous literature, and is necessary for describing dimensions of mortality change that are not considered in the forecasts of Statistics Sweden.

2 Data and method

2.1 Data

The following analyses are based on information from two different data sources. Our measures that use the number of deaths and the population numbers in different subgroups are derived from Statistics Sweden's population statistics, which provided us with ordered data on deaths and population size at the regional and monthly levels for the years 2017 to 2020, including the pandemic year. We supplemented this information with data from Statistics Sweden's official population forecast for 2020 onward (Statistics Sweden, 2020a). We attach the data delivered to us by Statistics Sweden as a supplemental file (available at https://doi.org/10.1553/populationyearbook2022.res2.2). Other demographic data can be downloaded freely from Statistics Sweden's data repository website, including data on all of the rates they used for their population forecasts. In the discussion section, we briefly relate our estimates to those based on other recent data sources, such as the Human Mortality Database series on Short-Term Mortality Fluctuations (STMF).

Additionally, the Swedish Public Health Agency has provided us with data on COVID-19-related deaths. These data are based on the agency's collection of data on diseases covered by the Swedish Communicable Diseases Act, SmiNet (National Board of Health and Welfare, 2020a; Public Health Agency, 2021a). The reporting of such deaths is based on information on individuals who had received a positive test result for COVID-19. This information has since been combined with statistics on all deceased individuals from the Swedish Tax Agency's register, which serves as a basis for the population register. If a person dies within 30 days of receiving a laboratory-confirmed positive test result, he or she is counted as having died from COVID-19. Some sorting is done for individuals with causes of death that were clearly unrelated to COVID-19 (for example, traffic accidents), but as a rule, data on causes of death are not used in this data source. Individuals who die more than 30 days after receiving a confirmed positive COVID-19 test result, or who have never tested positive for COVID-19, are not included in the data material. According to the Public Health Agency, these reporting practices have resulted in some cases of people who actually died from COVID-19, but who had not been registered as having a positive test result, not being counted as having died from COVID-19 (Public Health Agency, 2021a). Unlike our demographic data from Statistics Sweden, the raw data on COVID-19 deaths cannot be shared due to ethical restrictions, but all rates and estimates based on these data are available upon request.

The definition of the number of COVID-19-related deaths differs somewhat from the cause-of-death-based statistics produced by the Swedish National Board of Health and Welfare. We have access to both of these data sources, and briefly evaluate the differences in outcomes between those sources in our appendix. While each of these sources has strengths and weaknesses, they are in broad agreement, and would produce results similar to those presented here.

When reporting non-COVID-19-related deaths, we use data on the total number of deaths in a given population group minus the COVID-19-related deaths for the same population group.

2.2 Method

With the help of data from the Swedish Public Health Agency and Statistics Sweden, we base our analyses on the observed number of deaths and the population size for each age in 2020. We have received comparable data from Statistics Sweden for 2017–2019. We have created life tables based on the data for 2020 and the average of the data for the preceding three years. We also use age-specific death rates from Statistics Sweden's forecast for 2020. We rely on period-based life tables for most of our calculations. For our calculations with five-year age groups, we use the weighted average of the death risks in one-year age groups. We close our life tables at age 100.

For our decomposition of the changes in life expectancy, we use a method introduced by Arriaga (1984) where ${}_n\Delta_x$ is the contribution to the difference in life expectancy between population 1 and 2 from all-cause mortality in age group x to $x + n$. The method is based on the conventional life table functions l_x, T_x , and ${}_nL_x$.

$$ {}_n\Delta_x = \frac{l_x^1}{l_0^1} \cdot \left(\frac{{}_nL_x^2}{l_x^2} - \frac{{}_nL_x^1}{l_x^1} \right) + \frac{T_{x+n}^2}{l_0^1} \cdot \left(\frac{l_x^1}{l_x^2} - \frac{l_{x+n}^1}{l_{x+n}^2} \right) \tag{1} $$

We expand the decomposition with:

$$ {}_n\Delta_x^i = {}_n\Delta_x \cdot \frac{{}_nR_x^i(2) \cdot {}_nm_x(2) - {}_nR_x^i(1) \cdot {}_nm_x(1)}{{}_nm_x(2) - {}_nm_x(1)} \tag{2} $$

where the ${}_n\Delta_x^i$ is the contribution to the difference in life expectancy for the cause of death i in age group x to $x + n$, and the contribution this cause of death makes to the difference in life expectancy between the two populations. ${}_nm_x(1)$ and ${}_nm_x(2)$

represent the death rate for age group x to $x + n$, and ${}_nR_x^i\,(1)$ and ${}_nR_x^i\,(2)$ represent the proportion of deaths from the cause of death i for age group x to $x + n$ in the two populations. As was described in the first equation, ${}_n\Delta_x$ is the difference in mortality from all causes of death in age group x to $x + n$.

In Section 3.5, we use the Years of Potential Life Lost (YPLL) method. YPLL is calculated according to Equation (3) below, where d_x is the number of deaths at age x (in our case, COVID-19 deaths in 2020), and e_x is the remaining life expectancy at age x (in our case, according to Statistics Sweden's forecast), which is summed up over all ages. The limitations and the implicit and explicit assumptions of this method are described by Gardner and Sanborn (1990). The aim of this method is to quantify the extent of a change that negatively affects mortality at the population level.

$$YPLL = \sum_{x}^{\infty} d_x \cdot e_x \tag{3}$$

In our study, we also make forecasts of how excess mortality in 2020 has affected cohort life expectancy in Sweden using information on future mortality patterns based on the official Swedish population forecasts. For our cohort life expectancy table, which we present in Section 3.6, we use the death rates for 2020 linked to the population projection for 2020–2070 (Statistics Sweden, 2020a). A more detailed description of how these projections were generated is available in Statistics Sweden's (2020a) population forecasts. In our case, we calculate cohort life expectancy tables in which we compare the impact of the observed mortality in 2020 with that of the forecasted mortality for the same year, while keeping the forecasted death rates for 2021 onward intact. In other words, we examine how a single year of excess mortality in 2020 affects cohort life expectancy, assuming that the death rates in future years will be neither higher nor lower than the death rates that were forecasted before the pandemic. We show changes in life expectancy for men and women who had reached ages 55, 65, 75, 85 and 95 in 2020. Our calculations are based on the population numbers observed at the end of 2019.[1]

In the next section, we first discuss the life expectancy trends in Sweden over recent decades, and then describe the changes in life expectancy for women and men in Sweden in 2020. We start by placing excess mortality in 2020 in a slightly longer-term context (2000–2020). We then discuss the patterns in mortality changes in 2020 by age and sex, and the patterns in excess mortality by calendar-year month during 2020, when COVID-19-related deaths were concentrated in April-May and November-December. Next, we explore the regional impact of COVID-19 deaths, examining the excess mortality patterns by region (or county) of residence in Sweden. Finally, we decompose excess mortality in 2020 by the contributions

[1] Note that these numbers refer to those individuals who reached a certain age in 2020, as this information is included in the rates used by Statistics Sweden in their forecasts. The numbers do not refer to everyone born in a single year, but rather to those born in the second half of a given year and the first half of the subsequent year.

of changes in the age-specific mortality rates and in registered causes of death. We also calculate a metric based on years of potential life lost. Finally, by combining mortality data from 2020 and cohort projections of future life expectancy, we estimate the impact of COVID-19 during 2020 on the remaining life expectancy for selected cohorts of women and men in Sweden. These analyses combined provide one of the most comprehensive overviews of the effects COVID-19 on mortality in a country, in Sweden or elsewhere.

3 Results

3.1 Changes in life expectancy and number of deaths

Life expectancy has increased steadily over the past century for women and men in developed societies, including in Sweden (Wilmoth et al., 2000; Christensen et al., 2009). However, the increases in the most recent decades in Sweden have been somewhat slower than the increases observed many other European countries. This has mainly been due to mortality at the very highest ages declining more slowly in Sweden than in other countries considered to be global life expectancy leaders (e.g., Drefahl et al., 2014). However, mortality rates at older ages for men and at younger ages for both women and men are still lower in Sweden than they are in most other countries (Drefahl et al., 2014). In 2019, a near unprecedented reduction in mortality was observed in Sweden. In the context of an average annual increase in life expectancy in recent decades of 0.1–0.2 years, life expectancy in 2019 increased by half a year for both men (0.56 years) and women (0.48 years).

Following this positive development, 2020 was the first year in a long time – indeed, since 1968 – in which a substantive decline in life expectancy occurred in Sweden. Compared to 2019, life expectancy decreased in 2020 by 0.69 years for men and by 0.40 years for women. In Statistics Sweden's previous population forecast for 2020 based on assumptions made prior to the pandemic, life expectancy in 2020 was estimated to be 0.78 years (for men) and 0.43 years (for women) higher than the values that were actually observed. Thus, Statistics Sweden's forecast of life expectancy for 2020 was only marginally higher than the observed life expectancy for 2019.

In Table 1 and Figure 1, we show the development over time of life expectancy at birth, alongside residual life expectancies at ages 65 and 85, separately for men and women. Life expectancy at birth was 84.33 years for women and 80.66 years for men in 2020, or 0.46 and 0.78 years lower than Statistics Sweden's forecasted values of 84.79 and 81.44 years for the same year. The differences were about the same size for remaining life expectancy at age 65, while they were slightly smaller for life expectancy at age 85. As can be seen in Figure 1, life expectancy in 2020 was similar to 2018 levels for women, and was similar to 2017 levels for men (see Figure 1). Thus, mortality in Sweden in 2020 reverted to the higher mortality levels documented several years earlier.

Table 1:
Life expectancy at birth, age 65 and age 85 in Sweden, for 2019, 2020 and the forecast for 2020

Life expectancy	2019 observed	2020 observed	2020 forecast	2020 minus 2019	2020 observed minus 2020 forecast
Women					
From birth (e0)	84.73	84.33	84.79	−0.40	−0.46
From 65 (e65)	22.00	21.50	21.97	−0.50	−0.48
From 85 (e85)	7.11	6.72	7.03	−0.40	−0.32
Men					
From birth (e0)	81.35	80.66	81.44	−0.69	−0.78
From 65 (e65)	19.52	18.93	19.62	−0.59	−0.69
From 85 (e85)	5.93	5.48	5.91	−0.45	−0.43

Figure 1:
Life expectancy at birth, age 65 and age 85 in Sweden, for 2000–2020, and the forecast for 2020

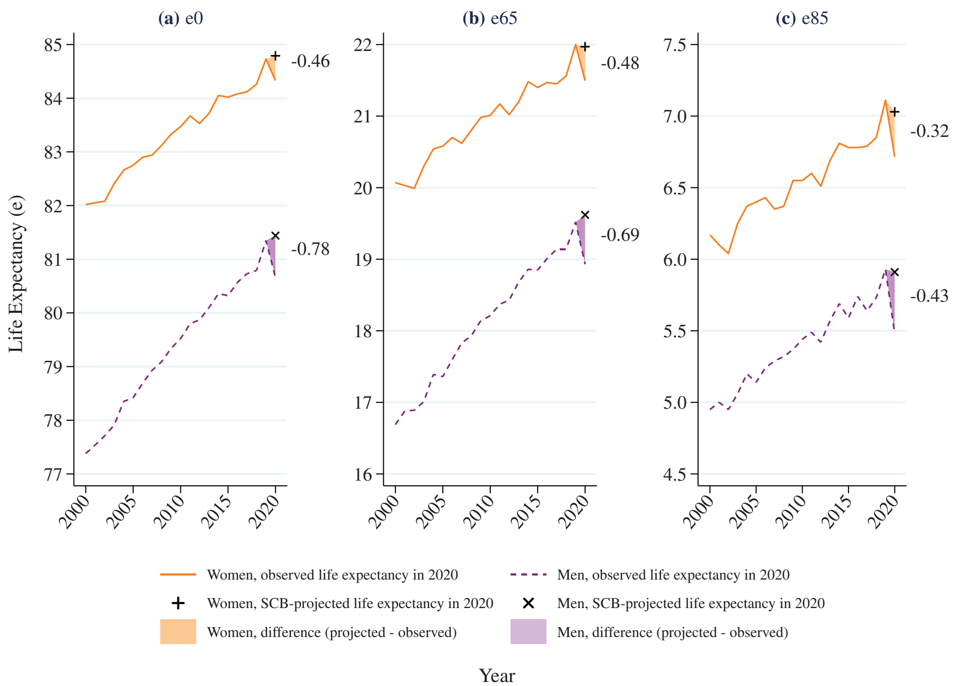
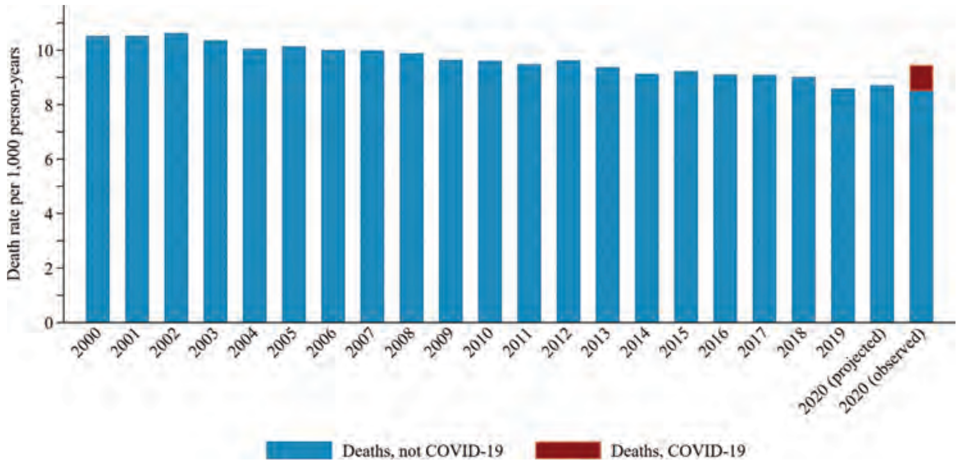


Figure 2:
Death rates per 1,000 inhabitants in Sweden, 2000–2020, and the 2020 forecast



In Figure 2, we show crude death rates calculated as the number of deceased persons in Sweden per calendar year during 1990–2020 in relation to the size of the population in each year. The figure provides the mortality per 1,000 individuals in 2020, including the portion that was due to COVID-19 mortality. The latter value is based on data on COVID-19 deaths provided by the Swedish Public Health Agency.

Figure 2 shows the same declining trend in overall mortality over time that was reported in Figure 1. However, these death rates are the product of two counteracting forces: the effects of declining mortality in each age group and the gradual aging of the Swedish population. Thus, the crude death rates per 1,000 individuals in the population are affected by changes in the population size through childbirth and migration, and also by changes in the population age structure through variations in cohort sizes among older men and women. In the short term, however, the changes in the population structure are small, and comparisons of the crude rates remain valid. For 2020, the crude death rate was 8.6 percent higher than the rate that had been forecasted by Statistics Sweden; it was 10.0 percent higher than the rate that was observed for 2019; and it was 4.9 percent higher than the rate that was observed for 2018. If we remove the number of deaths associated with COVID-19 from the total, the crude mortality rate is 2.3 percent lower than the rate that had been forecasted by Statistics Sweden. However, such a figure should be interpreted while taking into account that the number of deaths not associated with COVID-19 is not unrelated to the number of deaths associated with COVID-19. Consequently, the figure is likely overestimated.

The impact of COVID-19 played a slightly larger role in the development of the crude death rate during 2020 (Figure 2) than in the expected life expectancy

(Figure 1). This is because many COVID-19 deaths occurred at old ages, and thus did not affect remaining life expectancy as much as the increase in the absolute number of deaths itself would suggest. In the rest of our study, we focus primarily on analyses of changes in age-specific death rates, as well as calculations of the remaining life expectancy based on those death rates. A major advantage of relying on measures such as life expectancy at different ages is that they measure mortality that is independent of the age structure of a population, which is important when comparing mortality measures for different years and countries.

3.2 Age-specific death rates

In this section, we examine age variation in mortality patterns in 2020. We first present the number of deaths for different age groups during the calendar year in Table 2. We show separately the number of COVID-19 deaths and all deaths combined in the different age groups. At ages below 30, the number of COVID-19 deaths was very small (eight for women and 14 for men). The number of deaths was, as expected, highest at the older ages, regardless of whether the deaths were from COVID-19 or from other causes. During the year, the total number of COVID-19-related deaths was 9,816, while the total number of deaths from all causes was 98,124. Thus, 10.0 percent of all deaths in 2020 were from COVID-19. The COVID-19 deaths were even more strongly concentrated at older ages than deaths in general. The proportion of deaths from COVID-19 was higher among men than among women in all age groups from age 40 onward.

We then present the age-specific death rates for women and men in 2020 (Figure 3), which reflect the risk of dying during the year for individuals in different age groups. The figure has an exponential scale (whereby the distance between two scale lines in the figure corresponds to a 10-fold increase in mortality) to better showcase the patterns and the large differences in the risk of dying by age. The figure clearly shows that COVID-19-related mortality and mortality in general increase very sharply with age. For example, the age-specific death rate for men aged 40–44 years was 0.000043 deaths per person-year for COVID-19 and 0.000954 deaths per person-year for total mortality, while the respective values for women aged 60–64 years were 0.00019 and 0.00472, and the respective values for men aged 85–89 years were 0.017 and 0.136. The figure also shows that the share of COVID-19 deaths in total mortality is not the same across all ages, but is lowest at young ages, and is highest around ages 80–90.

As a next step, we compare the actual age-specific death rates for women and men in 2020 with the age-specific death rates that Statistics Sweden adopted in its latest forecast for 2020 *and* the average value of the observed death rates for 2017–2019 (Figure 4). We report the relative risk ratios: i.e., the difference in percent between the death rates as they appear in Figure 3 and those expected for 2020 in different age groups. Among older age groups, who experience significantly more deaths than younger age groups, an excess mortality rate of 10 percent leads to significantly

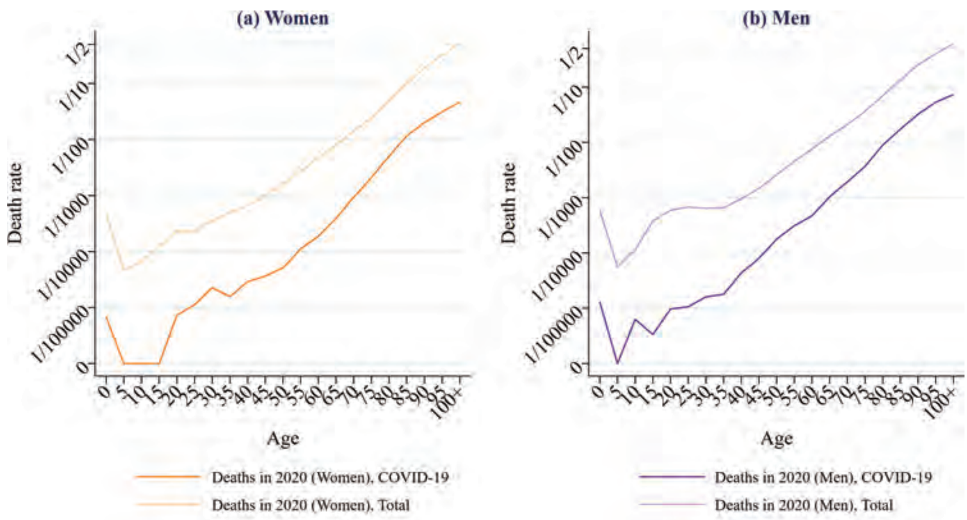
Table 2:
Number of deaths in different age groups in Sweden, all-cause mortality and COVID-19 mortality, 2020

	Women			Men		
Age group	**Deaths, COVID-19**	**Deaths, all causes**	**Deaths from COVID-19 as a % of all deaths**	**Deaths, COVID-19**	**Deaths, all causes**	**Deaths from COVID-19 as a % of all deaths**
0–29	8	348	2.3	14	786	1.8
30–34	8	126	6.3	6	241	2.5
35–39	5	157	3.2	6	221	2.7
40–44	9	208	4.3	14	308	4.5
45–49	12	327	3.7	27	497	5.4
50–54	17	541	3.1	61	881	6.9
55–59	35	846	4.1	99	1458	6.8
60–64	53	1340	4.0	134	2170	6.2
65–69	106	2199	4.8	278	3461	8.0
70–74	267	4021	6.6	523	5692	9.2
75–79	482	5723	8.4	782	7699	10.2
80–84	774	7469	10.4	1104	8639	12.8
85–89	1153	9716	11.9	1118	8750	12.8
90–94	1041	9806	10.6	801	6270	12.8
95–99	484	4912	9.9	276	2065	13.4
100+	90	1004	9.0	29	243	11.9
In total	**4544**	**48743**	**9.3**	**5272**	**49381**	**10.7**

more additional deaths than the corresponding relative excess mortality at younger ages. It appears that the observed mortality was higher than expected for men in all age groups starting at age 50, and for women in all age groups starting at age 70. The relative excess mortality among older individuals was higher among men than it was among women. Excess mortality was higher if we place greater emphasis on the comparison with Statistics Sweden's forecast than on the comparison with the average values for the 2017–2019 period. Compared with Statistics Sweden's forecast, the relative excess mortality was just over 10 percent among men aged 50 and above, it was just under 10 percent among post-retirement-aged women.

For younger age groups, we observe both excess and reduced mortality in 2020. The percentage variation between different years could be greater here, as the number of deaths was smaller. For men aged 30–49, we find reduced mortality in 2020, which could be explained by changes in behavior in response to various measures that may have discouraged different types of risky behavior. However, for women aged 30–49, we find the opposite pattern, with excess mortality being observed among women in their thirties. At very young ages, we also see some variation in relative excess and reduced mortality, with opposite patterns for men

Figure 3:
Age-specific death rates, in five-year age groups in 2020 in Sweden, for all-cause and COVID-19 mortality

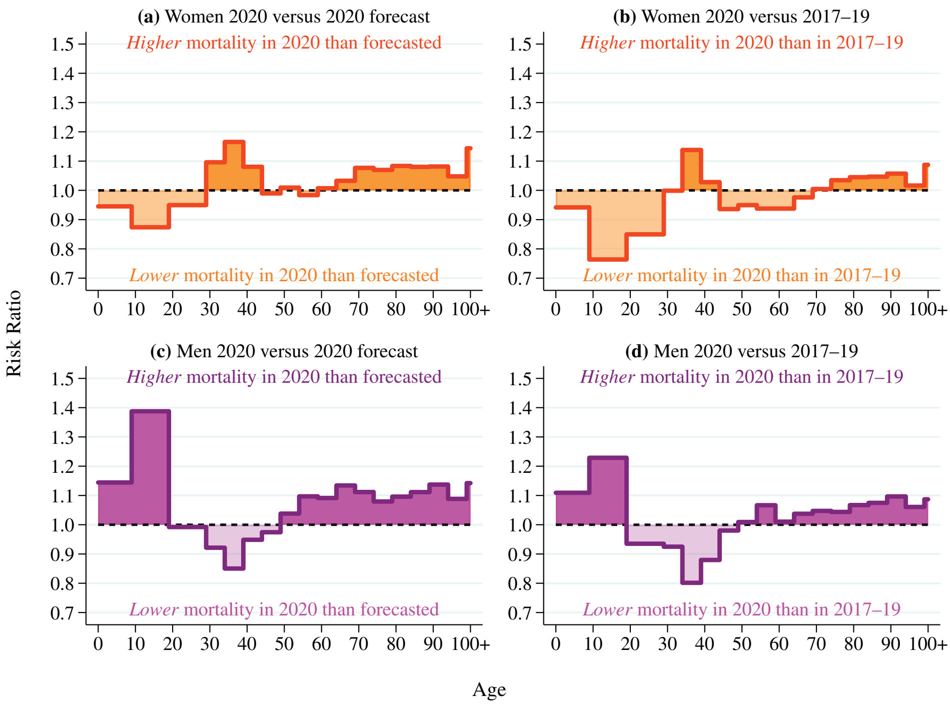


and women. For the very youngest age groups, the number of COVID-19 deaths was very small (Table 2), and the differences shown in Figure 4 may be due to variation in deaths from causes other than COVID-19. Mortality at these ages was so low that even a small number of deaths could lead to percentage changes in such comparisons.

3.3 Seasonal variation in mortality

The impact of COVID-19 was unequally distributed over 2020, with a first wave of deaths occurring in April–May 2020, and a second wave occurring in November-December 2020. Elevated mortality was also observed in January 2021. However, these deaths are not considered in this study. We show the monthly mortality trends in 2020 in Figure 5. Specifically, we present the monthly death rate per 100,000 person-years in four broad age categories (0–29, 30–64, 65–84 and 85+). We compare the death rates per month in 2020 (the solid orange line) with the observed average death rates per month for the average of 2017–2019 (the dashed orange line). Here, unfortunately, we are unable to provide comparisons with any forecasts, as Statistics Sweden does not produce such monthly forecasts. The shaded areas represent the differences between these two rates. Dark orange indicates that mortality was *higher* in a given month in 2020 than in the 2017–19 average, while light orange indicates that mortality was *lower* in a given month in 2020 than in the 2017–19 average. The purple line shows the death rate per 1,000 person-years

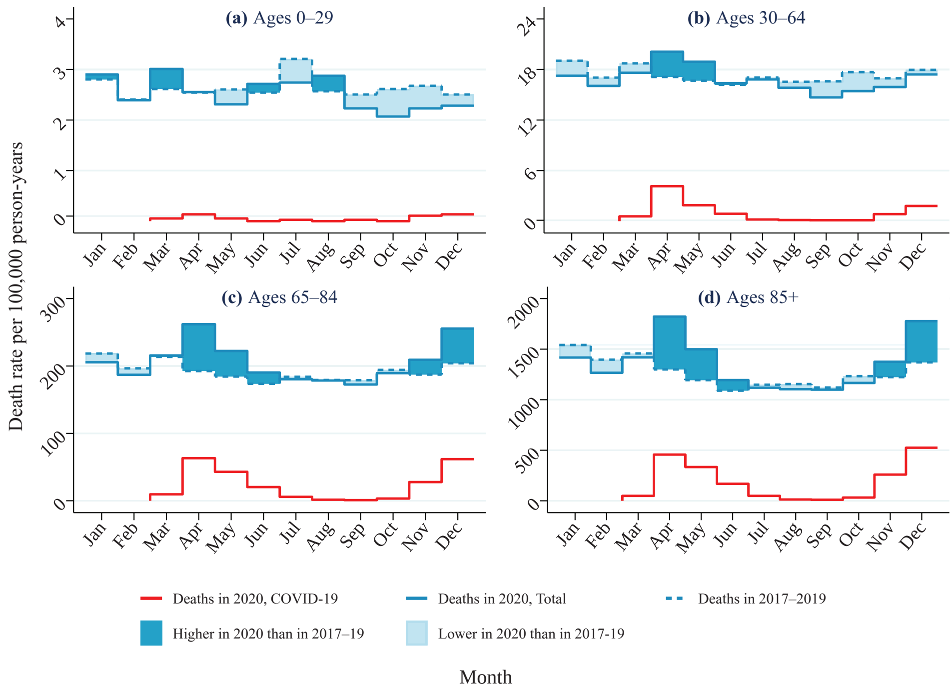
Figure 4:
Relative differences in observed mortality 2020 compared with the 2020 forecast, and the average of 2017–2019, for different age groups of women and men in Sweden



from COVID-19. Note the differences in scale across the age-specific panels. Here, at least visually, we can only make comparisons *within* the four panels, rather than *across* the panels.

Figure 5 shows that the impact of COVID-19 on total mortality in Sweden in 2020 was largest in the months of April, May (i.e., the peak of the first wave of the pandemic in Sweden), November and December (i.e., the start of the second wave), especially in the 65–84 and 85+ age groups. As expected, the trends in excess mortality in 2020 compared to the 2017–19 average closely track the fluctuations that we observe in mortality from COVID-19. Thus, larger blocks of dark orange, indicating excess mortality in 2020, correspond with higher mortality rates from COVID-19. For the 65–84 and 85+ age groups, we observe a similar or even greater impact of COVID-19 mortality on overall mortality in the second wave than in the first wave. This pattern can be seen in both the magnitude of the mortality rate from COVID-19 and the magnitude of the overall excess mortality in 2020. However, for the 30–64 age group, the mortality rate from COVID-19 was lower around the end of 2020 than it was in spring 2020. Thus, for this age group, we find excess mortality driven by COVID-19 in April and May only. We can only speculate why this was

Figure 5:
Death rates by month during 2020, by age group in Sweden, for the average of 2017-2019 and for 2020: all-cause and COVID-19 deaths

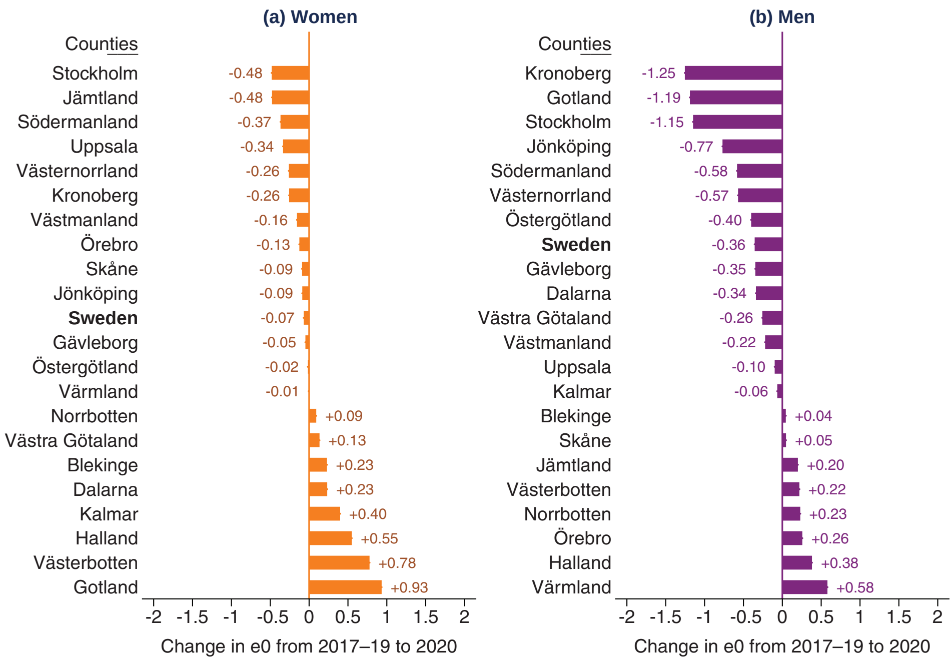


the case given the limits of our data, but one partial explanation could be that hospital treatments for COVID-19 became more effective over the year (National Board of Health and Welfare, 2020b). For the youngest age group (0–29), we find more fluctuations in excess mortality, including in the months in which COVID-19 mortality was actually the lowest (e.g., June and August). The number of COVID-19 deaths in this age group was very small, and the age range covers very different stages of mortality. These factors may explain why the pattern observed for this age group differs from that for other age groups.

3.4 Regional differences in mortality changes

Figures 6(a) and 6(b) show the impact of mortality from COVID-19 at the regional level. Here, our aim is to investigate whether COVID-19 had a similar or differential impact across counties in Sweden. The COVID-19 epidemic has had an unequal impact on different regions of Sweden, with the first phase of the pandemic being concentrated in the Stockholm region. It has been suggested that population density

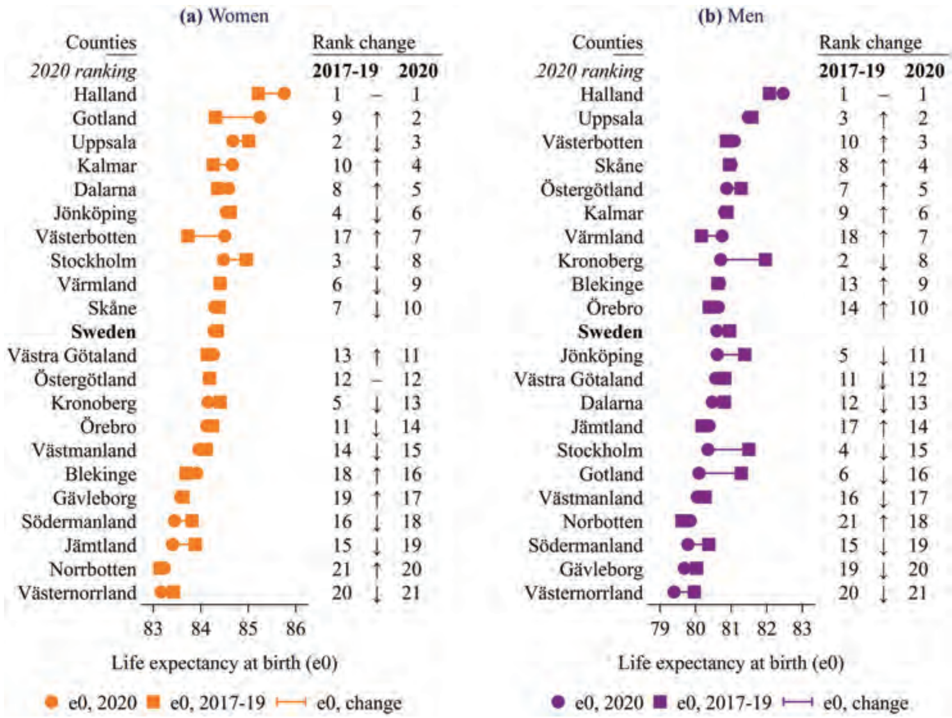
Figure 6(a):
Life expectancy (e_0) at birth in different regions of Sweden for 2017–2019 and 2020: Change in life expectancy



is a determinant of COVID-19 transmission (Quast et al., 2020). In Sweden, the highest population densities are found in the urban conglomerations centered around Stockholm, Gothenburg (Västra götaland) and Malmö (Skåne). Figure 6(a) shows the change in life expectancy at birth (from now on, e_0) between 2020 and the 2017–2019 average (i.e., e_0 in 2020 minus e_0 for the average of the years 2017–19) for women (panel a) and for men (panel b) in Sweden's 21 counties. A three-year reference period is necessary to obtain more stable comparisons when analyzing regions that have significantly fewer inhabitants than Sweden as a whole. Moreover, Statistics Sweden does not conduct forecasts at the county level. Our three-year average is based on a higher mortality baseline than that of the forecast, which illustrates the differences between the two approaches (and the advantages of using a reliable forecast as a comparison). Within both of the panels, the counties are ordered from those that were the most negatively impacted by COVID-19 (top) to that were the least – or not at all – negatively impacted by COVID-19 (bottom). As an additional comparator for the counties, we include the same metric for all of Sweden. In Figure 6(c), we include a map.

At the *country level*, e_0 in 2020 in Sweden was 0.07 years shorter among women and was 0.36 years shorter among men compared to the 2017–2019 average. At

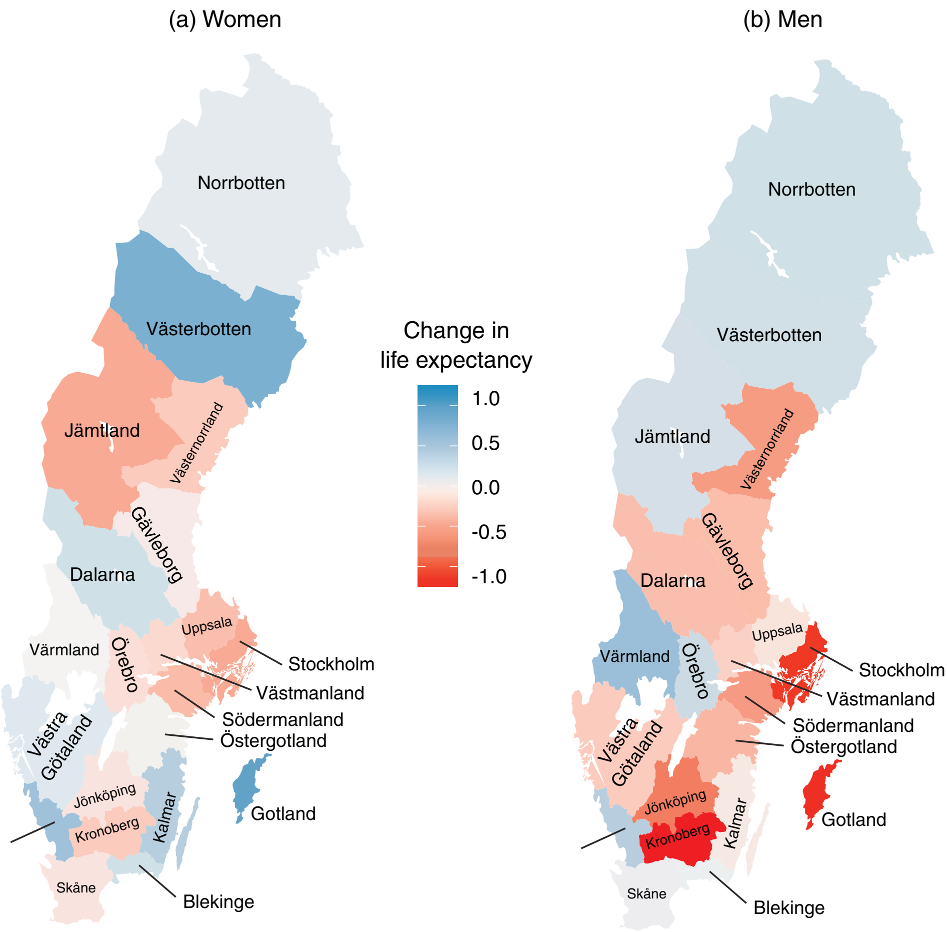
Figure 6(b):
Life expectancy (e_0) at birth in different regions of Sweden for 2017–2019 and 2020: Ranking of counties by life expectancy



the regional *county level*, we document substantial geographical variation in the impact of COVID-19, with the impact being much greater or much smaller on the populations of some counties than on the total population. We also find a significant amount of within-county variation by sex. However, we highlight the counties where the direction of the effect was similar for men and women. Some of our regions are quite small, with the populations of the counties at the end of 2020 ranging from 60,124 in Gotland to 2,391,990 in the Stockholm region, with a median value of slightly below 300,000. Among the issues that can arise when studying mortality changes in smaller regions is the impact of random variation (e.g., Scherbov and Ediev, 2011; Eayres and Williams, 2004).

Men in 14 counties experienced a decline in e_0 in 2020 relative to 2017–19, while men in seven counties experienced an increase. The changes in e_0 for men ranged from a decrease of 1.25 years in Kronoberg to an increase of 0.58 years in Värmland. Women in 12 counties experienced a decline in e_0, while women in nine counties experienced an increase. The changes in e_0 for women ranged from a decrease of 0.48 years in Stockholm to an increase of 0.93 years in Gotland. Among both sexes, Stockholm, Västernorrland, Kronoberg and Södermanland were

Figure 6(c):
Map of regional changes in life expectancy (e_0) at birth in different regions of Sweden for 2017–2019 and 2020



some of the worst affected counties, with e_0 for men and women declining in 2020 compared to 2017–19. Halland and Västerbotten were some of the least affected counties, with e_0 increasing for men and women in 2020 compared to 2017–19. However, as we alluded to above, the direction of the impact on e_0 was not always the same for men and women. The clearest example is in Gotland, where e_0 for men declined by 1.19 years (making it one of the worst affected counties for men), while e_0 for women rose by 0.93 years (making it the least affected of all counties for women). There were three other counties where e_0 for women increased while e_0 for men decreased: namely, Kalmar, Dalarna and Västra Götaland. Conversely, there were four counties where e_0 increased for men while e_0 decreased for women:

namely, Skåne, Jämtland, Örebro and Värmland. It is unclear exactly why COVID-19 mortality had a differential impact on men and women in the same county. While investigating this unexpected pattern is beyond the scope of this study, it may reflect noise in the estimates (especially for some of the smaller counties, including Gotland) or county- and sex-specific COVID-19 risk factors.

Figure 6(b) plots and ranks counties by their e_0 in 2020, and thus puts the magnitude of the losses or gains from Figure 6(a) in a wider perspective. Counties are ordered from those with the highest e_0 in 2020 (top) to those with the lowest e_0 in 2020 (bottom) for women (a) and men (b). As we can see, Halland retains its position as Sweden's most longevous county. This is unsurprising given that Figure 6(a) shows that between 2020 and 2017–19, e_0 increased by 0.55 years among women and by 0.38 years among men. Uppsala also retained its position as one of Sweden's most longevous counties, even though e_0 in the county decreased by 0.38 years among women and by 0.10 years among men. The rank change for Stockholm, previously one of Sweden's most longevous counties in 2017–19, was stark, with the county falling from third to eighth place for female e_0, and from fourth to 15th place for male e_0. We also find that some counties rose in these mortality rankings. Most notably, Västerbotten, which was formerly ranked 17th for e_0 for women and 10th for e_0 for men, rose to seventh place for female e_0 and to third place for male e_0. These rank changes were due to increases in e_0 between 2020 and 2017–19 of 0.78 years among women and 0.22 years among men. COVID-19 had the most disproportionate impact on Stockholm county in 2020.

In Figure 6(c), we map the decline in e_0. The figure confirms that the life expectancy reductions were higher in eastern Sweden than western Sweden, and it shows that neighboring regions and regions with strong transport links to Stockholm also had lower e_0 in 2020. Overall, the decline in life expectancy was most evident in Stockholm, its neighboring counties, Småland and the southern parts of the Norrland coast. The regions that were least affected by excess mortality were in western and southern Sweden and in upper Norrland. Overall, mortality was high in Stockholm, in line with its high population density; and was low in the most sparsely populated regions of Sweden. On the other hand, the two other densely populated counties in Sweden, Västra Götaland and Skåne, had below-average mortality during the year. A transmission-based explanation for the spread of COVID-19 in Sweden during 2020 – i.e., that the virus spread earlier and led to higher mortality in Stockholm and in regions with travel and migration networks centered around Stockholm than in more remote regions – may fit the regional patterns in mortality differentials better. We can see no clear regional socioeconomic pattern in excess mortality, even though mortality in the relatively wealthy region of Stockholm has been concentrated in the more vulnerable areas (Calderón-Larrañaga et al., 2020). However, the regional patterns of excess mortality have also changed during the course of the pandemic, not just in 2020, but in 2021. Stockholm was hit more severely in the early phase of the pandemic, while many regions that were less affected during the spring of 2020 were more affected during the pandemic's second and third waves that took place in late 2020 and early 2021. This changing geographical landscape of the pandemic within Sweden beyond 2020 resembles the fluctuations in the timing and the severity of COVID-19 waves that have been observed in other countries in Europe and across the world during the pandemic years of 2020 and 2021.

3.5 The impact of age-specific changes in mortality on period life expectancy

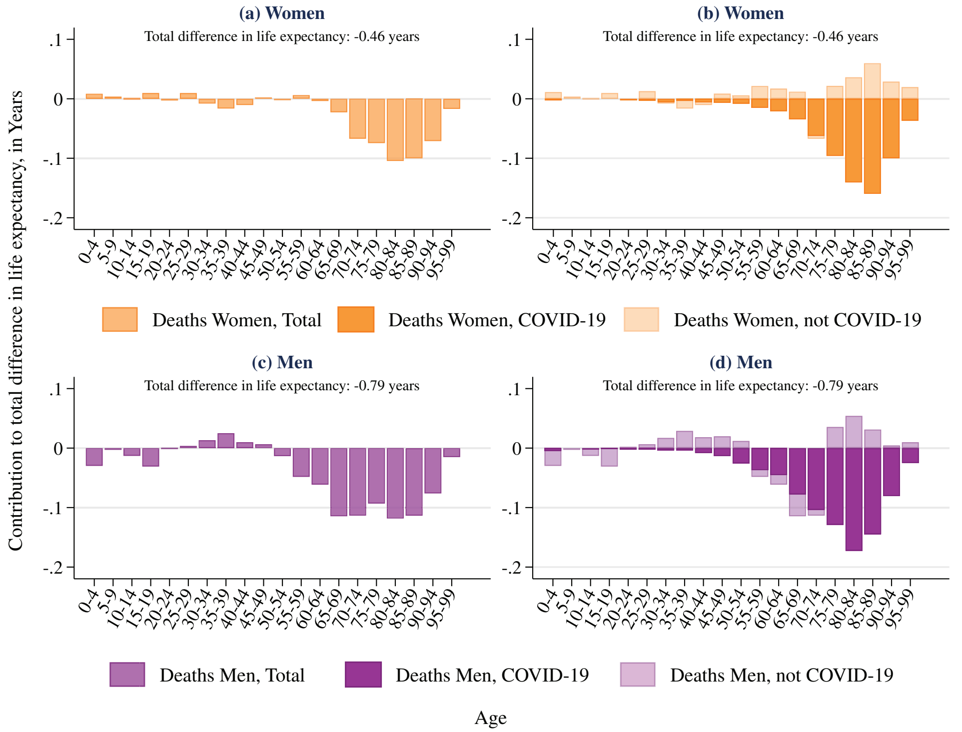
As a next step, we explore how changes in age-specific mortality during 2020 have contributed to the life expectancy changes in 2020, using an Arriaga decomposition approach as described in our methods section. In panels a and c of Figure 7, we present a breakdown of the contributions of different age groups to the total differences in life expectancy between the actual values observed for 2020 and the values that were forecasted for 2020 by Statistics Sweden. We show here the positive or the negative contributions to the reduced e_0 in 2020 (−0.79 years for men and −0.46 years for women) due to mortality changes in different five-year age groups of women and men. It is clear from Figure 7 that the decline in e_0 in 2020 was mostly due to increased mortality among men over age 55 and among women over age 70. For men, we note a positive contribution to e_0 due to mortality reductions among younger adult men. We also observe a minor negative contribution to e_0 due to increased mortality among boys, which can probably be attributed to random variation between different years, rather than to COVID-19. For women, we see few deviations in mortality in addition to the clear deviations that can be observed for the older age groups.

In panels b and d of Figure 7, we provide the same breakdown of differences in e_0, but with separate accounts of the contributions of COVID-19-related mortality and mortality from other causes. The contributions of COVID-19 mortality were always negative, while the contributions of mortality from other causes could be either negative or positive. The sum of the various bars gives the total difference between the actual e_0 in 2020 and the e_0 that was forecasted by Statistics Sweden for the same year.

The direct contributions of COVID-19-related mortality can mainly be attributed to increased mortality at older ages. For mortality that cannot be attributed to COVID-19, we see that the levels were mainly lower than expected. However, it is complicated to divide up different causes of death in this way because people who died of COVID-19 could not die of other causes during the year. Moreover, some of the reduced mortality in causes of death other than COVID-19 may be attributable to various behavioral changes, such as fewer traffic accidents or reductions in the incidence of infectious diseases other than COVID-19.

However, we can still state that we do not see any increased mortality from causes other than COVID-19 in 2020, which suggests that hypothetical displacement effects in health care had not yet significantly affected mortality in that year (Sprung et al., 2020). Moreover, the potential underreporting of COVID-19-related deaths

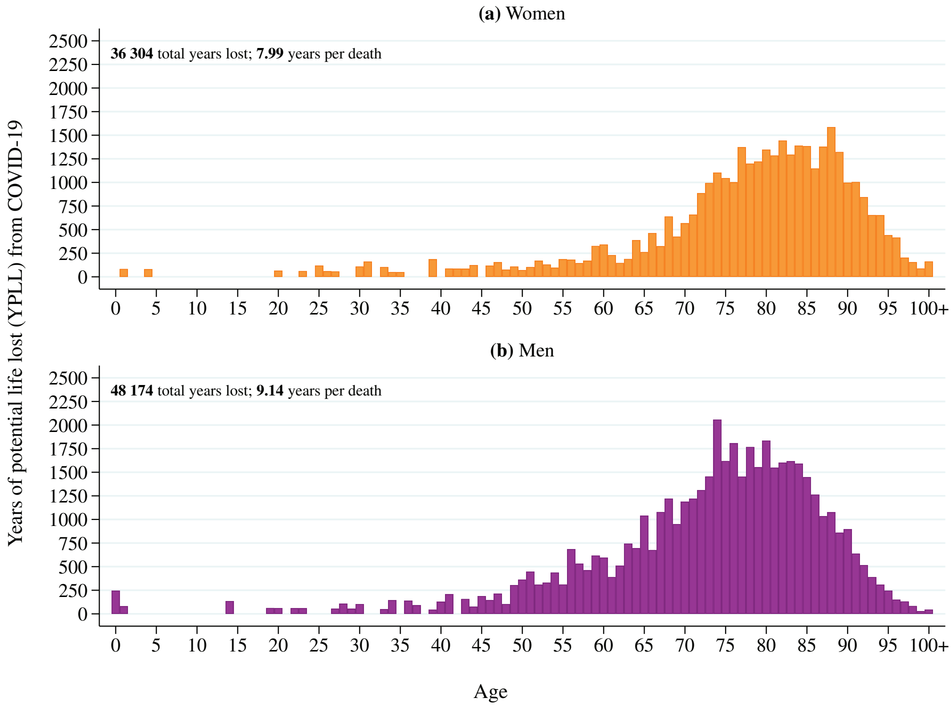
Figure 7:
Decomposition of the differences between the actual life expectancy in Sweden in 2020 the forecasted life expectancy for 2020 (in years), with positive and negative contributions of mortality changes in different age groups. Decomposition of all-cause mortality in panels a and c, and decomposition by type of mortality in panels b and d



(see appendix) could not have contributed to the patterns we observe for other types of mortality, which are shown in Figure 7.

In Figure 8, we present the Years of Potential Life Lost (YPLL) due to deaths from COVID-19 in 2020. This metric provides an alternative view, placing greater importance on the time lost than on the number of deaths. The time lost is based on the difference between the age at death and the maximum potential lifespan of a person at that age (and the summation of the differences). To illustrate, a girl who dies just after birth is assumed to have lost a potential 84.79 years of life (as per Figure 1), while a 65-year-old man who dies is assumed to have lost a potential 19.62 years of life (as per Figure 1). YPLL places greater weight on deaths that occur at younger ages, but crucially acknowledges that all deaths imply some loss of life (Gardner and Sanborn, 1990; Martinez et al, 2019). This is relevant given that some policy responses have been framed around the argument that COVID-19

Figure 8:
Years of Potential Life Lost (YPLL) attributed to deaths from COVID-19 in 2020, for women and men in Sweden by one-year age groups



mortality has mostly affected people who, even in the absence of COVID-19, would have died soon anyway from other causes (Pifarré i Arolas et al., 2021).

As Figure 8 shows, COVID-19 can be linked to 48,174 lost years of life for men and 36,304 lost years of life for women in Sweden. These values correspond to an average of 9.14 years lost per male death from COVID-19 and 7.99 years lost per female death from COVID-19. Regarding the distribution of the years of life lost, if we adopt the age groups defined in previous analyses, we find that men aged 0–29, 30–64, 65–84 and 85+ accounted for 2%, 20%, 60% and 18% of YPLL, respectively. Among women, the same age groups accounted for around 1%, 12%, 52% and 35% of YPLL, respectively. Thus, we can see that more potential years of life were lost at younger ages among men. Indeed, a fifth of all YPLL among men were concentrated between ages 30 and 64 (mostly at the upper end of this range). This is a not an insignificant share given that the death rates in this age group were lower than those in the older age groups. However, despite the greater weights placed on young deaths, 78% of all male YPLL and 87% of all female YPLL were attributed to deaths in the 65+ age groups. From a public health standpoint, these results provide an aggregated statistic on the degree to which life has been cut short in the Swedish population by COVID-19.

3.6 The impact of mortality on cohort life expectancy

Finally, we use a novel cohort approach to estimate how excess mortality in 2020 may have affected the remaining lifespan for selected birth cohorts of women and men in Sweden. We provide in Table 3 an estimate of how excess mortality in 2020 may have affected the remaining life expectancy for people in Sweden who were alive at different ages at the beginning of 2020. To do so, we use a so-called cohort life expectancy table and assumptions about future mortality patterns derived from Statistics Sweden's population forecast for 2021 onward, as described in the methods section. We compare the observed mortality in 2020 with the forecasted mortality for the same year, while retaining the forecasted mortality rates for the years 2021 onward. With this method, we estimate how much the increased mortality in 2020 affected the cohort life expectancy for men and women of different ages. Therefore, Table 3 shows the effects of COVID-19 mortality on remaining life

Table 3:
Changes in remaining life expectancy due to mortality changes at different ages during 2020, based on cohort life tables. Differences between the impact of observed mortality and forecasted mortality for 2020

Sex	Remaining life expectancy/ Number of people in life	Turned 55 years old in 2020	Turned 65 years old in 2020	Turned 75 years old in 2020	Turned 85 years old in 2020	Turned 95 years old in 2020
	Remaining life expectancy (years) with forecasted death rates	33.58	23.66	14.72	7.46	3.21
Women	Remaining life expectancy (years) with observed death rates	33.58	23.65	14.70	7.42	3.15
	Remaining life expectancy (years) with forecasted death rates	31.38	21.55	12.91	6.28	2.71
Men	Remaining life expectancy (years) with observed death rates	31.37	21.53	12.88	6.20	2.64
		Age 55	**Age 65**	**Age 75**	**Age 85**	**Age 95**
Women	Population, end of 2019	68104	54350	54018	16221	1956
Men	Population, end of 2019	69700	53745	51059	23265	5361

expectancy using an approach that, unlike those used in our previous sections, is not based on the synthetic cohorts for a single calendar year.

We show that the impact was relatively limited for 55- and 65-year-olds, but note that the effects were greater for people who were aged 85 years and older. At the age of 95, the average remaining life expectancy is relatively short (slightly more than three years for women and a little less than three years for men). It is estimated that due to the increased mortality in 2020, more than 5,000 95-year-old women had their lives shortened by an average of 21 days. The corresponding figure for 95-year-old men was 24 days. Among 85-year-olds, the average remaining life expectancy was shortened by 16 days for women and by 27 days for men. For 75-year-olds, the reduction in the average remaining life expectancy was seven days for women and 11 days for men, while for 65-year-old men, it was nine days. For 65-year-old women and 55-year-old men and women, the average reduction in life expectancy was less than a few days. To put our estimates into context, we note that the difference in the remaining life expectancy at age 65 for cohorts born between 1910 and 1920 was around 0.1 additional year per single birth year (Statistics Sweden, 2020b). Put differently, each subsequent cohort lived around 0.1 years (around five weeks) longer after age 65 than the cohort before them. Hence, for the oldest cohorts shown in Table 3, who turned age 85 and age 95 in 2020, the actual reduction in remaining life expectancy in 2020 (compared to the pre-pandemic forecast for Sweden) was around 0.04–0.08 years (around 2–4 weeks). The observed decline in cohort life expectancy was thus comparable in size to around half of a one-year cohort improvement in life expectancy. For those aged 55 to 75 years, the decline was smaller.

4 Conclusions

In our study, we examined the impact of the COVID-19 pandemic on mortality patterns in Sweden during the calendar year 2020. We found that the pandemic reversed recent gains in life expectancy in Sweden, causing period life expectancy to revert to levels last observed during the years 2017–2018. It is unusual for life expectancy to decrease to any significant extent between calendar years. The last time a significant decline in life expectancy levels for both sexes had been seen in Sweden was in 1968, although the decline in that year was less pronounced than the decrease in 2020.

The increase in mortality in Sweden in 2020 was concentrated among the older age groups, while some of the younger age groups had lower mortality than expected. Men were hit harder than women. Because the mortality increases were heavily concentrated at older ages, their impact on various age-adjusted mortality measures, such as remaining life expectancy, was smaller than the increases in the number of actual deaths would suggest. However, 2020 was indeed an unusual mortality context, as the COVID-19 pandemic led to 7,752 more deaths than had been forecasted for that year. Mortality was highest in April and December of 2020.

Our study makes several novel contributions to research on the impact of COVID-19 on overall mortality change. We focused on Sweden, a country that has received an unusual amount of attention for its COVID-19 policy response during the course of the pandemic. We provided a multifaceted account of the impact of COVID-19 on patterns of mortality change during 2020. Unlike most previous studies on this topic, we mainly used data based on forecasted mortality rates as the baseline for comparison when calculating our measures of excess mortality. While this approach has advantages as well as disadvantages, we consider a forecasted baseline to be a more plausible hypothetical counterfactual scenario than a baseline derived from the average of a few pre-pandemic years. Finally, we provide estimates of how the excess mortality in 2020 has affected the cohort life expectancy of men and women in Sweden.

Like in most other high-income countries, COVID-19 had a tangible influence on excess mortality in Sweden during 2020 (Aburto et al., 2021b; Achilleos et al., 2021; Pifarré i Arolas et al., 2021). As in other countries, the impact was greater at the older ages, and was larger among men than among women (Aburto et al., 2021b; Islam et al., 2021). Compared to the mortality levels in 2019, excess mortality in Sweden in 2020 was slightly above the average for other countries with comparable data, and was certainly above the levels observed for the other Nordic countries, to which the situation in Sweden has been compared (Aburto et al., 2021b; Achilleos et al., 2021; Islam et al., 2021). Declines in life expectancy of 0.69 years for men and 0.40 years for women in Sweden can be compared to declines of around two years for men and more than 1.5 years for women in the United States (Aburto et al., 2021b); and to declines of 0.8 to 1.5 years in Spain, Italy, England and Belgium (Aburto et al., 2021b). By contrast, the Nordic countries neighboring Sweden had very low COVID-19-related mortality in 2020, with essentially no reductions in life expectancy between 2019 and 2020 (Aburto et al., 2021b). For their analysis of the effects of the pandemic in Sweden, Aburto et al. (2021b) relied on the Short-Term Mortality Fluctuations (STMF) data series (2021). Their results were largely similar to our own, although the STMF data for Sweden showed slightly higher mortality in 2020: i.e., they found a decline in life expectancy for 2020 that was around 0.1 years larger than the decline observed in our calculations. Explaining the differences and the similarities in mortality between Sweden and other countries is an important task for future research. If other countries produce data like those presented in our study, further comparisons of mortality patterns in which adjustments for the effects of different population age structures can be made will become possible.

Our study was limited to quantifying the influence of the pandemic during 2020. However, mortality associated with COVID-19 was also significant during the first two months of 2021 (Public Health Agency, 2021b), and small numbers of COVID-19-related deaths have been reported throughout the spring, summer and autumn of 2021. As a consequence, Sweden may experience excess mortality in 2021 as well as in 2020. Furthermore, we currently lack knowledge about the possible long-term impact of COVID-19 on the health and mortality of the population. In addition, our aggregated data did not allow us to examine socioeconomic differences in outcomes, or differences between the native and the immigrant population (cf. Drefahl et al., 2020; Brandén et al., 2020; Rostila et al., 2021; Aradhya et al., 2021). COVID-19 will continue to have an impact on different aspects of Sweden's demographic dynamics over the next few years. In 2020, COVID-19 mostly had an effect on the Swedish age structure through excess mortality at older ages. The extent to which the indirect effects of COVID-19 will (continue to) spill over to other demographic processes, such as those related to childbearing and international and domestic migration, remains to be seen.

Supplementary Material

Available online at https://doi.org/10.1553/populationyearbook2022.res2.2

Supplementary file 1. Mortality by sex, age and county 2017–2020

Acknowledgements

We are grateful for financial support from the Swedish Public Health Authority, which partially financed the study; as well as for support from the Swedish Research Council for Health, Working Life, and Welfare (FORTE) for an aging research project, grant number 2016-07115. The funders of the study had no role in the study design, data analysis, data interpretation or writing of the report. The authors received funding from the Swedish Public Health Authority with a free and open mandate to write a (Swedish language) report on excess mortality in Sweden in early 2021.

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Appendix

Comparisons between different measures of COVID-19 mortality

Our analysis is based on four different mortality statistics: the average number of deaths in 2017–2019, the number of deaths in 2020, the number of deaths according to Statistics Sweden's forecast for 2020, and the number of deaths related to COVID-19 according to the Swedish Public Health Agency's monitoring system SmiNet. The National Board of Health and Welfare (*Socialstyrelsen*) produces official statistics on causes of death that can also be used to estimate COVID-19 mortality. With the help of microdata on deaths in Sweden provided by the National Board of Health and Welfare, we have been able to make supplementary estimates of mortality for different months of 2020 based on data from different sources. We have compared the mortality rates for April and December, which were the two months with the highest mortality levels in 2020.

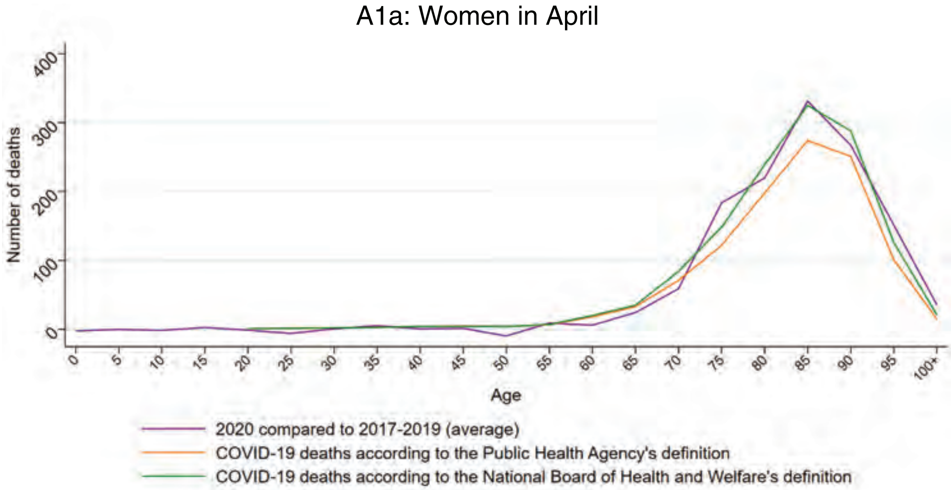
The Public Health Agency's estimates of deaths are linked to testing (Public Health Agency, 2021a). Tests were performed more frequently in late 2020 than in the spring of that year. This could mean that there was some under-reporting of COVID-19 when tests were less frequent at the beginning of the year, and that there was over-reporting of COVID-19 when tests were performed more extensively at the end of the same year (because people who died from other causes, but who had a positive COVID-19 test result, may have been included in the SmiNet statistics). The Public Health Agency (2021a) has previously described differences in the reporting of deaths in different data sources. The National Board of Health and Welfare (2021) has noted that at the end of 2020, slightly more COVID-19 deaths were reported in the Public Health Agency data than in the National Board of Health and Welfare statistics.

In Figure A.1, we show the excess mortality estimates for a spring month and a winter month in 2020 with high mortality compared to the COVID-19-related mortality estimates based on data from the Public Health Agency's SmiNet data and the National Board of Health and Welfare, respectively, for different age groups. In general, we see that the different mortality measures are quite similar. For April, the Swedish Public Health Agency's definition is slightly below the definition based on causes of death, and is also below our measure based on excess mortality. This is probably because SmiNet underestimated COVID-19 mortality to some extent during the beginning of the epidemic due to lower testing (Public Health Agency, 2021a). The total number of COVID-19 deaths for 2020 is 9,816 based on the data from SmiNet is, while it is 10,256 based on our summary of data from the cause-of-death register.

For December, we see the opposite pattern, as the number of COVID-19 deaths according to the Swedish Public Health Agency's definition is slightly higher than when COVID-19 deaths are defined according to registered causes of death. For women in December, both data sources' measures of COVID-19 mortality exceed our measure of excess mortality. For men in April, we see some excess mortality at ages 70–79 that is not visible in the data on COVID-19 deaths from the Swedish Public Health Agency or from the National Board of Health and Welfare. Our data do not allow us to examine in more detail why the different data sources deviate slightly from each other over the year.

Overall, however, we note that the measures of COVID-19 deaths based on both the Public Health Agency's and the National Board of Health and Welfare's definitions correspond well with our measures of excess mortality in 2020. We therefore believe that our study describes the patterns of COVID-19 mortality during the year reasonably well.

Figure A.1:
Number of deaths in April and December 2020 for men and women in different age groups. Excess mortality compared to 2017–2019, COVID-19 deaths according to the Public Health Agency's SmiNet, and COVID-19 deaths according to the cause-of-death register of the National Board of Health and Welfare



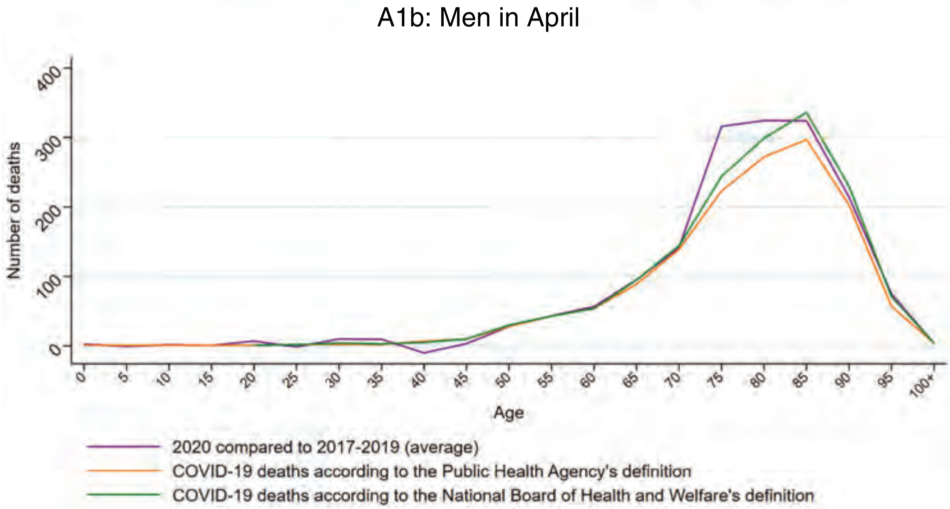
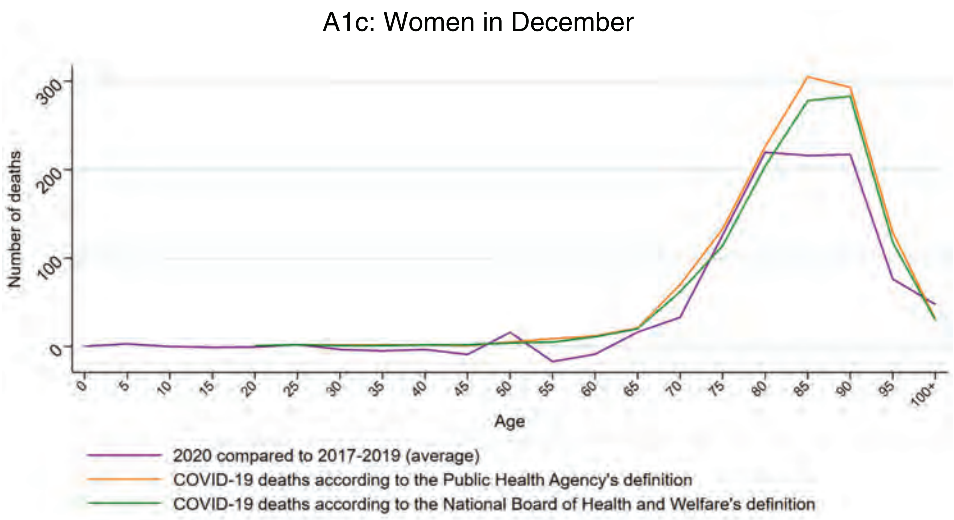
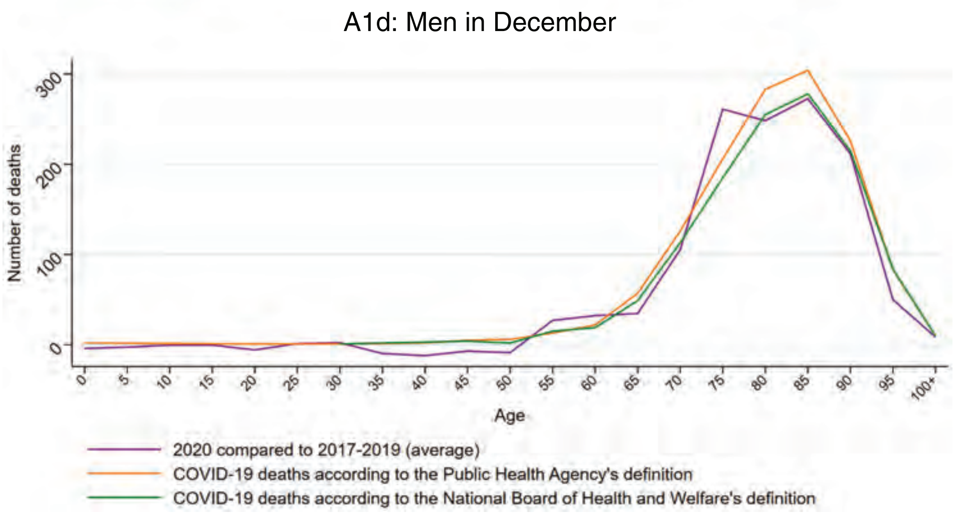


Figure A.1: Continued





Regional COVID-19 mortality in Brazil by age

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Abstract

In this study, we use ternary color-coding to visualize and compare the age structure of deaths from COVID-19 in Brazilian meso-regions using the tricolore package in R, in two different phases of the pandemic. The analysis of the age profile is important to better understand the dynamics of the pandemic, and how it has affected the population over age 25, according to age groups (25–59, 60–79 and >80 years) and subpopulations of the country. The analysis focuses on the first wave of the pandemic, until the end of 2020, and the more recent wave. Overall, the results suggest that when the two recent waves of the pandemic are compared, different spatial patterns in the distribution of deaths across the country by sex and by age emerge. While the distribution of deaths is found to be concentrated at older ages, we also observe in the more recent period some areas of the country with a concentration of deaths among younger adults. The analysis further indicates that even in areas with a younger population age structure, which could act as a protective factor against complications, the age pattern of mortality is very heterogeneous, and we do not find a clearly defined age and spatial pattern. Our results highlight the importance of looking at the distribution of COVID-19 mortality across small areas, and show that there are many different levels of the pandemic in Brazil at the same time, rather than just one.

Keywords: COVID-19; mortality; age structure; ternary color-coding; meso-regions; Brazil

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DOI: 10.1553/populationyearbook2022.res2.3

1 Introduction

The COVID-19 pandemic has negatively impacted public health worldwide, affecting trends in life expectancy at birth and placing additional burdens on health care systems. Since the early stages of the pandemic, Brazil has been among the countries hit the hardest by COVID-19 (Castro et al., 2021; Lima et al., 2021a; The Lancet, 2020). Thus, the pandemic brought a public health crisis to a country that had already become politically and socioeconomically fragile in recent years. In addition, Brazil's central authorities decided not to follow WHO recommendations, and hence ignored advice to employ measures to prevent the spread of the disease that were implemented in most countries that successfully controlled the pandemic. This failure to follow public health advice may have exacerbated the negative effects of the pandemic (Castro et al., 2021). Until September 2021, Brazil was ranked third globally in the number of confirmed cases, behind only the United States and India; and was ranked second globally in the number of deaths, surpassed only by the United States (Dong et al., 2020). Although these data reflect the large population sizes of these countries, they also indicate how their governments (mis)managed efforts to contain the pandemic. Moreover, there have been important regional disparities in the progression of the pandemic in Brazil, which motivated us to investigate and evaluate the spatial distribution of COVID-19 mortality in the country; and, in particular, to examine the question of how the pandemic spread across regions in a less developed country with a young population age structure (Candido et al., 2020; Castro et al., 2021; Lima et al., 2021a; Souza et al., 2020).

Deaths from COVID-19 have a steep age gradient, which is very similar to the age gradient observed in the general mortality rates of a population (Goldstein and Lee, 2020). The mortality rates are much higher for the elderly than they are for middle-aged and younger age groups; and in most countries, the mortality rates are higher for males than for females. Therefore, the population age structure can also be a risk factor for higher mortality, as locations with an older population can expect to have a relatively high overall number of deaths (Dowd et al., 2020; Goldstein and Lee, 2020). However, COVID-19 also appears to be more dangerous for people with previous health problems, as empirical evidence shows that infected people with cardiovascular diseases, diabetes or obesity face an increased risk of complications and of death (Jordan et al., 2020; Nepomuceno et al., 2020; Shuchman, 2020). While these research findings are important for understanding the different aspects of the spread of the pandemic at the national level, sub-national variations should also be investigated to provide support for public health interventions. In the context of the COVID-19 pandemic in Brazil, conducting sub-national analyses in Brazil is important because of the political approach taken by the federal government during the crisis. The responsibility for dealing with the spread of the disease was delegated to the municipalities. Mayors became responsible for the lockdowns, and population mobility restrictions policies and vaccination campaigns were also regulated by local authorities (Ribeiro and Leist, 2020; Storopoli et al., 2020).

In the early stages of the epidemic in Brazil, the largest numbers of deaths were concentrated in places where the first Sars-CoV-2 infections were registered (Castro et al., 2021; Lima et al., 2021a; Souza et al., 2020). However, having more knowledge about the spatial pattern of mortality (Baptista and Queiroz, 2019a; Schmertmann and Gonzaga, 2018) and about the age structure of the population (Dowd et al., 2020; Kashnitsky and Aburto, 2020) over the course of the pandemic could have helped to mitigate regional differentials in mortality caused by this disease, and improved our understanding of the differences in the age structure of COVID-19 mortality (Barreto et al., 2020). In Brazil, as has been observed elsewhere, the risk of death from COVID-19 is largely related to the age structure, the general health conditions and the socioeconomic status of the population (Borges, 2017; Clark et al., 2020; França et al., 2017). We argue that in a country characterized by major regional and socioeconomic differences (Ribeiro and Leist, 2020), which occur regardless of geographic level (Baptista and Queiroz, 2019a; Queiroz et al., 2017; Schmertmann and Gonzaga, 2018), having detailed knowledge about the age patterns of localities is essential for understanding the mortality risks associated with COVID-19. Additionally, there is a hypothesis that the incidence of COVID-19 mortality among young people has been higher in Brazil than in other countries (Guilmoto, 2020), and this spatial analysis might shed some light on the validity of this claim.

In this study, we use ternary color-coding (Baptista et al., 2021; Kashnitsky and Schöley, 2018; Schöley, 2021) to visualize and compare the age structure of deaths from COVID-19 in Brazilian meso-regions in two different stages of the pandemic. This technique encodes the relative shares in three parts of a whole – in our case, in three age groups – and provides a visualization of the distribution of data marginalized over the geographical surface (Schöley, 2021). In addition, we calculate COVID-19 case fatality rates and mortality ratios to compare outcomes across regions and population age groups. The analysis of the age profile is important, as it can help us better understand the dynamics of the pandemic (Dudel et al., 2020; Guilmoto, 2020), and how they affect different age groups (25–59, 60–79 and >80 years), and different regions of the country. While the evidence indicates that COVID-19 mortality has been higher for older individuals in most countries (Goldstein and Lee, 2020; Jin et al., 2020; Kang, 2020), recent research has pointed to the possibility that mortality rates for younger people may be higher in less developed economies. In the case of Brazil, it could be added that large regional differences may also play an important role in the risk of COVID-19 mortality (Nepomuceno et al., 2020; Rezende et al., 2020).

2 Data and methods

2.1 Data source and level of analysis

We use data from the Brazilian Ministry of Health's database, DATASUS, which is publicly available online (https://opendatasus.saude.gov.br/dataset). The Ministry of Health, through the Health Surveillance Secretariat (SVS), has been developing surveillance for specific respiratory diseases in Brazil, including, since 2009, for Serious Acute Respiratory Syndrome (SARS) due to the Influenza A (H1N1) pandemic. SARS was incorporated into the surveillance network for influenza and other respiratory viruses, and, recently (2020), COVID-19 was also included in the network.

We collected the information on April 10, 2021, when Brazil had registered 351,334 deaths from and 13,445,006 cases of COVID-19. In addition, we made a break in the data in order to understand and compare the age structure of deaths from COVID-19 in the two waves observed in the country. In this study, the first wave started on February 24, 2020 (first case registered in the country), reached its peak between the months of May and July 2020, and ended on October 31, 2020. The second wave began on November 01, 2020, and ended on April 10, 2021.

The original data are available at the individual level (case by case) and by municipality. The main limitation in using municipal-level data in Brazil is that the numbers of cases and deaths in each municipality may be small, given the limited number of people exposed to the risk of developing the disease in any given area, which may, in turn, lead to many random fluctuations in the estimates. To avoid such problems, while also pursuing our goal of analyzing and understanding regional variations, we aggregated municipalities into 137 comparable small areas (Annex 1) using the IBGE definition of geographic meso-regions. These geographical areas are statistical constructions that are aggregated and defined by regional and socioeconomic similarities, and that have not changed their boundaries over time. In addition, they have been used elsewhere (Baptista and Queiroz, 2019a,b; Baptista et al., 2021; Lima and de Queiroz, 2014; Lima et al., 2021a). We also produced estimates using standardized rates to enable us to compare COVID-19 mortality levels, thereby eliminating the effects of the population age structure (Dowd et al., 2020).

2.2 Case fatality ratio and mortality levels

In this study, we analyze the regional disparities in COVID-19 mortality based on the spatial distribution of proportional deaths from this illness, disaggregated by age group and across 137 small areas of Brazil. We also compared the overall mortality levels, by age group and sex, in the two waves of the analysis to provide a descriptive view of the pandemic in Brazil over the course of the pandemic, and to contribute to the discussion on excess mortality (Lima et al., 2021b) and on the impact of COVID-19 on life expectancy (Castro et al., 2021).

One important measure of the dynamics of the pandemic is the severity of infection. In general, examining fatality rates can improve our understanding of the severity of the disease, help us identify the population at risk, and give us some idea of how the health care system is dealing with the pandemic. There are two main measures used to investigate the effects of a disease (Green et al., 2020; Kelly and Cowling, 2013; Spychalski et al., 2020). The first measure is the infection fatality ratio (IFR), which refers to the ratio of deaths among the entire infected population. In other words, the IFR can be defined as the number of COVID-19-associated deaths divided by the total number of infections. The second measure is the case fatality ratio (CFR), which is the ratio of deaths among confirmed cases (Dudel et al., 2020; Kelly and Cowling, 2013; Sánchez-Romero et al., 2021). However, a limitation of using the CFR to measure the risk of COVID-19 mortality is that the ratio is influenced by the number of people who receive the proper diagnosis. In other words, in countries with very few tests, we may observe higher CFRs because only people who have been admitted to hospitals or who have severe symptoms have been tested. In addition, we are counting deaths at a specific point in time, but some individuals with the disease might have a positive or a negative COVID-19 test outcome.

In contrast to the case fatality ratio (CFR), the IFR is not based only on the number of confirmed cases, and should therefore not be biased by potential shifts in testing policies, although it still has some limitations. One advantage of the IFR is that it incorporates asymptomatic and undiagnosed cases. However, the biggest problem that arises in determining these ratios is accurately establishing the numbers of cases (symptomatic and total) and deaths (Kelly and Cowling, 2013). As our current data do not provide enough information to enable us to estimate IFRs, we did not pursue analyses using this indicator. Unfortunately, Brazil's COVID-19 testing rates are among the lowest in the world, albeit with considerable regional heterogeneity. While a few previous studies have estimated IFRs in the country based on seroprevalence surveys, they did not cover the areas that are the focus of this paper (Marra and Quartin, 2021).

2.3 Ternary color-coding

We used the approach proposed by Kashnitsky and Schöley (2018), later detailed by Schöley (2021), to investigate the spatial variation in deaths from COVID-19 in Brazilian meso-regions. We map the deaths from COVID-19 by age group (25–59, 60–79 and >80 years) using ternary color-coding. This visualization technique maximizes the amount of information conveyed by colors. It works by expressing the relative shares among three parts – in our case, among three age groups – as the mixture of three primary colors (we define yellow as the primary color for the 25–59 age group, cyan as the primary color for the 60–79 age group and magenta as the primary color for the 80+ age group). In other words, ternary color-coding is designed to visualize proportions of a whole; that is, anything that splits into three non-negative parts that add up to a unified whole. This approach is perhaps its biggest limitation. A second problem can occur when the data are unbalanced; that is, if the observations are concentrated in one specific age group.

In this study, we find that COVID-19 deaths are concentrated at ages 40 and older; that is, that there is little variation with regard to the visual reference point, which is the threshold that marks perfectly balanced proportions (Baptista et al., 2021; Kashnitsky and Aburto, 2019; Schöley, 2021). In addition, we have also limited the lower bound age group, which starts at age 25 instead of at zero years old. Therefore, we have changed the age point of reference to the location of the average structure of COVID-19 mortality in Brazil, and have thereby visualized the direction and the magnitude of the deviations from that average.

3 Results

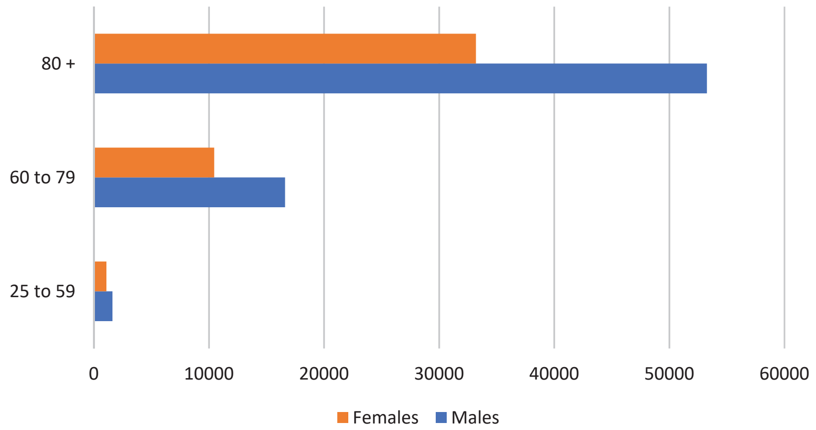
3.1 Preliminary analysis of COVID-19 mortality

Figure 1 shows the age-specific mortality rates for COVID-19. The goal here is to show the mortality differences by age and sex in Brazil. We opt to present this measure instead of the more traditional CFR, because, as we mentioned above, the latter is not an appropriate measure of COVID-19 mortality risk, since it is influenced by the number of people who receive the proper disease diagnosis. In the case of Brazil, we find that the age-specific mortality rates for males are higher than those for females in all age groups, in line with patterns observed in many other countries. However, for younger adults, the mortality risks in Brazil are shown to be greater than those observed in other countries.

Other studies have also investigated the impact of the pandemic using other measures. According to Lima et al. (2021b), Brazil had excess mortality of around 19% during the pandemic compared to previous years, but with large regional variation, with the less developed Northern part of the country experiencing much higher excess mortality than the more industrialized Southern and Southeastern parts of Brazil. In the same vein, Castro et al. (2021) estimated the impact of the pandemic on life expectancy at birth and at age 65 in Brazil. The results showed a reduction of about 1.3 years in life expectancy between 2019 and 2020, but with greater declines in the Northern than in the Southern states of the country.

Table 1 shows summary results for the country and its main regions. The distribution of COVID-19 deaths by age in Brazil follows a pattern similar to that observed in other countries. For males, we find that around 28% of deaths are of individuals aged 25 to 60, about 50% are of individuals aged 60 to 79 and 22% are of individuals aged 80 or older. For females, these values are 24%, 48% and 28%, respectively. In addition, there is some variation across regions of the country,

Figure 1:
COVID-19 mortality rates per 100,000, by age group and sex, Brazil, 2021



Source: Ministry of Health (2021).

which we will highlight later in the spatial analysis. One interesting result is that the distribution of deaths differs slightly by sex. For example, more of the female than the male deaths are concentrated at older ages, while slightly more men than women died at young adult ages.

Despite its limitations, in Table 1, we also show estimates of case fatality ratios by region of the country. The overall CFR in Brazil is 0.0280, ranging from 0.0345 in the Southeast to 0.0223 in the South. Recent data indicate that compared to all other countries in South America, Brazil has the highest CFR. Moreover, when we compare age-standardized measures for Brazil with those for 178 other countries in

Table 1:
Summary statistics, COVID-19, Brazil and regions, 2021

Region	CFR	M/F deaths first wave	M/F deaths second wave	% deaths under 60 first wave	% deaths under 60 second wave
North	0.0255	1.39	1.10	0.2227	0.2343
Northeast	0.0245	1.38	1.35	0.2619	0.2607
Center-West	0.0254	1.31	1.17	0.2893	0.2609
Southeast	0.0345	1.31	1.26	0.2901	0.2659
South	0.0223	1.43	1.37	0.2728	0.2512
Brazil	0.0280	1.36	1.25	0.2625	0.2545

Source: Ministry of Health (2021).

the world with available data, we find that the mortality levels in Brazil are greater than in 90% of these countries.

Additionally, we observe an interesting gender pattern of COVID-19 mortality in Brazil. During the first pandemic wave, the male-to-female ratio of deaths was 1.36. This means that there were 136 male deaths to every 100 female deaths. We also observe variations in this measure across regions. This ratio ranges from 1.43 in the South to 1.31 in the Center-West and Southeast. When we compare the first and the second waves, we see a decline in the gender differences in COVID-19 mortality for all regions of the country. For Brazil as a whole, the ratio went from 1.36 to 1.25 between the first and the second pandemic waves. Despite this reduction, males still had higher mortality levels than females, as shown in Figure 1. This gender differential in COVID-19 mortality has also been reported in other studies (Souza et al., 2020). Moreover, it can be argued that pre-existing gender gaps in mortality, such as those caused by the higher risks of external causes of death in males, were present even before the virus affected the population. In addition, in Brazil during the pandemic, males have accounted for almost 60% of deaths and 53% of hospitalizations related to COVID-19, and for over 70% of deaths and 40% of hospitalizations related to respiratory diseases besides COVID-19 (SARI) (Souza et al., 2020). In general, males in Brazil have higher mortality rates than females, and they have significantly higher rates of death from external causes. In the first stages of the pandemic, it was observed that mortality rates for younger adults declined due to changes in external causes of death (Santos et al., 2021). In other countries and regions, for example, the risk of dying was found to be higher for males than for females, but with a decline above age 80 (Ahrenfeldt et al., 2021). Aburto et al. (2021) also investigated the impact of the pandemic on life expectancy at birth and at age 60 for a series of countries. The study showed that the impact of the pandemic on life expectancy was greatest for males. This cause of death has been largely responsible for the elevated mortality risk among males during the pandemic, and explains a considerable share of the gender differentials in mortality in Brazil (Aburto et al., 2021). However, other empirical evidence indicates that that the restrictions imposed to limit the spread of COVID-19 have reduced external causes of death during the pandemic (Santos et al., 2021). Hence, it is possible that the new disease was responsible for causing another mortality gender gap.

3.2 Ternary color-coding results

Figure 2 (females) and Figure 3 (males) show the proportional distribution of COVID-19 deaths by age group and pandemic wave across Brazilian meso-regions. Before presenting the main findings, we show an example of how to interpret the ternary color-coding that uses females (Figure 2) for the first wave (left) as an example. Each point within the triangle represents a meso-region. The reading on the percentage of deaths from COVID-19 observed in each age group and meso-region occurs in a clockwise direction. Therefore, in this study, the percentage of deaths in the 25–59 age group can be read on the left side of the triangle; the percentage of deaths in the 60–79 age group can be read on the right side of the triangle; and the percentage of deaths in the 80+ age group can be read at the bottom of the triangle. Taking the visual reference point (point of intersection of the three lines within the triangle) as an example, which is the average structure of COVID-19 mortality in Brazil, the observed percentages are 24.5, 46.4 and 29.2 for ages 25–59, 60–79 and 80+, respectively. The colors represent the direction and the magnitude of the deviation from the average distribution of COVID-19 mortality in Brazil by age group. Yellow, cyan and magenta represent, respectively, a higher-than-average share of COVID-19 deaths in the 25–59, 60–79 and 80+ age groups. The saturation of the colors expresses the amplitude of the deviation, with perfect gray indicating a region that has an age distribution of mortality composition equal to the Brazilian average (Kashnitsky and Schöley, 2018).

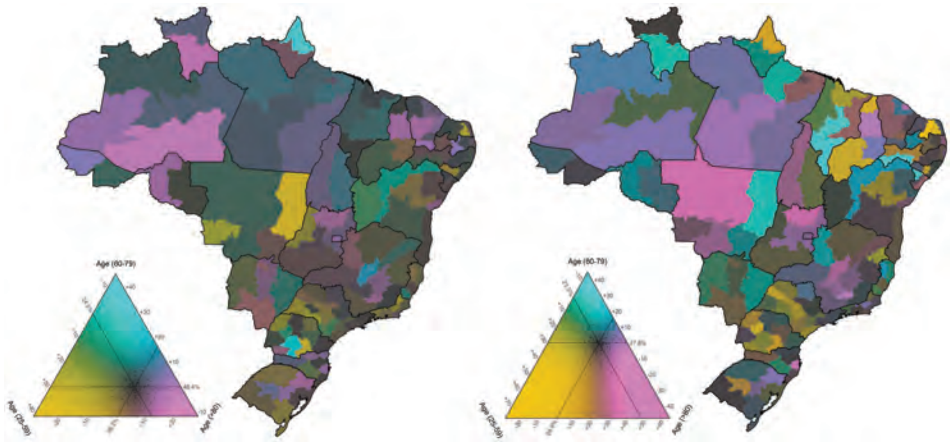
The overall results indicate that, for both sexes, the percentage of deaths in the 60–79 age group is higher in almost all meso-regions in both waves. When we compare males and females, we see that in the 25–59 and 60–79 age groups, there are more meso-regions in which the number of male deaths from COVID-19 is higher than the national average than in which the number of females deaths from COVID-19 is higher than the national average; while in the 80+ age group, the opposite pattern is observed.

Another important finding is that the gap has narrowed between the two waves studied. That is, whereas in the first wave, the number of deaths from COVID-19 among men in the 25–59 age group was higher in approximately 83% of the meso-regions; in the second wave, this share had declined to ∼67%. In addition, it is not possible to observe a clear spatial pattern (or cluster) between the meso-regions for both sexes, although the results confirm that the ternary compositions are more spread out for men, especially in the first wave, since the data are more balanced. These overall results provide us with some clues that will be explored in more detail below.

A more specific analysis of the spatial variation by sex shows that there is no clear trend in deaths from COVID-19 for females (Figure 2). Roughly speaking, when we compare the two waves, we see that in the most developed region, the Southeast, the proportion of deaths from COVID-19 increased in the 60–79 age group; and, consequently, the proportion of deaths decreased in the 25–59 and 80+ age groups. In the Center-West region, mortality increased in the 60+ age groups and decreased in the younger age groups (25–59). On the other hand, when we look at the proportion of deaths from COVID-19 in the meso-regions in the North, Northeastern and Southern regions, we see no clearly defined patterns, as the spatial variation appears to be quite heterogeneous.

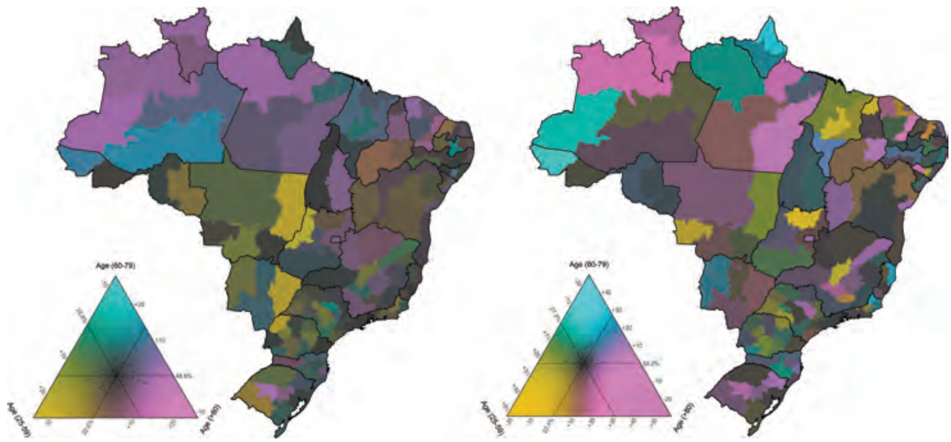
For males (Figure 3), we also observe no clear trend in deaths from COVID-19. In the Southern and Southeastern regions, the proportion of deaths from COVID-19 in the 60–79 age group increased, and the proportions of deaths in the 25–59 and 80+ age groups decreased. In the latter case, this may already be a reflection of vaccinations, which, in Brazil, followed age criteria, and occurred more quickly in

Figure 2:
Spatial distribution of deaths from COVID-19 by age group in Brazilian meso-regions, females – first wave (left) and second wave (right)



Source: Ministry of Health (2021).

Figure 3:
Spatial distribution of deaths from COVID-19 by age group in Brazilian meso-regions, males – first wave (left) and second wave (right)



Source: Ministry of Health (2021).

precisely these regions. In the other regions, the spatial variation observed is again quite heterogeneous.

4 Discussion

In Brazil, like in most other countries, COVID-19 outbreaks have varied greatly across regions and over time (Castro et al., 2021; Lima et al., 2021a). While the rhythms and stages of these outbreaks have depended on several factors, it is clear that COVID-19 mortality is strongly age-dependent (Castro et al., 2021; Dowd et al., 2020; Lima et al., 2021a; Nepomuceno et al., 2020). Additionally, the country is characterized by large socioeconomic and health inequalities, and, to a considerable extent, these differences are defined geographically (Castro et al., 2021; Lima et al., 2021a). Health inequalities are persistent in Brazil, due to factors such as differences in access to health care, the unequal provision of health care by the public and private sectors, and socioeconomic inequalities. The interaction between inequality and the COVID-19 pandemic is an important issue to be addressed. Hence, exploring the spatial pattern of COVID-19 mortality and infections across small regions of the country is of considerable relevance, as the results may shed light on how the COVID-19 pandemic has influenced pre-existing health inequalities in Brazil.

To explore the association between the pandemic and geographical inequalities in health, we used ternary color-coding to visualize and compare the age structure of deaths from COVID-19 in Brazilian meso-regions during two waves of the COVID-19 crisis. The analysis of the age structure is important for understanding the effects of the pandemic on the population as a whole (Dudel et al., 2020; Guilmoto, 2020), and by age group and region of the country – although there are, for example, differences in the underestimation of deaths and in their age structure due to the failure to correctly detect the cause of death. In addition, in all countries, COVID-19 mortality has been higher for older individuals (Goldstein and Lee, 2020; Jin et al., 2020; Kang, 2020), although recent research has pointed to the possibility that there have been high COVID-19 mortality rates at younger ages in less developed and middle-income countries. In the case of Brazil, large regional differences may also play an important role in mortality risks (Nepomuceno et al., 2020; Rezende et al., 2020). A combined analysis that takes into account the age and spatial patterns of COVID-19 deaths was previously lacking for Brazil. Our results go in the same direction as those of other studies on the effects of the pandemic. Castro et al. (2021) showed the differences in the impact of the pandemic on life expectancy at birth and at age 65 across states in Brazil, while Lima et al. (2021a) estimated the excess mortality across states in Brazil and other selected countries in Latin America. Both showed that the negative impacts were greater in the less developed states of the country; i.e., in the states located in the Northern and Northeastern regions.

Overall, our results suggest that the spatial pattern in the distribution of deaths across the country by sex differed in the two recent waves of the pandemic, and that the two waves differed in other interesting ways as well. While the distribution of deaths was concentrated at older ages, we also observed that in the more recent period, some areas of the country had high concentrations of deaths among younger adults. For example, we found that in the more developed areas of the Southeastern region, there was an increase in the proportion of deaths in the 60–79 age group, and a reduction for other ages.

The analysis also indicated that even in areas with a younger population age structure, the age pattern of mortality was very heterogeneous, and there was no clear spatial pattern. The regions with a young age structure were mainly characterized by worse health conditions overall and less access to proper health care, which might have influenced the distribution of mortality by age group and the recent evolution of the pandemic. Previous studies have shown that Brazil has smaller numbers of hospital beds and ICUs than more developed economies (Noronha et al., 2020). Furthermore, overall access to health care is uneven in Brazil, with poorer individuals living in less developed areas having worse access to proper medical care than their counterparts in the more developed regions of Brazil. The previous health conditions of the population also play an important role, and are related to the observed results. Baptista et al. (2021) pointed out that, until 2019, areas in the Northern and Northeastern regions of Brazil still had a high prevalence of infectious diseases, although a rapid increase in mortality from chronic and degenerative diseases, such as cardiovascular diseases, has also been observed.

The separate analysis of the two waves showed that Brazil did not see a reduction in pandemic conditions over the period studied. The main difference was, however, that whereas in 2020 a temporal spread was observed across the country, with some regions being hit before others; in the more recent wave, the progression of the pandemic was similar all over the country (Castro et al., 2021; Lima et al., 2021a). This scenario, combined with the weakening of measures for dealing with the pandemic, as well as the slowing of the vaccination process, are conditions that need to be considered when seeking to change the future course of the pandemic and its effects on the population. In a country characterized by high levels of regional and socioeconomic heterogeneity, general mortality risks have been much higher in certain areas due to a lack of good health care infrastructure (Noronha et al., 2020), and because large shares of the population need emergency assistance from the government, and significant numbers of elderly people with comorbidities are not practicing social isolation. The populations in these areas face a greater risk of the collapse of the health care system, which could, in turn, lead to a considerable increase in the number of deaths from COVID-19, and to an increase in the number of deaths from all causes across different age ranges due to the indirect effects of the pandemic.

Our analyses are also subject to limitations. The first limitation, which is more general, is the insufficient quality of the COVID-19 data in the country due to the lack of adequate testing and reporting (Lima et al., 2021a). For these reasons, the data may be seriously underestimated, which directly affects estimates of the mortality levels and life expectancy of the population. The second limitation is that we needed to set an “arbitrary" time frame to carry out the study, even though we are aware that COVID-19 cases and deaths are still ongoing. However, the results of the analysis contribute to our understanding of the heterogeneity of the impacts of the COVID-19 pandemic in Brazil, which was also shown using excess mortality at the state level (Lima et al., 2021a). Finally, this study did not take into account other major risk factors associated with COVID-19 deaths, such as non-communicable diseases (e.g., cardiovascular disease and cancer), obesity, smoking, diabetes and socioeconomic status (Selvan, 2020; Wolff et al., 2021). Nevertheless, we argue that investigating the geographic variation in deaths from COVID-19 across Brazilian meso-regions by age and sex is an important contribution to identifying priority areas for intervention.

Availability of data and materials

This data is publicly available at https://opendatasus.saude.gov.br.

Acknowledgements

We are thankful for the helpful comments of the editors and reviewers in preparing the manuscript. Dr. Lima receives a productivity scholarship from CNPq (number 308219/2019-8). Dr. Queiroz receives a CNPq grant (Number 303341/2028-1).

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Annex 1

Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 367–390

Are homicides and robberies associated with mortality due to COVID-19? Lessons from Urban Mexico

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Abstract

Studies on the symbiosis of crime and COVID-19 have analyzed government-mandated lockdown effects. However, it is unknown to what extent previous crime rates determined a larger and more mortal spread of the pandemic. We study how homicides and robberies in the pre-pandemic year of 2019 are associated with 2020 mortality rates due to COVID-19 in urban municipalities in Mexico. Considering sex differentials in health, exposure to the virus and experiences of violence, we study whether gender differences in mortality exist in 2020. Using publicly available data on deaths due to COVID-19 provided by the Mexican Secretariat of Health, along with a series of indicators to characterize local pre-pandemic conditions of urban municipalities, we estimate a series of ordinary least squares (OLS) regression models on age-standardized crude death rates (ASCDR) by sex. Findings show that homicides—a proxy for criminal violence that might encourage people to stay home—show significant negative associations with mortality rates. Comparatively, robberies—a proxy of local violence and safety—were positively associated with mortality rates for both sexes. Sex differences in the determinants of ASCDR are discussed.

Keywords: COVID-19; criminal violence; social determinants of mortality; gender differences in mortality; urban areas; Mexico

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DOI: 10.1553/populationyearbook2022.res2.4

1 Introduction

The link between COVID-19 and violence has been studied by analyzing to what extent physical distancing measures, lockdowns, and stay-at-home mandates impact the incidence of different types of crime, such as domestic and child abuse, crime in public spaces and crime by gangs and organized groups. For example, research on cities in the United States, Canada and Australia has shown that while lockdown measures led to reductions in thefts, robberies and crime in public spaces; and to increases in domestic violence and other types of crimes committed in private spaces, as well as in phone extortion and cybercrime; these measures had no effects on homicides and kidnapping by organized crime groups (Abrams, 2021; Boman and Gallupe, 2020; Hodgkinson and Andresen, 2020; Mohler et al., 2020; Payne and Morgan, 2020). Such findings are in line with research for Mexico City: while conventional crime declined, organized crime remained steady (Balmori de la Miyar et al., 2021). Although many of these studies took prior crime into account in their analyses of crime levels after the onset of the pandemic, it is unclear to what extent adverse social contexts characterized by high levels of violence and a lack of safety are associated with a wider spread of and higher mortality from SARS-CoV-2.

In this paper, we investigate the complex association between COVID-19 and crime and violence by considering whether crime and violence rates in communities prior to the COVID-19 pandemic were associated with 2020 mortality rates due to COVID-19 in urban Mexico. Although our analysis does not allow us to make causal claims, it sheds light on how past vulnerabilities and socioeconomic conditions in general shaped the impact of the pandemic. We also consider whether these associations vary for men and women, taking into account (1) that mortality due to COVID-19 differs by sex, and (2) that men and women experience crime differently. Understanding the association between violence and crime rates in the pre-pandemic year of 2019 and mortality rates attributed to COVID-19 in 2020 provides insights into crime as a social determinant of the severity of the pandemic. Mexico is an interesting case study due to its high levels of socioeconomic inequality, including disparities related to development levels, access to health services, demographic characteristics, gender and other indicators (El Colegio de México, 2018). Moreover, violence has not ceased over the last 15 years since President Calderón declared the so-called War on Drugs in December 2006: confrontations between cartels have increased deaths, and violence has dispersed widely from northern and western Mexico to the rest of the country (Arteaga-Botello et al., 2019). Some regions have been more affected than others, and even during the pandemic, there have been disputes over the cartel control of territories in terms of production, transportation, distribution and sales of illicit drugs (Nájar, 2020a).

2 Background

2.1 Neighborhood effects on health

The prevalence of COVID-19, similar to other diseases, is associated with social processes rooted in historical systems of income inequality, social stratification and residential segregation. Many of these processes occur locally, in the neighborhoods where people live and work, and affect exposure to the virus due to overcrowding, population density and on-the-job risk exposure. The likelihood of being infected with COVID-19, and the severity and fatality of such an infection, depend on an individual's stressors, underlying chronic conditions/comorbidities and access to quality care (DiezRoux, 2020). According to the *theory of syndemics*, the consequences of a disease can interact with social, environmental and economic factors, which can in turn, worsen the effects of the disease and exacerbate health inequities (Tsai et al., 2017). Disparities in local conditions may amplify inequalities in health behaviors, as the pandemic has created a larger health burden in already vulnerable places, affecting people from lower socioeconomic groups in urban areas the most, as evidenced in Great Britain (Kulu and Dorey, 2021). For example, perceived neighborhood conditions have shaped the impacts of COVID-19 on mental health and physical activity among adults in the United States (Yang and Xiang, 2021) and among children in Canada (Mitra et al., 2020) by adding health burdens to residents of disadvantaged neighborhoods. Neighborhoods with low poverty and a lack of negative conditions (such as low levels of crime, violence or traffic) tend to have health-promoting conditions prior to the pandemic that resulted in their residents having better mental health and more physical activity during the pandemic (Yang and Xiang, 2021). Moreover, positive neighborhood conditions can protect against other health problems: for example, neighborhood social cohesion is associated with successfully quitting smoking in Mexico (Lozano et al., 2016).

Physical distancing—commonly imposed by public health officials as a means of preventing the spread of COVID-19 (WHO, 2021)—is almost impossible among the urban poor (Wasdani and Prasad, 2020). The neighborhood exerts short-term influences on behaviors, attitudes and health care utilization, and has long-term weathering effects that accumulate over time, making populations of poorer communities more vulnerable to a given disease (Ellen et al., 2001). In urban Mexico, for example, local conditions—such as the retail food environment—have been associated with the prevalence of diabetes (Perez-Ferrer et al., 2020), exposing people to further health risks. Mexico has long had severe public health problems due to the prevalence of obesity and diabetes (Moreno-Altamirano et al., 2014). The prevalence of obesity continues to increase, regardless of socioeconomic level, region or locality (Barquera et al., 2020). Moreover, obesity and undernutrition coexist in Mexico (Rivera et al., 2014). Type 2 diabetes impacts the Mexican adult population aged 45 and older, particularly men, and homicides[1] due to criminal violence impact youth aged 15 to 44. These two public health challenges of high rates of diabetes and homicide are mainly responsible for the stagnation of life expectancy in Mexico since 2000 (Canudas-Romo et al., 2015). Obesity and diabetes are well-known comorbidities associated with COVID-19 (Denova-Gutiérrez et al., 2020; Ejaz et al., 2020), and they are major risk factors for death in patients with COVID-19, particularly for older men in Mexico (Bello-Chavolla et al., 2020; Peña et al., 2021).

Although adverse socioeconomic circumstances are consistently associated with higher mortality (Nandi and Kawachi, 2011) and low birth weight (Morenoff, 2003), these associations vary and are moderated by individual-level characteristics. Only a few studies have analyzed the neighborhood effects on the incidence of COVID-19, including a study on the incidence of COVID-19 in New York City (Sy et al., 2021); a study on predictors of COVID-19 cases and deaths at the county level in the United States that focused on the vulnerability of Latino populations (Rodriguez-Diaz et al., 2020); and a study on how socioeconomic status was associated with the incidence of and mortality from COVID-19 in Santiago, Chile (Mena et al., 2021). Overall, these analyses found that the neighborhood demographic profile and socioeconomic status matter, i.e., that higher rates of employment in frontline occupations, higher rates of heart disease and less physical distancing were positively associated with COVID-19 cases at the county level. However, there are reasons to believe this might be different in Mexico, as at the beginning of the pandemic, the incidence of COVID-19 was concentrated in large metropolitan areas with low levels of poverty (CONEVAL, 2020). Although COVID-19 spread throughout the country, poor rural and urban municipalities in Mexico sought to prevent the spread of the virus by implementing measures aimed at promoting physical distancing and restricting the entry of tourists and foreigners (García , 2020; Olivera, 2021). These measures may have had effects similar to those observed in Argentina, where, at a national level, the COVID-19 death rates were not higher in areas with lower socioeconomic conditions (Leveau, 2021). Overall, it is unclear to what extent neighborhood violence has also been a determinant of deaths from COVID-19 during the pandemic.

2.2 Health and well-being in violent areas

According to the World Health Organization (WHO), violence is not only a risk factor for the increased prevalence of communicable disease, it is also a global public health problem (WHO, 2002). Studies on how crime and violence affect the spread of diseases show different mechanisms. They can affect proximal causes of a disease: for example, by impeding vaccination (Guarino et al., 2017). Moreover,

[1] Here, we refer to intentional homicides only, and exclude accidental homicides.

high violence levels may block access to preventive health care, thus affecting disease transmission (Krystosik et al., 2018). Providing health care in dangerous areas with high urban violence may be challenging (Bellas et al., 2019). While the impact of violence on health is a global problem, it is especially concerning in low- and middle-income countries (Matzopoulos et al., 2008). In Mexico, violence—as measured by homicide rates—and poverty have been found to affect cardiometabolic risk biomarkers (Gaitán-Rossi, 2017): homicides impact fear of crime, and perceptions of risk and safety are amplified by poverty and inequality (Gaitan-Rossi and Shen, 2018). The indirect negative impact of crime and the fear of crime on health and well-being has also been observed in other contexts, according to a review of the theoretical and empirical literature (Lorenc et al., 2012). Whether this is also the case for the COVID-19 pandemic is still an open question.

2.3 Crime and violence in Mexico: Before and during the pandemic

The Mexican government implemented a strategy to reduce social mobility, limited to essential work, and promoted staying at home with a nonmandatory lockdown in March 2020 (DOF, 2020). Despite the apparent decline in reports of various crimes following the implementation of the stay-at-home measures, homicides increased in 2020. According to official data from the National Public Security System (SESNSP, in Spanish), the second-highest monthly number of intentional homicides in Mexico's recent history was recorded in March 2020, at 3,119 homicides. Post-confinement, the situation did not improve much: between March and December 2020, more than 3,000 homicides were registered over five months, and the average monthly number of homicides was 2,942 (SESNSP, 2021).

Many of these homicides were the result of armed clashes between organized crime groups fighting for territory control. Thus, criminal activity might reflect a lack of obedience to stay-at-home measures or of willingness to adhere to general public health guidance, as well as a different conception of the rule of law (International Crisis Group, 2020). The media has reported possible implications of COVID-19 for the large drug-related industry. Various criminal groups have seen the pandemic as an opportunity to continue creating and weaving their security and support networks around territories they control or are in dispute over. Diverse media outlets have documented how the *Jalisco Nueva Generación*, *Sinaloa* and *Golfo* cartels, as well as other criminal groups in northern and western Mexico, provided cash transfers, credits or groceries and basic goods to local populations (Grillo, 2020; International Crisis Group, 2020; Nájar, 2020a). These provisions occurred in the face of increasing unemployment, a reduction of income sources and lack of support from local and federal governments. In 2020, homicides and crime committed in private spaces—that is, the home and workplace—increased, especially against women, children and other vulnerable groups (Hoehn-Velasco et al., 2020). Despite an initial drop in the number of complaints registered at the beginning of confinement, crime increased in various regions and reached levels similar to or higher than those prior to 2020, according to SESNSP data and emergency call records to 911 (Balmori de la Miyar et al., 2021). It is unclear whether areas with high violence between gangs or criminal groups might indirectly promote stay-at-home decrees due to the perception of insecurity, thus reducing COVID-19 risk, or whether violence and this adverse environment discourage people from seeking testing for COVID-19 or going to a hospital if the disease becomes serious.

2.4 The current study

Few studies have analyzed the association between prior crime or violence and mortality due to COVID-19. Studies on the impact of the pandemic on crime during 2020 and beyond may suffer from reverse causality because crime may be positively associated with the incidence of COVID-19. To fill this gap in the literature, our overarching research question is: *What is the association between criminal violence and robbery prior to the pandemic and current mortality due to COVID-19?* Specifically, we ask: (1) What is the association of these two types of crime in the pre-pandemic year of 2019 with ASCDR due to COVID-19 in 2020 at the municipality level among urban municipalities in Mexico; and (2) does this association differ by sex? In other words, do different sources of crime show different associations with men's and women's COVID-19 mortality rates? This last question is relevant given the sex differences in the impact of violence and crime, in the incidence of the disease (Betron et al., 2020; Bwire, 2020) and in mortality more broadly.

3 Data, measures and methods

3.1 Data

We use publicly available data from the Mexican Secretariat of Health (DGE, 2021), with individual data for 192,797 deaths from COVID-19 as of December 31, 2020, published on July 31, 2021.[2] From January 1 to December 31, 2020, the data show a cumulated total of 71,681 female deaths and 121,116 male deaths attributed to the COVID-19. The data include information on comorbidities as well as basic demographic characteristics, such as age, sex, place of birth, municipality of residence and municipality of testing. This database considers confirmed and suspicious deaths from COVID-19, with a regular lag period of approximately

[2] These official, publicly available data are updated every day, and feed the COVerAGE-DB database, an open-access database that includes data from more than 108 countries (Riffe et al., 2021).

15 to 20 days (DGE, 2021). According to official information from the Mexican Secretariat of Health, all suspicious deaths are tested for COVID-19 independently of age (DGE, 2021).[3] Thus, we do not expect systematic age biases in COVID-19 death undercounts, although our estimates on the severity of mortality due to COVID-19 are conservative. By using data published on July 31, 2021, we reduce biases associated with late registration; and by considering confirmed *and* suspicious deaths, we reduce differences in testing availability within the country. Until vital registration data are published in December 2021 by the National Institute of Statistics and Geography (INEGI), publicly available data from the Mexican Health Secretariat on deaths attributed to COVID-19 are the best-suited data for studying mortality. We are aware that no single data source is fully accurate in terms of incidence or fatalities (Riffe et al., 2021).

We aggregate data by municipality of residence to generate the total numbers of female and male deaths due to COVID-19 in 2020.[4] Municipalities are the second-level administrative divisions of Mexico, and states are the first level. We calculate crude death rates by sex considering Mexican official population projections as of mid-2020 (CONAPO, 2018)[5] as the quotient between the total number of male (female) deaths by municipality of residence for every 10,000 inhabitants of the projected male (female) population in the municipality as of mid-2020. We further calculate age-standardized crude death rates (ASCDR) by sex using the national age structure of the population projection for both sexes as of mid-year 2020 following Preston and colleagues (2001). This standardization allows for comparisons by sex and municipalities. Of the 2,457 municipalities in the country,[6] 2,416 had female deaths and 2,420 had male deaths in 2020. We narrow the bias in COVID-19 undertesting by restricting our analyses to deaths of residents of urban municipalities, but we expect that our results will be conservative for smaller and more isolated urban areas with limited transportation to large urban and metropolitan areas where hospitals and clinics are available. Once we restrict our sample to the 1,194 urban municipalities with a population of more than 15,000, we consider 69,862 female deaths and 118,125 male deaths. Our working sample,

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[3] According to the Health Secretariat, Mexico has followed the guidelines established by the WHO, and underreporting of COVID-19 in Mexico has been decreasing over time (DGE, 2021).

[4] The first case of death due to COVID-19 in Mexico recorded in the database dates to January 2, 2021.

[5] The complete methodology of the population projections is available at the CONAPO website. These population projections have been created by a group of demographers, and constitute the official information used for national decision-making.

[6] Mexico has 2,457 municipalities located in 32 states. More than 400 municipalities are located in the state of Oaxaca, and most of these municipalities are small rural areas governed by indigenous customary law. This fine division into small areas in the state reflects Oaxaca's greater rurality and isolation compared with other states.

after we consider missing values in covariates and outliers,[7] is 1,113 municipalities for studying female mortality (cumulated 69,749 deaths) and 1,150 municipalities for studying male mortality (cumulated 117,960 deaths). The data on deaths have fewer biases associated with test availability than the data on confirmed cases. The underestimation of confirmed number of COVID-19 cases has been documented in other contexts, such as in the United States, where rural-urban differences are partially attributable to underreporting (Souch and Cossman, 2020).

3.2 Measures

We study ASCDR of COVID-19 for men and women in urban municipalities, using the logarithm transformation to account for nonlinear relationships. Our two dependent variables are the natural logarithm of male and female ASCDR by municipality, based on the projected population by sex in 2020 (CONAPO, 2018). Our key independent variables—homicides and robberies—capture violence and crime prior to the COVID-19 pandemic. We consider the natural logarithm of the rate of criminal reports in 2019 by the projected population of the municipality by 2019 (per 10,000). Intentional homicides do not include deaths by accident or by negligence, while robberies are defined as crimes in which property is unlawfully taken in public and private spaces through the use of violence. Thus, a robbery (violent) should not be confused with a theft or burglary (nonviolent). These data are provided by the SESNSP and include cases reported to a public ministry for which an investigation file was opened (SESNSP, 2021). Although these data may present biases of underreporting, these are the most recent available data at the municipality level before the pandemic and the most widely used data to study crime in Mexico. Underreporting bias is expected to be larger in rural and smaller urban areas that are isolated or are located far from a public ministry office. Underreporting of robbery and homicides might also be more common in places with high crime rates. In other words, results will be conservative due to underestimation of crime rates.

We control for a series of independent variables at the municipality level prior to the onset of the pandemic that are known to influence mortality. We control for the old-age structure of the municipality using the natural logarithm of the aging index, calculated as the relationship between the elderly population aged 65 and older and children under age 15 according to the population projection as of mid-2020. We control for the natural logarithm of population density defined as total population in the municipality per square kilometer. We include two independent variables for health conditions that are known to be associated with severe COVID-19 cases in Mexico (Denova-Gutiérrez et al., 2020) and elsewhere: namely, the natural logarithm of the prevalence of obesity and diabetes in 2018, as estimated by the Ministry of Health using data from the 2018 Mexican National Health Survey

[7] We omitted 16 municipalities with small population sizes that were considered outliers in terms of their homicide rates, robbery rates, obesity prevalence, Gini index, mean salary income and EAP.

(ENSANUT) and small-area estimation procedures (INEGI, 2021). To capture geographic and social accessibility or isolation, we define a categorical variable using the 2020 Degree of Accessibility to a Paved Road[8] provided by the Mexican Council for Evaluation of Social Development Policy (CONEVAL, 2021). At the municipality level, CONEVAL publishes the percentage of the population with very low or low access to a paved road. We define the quintile categorical variable to distinguish between very low, low, medium, high and very high (reference group) inaccessibility to a paved road. By controlling for access to a paved road, we take into account the potential underestimation bias of mortality associated with COVID-19 testing and reporting, but most importantly, we consider the isolation of communities, which may act protectively against the disease.[9] We control for economic inequality within the municipality using the Gini index for 2015, also provided by CONEVAL. Finally, we use 2020 Mexican census data (INEGI, 2021) to define two economic variables. We consider the natural logarithm of the male and female economically active population (EAP) to take into account the working-age population by sex, and the natural logarithm of mean salary income for the population aged 15–64 years.[10]

3.3 Methods

First, our descriptive analysis includes summary statistics of our dependent and independent variables (before transformations) in urban municipalities with female and male COVID-19 deaths, respectively, as well as correlation matrices. Second, we estimate a series of OLS regression models on the natural logarithm of male and female ASDCR. Each of the first two models include one of the crime indicators (homicides and robberies, respectively); the third model includes both indicators; the fourth model incorporates the aging index and the population density; the fifth model adds health conditions; and the sixth model is the fully adjusted model that adds socioeconomic variables as captured by inaccessibility, inequality, EAP and income. We also calculate the marginal effects of each variable in the fully adjusted models. To illustrate the associations between crime and mortality, we

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[8] This is one of the indicators used in multidimensional poverty included by law, and estimated by CONEVAL.

[9] Preliminary analyses considered poverty instead of accessibility to a paved road as well as years of schooling. We prefer to use access to a paved road over poverty and other indicators due to the higher goodness of fit in the estimated models, and because it takes into account geographical and social connectivity. The most recent indicators of poverty at the municipality level published by CONEVAL, the agency that is responsible for publishing such indicators by law, are only multidimensional poverty indicators, and are available for 2015. Marginality (a widely used indicator in Mexico, calculated as an index similar to HDI) is available for 2015 and 2020 at the municipality level.

[10] We decided to include the continuous variable for parsimony, but results are robust to the inclusion of mean salary income as continuous or categorical variables using deciles, as well as to the 2015 and 2020 marginality index, and the multidimensional poverty for 2015.

show graphs of the average estimated ASCDR at different levels of the logarithm of rates of reports of homicides and robberies. We perform heteroskedasticity and multicollinearity tests, and we use BIC and AIC indicators of goodness of fit.

4 Results

4.1 Descriptive analysis

Similar to other countries, the number of deaths due to COVID-19 in Mexico in 2020 was higher among men than among women. Table 1 shows summary statistics for selected characteristics for municipalities with female and male deaths displayed separately. Mean and median ASCDR due to COVID-19 are 45% and 50% higher, respectively, for men than women. Overall, indicators do not differ much for municipalities with male or female deaths. Urban municipalities with female deaths have similar but slightly higher average rates of intentional homicides and robbery than urban municipalities with male deaths (2.09 and 2.08 homicides per 10,000; and 32.57 and 31.7357 robberies per 10,000, respectively). The average aging index is 31% of adults aged 65 years and older for every child younger than 15. Female labor force participation in Mexico is low: the mean percentage of female EAP is 45.2% compared with an average male EAP of 77.0%. In urban municipalities with deaths due to COVID-19, approximately 9% of the population, on average, has low accessibility to paved roads. The median Gini index is 39.9 for both types of municipalities. In terms of health conditions, the average prevalence of obesity at the municipality level is more than 1 in 3; and of diabetes, more than 1 in 10. As we noted previously, these two comorbidities are important risk factors for mortality associated with COVID-19. Finally, the average salary income at the municipality-level is over 6,000 pesos per month (approximately US $300).

In Mexican urban municipalities, homicide rates and robbery rates are negatively correlated with the Gini index even if this correlation is small (see Table 2). As expected, homicide and robbery rates are positively correlated in both types of urban municipalities. Although the correlations of variables used in the model could be considered low, a couple of them are above 0.5 and worth noting. First, the correlation of the aging index with diabetes is as expected. Second, the female EAP and the robbery rate in municipalities with female deaths reflect greater female labor force participation in larger and more-affluent urban areas. For future reference, Appendix A shows scatterplots for these variables (see Figures A.1 and A.2).

4.2 Results: OLS regression models

Table 3 shows the results from a series of OLS regression models on the natural logarithm of female and male age-standardized crude death rates (ASCDR) due to COVID-19 of urban municipalities in Mexico. In the unadjusted models that

Table 1:
Summary statistics of selected characteristics of urban municipalities in Mexico

	Urban municipalities with female cases										
	ASCDR (per 10,000)	**Homicides (per 10,000)**	**Robberies (per 10,000)**	**Aging index**	**Population density**	**Obesity (%)**	**Diabetes (%)**	**Inaccessibility (%)**	**Gini index**	**Female EAP (%)**	**Mean income**
Minimum	0.02	0.00	0.00	0.06	1.54	15.25	5.85	0.00	30.00	15.00	1430.70
Maximum	3.12	20.35	291.64	1.35	18057.01	66.97	17.97	94.22	56.00	69.90	39423.30
Std. Dev.	0.57	2.23	34.13	0.12	1797.19	6.53	2.07	13.52	3.28	7.76	2875.35
Median	0.64	1.35	20.48	0.29	110.17	34.28	10.17	1.97	39.00	46.10	5820.20
Mean	0.79	2.09	32.57	0.31	577.92	35.09	10.46	8.38	39.86	45.18	6201.58
N	1113	1113	1113	1113	1113	1113	1113	1113	1113	1113	1113
	Urban municipalities with male cases										
	ASCDR (per 10,000)	**Homicides (per 10,000)**	**Robberies (per 10,000)**	**Aging index**	**Density**	**Obesity (%)**	**Diabetes (%)**	**Inaccessibility (%)**	**Gini index**	**Male EAP (%)**	**Mean income**
Minimum	0.03	0.00	0.00	0.06	1.54	13.48	5.85	0.00	30.00	56.60	1214.70
Maximum	4.78	20.35	291.64	1.35	18057.01	66.97	17.97	94.22	56.00	89.40	39423.30
Std. Dev.	0.80	2.22	33.92	0.12	1770.02	6.67	2.08	14.13	3.30	3.92	2890.51
Median	0.96	1.33	19.77	0.29	107.80	34.18	10.16	2.23	39.00	77.00	5770.25
Mean	1.14	2.08	31.73	0.31	562.85	34.84	10.42	9.00	39.87	76.98	6105.73
N	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150

Source: Authors' own calculations with data from DGE, SENSP, CONEVAL and INEGI.

Table 2:
Correlation matrix of continuous variables used in the analysis for municipalities with female (A) and male (B) deaths due to COVID-19

A. Females

	ln(ASCDR)	ln(Homicide rate)	ln(Robbery rate)	ln(Aging index)	ln(Density)	ln(Obesity)	ln(Diabetes)	Gini index	ln(Female EAP)	ln(Income)
ln(ASCDR)	1									
ln(Homicide rate)	0.1018	1								
ln(Robbery rate)	0.5016	0.2855	1							
ln(Aging index)	−0.0393	−0.0095	0.0063	1						
ln(Density)	0.365	0.0351	0.4596	−0.1515	1					
ln(Obesity)	0.3593	0.0799	0.2156	0.0089	−0.0436	1				
ln(Diabetes)	0.1355	0.0583	−0.0221	0.5871	−0.1273	0.2599	1			
Gini index	0.3718	0.1006	0.3858	−0.1736	0.4314	0.1732	−0.0991	1		
ln(Female EAP)	−0.1971	−0.0562	−0.1355	0.0177	−0.1186	−0.1905	−0.0856	0.0128	1	
ln(Income)	0.5981	0.1524	0.5912	0.109	0.3315	0.4106	0.0359	0.3858	−0.2229	1

B. Males

	ln(ASCDR)	ln(Homicide rate)	ln(Robbery rate)	ln(Aging index)	ln(Density)	ln(Obesity)	ln(Diabetes)	Gini index	ln(Male EAP)	ln(Income)
ln(ASCDR)	1									
ln(Homicide rate)	0.1192	1								
ln(Robbery rate)	0.5638	0.3044	1							
ln(Aging index)	0.0028	0.0129	0.0564	1						
ln(Density)	0.3667	0.0303	0.4377	−0.147	1					
ln(Obesity)	0.4598	0.0927	0.2737	0.053	−0.0355	1				
ln(Diabetes)	0.1581	0.076	0.028	0.6009	−0.1225	0.2813	1			
Gini index	−0.181	−0.0402	−0.1052	−0.3386	−0.0542	−0.0396	−0.2552	1		
ln(Male EAP)	−0.1581	−0.0445	−0.1308	0.0046	−0.1158	−0.1868	−0.0895	−0.0327	1	
ln(Income)	0.6448	0.176	0.6298	0.156	0.3139	0.4584	0.083	−0.2418	−0.208	1

Source: Authors' own calculations with data from DGE, SENSP, CONEVAL and INEGI.

Table 3:
OLS regression models on the natural logarithm of the ASCDR due to COVID-19 in Mexican urban municipalities

	Female							Male						
	ln(Female ASCDR due to COVID-19)							ln(Male ASCDR due to COVID-19)						
	I	II	III	IV	V	VI	Marginal effects on ASCDR	I	II	III	IV	V	VI	Marginal effects on ASCDR
ln(Homicide rate)	0.093***		−0.041*	−0.026	−0.038*	−0.037*	−0.026*	0.108***		−0.052**	−0.038*	−0.043**	−0.042**	−0.043**
ln(Robbery rate)		0.370***	0.380***	0.321***	0.270***	0.108***	0.075***		0.400***	0.413***	0.365***	0.282***	0.129***	0.134***
ln(Aging index)				−0.039	−0.257***	−0.398***	−0.276***				−0.011	−0.193***	−0.361***	−0.375***
ln(Density)				0.086***	0.113***	0.027*	0.019*				0.075***	0.111***	0.0337***	0.035***
ln(Obesity)					1.123***	0.309***	0.214***					1.427***	0.733***	0.762***
ln(Diabetes)					0.755***	0.977***	0.677***					0.577***	0.746***	0.776***
Inaccessibility														
Very low						0.493***	0.299***						0.650***	0.576***
Low						0.519***	0.320***						0.643***	0.567***
Medium						0.411***	0.239***						0.494***	0.401***
High						0.180***	0.093***						0.302***	0.221***
Very high						0	0						0	0
Gini index						0.002	0.001						0.015***	0.016***
ln(EAP)						0.274**	0.190**						−0.809**	−0.841**
ln(Income)						0.753***	0.522***						0.613***	0.637***
Constant	−0.568***	−1.633***	−1.648***	−1.942***	−7.920***	−11.52***		−0.186***	−1.314***	−1.333***	−1.576***	−8.116***	−11.99***	
N	1113	1113	1113	1113	1113	1113		1150	1150	1150	1150	1150	1150	
AIC	2762.3	2451.3	2450.6	2421.2	2260.5	2016.0		2845.4	2421.9	2418.8	2394.8	2146.1	1855.5	
BIC	2772.4	2461.4	2465.6	2446.3	2295.7	2086.2		2855.5	2432.0	2434.0	2420.1	2181.4	1926.2	

Notes: $^{*}p < .1$, $^{**}p < .05$, $^{***}p < .01$; Marginal effects (dy/dx) are estimated for the equation exp(predicted ln(female/male ASCDR)) on Models V for female and male mortality, respectively.

Source: Authors' own calculations.

include them one at a time (I and II), 2019 crime rates are positively associated with ASCDR in 2020. The direction of the association between homicide rates and mortality changes after we control for aging and population density for men (Model IV). Fully adjusted models (VI) show a negative significant association ($p < .1$) between intentional homicide rates and female and male ASCDR, and a positive association ($p < .001$) between robbery rates and ASCDR for both sexes. In other words, homicides (a proxy for criminal violence) and robbery (a proxy for safety concerns) in the pre-pandemic year of 2019 have different associations with ASCDR due to mortality in 2020. In both cases, the marginal effects of crime rates are larger for male mortality than for female mortality.

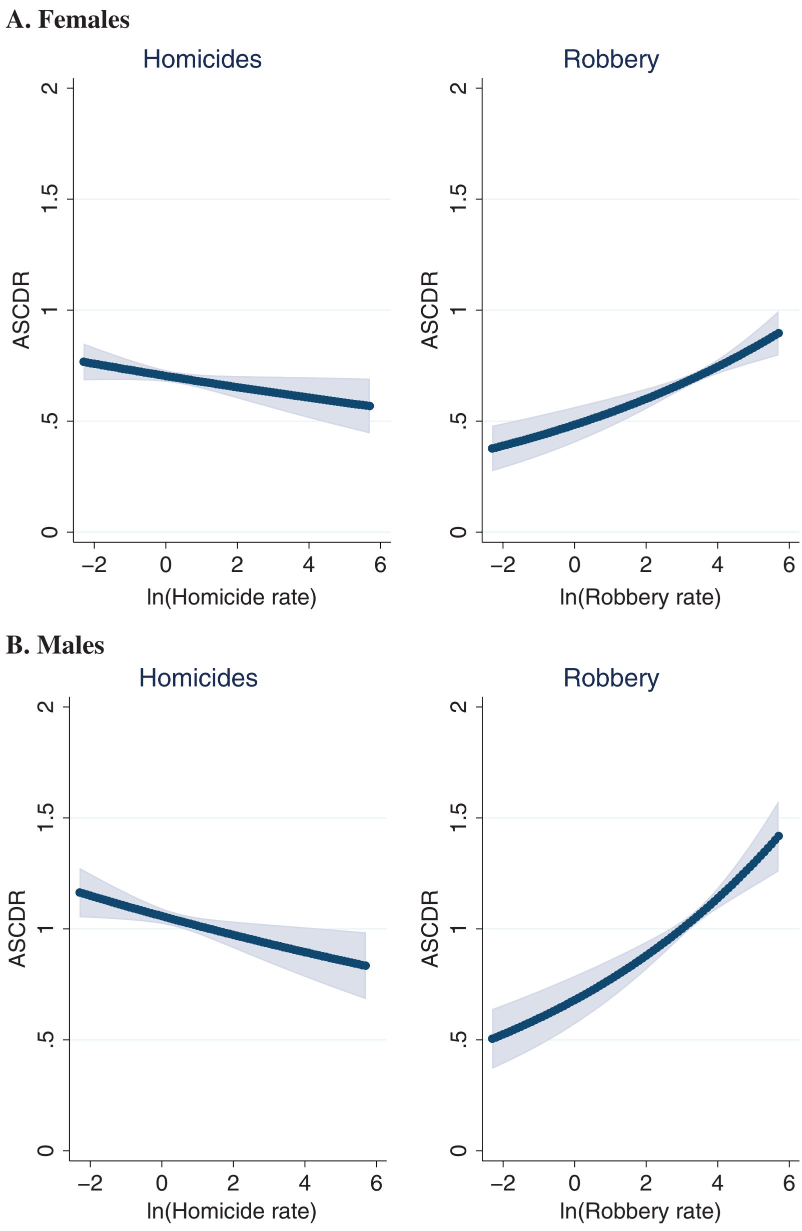
Figure 1 illustrates these associations with graphs of average estimated female (panel A) and male (panel B) ASCDR at different levels of the logarithm of rates of reports of homicides and robbery (from Models VI by sex). The graphs clearly show that urban municipalities that had higher robbery rates tended to have higher mortality due to COVID-19, and that this association is stronger for men than for women.

Estimated associations of ASCDR and other indicators show interesting differences by sex that can help explain the role of the social determinants of mortality due to COVID-19 for men and women. It is worth noting that the association of the EAP differed between men and women. A higher percentage of female EAP is associated with an increase in the logarithm of mortality due to COVID-19 among women, whereas male EAP is negatively associated with mortality. In other words, although female labor force participation generally empowers women in Mexico, during the pandemic, women were more exposed than men to economic activities with greater risk of contagion and mortality. Another related explanation is that female labor force participation is associated with other socioeconomic characteristics that put women at risk. For the rest of the indicators, results show similar associations and marginal effects for male and female ASCDR. The prevalence of obesity and diabetes put men and women at risk of death, although the risk is much larger for men. By contrast, isolation and less access to a paved road protects communities from contagion and death. The negative association between aging in the municipality and ASCDR suggests that in the context of the pandemic, older adults were made aware of their vulnerability to COVID-19, and thus avoided contagion by staying home. Interestingly, mean salary income was positively associated with ASCDR, and the larger marginal effects for male ASCDR and the positive and significant association with the Gini index reflect different processes linking economic characteristics and male mortality.

5 Discussion

Findings from OLS regression models show that the pre-pandemic intentional homicide rates have a significant negative association with ASCDR due to COVID-19 for both men and women, whereas the robbery rate is positively associated with

Figure 1:
Average estimated female (A) and male (B) ASCDR due to COVID-19 at levels of homicide and robbery rates in urban municipalities in Mexico



Source: Authors' own calculations from predictions for Models V for female and male mortality, respectively, Table 3.

ASCDR due to COVID-19. These findings suggest that violence and crime affect mortality differently depending on whether these events happen in private or public spaces, but also on their severity and nature, reflecting more profound differences in contexts and social environments. Robberies prior to the COVID-19 pandemic affected mortality during the pandemic. Our findings suggest the need to better understand the role of violence in local contexts before and after the outbreak of the disease. Our results also suggest the need to consider differently the nature of violence as well as its implications for health protective measures for men and women.

We need to be cautious when stating that a climate of criminal violence protected the population from dying of COVID-19. Although homicides themselves may reduce the likelihood of venturing out if leaving home is risky—similar to what has been found in places with high urban violence and conflict for other diseases (Krystosik et al., 2018)—areas controlled by drug cartels might limit access to health authorities, and fewer medical personnel may have been sent to these risky areas by federal and state governments. Although we use death data published by the end of July 2021, which allowed enough time for deaths from COVID-19 to be registered in the publicly available database, the uncertain reliability of the data from municipalities with very high crime rates controlled by drug cartels could be affecting our results. In addition, the people living in municipalities with high levels of violence were more likely to be internally displaced and may have left these violent areas during 2020 in search of protection and safety (Rodríguez Chávez, 2021; 2022). It is also possible that criminal groups operated differently during the pandemic, which led to reductions in the risk of contagion, and, in turn, to reductions in mortality due to COVID-19. For example, in China, the COVID-19 pandemic affected the production of synthetic drugs, such as fentanyl and methamphetamines, which have displaced marijuana, cocaine, and heroin in the United States, generating millions of dollars for Mexican cartels and their Chinese allies (Nájar, 2020b; Pastor, 2020). The pandemic caused a shortage in supplies of synthetic drug precursors, and cartels had to seek new sources of supplies and implement new production processes (UNODC, 2020). Lockdown measures and strengthened U.S. border controls made it difficult for drugs to reach consumers during 2020, thus reducing traditional drug-trafficking routes, increasing costs and risks and making drug sales in public places more difficult. All of these factors led to increases in online drug sales that were made through the so-called darknet, and were delivered by mail or parcel post (Pastor, 2020; UNODC, 2020). Whether these changes in how cartels operated during 2020 translated into a more favorable context is uncertain.

The consistent increase in homicide rates and in diabetes prevalence have contributed greatly to the reductions in life expectancy in Mexico (Canudas-Romo et al., 2015). More recently, using the same data as we do (DGE, 2021), a study that examined the negative impact of the COVID-19 pandemic on Mexican life expectancy estimated that in 2020, life expectancy at birth declined 2.5 years for females and 3.6 years for males, although these losses varied by state, with the effects of the COVID-19 pandemic being smaller in poorer states (García-Guerrero and Beltrán, 2021). Comparing the impact of violence and the impact of COVID-19 on life expectancy in Mexico is beyond the scope of this paper. Time will tell whether the effects of the pandemic are larger or smaller than the effects of drug-related violence. In absolute terms, from January 1, 2020 to December 31, 2020, the number of deaths attributed to COVID-19 (192,797) was more than five times as high the number of homicides recorded (35,531). However, a better understanding of the interrelationship of these global health problems, and of the contextual factors that put population health at risk, is still needed.

What we know about COVID-19 in Mexico—and globally—is highly influenced by government strategies for managing the pandemic, from testing and the implementation of lockdown measures, to providing economic support to businesses and economic resources to the health sector. Other social processes also influence our data. For example, of particular interest in the context of our research questions are the potential gender differences associated with access to preventive health, knowledge of comorbidities, COVID-19 testing and perceptions of risk factors, which, in turn, may have affected the confirmation rates and the data on the incidence of COVID-19. All these processes might be influenced themselves by neighborhood effects and local violence and insecurity. Moreover, although we focus on urban municipalities, future research should study conditions in rural areas in order to better understand the severity of the pandemic in smaller municipalities. Such research should be possible after vital official statistics for 2020 are published. Including these areas would, for example, make it possible to perform multivariate spatial analysis, although caution is advised given the biases and other processes associated with differences in how indicators of independent variables are reported in rural and urban areas. For example, if we are interested in studying how past forms of other types of crimes, such as domestic violence, are related to current COVID-19 incidence or mortality, it would be important to take into account biases in underreporting, not only due differences in the likelihood of filing a report, but also because gender roles shape who considers this crime worth reporting. We hope that our study opens new venues of research on the complex relationship between COVID-19 and its contextual determinants.

Acknowledgements

We are grateful for the Mexican funding agency that indirectly supported our research. Claudia Masferrer is a member of the National Researchers System (SNI, from its acronym in Spanish) of *Consejo Nacional de Ciencia y Teconología* (CONACYT), and El Colegio de la Frontera Norte receives funding from CONACYT. We appreciate comments we received from Víctor Manuel García-Guerrero and three anonymous reviewers that improved our analysis.

Availability of data and code

Data are available at https://www.gob.mx/salud/documentos/datos-abiertos-152127, and the code is available upon request.

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Appendix A: Scatterplot graphs of continuous variables used in the analysis for municipalities with female (A.1) and male (A.2) deaths due to COVID-19

Figure A.1:
Females

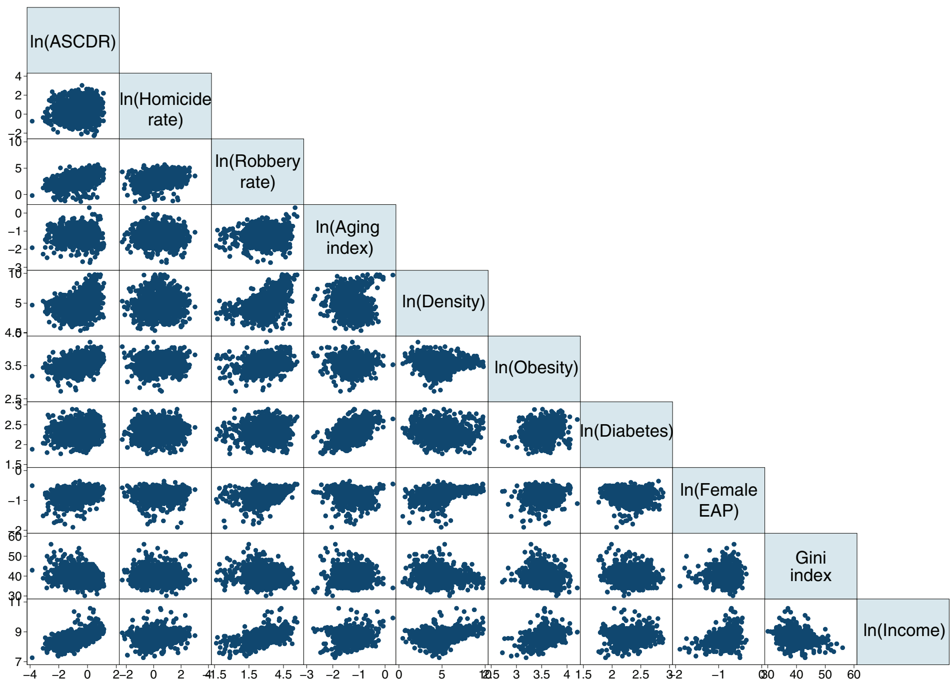
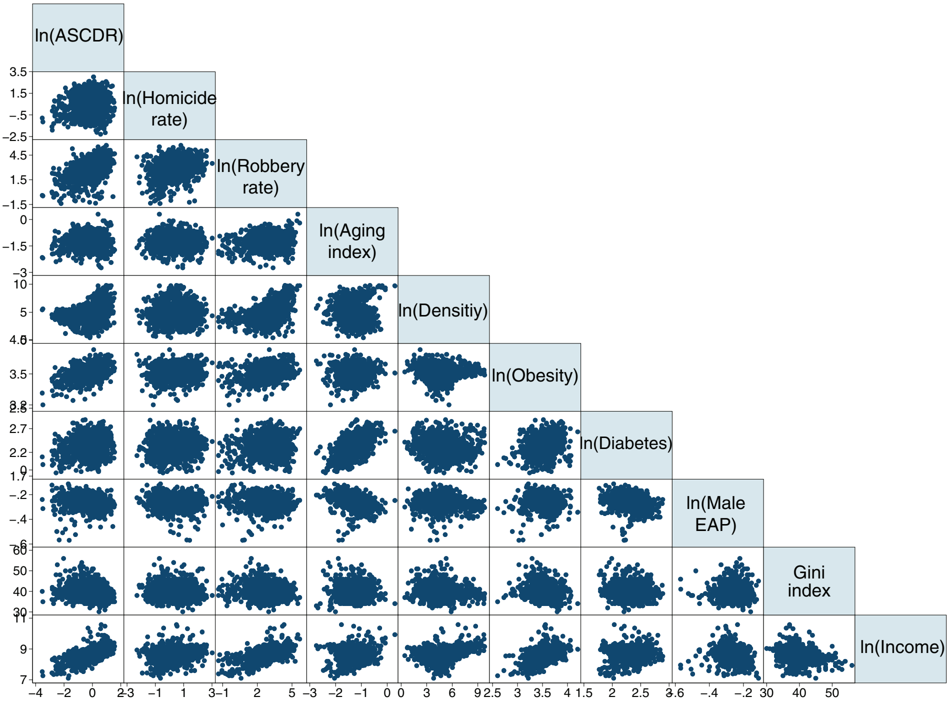


Figure A.2:
Males



DATA & TRENDS

Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 393–414

Assessing excess mortality in Vienna and Austria after the first year of the COVID-19 pandemic

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Abstract

In Austria, the first confirmed COVID-19 death occurred in early March 2020. Since then, the question as to whether and, if so, to what extent the COVID-19 pandemic has increased overall mortality has been raised in the public and academic discourse. In an effort to answer this question, Statistics Vienna (City of Vienna, Department for Economic Affairs, Labour and Statistics) has evaluated the weekly mortality trends in Vienna, and compared them to the trends in other Austrian provinces. For our analysis, we draw on data from Statistics Austria and the Austrian Agency for Health and Food Safety (AGES), which are published along with data on the actual and the expected weekly numbers of deaths via the Vienna Mortality Monitoring website. Based on the definition of *excess mortality* as the actual number of reported deaths from all causes minus the expected number of deaths, we calculate the weekly prediction intervals of the expected number of deaths for two age groups (0 to 64 years and 65 years and older). The temporal scope of the analysis covers not only the current COVID-19 pandemic, but also previous flu seasons and summer heat waves. The results show the actual weekly numbers of deaths and the corresponding prediction intervals for Vienna and the other Austrian provinces since 2007. Our analysis underlines the importance of comparing time series of COVID-19-related excess deaths at the sub-national level in order to highlight within-country heterogeneities.

Keywords: mortality; excess mortality; COVID-19; regional analysis; Austria

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DOI: 10.1553/populationyearbook2022.dat.1

1 Introduction

In Vienna, the first coronavirus infection case was reported on 26 February 2020. The first COVID-19-related death in Austria was registered a week later (5 March 2020) in the province of Tyrol. More than one and a half years later (at the end of August 2021), the total number of reported cases of COVID-19 in Austria was over 700,000, despite the implementation of public health measures aimed at limiting the spread of the disease (i.e., physical and social distancing, lockdowns, curfews, mask mandates etc.) (AGES, 2021a).[1] Moreover, it is broadly assumed that the number of undetected cases is many times higher (Roser et al., 2020; Statistik Austria, 2020a). By the end of August 2021 (week 34-2021), or just over a year and a half after the first death from COVID-19 occurred in Austria, the official number of COVID-19-related deaths in Vienna and in Austria had surpassed 2,000 and 10,000, respectively (AGES, 2021a).

According to the German Robert Koch Institute (RKI, 2021), COVID-19 has an incubation time of five to six days, and there is usually a lag of several days before the results of COVID-19 tests are included in the official statistics. In general, it is assumed that changes in social behaviour, which might or might not be triggered by various government-imposed measures, are reflected in the official case count with a lag of 10 to 14 days; and that deaths from COVID-19 usually occur within four weeks of the initial infection (Nivette et al., 2021; RKI, 2021).

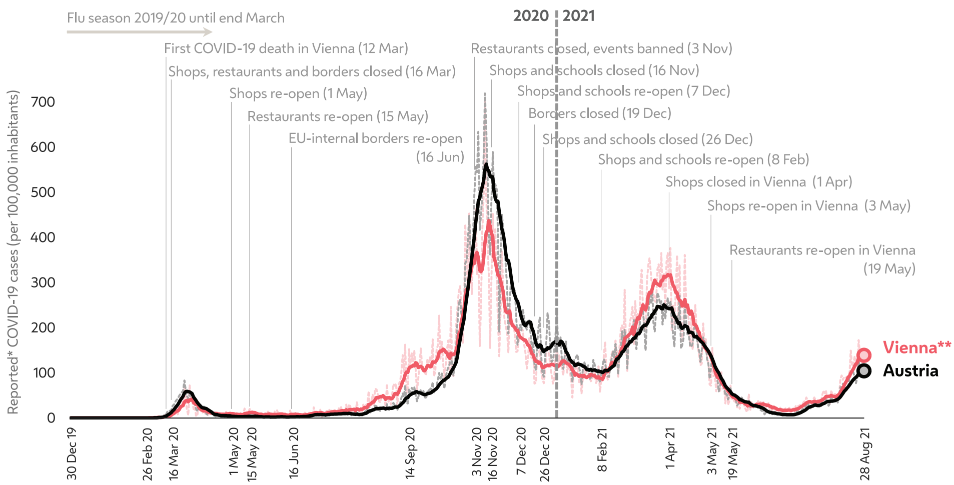
During the first one and a half years of the *pandemic*,[2] the number of reported COVID-19 infections in Austria had already peaked three times: the first wave was in March 2020; the second wave was in autumn/winter 2020/21; and the third wave started in February 2021, and lasted until the end of May 2021. Since the beginning of August 2021, the number of COVID-19 cases has again been rising, marking the start of a fourth wave, the full extent of which will only become apparent in the coming weeks and months (see Figure 1).

However, when analysing COVID-19-related deaths, it is important to keep in mind that the reporting of COVID-19 as a cause of death could be inaccurate or subject to undercounting (Aron et al., 2020). This was especially likely to be the case during the early phases of the pandemic, when reliable tests were not yet widely available, or were simply not administered across the board. It is, for instance, probable that many people who died while infected with COVID-19 were never tested for the virus (The Economist, 2021). Yet it is also likely that as testing has increased sharply since the onset of the pandemic, cases

[1] Data retrieved on 6 May 2021 from the Austrian COVID-19 dashboard, provided by AGES/Federal Ministry of Social Affairs, Health, Care and Consumer Protection: https://covid19-dashboard.ages.at/.

[2] On 11 March 2020, the WHO Director General declared COVID-19 a pandemic (WHO, 2020). A *pandemic* is loosely defined as an "(...) *epidemic occurring over a very wide area, crossing international boundaries and usually affecting a large number of people*" (Porta, 2014, p. 209). Despite fitting this definition, seasonal epidemics like influenza ("flu") are normally not considered pandemics (Kelly, 2011; WHO, 2013, 2021a).

Figure 1:
Number of reported COVID-19 cases per day (per 100,000 inhabitants) in Vienna and Austria since week 1-2020



Notes: *Please note that there is a 10- to 14-day lag between the time of infection and the reporting date shown in the chart. **The dotted line shows the daily reported cases, and the solid line shows the seven-day average per 100,000 inhabitants.
Data Source: AGES (2021a) and own calculations.

of people who have died of causes other than COVID-19 (e.g., from car accidents), but who tested positive for the virus, might have contributed to a certain degree of over-reporting of COVID-19-related deaths; i.e., some deaths may have been misclassified in the official statistics as deaths from COVID-19 (CDC, 2021) if it was unclear whether these individuals died because of COVID-19 or simply while infected with COVID-19. Furthermore, voluntary and government-mandated changes in behaviour may have influenced the number of infections and deaths. Since March 2020, people living in Vienna, across Austria and in many other parts of the world have been travelling and commuting less than they did previously (because of remote work orders, social distancing mandates, bans on events and border closures), which should have led to fewer human interactions (Google LLC, 2021; Ritchie et al., 2021; Statistics Vienna, 2021a). Reductions in mobility and in personal interactions might have contributed, for example, to reductions in traffic accidents/fatalities (Statistik Austria, 2020b)[3] or influenza infections (City of Vienna Health Service, 2021). At the same time, however, the incidence of

[3] In the first half of 2020, the number of traffic accidents, injuries and fatalities was almost 25% lower than it was in the corresponding reference period in 2019 (Statistik Austria, 2020b). Nevertheless, out of all deaths, the share that is attributable to traffic accidents is relatively small.

household accidents (ORF, 2021a), domestic violence (especially against women) (ORF, 2021b) or suicides might have increased (Prlić, 2021). Additionally, people with health conditions (e.g., cancer) might have deliberately postponed necessary treatments at medical facilities due to concerns about safety, or they may have been unable to access care if the health system was overwhelmed by COVID-19 cases, or if providers decided to prioritise patients with COVID-19 over those with other symptoms (CDC, 2021; The Economist, 2021). For these reasons, mortality due to non-COVID-19-related causes of death, like cancer, respiratory diseases and circulatory diseases, may have increased over the course of the pandemic (Aron et al., 2020).

All of these factors complicate our efforts to answer the question of whether and, if so, when and to what extent the COVID-19 pandemic has led to an increase in the number of deaths; i.e., to excess mortality. By definition, *excess mortality* is the number of deaths from all causes in a given period relative to the number of deaths that would have normally been expected to occur in that period. For assessing the direct and indirect impacts of COVID-19 on overall mortality, excess mortality for all causes of deaths is a well-established indicator (Aburto et al., 2021; Aron et al., 2020; Ghislandi et al., 2021; Schöley, 2021).

Since June 2020, and based on the concept of *excess mortality*, Statistics Vienna has been monitoring and evaluating the weekly mortality trends in Vienna and in other Austrian provinces (Bauer et al., 2021a, 2021b; Statistics Vienna, 2021b), as well as in selected European cities (Statistics Vienna, 2021c). In this paper, we aim to quantify the impact of COVID-19 on the overall mortality level (all causes) in Vienna and in other provinces of Austria, and to examine to what extent the number of reported COVID-19 deaths corresponds to the overall mortality level during the first year of the pandemic; i.e., from week 1-2020 to the end of August 2021 (week 34-2021). In the following sections, we briefly describe our methodological approach (Section 2), and then present our findings (Section 3), as well as a discussion of the results (Section 4).

2 Data and methods

In order to assess whether there was any *excess mortality,* and, if so, to what extent it deviated from *“normal”* mortality, it is necessary to define the *“expected”* number of deaths based on mortality trends observed in the (recent) past. In this section, we briefly explain the required input data and the basic principles that underlie our excess mortality model, but without going in too much detail, as the methodology is well documented in Bauer et al. (2021a, 2021b) and in Frühwirt and Seidl (2020).

In general, we seek to quantify the range of the expected weekly number of deaths. For this reason, we have defined *prediction intervals* (*“bands”*) comprising 99% of the expected values, while assuming a random and independent distribution of the weekly number of deaths for two broad age groups (0 to 64 years and 65 years and older).[4] These *"bands"* take into account seasonal fluctuations (caused, for example, by summer heat waves or winter flu epidemics) and changes in population size, age structure and life expectancy (BFS, 2020a, 2020b; Frühwirt and Seidl, 2020). Based on these prediction intervals, all values of weekly deaths exceeding the upper limit of the defined range (i.e., "bands") are classified as excess mortality.

2.1 Data

In our excess mortality model, which was developed for the *Vienna Mortality Monitoring* project (Bauer et al., 2021a)[5] to quantify the impact of COVID-19 on overall mortality, we use data from the *Austrian Population Register* (POPREG) and from the *Register of Vital Statistics* (ZPR) provided by Statistik Austria (Statistik Austria, 2021a,b):

- **Input Data**
  - **Population** (at the beginning of the year) by 1-year age groups and Austrian provinces, 2002–2021 (Statistik Austria, 2021a)
  - The number of **daily deaths** (date of death) by 1-year age groups for all causes of death in the Austrian provinces, 2002–2019 (Statistik Austria, 2021b)
- **Output Data**[6]
  - The **predicted weekly number of deaths** and the **prediction interval** (by calendar week) for two broad age groups (0 to 64 years, 65 years and older) for all causes of death in the Austrian provinces, 2007–2021 (Statistics Vienna, 2021d), and

[4] At the time of the analysis, more detailed mortality data by one-year age groups were only available for the years 2002 until 2019. The 2020 data were only recently published (in summer 2021), and were not used to calculate the "bands", as COVID-19 deaths had already biased mortality behaviour. Additionally, our aim was to show how the reported number of deaths during the pandemic might have deviated from the expected number of deaths. As more recent weekly data have been published only for the broader age groups 0 to 64 years and 65 years and older, a more age-detailed estimation of mortality bands is currently not possible.

[5] The methodological approach behind the model is based on the methodology introduced by the Federal Statistical Offices, Switzerland (BFS, 2020a).

[6] At the time of the final submission of this paper, the data for 2021 were available up to calendar week 34-2021 (i.e., the week of Monday, 23 August to Sunday, 28 August 2021).

- The corresponding **weekly number of deaths** (by calendar week) for two broad age groups (0 to 64 years, 65 years and older) for all causes of death in the Austrian provinces, 2007–2021 (Statistik Austria, 2021c)[7]

The temporal scope of this paper focuses on a weekly analysis of excess mortality during the period of January 2020 (week 1-2020) to August 2021 (week 34-2021), based on the weekly number of deaths (from all causes) during the reference period of 2015 to 2019. All deaths of people with a residence in Austria and who died in Austria during these periods are included in the analysis.

2.2 Excess mortality model

To assess whether there has been any *excess mortality* in Austria's provinces during the COVID-19 pandemic, it is necessary to determine the *expected* and the *normal weekly number of deaths* in order to calculate the respective confidence intervals (*"bands"*). The prediction intervals comprise 99% of the expected values assuming a random and independent distribution of the weekly number of deaths for two broad age groups: 0 to 64 years and 65 years and older (BFS, 2020a, b; Frühwirt and Seidl, 2020).

The expected number of deaths is estimated based on mortality data from the previous five-year period. In our analysis of excess mortality, we used the 2015 to 2019 reference period for both years of the pandemic: i.e., 2020 and 2021. Since the COVID-19 pandemic definitely affected mortality in 2020, we have decided not to shift to the 2016 to 2020 reference period for the calculation of excess mortality in 2021, but to instead use the 2015 to 2019 reference period for 2021 as well. Based on the available data from the Austrian register of vital statistics (ZPR), which date back to 2002, we are able to calculate expected mortality and excess mortality dating back to 2007 (starting with the 2002 to 2006 reference period). The calculation of the expected number of deaths and bandwidth is based on the reported weekly number of deaths in the respective previous five years.

Our calculation of the *expected weekly mortality for the year of analysis* is based on the methodological approach developed by our Swiss colleagues from the Federal Statistical Office, Switzerland (BFS, 2020a,b), and takes two elements into consideration: the *expected number of deaths for the year of analysis* by age group and *seasonality*; i.e., how those deaths are distributed across the weeks of the year. Both elements are calculated based on the median of the *weighted weekly number of deaths* by age group for the reference period.

[7] These data are not used in the model, but they are used in the visualisation of the data in Section 3. Please note that the number of deaths in the two latest available weeks have not yet been fully registered, and are therefore only partially estimated by Statistics Austria. Data on weekly deaths since 2007 in Austria at the scale of provinces (NUTS 2), as well as the prediction intervals, are published at the Austrian Open Data portal: https://www.data.gv.at/katalog/dataset/feaddbdf-ed07-4c37-818a-db63447d5567.

In the first step, we convert the calendar weeks of our base year 2020 into ISO weeks (ISO, 2019a, 2019b)[8] to retrieve a date sequence[9] that is applied to all reference years in order to obtain standardised week units. Standardising all years to the same number of calendar weeks and days ensures the comparability of the findings across all years included in the analysis.

In the next step, the daily numbers of deaths by one-year age groups (Statistik Austria, 2021b) are allocated to the recoded (calendar) weeks for each reference year. Those weekly deaths are weighted by the population size by age and sex in the respective reference years in order to obtain a ratio that can be used to estimate an age- and life expectancy[10]-adjusted expected number of deaths in 2020 and in 2021 (Frühwirt and Seidl, 2020).

The seasonality effects of mortality for both age groups (0 to 64 years and 65 years and older) make it necessary to calculate the median of the *weighted weekly number of deaths* by age group for every week of the reference years. Those weekly median values represent the expected seasonal values for the calendar weeks in the year of analysis for each age group. At this point, seasonality is smoothed using a *local regression* method (*Locally Estimated Scatterplot Smoothing* regression, LOESS) and extrapolated to derive the *expected annual and weekly numbers of deaths* in 2020 and 2021. In the last step, we apply a Poisson prediction interval of 99% to the expected number of deaths per week and age group to obtain a *"band"* that reflects the "normal" mortality range, which we can then use to detect the excess mortality – or even the mortality deficits – for each week.

3 Findings

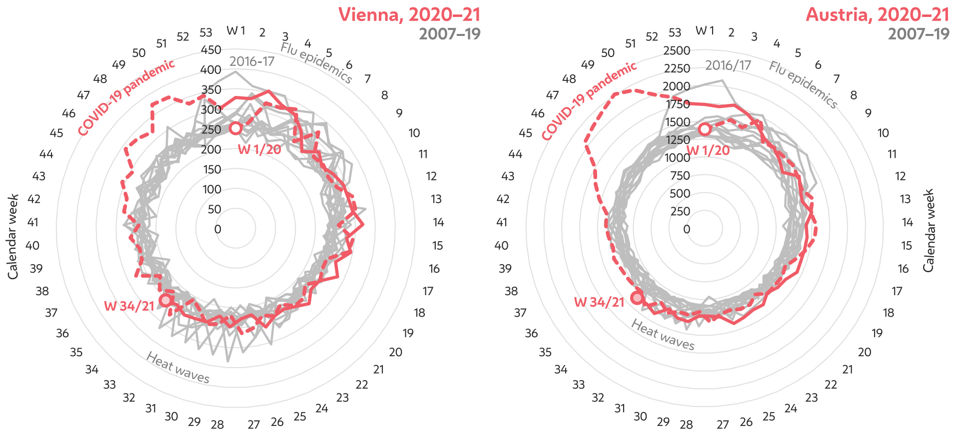
A comparison of the weekly numbers of deaths in Vienna and Austria over our study period reveals the exceptional nature of the mortality patterns in 2020 and 2021. While taking into account that the risk of dying from a COVID-19 infection is considerably higher for older than for younger people (Mallapatty, 2020), Figure 2 shows the weekly number of deaths among the population aged 65 and older since 2007 (until week 34-2021). The visualisation depicts seasonal patterns and peaks of higher mortality during winter flu epidemics and summer heat waves. The years of

8 An International Organization for Standardization (ISO) year contains of 52 or 53 full ISO weeks with 364 or 371 days that can leap into the previous and the following year. Each week has a day sequence from Monday to Sunday ISO weeks follow a leap week calendar system (ISO, 2019a, 2019b).

9 The basic date sequence for the ISO year 2020 runs from Monday, 30 December 2019 to Sunday, 3 January 2021.

10 Since 2002, life expectancy at birth for both men and women has, on average, increased by about two months per year. However, due to COVID-19 pandemic, life expectancy at birth in Austria dropped by seven months for men and by six months for women between 2019 and 2020. In Vienna, these declines were even larger, as life expectancy at birth decreased over this period by more than 8.5 months for men and by about eight months for women (Statistik Austria, 2021d).

Figure 2:
Weekly numbers of deaths (all causes) in the age group 65 and older in Vienna and Austria since week 1-2007

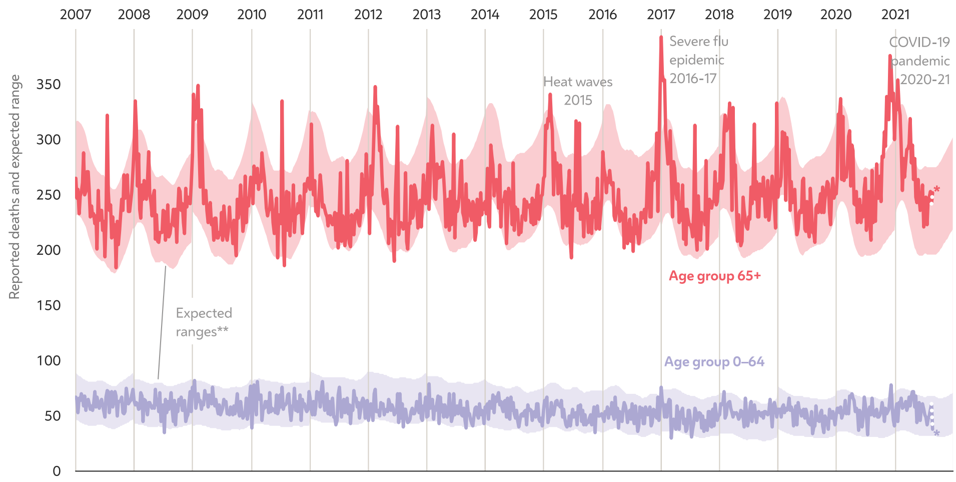


Data Source: Statistik Austria (2021c) and own calculations.

the coronavirus pandemic (i.e., 2020 and 2021) are highlighted in red. The results indicate that the weekly number of deaths increased noticeably for the first time in March and April 2020 (between week 12-2020 and week 18-2020). After a period of relatively *normal* mortality levels during the summer of 2020, the weekly numbers of deaths in Vienna and Austria again rose sharply starting at the end of September (from week 40-2020 onwards), and then returned to *normal* levels during the early weeks of 2021. The numbers of registered cases increased again in February 2021, but had flattened by the end of August (i.e., week 34-2021, which also marks the end of the temporal scope of this analysis). However, this *third wave* of infections did not result in the large increases in weekly mortality that had been reported during the *second wave* in the latter months of 2020. A similar pattern could be observed in summer 2021, when the numbers of infections again started to increase.

A descriptive comparison of the weekly numbers of deaths (as shown in Figure 2) allows us to quantify the deviation of the weekly numbers of deaths from the numbers of deaths in the corresponding weeks in previous years (usually the most recent five years; see, for example, Destatis, 2021; EuroMOMO, 2021; Eurostat, 2021; or Giattino et al., 2021), but usually does not consider changes in population size and age structure, which, in turn, affect the actual numbers of deaths. In order to quantify the impact of COVID-19 on overall mortality (all causes) in Vienna and in other provinces of Austria, we apply our model that takes into account not only changes in the seasonality of mortality, but also changes in population size and age structure with respect to the reference period (cf. Section 2.1).

Figure 3:
Numbers of deaths and expected range per week and age group in Vienna since week 1-2007

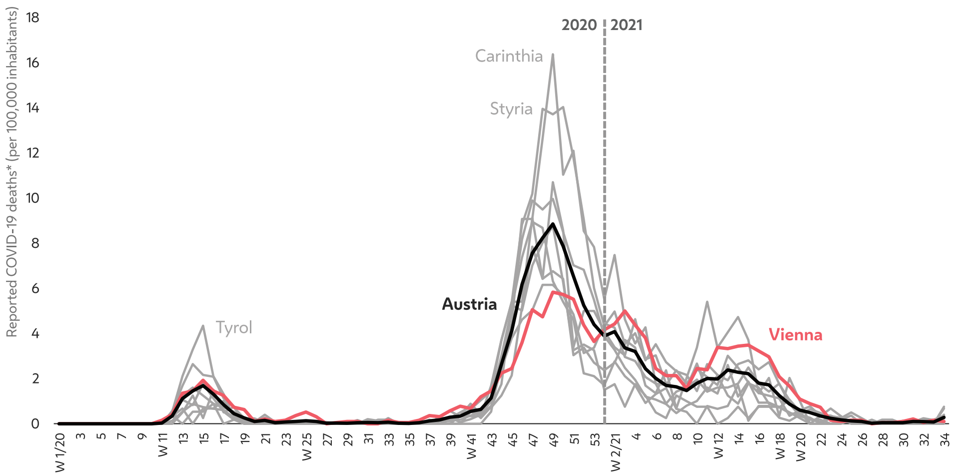


Notes: *Data for the two most recent weeks are partially estimated (dotted). **99% prediction interval.
Data Source: Statistik Austria (2021c) and own calculations.

Figure 3 shows the weekly numbers of deaths in the age groups 0 to 64 years (blue) and 65 years and older (red), as well as the expected range of the weekly numbers of deaths since 2007 in Vienna in the respective age groups. These longer time series, which extend beyond the COVID-19 pandemic period, demonstrate that periods of excess mortality – i.e., when the data points exceed the range of expected values – are not at all unusual. Some seasonal events, like extreme *heat waves* (during the summers of 2010, 2012, 2015 and 2018) and severe *flu epidemics* (e.g., during the winter of 2016/2017), have caused excess mortality among the elderly population in Vienna and Austria in the recent past. While the durations of such seasonal events were generally relatively short (i.e., a few weeks), the COVID-19 pandemic caused a considerably longer period of continuous excess mortality among people aged 65 years and older that lasted several months. In Austria as a whole, this period lasted from mid-October 2020 (week 43-2020) until the end of January 2021 (week 4-2021) (see also Figure 5).

According to AGES (2021a), more than 10,000 COVID-19-related deaths were registered in Austria until the end of August 2021 (week 34-2021). Overall, approximately 7.2% of all people who died in Austria between week 1-2020 and week 34-2021 were diagnosed with COVID-19. The provinces with the highest shares of COVID-19-related deaths were Styria (9.1%) and Vienna (8.3%), while the provinces with the lowest shares of COVID-19-related deaths were Vorarlberg (5.8%), Burgenland (5.7%) and Lower Austria (5.5%)

Figure 4:
Number of reported COVID-19 deaths per week (per 100,000 inhabitants) in Austria's provinces since week 1-2020

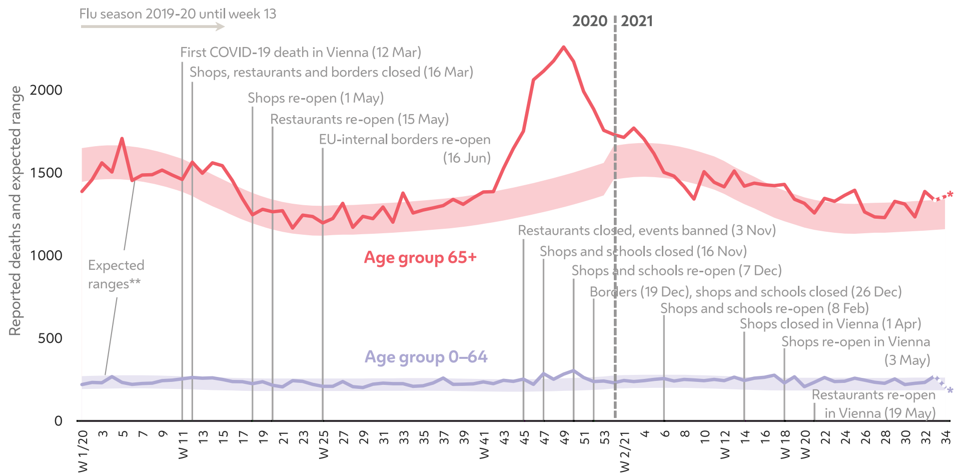


Notes: *COVID-19 deaths are reported by date of death.
Data Source: AGES (2021a) and own calculations.

(AGES, 2021a; Statistik Austria, 2021c). To contextualise the overall mortality levels, Figure 4 illustrates the weekly numbers of COVID-19 deaths per 100,000 inhabitants in Austria and its nine provinces. The province of Tyrol was hit especially hard by COVID-19-related deaths during the *first wave* of infections (in March and April 2020). However, during the *second wave* (in the autumn and winter in 2020/2021), the provinces with the highest relative numbers of COVID-19-related fatalities were Carinthia and Styria. The *third wave* of infections, which peaked in March 2021, resulted in fewer reported COVID-19 cases and deaths than the second wave (see Figure 1 and Figure 4). However, in the third wave, the number of COVID-19-related *intensive care unit* (ICU) admissions was similar to that in the second wave. COVID-19 vaccination started at the beginning of 2021 for the oldest age groups. By the end of August 2021 (week 34-2021), more than 5.5 million (69.7%) of the population aged 12 years and older and 1.5 million (87.5%) of the population aged 65 years and older in Austria had received at least one shot of a COVID-19 vaccine (BMSGPK, 2021). This high vaccination rate contributed to the reduction in the number of deaths among people aged 65 and older during the third wave of infections (in the spring of 2021).

Focusing on excess mortality (all causes) during the COVID-19 pandemic (i.e., in 2020 and 2021), Figure 5 and Figure 6 show the weekly numbers of deaths in

Figure 5:
Numbers of deaths and expected range per week and age group in Austria since week 1-2020**

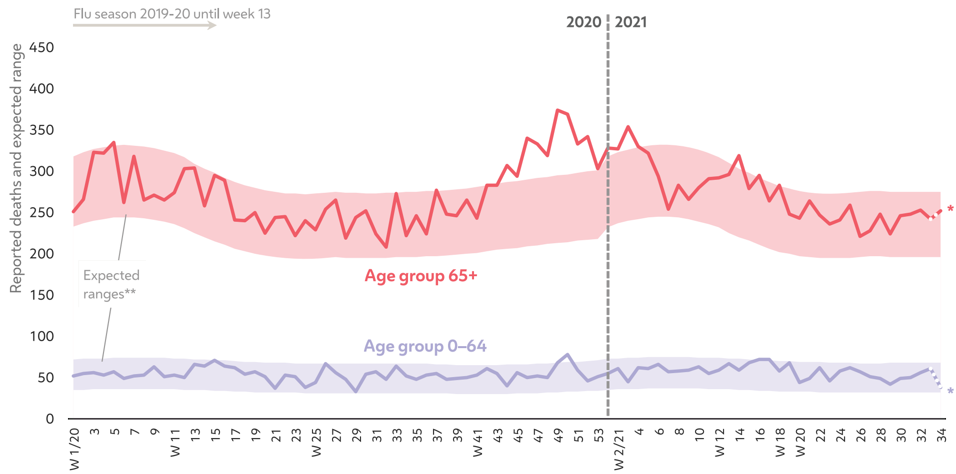


Notes: *Preliminary data: Data for the two most recent weeks partially estimated (dotted). **99% prediction interval. Please note that there is a three- to four-week lag between the point in time when individuals are infected with SARS-CoV-2, and the time of death.
Data Source: Statistik Austria (2021c) and own calculations.

the 0 to 64 years and 65 years and older age groups in Austria and Vienna.[11] The visualisations clearly depict the weeks and periods with prevailing excess mortality – i.e., when the data points exceeded the upper range of the expected values. Almost all of the excess mortality can be observed among the population aged 65 years and older, while almost no quantifiable excess mortality can be detected among the population under age 65 years (with the exception of a few weeks in late 2020). In general, it appears that the patterns of excess mortality in Austria and Vienna were largely in line with the timing and the extent of the respective peaks. It should be noted that since the population of Vienna accounts for 21% of the Austrian population (at the beginning of 2021), the mortality trends in Vienna have a substantial impact on the overall mortality levels in Austria.

[11] *Why do prediction bands "jump" at the turn of the year?* At the turn of the year 2020 to 2021, the prediction bands in the visualisations *"jump up"*. This is partly because estimated mortality tends to increase in January due to seasonal flu epidemics. Above all, the *"jump"* is a statistical artefact: the prediction bands are (among other factors) based on the population size and the age structure on 1 January of the respective year, and are then smoothed over this period. At the turn of the year, these parameters and the reference period for smoothing change. Hence, the prediction bands appear to *"jump"*.

Figure 6:
Numbers of deaths and expected range per week and age group in Vienna since week 1-2020**

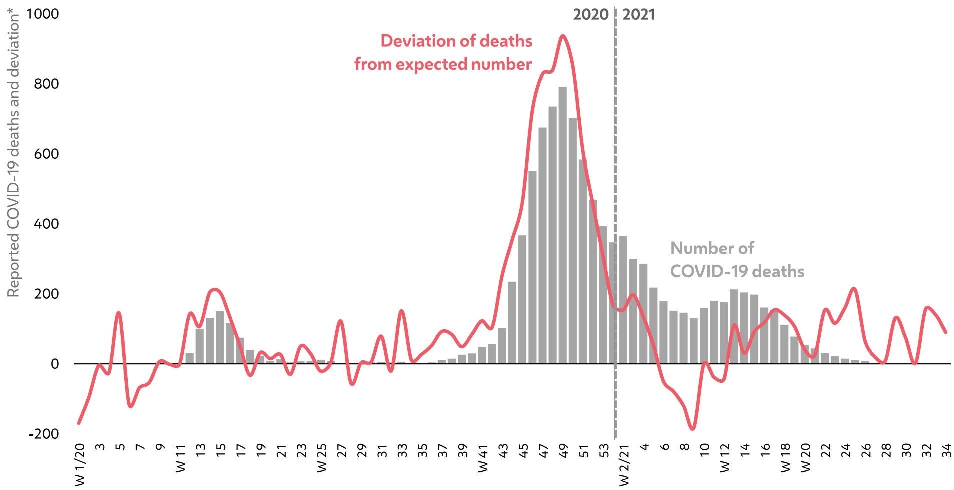


Notes: *Preliminary data: Data for the two most recent weeks partially estimated (dotted). **99% prediction interval. Please note that there is a three- to four-week lag between the point in time when individuals are infected with SARS-CoV-2, and the time of death.
Data Source: Statistik Austria (2021c) and own calculations.

A comparison of Figure 5 (Austria) and Figure 6 (Vienna) demonstrates another effect related to population size. As we described in Section 2.2 (Excess Mortality Model), the higher number of deaths (events) that occurred in Austria compared to in Vienna (and other provinces) affects the range of the expected values. The population size determines the width of the prediction interval, and, thus, how clearly excess mortality can be assessed. The larger the population and, hence, the larger the numbers of corresponding deaths, the narrower the expected variance in the weekly numbers of deaths is, and, in turn, the narrower the width of the prediction intervals is. Ultimately, a larger number of events (deaths) allows for a more precise assessment of excess mortality. When interpreting the ranges of the expected values of the weekly numbers of deaths by age group, it should be taken into account that the prediction intervals cannot be used to directly compare events and trends in regions with different population sizes. Instead, the prediction intervals show how accurately (with respect to statistical significance) excess mortality is assessed for the respective week in the respective region.

In order to assess to what extent the numbers of COVID-19 deaths correspond to the identified excess mortality, we compare the weekly numbers of reported COVID-19 deaths with the deviation from the median expected weekly numbers of deaths in 2020 and 2021 in Austria (Figure 7). The results indicate that overall, the number of COVID-19-related fatalities corresponds quite well to the deviations

Figure 7:
Numbers of reported COVID-19 deaths (columns) and the deviation of the numbers of deaths from the expected values (line) in Austria since week 1-2020



Notes: *Numbers of COVID-19 deaths (columns) and the deviation of the numbers of deaths from the expected values (line).
Data Source: AGES (2021a) and own calculations.

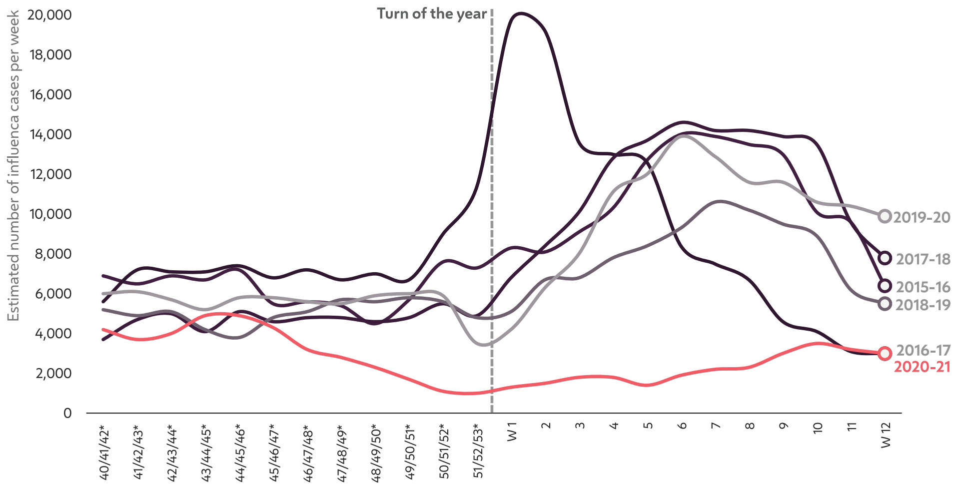
in overall weekly mortality (based on our excess mortality model). This nationwide pattern also appears to reflect the developments in Vienna and in other provinces of Austria during the first year of the COVID-19 pandemic.[12]

The observed positive deviations of the actual weekly numbers of deaths from the median of the range of the expected numbers of deaths during the first weeks of 2020 and the summer months in 2020 and 2021 (as shown in Figure 7) can be attributed to the annual flu season and heat waves in Austria during the 2015–2019 reference period (as shown in Figure 3). Generally, the findings indicate that the calculation of the range of expected values is highly influenced by seasonal events, like flu epidemics during the winter months or extreme heat waves during the summer months in the respective reference periods.

The first COVID-19 deaths in Austria and Vienna were reported in week 11-2020. A week later, the first nationwide lockdown went into effect in Austria, and the

[12] For Austria as a whole, the numbers of COVID-19-related deaths seem to match the deviations in weekly mortality more clearly than they do for Vienna and other provinces of Austria. This might be attributed to the smaller numbers of people (and of events) at the level of provinces, which may, in turn, result in more (short-term) fluctuations and variations in such high frequency indicators as the weekly number of deaths.

Figure 8:
Estimated numbers of influenza and flu-like infections per week in Vienna since 2015

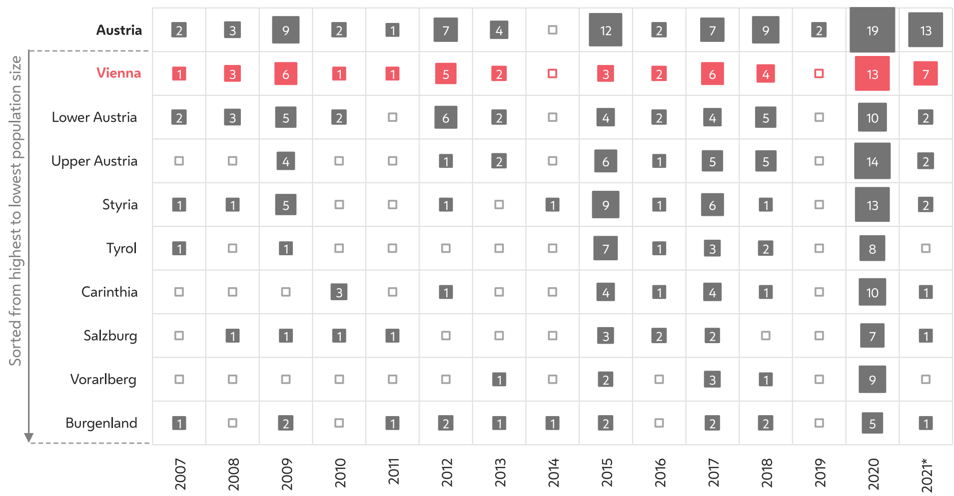


Notes: *Different number of calendar weeks per year.
Data Source: City of Vienna Health Service (2021).

2019/2020 flu season ended prematurely.[13] Between week 12-2020 and week 18-2020, the numbers of COVID-19-related deaths started to increase, along with the positive deviation from the expected numbers of deaths. The pattern of COVID-19-related deaths corresponding to unexpectedly high numbers of deaths was also visible during the start of the second wave of infections in autumn 2020. As Figure 7 shows, there was a small but consistent difference between COVID-19-related deaths and excess mortality until early December 2020 (i.e., around week 50-2020), which suggests that there was a slight under-reporting of COVID-19-related deaths in Austria. This pattern reversed during the last weeks of 2020, and from then on the number of COVID-19-related deaths exceeded the positive deviations from the expected number of deaths. These trends suggest that there was some over-reporting of COVID-19-related deaths. However, the change in the direction of the difference is not a surprise, given that our model is based on actual mortality between 2015 and 2019 (cf. Section 2.1). In this reference period, there were regular flu seasons during the winter months, including a severe influenza season during the winter of 2016/2017 (see also Figure 3). In the winter of 2020/2021, there was almost no flu season at all in Vienna (City of Vienna Health Service, 2021), in Austria

[13] Figure 8 shows the weekly number of influenza and flu-like infections in Vienna and highlights the relatively low number of registered infections during the annual flu season in 2020/2021, which might be attributed to COVID-19-related changes in behaviour. This trend can be observed in most countries of the world, irrespective of the government-mandated restrictions (WHO, 2021c).

Figure 9:
Numbers of weeks with excess mortality in the age group 65 and older in Vienna and Austria's provinces since week 1-2007



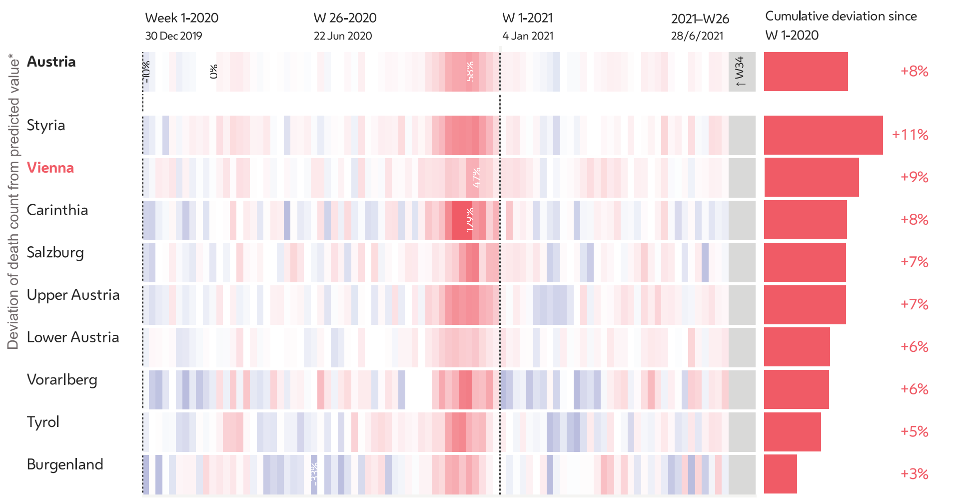
Notes: Preliminary count up to week 34-2021.
Data Source: Statistik Austria (2021c) and own calculations.

(AGES, 2021b) or in most other parts of the world (WHO, 2021b,c). Thus, it can be assumed that the expected overall number of deaths should be lower in 2020/2021 than it was in previous years.[14] It remains unclear whether and, if so, to what extent the (slight) over-reporting of COVID-19-related deaths in Austria and Vienna or the absence of the annual flu season might have contributed to this change in the direction of the differences between registered COVID-19-related deaths and actual excess mortality at the turn of the year 2020/2021.

Finally, we looked at weekly mortality trends in Vienna, and compared them with trends in other Austrian provinces. The time series of our excess mortality model allows for the analysis of mortality trends at the spatial level of Austrian provinces from 2007 onwards. Figure 9 shows the number of weeks in which excess mortality can be observed among people aged 65 years and older (who are, in general, the age group most likely to be affected by excess mortality) in Austria and its nine provinces. Since 2007, there was just a single year (i.e., 2014) when there was no week in which this particular age group was affected by excess mortality at the national level. The visualisation, which is sorted by the population size of the provinces, again illustrates the sensitivity of the excess mortality model to population size (and the corresponding number of events), as

[14] Austrian influenza monitoring by AGES (2021b): https://www.ages.at/themen/krankheitserreger/grippe/saison-202021/ (retrieved 27 April 2021).

Figure 10:
Deviations of the weekly and cumulative numbers of reported deaths from the predicted values* in Austria's provinces since week 1-2020



Notes: Preliminary data: Data for the two most recent weeks are partially estimated. *Predicted values are based on mortality in 2015–2019, current population size and structure and trends in life expectancy; deaths abroad are not included.
Data Source: Statistik Austria (2021c) and own calculations.

it shows that the magnitude of the deviation of the numbers of actual deaths from the predicted numbers of deaths is comparable only between provinces with similar population sizes (e.g., Vienna and Lower Austria or Vorarlberg and Burgenland). The visualisation also clearly indicates that in Austria as a whole and in all nine provinces, the period with by far the most weeks of excess mortality was during the COVID-19 pandemic in 2020.[15]

To assess the differences and the similarities in the impact of excess mortality across all nine Austrian provinces during the COVID-19 pandemic, we examined the developments in the weekly numbers of deaths since the beginning of 2020. More precisely, we analysed the deviations of the actual weekly numbers of deaths from the median of the expected numbers of deaths (as predicted by our model). Figure 10 illustrates the course of the pandemic by indicating the direction of the deviation of the actual from the expected weekly numbers of deaths in Austria and its provinces since week 1-2020. Tyrol was more affected than other Austrian

[15] Our analyses only include data until week 34-2021 (Monday, 23 August to Sunday, 28 August 2021). Therefore, the number of weeks with excess mortality in 2021 cited in this paper is still preliminary, as the total number cannot be assessed before early 2022.

provinces by excess mortality during the first wave. During the second wave, the COVID-19-related death toll was much higher and affected all Austrian provinces, though the provinces that were hardest hit during this period were Styria and Carinthia.

Figure 10 also shows the cumulative deviation of the actual from the expected number of deaths (all ages) by province between week 1-2020 and week 34-2021 (which corresponds to the end of August 2021). Across the entire observation period, the province of Styria experienced the greatest cumulative deviation from the expected number of deaths (+11%). The provinces with the lowest cumulative excess mortality levels were Tyrol (+5%) and Burgenland (+3%); while Vienna (+9%), Carinthia (+8%) and Salzburg (+7%) had cumulative excess mortality levels that were around the level for Austria as a whole (+8%).

4 Discussion

Our analysis of weekly mortality in Austria and its nine provinces since 2007 (until week 34-2021) showed that there was a significant increase in the number of deaths during the COVID-19 pandemic. We developed an *excess mortality model* that was sensitive to the seasonality of mortality, as well as to changes in population size and age structure (with respect to the reference period). This model allowed us to quantify excess mortality for the age groups 0 to 64 years and 65 years and older at the spatial level of the Austrian provinces.

Our findings clearly indicate that during our study period, the elderly population (aged 65 years and older) was the most affected by excess mortality, not only during the COVID-19 pandemic, but also during summer heat waves and winter flu seasons (Fouillet et al., 2008; Pascal et al., 2018; Phu Pin et al., 2012). In addition, our analysis of excess mortality in Vienna and in the other Austrian provinces during the COVID-19 pandemic period (i.e., week 1-2020 to week 34-2021) uncovered regional differences in the extent of the COVID-19-related peaks in excess mortality. We found that in general, the regional mortality trends in the Austrian provinces followed the national pattern of the course of the (three) observed waves of COVID-19 infections. Our results showed that overall, the numbers of registered COVID-19 deaths in Austria matched the extent of the excess mortality, as quantified by our model.

A methodological challenge researchers face when conducting regional analyses is the sensitivity to small numbers. This problem also affected our analysis of excess mortality in Austrian provinces, as we observed that smaller numbers of events resulted in broader and less continuous prediction intervals. This issue was especially apparent for provinces such as Burgenland and Vorarlberg, which had fewer than 6,000 reported deaths (from all causes) each during the observation period of more than one and a half years (week 1-2020 until week 34-2021). Thus, it would not be feasible to further disaggregate the analysis of excess mortality in

Austrian provinces using smaller age groups, or to apply the method to even smaller administrative areas.

Our comparison of excess mortality during the COVID-19 pandemic in Vienna and Austria demonstrated the importance of performing analyses at the sub-national level in order to shed light on within-country heterogeneities. To compare the impact of COVID-19 on mortality in Vienna with that in other metropolises, it would be necessary to look beyond Austria. Regional comparative analyses at the European level (Goujon et al., 2021; Schöley, 2021; EuroMOMO, 2021) are still limited, since Eurostat does not (yet) provide up-to-date mortality data for European cities and regions with a level of demographic detail similar to the level we used in our analysis (based on data provided by Statistik Austria). With respect to further research, we are currently investigating the availability of such data from European cities, which would allow us to analyse the specific characteristics of COVID-19-related excess mortality in the urban context. Future analysis by Statistics Vienna will also focus on excess mortality during summer heat waves, as well on other factors that affect mortality in Vienna.

Acknowledgments

This article has greatly benefited from the contributions and support of our colleagues at the City of Vienna, especially Daniel Jost and the Head of Department Peter Wieser at the City of Vienna's *Department for Economic Affairs, Labour and Statistics* (MA 23). We are grateful for the support in our efforts to provide quantitative evidence on the effects of COVID-19 on overall mortality by the *Administrative Group for Finance, Business, Labour, International Affairs and Vienna Public Utilities* (GFW) and its Executive City Councillor, Peter Hanke, and his staff at the City of Vienna. Our analyses relied on data from the *Austrian Population Register* (POPREG) and the *Register of Vital Statistics* (ZPR) provided by Statistik Austria's Alexander Wisbauer and colleagues. In the development of our methodology, we have received valuable support from our colleague Christoph Junker at the Swiss Federal Statistical Office (BFS), as well as from Johannes Klotz.

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Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 415–435

COVID-19 in Hong Kong: Policies and community actions mitigate the effects of age structure and population density

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Abstract

Despite the various socio-demographic vulnerabilities of Hong Kong to the COVID-19 pandemic, the city has successfully managed four waves of local outbreaks, as shown by its comparatively low numbers of confirmed cases and deaths. In this paper, we identify and differentiate the unique characteristics of Hong Kong's COVID-19 outbreaks from those of other territories, and analyse the factors that shaped these characteristics. In particular, we examine four local demographic factors – older age structure, high population density, poor housing conditions and a large migrant population – which, according to current scientific evidence, would likely indicate that the city faces a relatively high risk of the significant spread of COVID-19. We analyse and explain how multiple policies related to border controls, social distancing, testing and tracing, partial lockdowns and housing management, as well as sustained community actions, helped to mitigate the effects of these significant disadvantages.

Keywords: COVID-19; age structure; population density; policy responses; community action; Hong Kong

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DOI: 10.1553/populationyearbook2022.dat.2

1 Introduction

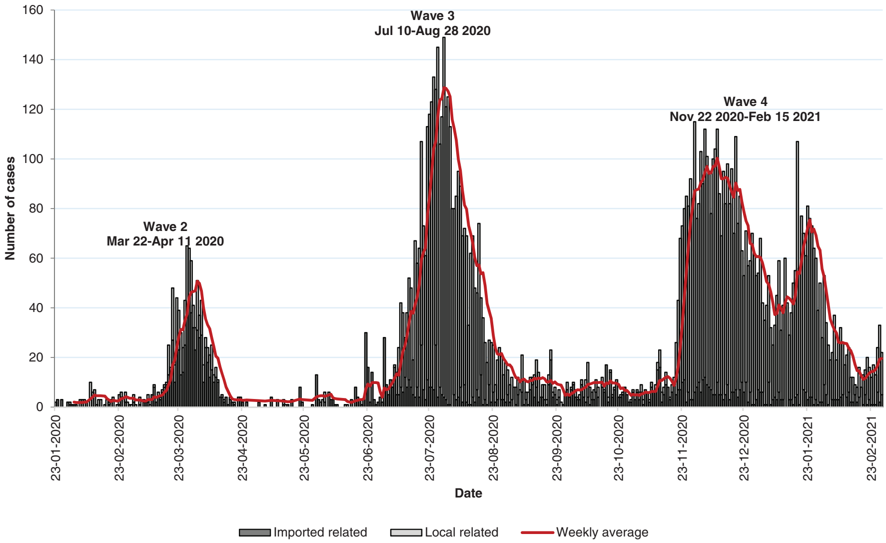
This paper examines and explains the extent to which demographic insights can shed light on the nature of the spread of COVID-19 in Hong Kong, Special Administrative Region of the People's Republic of China (hereafter "Hong Kong"). Hong Kong has some of the world's most densely populated neighbourhoods, and a rapidly ageing population. Based on the current scientific evidence, these factors should indicate that Hong Kong is highly vulnerable to severe outbreaks of the virus. Nonetheless, compared to the global average, the total numbers of confirmed positive cases of COVID-19 in Hong Kong have been very low. As of 28 February 2021, there had been 11,006 positive confirmed cases of COVID-19 out of a population of approximately 7.5 million people residing in an area of 1,104 square kilometres. In addition, mortality rates from COVID-19 in Hong Kong have been low relative to global averages, in terms of both population mortality and case fatality rates. We analyse and explain how, in the face of these demographic vulnerabilities, well-targeted government policies combined with community actions helped to mitigate the serious spread of the virus in Hong Kong.

Kowloon is the most densely populated area in the city and in the world, with approximately 48,930 persons per square kilometre (United Nations, Department of Economic and Social Affairs, Population Division, 2019). The "housing problem" – i.e., a lack of affordable homes of reasonable quality and size – is a critical and, at times, seemingly intractable, social and policy issue in Hong Kong. By some estimates, the ratio of house prices to median wages in Hong Kong is by far the highest in the world (Cox, 2021). Hong Kong also has an ageing population, with people in the 65 and older age group comprising about one-fifth (19.1%) of the city's total population in 2020. In addition, Hong Kong has one of the highest life expectancies in the world, at 82.9 years for males and 88.0 years for females (Census and Statistics Department, 2021).

Despite these potential vulnerabilities, Hong Kong appeared to have the first wave of the virus "under control" by late April 2020, less than three months after the first case was reported on 23 January 2020. From April to mid-July 2020, the rate of the spread of the virus was low, with the number of daily recorded positive cases of COVID-19 ranging from zero to 30 (Figure 1). In mid-July, the third wave of the pandemic began in Hong Kong. By late August 2020, the pandemic had again been brought "under control", with the number of cases declining to fewer than 20 per day. A prolonged fourth wave began in November 2020, and continued until late February 2021, when the local spread of COVID-19 appeared to have returned to low levels, with the number of new cases again falling to fewer than 20 per day.

Our research paper published in May 2020 highlighted the unique age structure of positive COVID-19 cases in the first and second waves of the outbreak in Hong Kong (Cruz et al., 2020). Despite Hong Kong's rapidly ageing population, the cases in the city were initially concentrated among the younger age groups, with the highest incidence of cases reported in the 15–24 age group. Our analysis of detailed case and travel history data highlighted the large proportions of imported cases in Hong Kong's first and second waves, and emphasised the contributions of return

Figure 1:
Number of daily confirmed cases by transmission type and waves and seven-day averages, Hong Kong (n = 11,006, 23 January 2020 to 28 February 2021)



Data source: Hong Kong Center for Health Protection, Department of Health.

Note: The seven-day averages are the authors' own calculations.

migration to the spread of COVID-19, with large numbers of students and working-age citizens returning from emerging pandemic hotspot countries overseas. In this paper, we update those findings by compiling detailed case data in order to assess the shifts in demographic characteristics in the subsequent waves.

The paper is organised as follows. First, we explain the data and methods we used to conduct our analyses. Second, we present the characteristics of Hong Kong's COVID-19 outbreaks, and analyse the influence of socio-demographic factors on Hong Kong's vulnerability to the spread of the virus. We then examine and explain how local policy responses and social norms have shaped Hong Kong's unique experience of the pandemic. In particular, we discuss the contributions of border controls, quarantine requirements, social distancing measures, testing and tracing regimes, housing management, partial lockdowns, the efficient health care system, nursing home management and community actions.

2 Data and methods

Data on positive COVID-19 cases were drawn from the Centre for Health Protection (CHP) of the Hong Kong Department of Health. We reviewed the daily confirmed cases and the transmission types (local, local-related or imported-related), as well as the trend of the cumulative cases by age group from 23 January 2020 to 28 February 2021. Then, we calculated the seven-day averages of confirmed cases, which became our basis for defining the COVID-19 waves in Hong Kong. We defined these waves using a weekly average cut-off of 20 cases; i.e., a wave begins in the first week in which the average number of weekly cases is above 20, and ends in the week in which the average number of weekly cases falls below 20. Using this classification, we defined three waves of the pandemic, as shown in Figure 1. Wave 2 is from 22 March to 11 April 2020 (n = 683), Wave 3 is from 10 July to 28 August 2020 (n = 3,403) and Wave 4 is from 22 November 2020 to 15 February 2021 (n = 5,228). The officially defined "first wave" was excluded from our discussion because of the relatively small number of confirmed COVID-19 cases (fewer than 10 cases) that were reported during this period.

For each wave, we assessed the age and the sex distribution of the confirmed cases, and the mortality status of these cases. We calculated and analysed the overall case fatality rate (CFR) and broke it down by age and sex. The data on the geographical location of all known confirmed cases were drawn from the Centre for Health Protection Geodata dashboard. We also gathered data on the policy measures implemented in Hong Kong from government websites. For our comparative demographic analyses, we utilised the population estimate for the end of 2020 from the Hong Kong Census and Statistics Department.

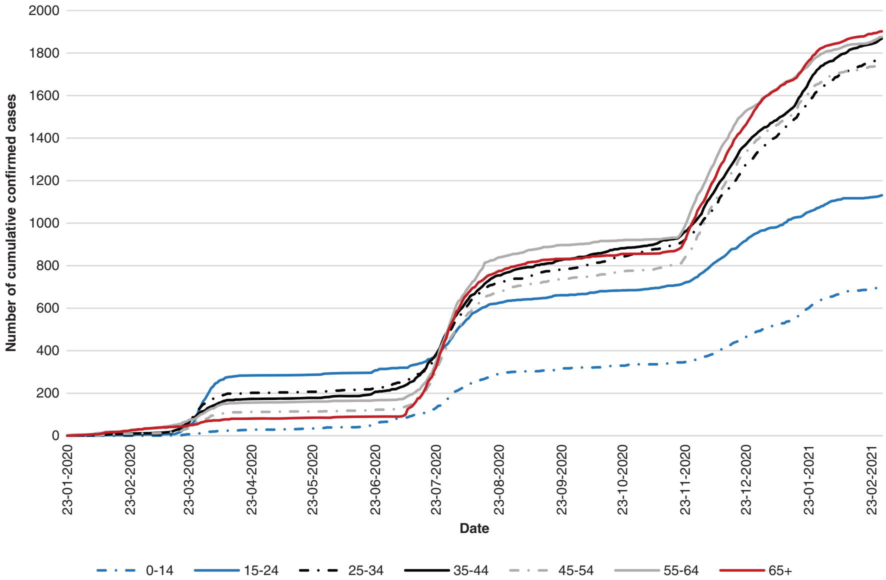
3 Characteristics of Hong Kong's COVID-19 outbreaks

3.1 The shifting age profile of COVID-19 cases

Looking at Figure 2, we can see that there were major changes in the age structure of the cumulative confirmed cases in Hong Kong during our research period. Among the seven age groups, we observed the most drastic changes for the 15–24 and 65 and older age groups. Over time, the older population (aged 65+) replaced the younger population (aged 15–24) as the age group in Hong Kong with the highest proportion of total confirmed cases. By the end of the second wave (11 April 2020), the 15–24 age group accounted for 27.47% of the 1,001 cumulative confirmed cases; whereas the 65 and older age group accounted for just 7.69% of the total cases. However, by the end of the fourth wave (15 February 2021), the proportion of the 10,789 cumulative confirmed cases that were in the 15–24 age group had dropped to 10.35%, while the proportion that were in the 65 and older age group had risen to 17.78%.

We grouped the COVID-19 confirmed cases by waves, and in Figure 3 we present three comparable pyramids. Despite Hong Kong's rapidly ageing population, the confirmed COVID-19 cases in Wave 2 were initially concentrated among the younger age groups, with the largest incidence of cases reported in the 15–24 age group. Thus, we observed that during the first and second waves of COVID-19 in

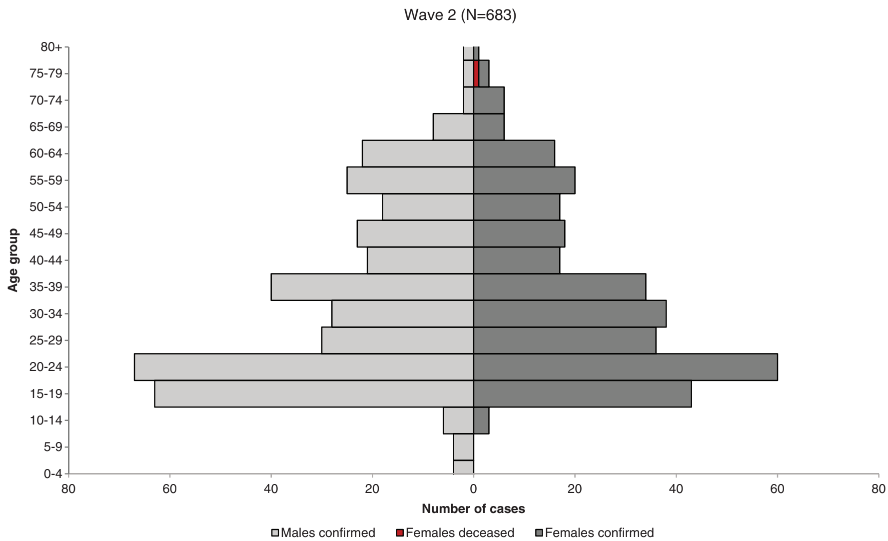
Figure 2:
Number of cumulative confirmed cases by age groups, Hong Kong (*n* = 11,006, 23 January 2020 to 28 February 2021)

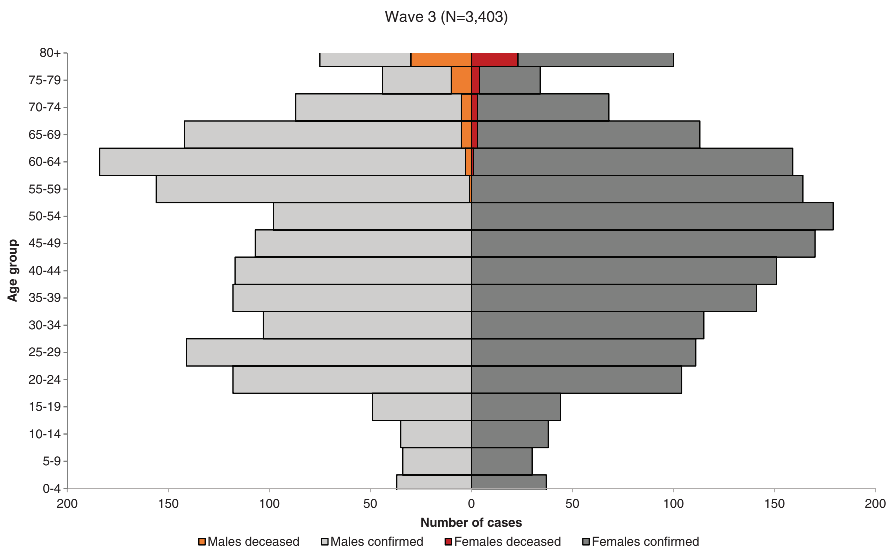


Data source: Hong Kong Center for Health Protection, Department of Health.

Hong Kong, the confirmed cases had a very different age distribution than that of the city's ageing population, with the highest number of cases occurring in the 15–24 age group, and the majority (63.8%) of positive cases occurring in the 15–44 age group (Cruz et al., 2020). By contrast, less than a tenth (4.39%) of the cases occurred in the 65 and older age group. This age distribution of confirmed cases of COVID-19 was clearly very different from the general age profile of COVID-19 cases in other countries during this period, where infections were concentrated among people in the older age groups (Dowd et al., 2020). However, in the third wave pyramid (Figure 3, Wave 3), the age profile of COVID-19 cases in Hong Kong had shifted dramatically. For example, the share of cases that occurred in the 15–24 age group decreased from 34% in Wave 2 to 9.3% in Wave 3, representing the largest drop in the percentage of confirmed cases among the age groups. Conversely, the share of cases that occurred in the 55–64 and 65+ age groups increased substantially, from 12.2% and 4.4%, respectively, in Wave 2 to 19.5% for both groups in Wave 3. In November 2020, the fourth and more protracted wave of the COVID-19 pandemic began in Hong Kong (Figure 3, Wave 4). In line with the pattern observed in the third wave, the cases in this wave were concentrated among the older age groups, with the highest shares of cases being reported among people in the 55–64 (17.0%) and

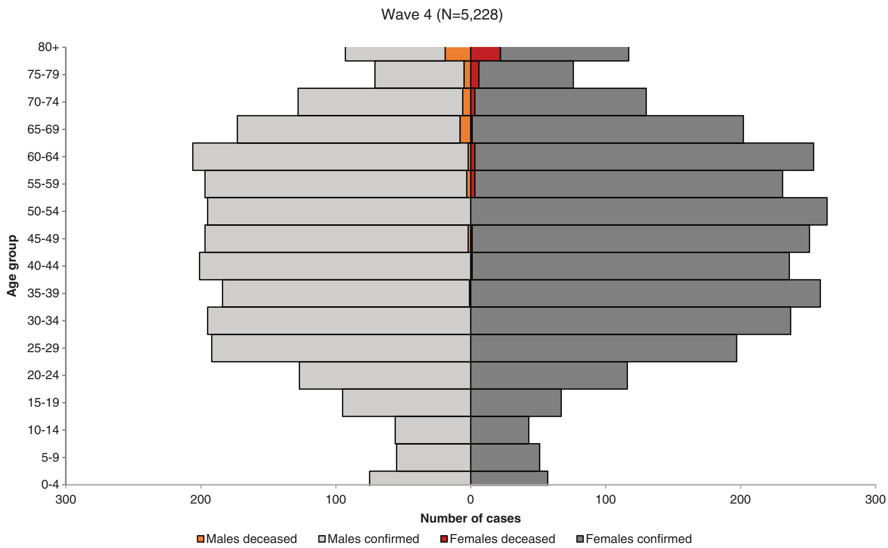
Figure 3:
Age and sex distribution of confirmed COVID-19 cases, Waves 2–4, Hong Kong





Continued

Figure 3:
Continued



Data source: Hong Kong Center for Health Protection, Department of Health.

the 65+ (18.9%) age groups. In stark contrast to the second wave, in the fourth wave the share of cases that occurred in the 15–24 age group was very low, at just 7.80%.

3.2 Low COVID-19 mortality and case fatality rates in Hong Kong

Despite the shifting age profile of the confirmed cases, COVID-19 mortality in Hong Kong has remained low relative to the levels in other countries, at 2.7 deaths per 100,000 population. According to recent estimates, the three countries with the highest COVID-19 mortality rates are San Marino, Czechia and Belgium, with 237, 236 and 199 deaths per 100,000 population, respectively; while Cambodia has the lowest COVID-19 mortality rate, at 0.03 deaths per 100,000 (Johns Hopkins University and Medicine, 2021). Among the territories in East Asia, Hong Kong ranks third after Japan (seven deaths per 100,000 population) and South Korea (three deaths per 100,000 population). China, Mongolia and Taiwan Province of China (hereafter "Taiwan") have even lower COVID-19 crude mortality rates (below one death per 100,000 population) (Johns Hopkins University and Medicine, 2021).

In line with this trend of low but increasing mortality rates, the overall COVID-19 case fatality rate (CFR) in Hong Kong was 0.15% during the first two waves, and had increased to 2.6% in Wave 3. In the protracted Wave 4, the CFR was 1.6% as of 28 February 2021. Although comparisons of the CFR are challenging due to significant

Table 1:
Case fatality rate (%) by gender and age groups, Hong Kong (23 January 2020 to 28 February 2021)

	Males		Females		Both sexes	
Age group	*%*	*n*	*%*	*n*	*%*	*n*
0–54	1.0	3,446	0.4	3,782	0.7	7,228
55–59	1.1	450	0.6	469	0.9	919
60–64	1.1	470	1.0	487	1.0	957
65–69	3.6	363	1.1	359	2.4	722
70–74	6.0	252	3.0	232	4.5	484
75–79	12.9	147	12.0	125	12.5	272
80+	30.2	189	20.9	235	25	424
ALL	2.2	5,317	1.5	5,689	1.8	11,006

Data source: Hong Kong Center for Health Protection, Department of Health.

Note: Calculations performed by authors.

differences between countries in the testing and reporting of confirmed COVID-19 cases and deaths, Hong Kong's total CFR from 23 January 2021 to 28 February 2021 has been estimated at 1.8% (Table 1), which is lower than the levels in many other global territories. The countries with the highest CFRs are Yemen (22%), Mexico (9%), Syria (7%), Sudan (6%) and Egypt (6%); while Singapore has the lowest reported CFR, at less than 0.1% (Johns Hopkins University and Medicine, 2021). Hong Kong's overall COVID-19 CFR of 1.8% is comparable to the CFR estimates of its East Asian neighbours that also have ageing populations, like Japan (1.9%), South Korea (1.7%) and Taiwan (1.0%) (Johns Hopkins University and Medicine, 2021).

4 Factors shaping the Hong Kong COVID-19 experience

4.1 Socio-demographic risk factors and vulnerabilities

Recent research has highlighted that certain socio-demographic conditions may facilitate the rapid spread of COVID-19 infections and deaths, such as a high proportion of older people in the population, high levels of institutional residence and intergenerational co-residence (extended family living together in a household), high population density, poor housing conditions and management, and a high number of foreign domestic workers.

Scholars have established a positive relationship between old-age population structures and COVID-19 mortality *between* territories; that is, the older the population, the higher the COVID-19 mortality rate (Farzanegan, 2020). Another study that examined 56 European areas highlighted the relationship between ageing and COVID-19 mortality, reporting a positive relationship between the median age and the case fatality rate (i.e., the case fatality rates increase as the median age increases) (Wang et al., 2020). As we noted above, during the first two waves of the COVID-19 pandemic in Hong Kong, only around 10% of the 683 confirmed cases occurred in the 60+ age group, and there was only one death during this period. Hong Kong's very low mortality rate in the first and second waves is largely attributable to the infection being concentrated in the younger population (Cruz et al., 2020). However, during Waves 3 and 4, infection rates among older age groups increased, accounting for about 30% of the total number of confirmed cases. The number of deaths also increased, with nearly all deaths occurring in the older age groups. The shift in Hong Kong in the age profile of COVID-19 infections and deaths away from the younger population and towards the older population follows the observed global pattern, which highlights the vulnerability of older people to the virus. In addition, research has shown that *within* territories, the general pattern of COVID-19 death rates is that they increase with age, and that men have a higher risk than women of dying from COVID-19 (Chamie, 2021; Hoffmann and Wolf, 2021; Undurraga et al., 2021). This pattern was also evident during Waves 3 and 4 of the Hong Kong pandemic, as the CFR increased with age, and there were more COVID-19-related deaths among older men than older women (see Table 1).

In addition to the share of older people in the population, a second factor that may have increased Hong Kong's level of vulnerability to COVID-19 mortality is the prevalence of older people living in residential care facilities. As an ageing society in which about 18% of the population are over the age of 65 (Wong and Yeung, 2019), care homes have increasingly become a residential option for older people in Hong Kong. According to the statistics released by Hong Kong's Elderly Commission in 2009, around 7% of older people aged 65 and older were living in residential facilities, compared to 2–3% in other Asian regions and 3–4% in some western societies (e.g., Canada and the US) (Elderly Commission of Hong Kong, 2009). By 2016, the proportion of older people in Hong Kong who were living in residential facilities had risen to 8.5% (Research Office of the Hong Kong Legislative Council Secretariat, 2017). Researchers have established the extreme vulnerability of nursing homes and other residential facilities around the world to the spread of COVID-19 and to high mortality from the virus. For example, it has been shown that a substantial proportion of COVID-19 deaths in the US have been among care home residents (Wagner, 2020).

Moreover, it has been observed that "intergenerational interactions, co-residence, and commuting may have accelerated the outbreak in Italy through social networks that increased the proximity of elderly to initial cases" (Dowd et al., 2020, 1). This also describes a potential COVID-19 transmission chain in Hong Kong, as co-residence is common in the city (Ko, 2012), with around half of older people living with their adult children (Tong et al., 2019). This prevalence of co-residence is much higher than it is in North America and Europe, where, apart from an exceptionally high prevalence of 61% in Albania, the proportion of older people who live with their family ranges from 6% in the Netherlands to 36% in Romania (United Nations, Department of Economic and Social Affairs, Population Division, 2017). Hong Kong's extremely high population density and efficient transport systems also make it easy for older adults and their adult children or grandchildren to remain in regular contact. In addition, during all waves of the pandemic, there have been no legal restrictions on gatherings in private residences. An analysis of confirmed cases in Hong Kong that were transmitted through local infections during the first and second waves showed that 54.4% of cases were transmitted through households, 33.1% of cases were transmitted through social settings outside the home and 11.9% of cases were transmitted through work settings (Adam et al., 2020). However, these results may be biased somewhat by the fact that the tracing of case contacts is significantly easier among families than it is among strangers in social settings.

Another socio-demographic factor that is critical to Hong Kong's vulnerability to the spread of COVID-19 is the very high level of population density. Multiple studies have found connections between population density and the spread of COVID-19 in Iran (Ahmadi et al., 2020), Turkey (Coşkun et al., 2021) and Japan (Kodera et al., 2020). Hong Kong certainly faces a high risk of COVID-19 transmission because of its extremely high population density and poor housing conditions in certain districts. Due to the limited availability of residential land in the territory, many residents live in extremely small and cramped apartments, and the conditions are especially concerning for low-income residents. In 2016, an estimated 209,700 people in Hong Kong were living in subdivided flats (Census and Statistics Department, 2016), which are sometimes referred to as "coffin houses" because of their tiny size and very cramped conditions (Wong, 2018). In 2016, there were 27,100 such apartments divided into an average of 3.4 subdivided units, with each subdivided unit housing an average of 2.3 persons (Census and Statistics Department, 2016). The median floor space per resident was just 5.3 square metres. These flats are characterised by poor hygiene and sanitation, environmental concerns (Lai et al., 2017) and safety problems (Leung and Cheuk, 2016). The districts with the highest numbers of subdivided flats are Yau Tsim Mong, Sham Shui Po and Kowloon City, all of which are located in the Kowloon region. Hong Kong also has a number of so-called "three-nil buildings", which have no apparent owner, and are not overseen by a property management corporation or a resident organization. Because they lack effective management, these buildings tend to be poorly maintained and dilapidated, particularly since many of them are old buildings (Hong Kong Government, 2019). In 2019, there were 5,300 of these buildings, primarily located in districts of the Kowloon region (Hong Kong Government, 2019). In areas with this extreme building density – which is generally associated with lower wind and air ventilation – and high building heights, a higher incidence of COVID-19 cases has been observed (Kwok et al., 2021). Thus, poor housing conditions and inadequate building management exacerbate the impact of high population density in Hong Kong, which, in turn, means that more people in the city are vulnerable to COVID-19 infections.

Another demographic vulnerability in Hong Kong is the proportion of low-wage migrant workers in the population, as the experiences of other territories indicate that people in this demographic group are at significantly higher risk of catching COVID-19 due to their often cramped housing conditions. Moreover, migrant workers tend to be employed in occupations that require physical labour, and that do not provide opportunities for "teleworking", or working from home. During the second wave of the pandemic in Singapore, for example, more than half of the purpose-built and factory-converted dormitories for guest workers were affected by COVID-19 outbreaks (Humanitarian Organisation for Migration Economics, 2020). It has been estimated that around 80% of all cases during the second wave in Singapore were linked to these dormitories (Humanitarian Organisation for Migration Economics, 2020). Hong Kong is also home to a large population of migrant "guest workers" who may be vulnerable to spread of the virus. Most of these workers are classified as "Foreign Domestic Workers" (FDWs), and are required to live in their employer's home. In 2019, there were almost 400,000 migrant domestic workers in Hong Kong, making up more than 10% of the city's labour force (Labour and Welfare Bureau, 2019). The overwhelming majority of these migrant workers are women from Southeast Asia. These workers run a particularly high risk of catching COVID-19 because their jobs entail intra-household and, often, inter-household relations.

4.2 Protective factors: Policy responses and community actions

Two notable shifts occurred in the profile of confirmed COVID-19 cases in Hong Kong from wave to wave: i.e., a shift in the age profile of cases from younger to older ages, and a shift from imported to local transmission. In our previous analysis, we attributed a large proportion of the positive cases to members of the student-age and working-age populations returning to Hong Kong from COVID-19 hotspots in the initial stages of the pandemic. We showed that most of the confirmed cases in the first and second waves were imported, and we highlighted the important role of members of the Hong Kong diaspora, and particularly of the large overseas student population, who had returned to Hong Kong from COVID-19 hotspot areas overseas (Cruz et al., 2020). An analysis of detailed travel history data tracked by the CHP revealed that of the COVID-19 cases involving an individual with an overseas travel history, nearly half (47.4%) were imported from the United Kingdom (UK), 9.1% were imported from the United States (US), and 3.9% each were imported from Qatar, Canada and Switzerland (Cruz et al., 2020). In addition, our research found that a very high proportion of the confirmed cases in the 15–24 age group (90%) and the 25–34 age group (43%) could be classified as "imported-related" (i.e., cases that were imported from overseas or could be directly linked to an imported case). However, throughout the third and fourth waves, strict border controls designed to prevent or greatly discourage overseas travel vastly reduced travel in and out of Hong Kong. In line with these reductions in travel, a minority of cases in the third and fourth waves were imported. Thus, during these waves, the pandemic was driven by the local spread of COVID-19. The results of our analysis indicate that a significantly lower proportion of cases in the third and fourth waves were imported, with such cases accounting for 35.8% of the total confirmed cases during the third wave, and just 7.6% of the total confirmed cases during the fourth wave (see Figure 1).

It is, however, of critical importance that government-mandated border controls changed over time and helped to mitigate the increase in imported and related cases in Hong Kong. From 25 March 2020 onwards, all non-residents were barred from entering the territory except for nationals of Macau Special Administrative Region of the People's Republic of China (hereafter "Macau"), Taiwan or Mainland China. By the end of March 2020, new 14-day home quarantine requirements were put in place for all people arriving in the city, regardless of whether they were residents. As a result of these requirements, passenger traffic decreased sharply. The longer-term effect of these policies was to dampen inbound travel for the rest of 2020, which undoubtedly contributed to the significantly lower proportion of imported cases in later waves. According to the data we retrieved from the Hong Kong Immigration Department, the number of people arriving in the city remained at around 25,000 per day before dropping significantly at the end of March 2020 to below 2,000. Government-mandated border controls as well as aggressive test-and-trace and quarantine regulations contributed to the decline in COVID-19 cases during the month of April 2020 (Cowling et al., 2020). During the third wave, strict border controls remained in place, and travel quarantine requirements became even more stringent. For example, although residents were initially permitted to quarantine at home, they were issued a tracking bracelet connected to the Global Positioning System (GPS), and were tested for COVID-19 before and during the quarantine period.

In addition, on 25 July 2020, the government introduced a list of "high-risk" territories. Travellers from these locations were subject to stricter quarantine requirements, including rules mandating that they have a negative test before travelling and spend the quarantine period in a government-designated hotel (Hong Kong Government, 2020b). These restrictions contributed to the significantly lower numbers of imported confirmed cases in the third wave than in the second wave, during which the cases were concentrated among younger age groups.

As the fourth wave of COVID-19 in Hong Kong – which was linked to transport staff – started prior to the holiday season in December 2020, the border control and quarantine regulations were further tightened to protect Hong Kong from international transmission. In November 2020, the government introduced new travel restrictions and expanded the 14-day hotel quarantine requirement to cover travellers who entered Hong Kong from any destination except Taiwan, Macau and Mainland China. The UK, the US, France and Germany were added to the list of high-risk countries, which already included many countries in Asia, such as Indonesia, the Philippines, India, Nepal and Pakistan. Under these newly imposed restrictions, travellers also had to secure a negative COVID-19 test 72 hours before arriving in Hong Kong. On 25 December 2020, the length of the mandatory hotel quarantine was extended to 21 days for travellers arriving from all regions except Taiwan, Macau and Mainland China. At that time, this was the longest travel quarantine period in the world. In addition, all travel was banned from the UK and South Africa, including for Hong Kong residents. According to the travel data retrieved from the Hong Kong Immigration Department, the numbers of inbound and outbound travellers remained very low from December 2020 to February 2021, and thus over the Christmas and Lunar New Year holidays, which are usually the busiest travel period for Hong Kong. During this period, the daily average number of arrivals was lower than 2,000, and the daily average number of departures was around 2,500. Hong Kong has a large overseas population of secondary school- and university-age students, especially in the UK and the US, and a large share of Hong Kong residents are also nationals of the UK, the US and Canada. These populations are believed to have triggered the second wave outbreak in Hong Kong (Cruz et al., 2020). In addition, Hong Kong is home to large populations of nationals from the Philippines, Indonesia, India, Nepal and Pakistan (Cruz et al., 2020). Given that all of these countries imposed even stricter travel regulations from November 2020 onwards, it is likely that these restrictions strongly discouraged travel, leading to significantly lower numbers of imported cases in the fourth wave than in the two earlier waves.

In addition to border control measures designed to limit the number of imported cases, another set of critical policy tools used by the Hong Kong government were social distancing measures aimed at mitigating local transmission. These social distancing regulations were generally implemented when needed, and were adapted to the local pandemic conditions. These measures included reductions in the opening hours of restaurants; restrictions on the sizes of public gatherings; and closures of schools, universities, entertainment venues, recreational facilities, outdoor spaces and certain types of businesses, such as gyms, bars, nightclubs, beauty salons, massage parlours, sports and exercise facilities, beaches and playgrounds. Although these measures clearly had deleterious effects on local businesses, social activities and social interactions, the evidence suggests that from a public health perspective, they were effective in containing the spread of COVID-19. For example, research indicates that during the second wave of the pandemic in Hong Kong, a combination of adherence to social distancing and mask-wearing regulations, remote working and school closures led to a reduction in seasonal influenza incidence of around 44.0% (Cowling et al., 2020).

A third set of key government policies designed to reduce local transmission chains were testing and tracing measures. Under these rules, anyone who had come into contact with a confirmed case was pre-emptively placed in a government isolation centre for 14 days and tested regularly. It has been shown that these very thorough contact tracing processes and strict quarantine requirements were highly effective in interrupting chains of transmission during the first and second waves

(Adam et al., 2020), and may have played a role in mitigating the local spread of the virus.

Although the city's high population density and poor housing conditions in many communities posed risks for Hong Kong during the pandemic, the government attempted to compensate for these disadvantages by deploying various policy measures, most notably measures related to housing and building management, as well as community-level lockdowns. The Housing Authority (HA) implemented a number of public health measures after the start of the pandemic, such as the intensification of daily cleaning and disinfection in public areas, including of escalators, elevators, passages and drainage facilities. Whenever a COVID-19 case was confirmed by the Department of Health, the HA arranged for the thorough cleaning and disinfection of the affected buildings, and conducted comprehensive inspections of any units that shared sewerage and pipes with the unit in which the confirmed case was detected. The authority also distributed and collected voluntary testing bottles from residents, and collected environmental samples from affected public facilities (Hong Kong Housing Authority, 2020). During the fourth wave, the government imposed numerous partial lockdowns – i.e., compulsory testing orders – of certain residential blocks. These lockdowns were, for example, implemented in response to concerns about a number of community clusters that emerged in several districts in Kowloon (Jordan, Yau Ma Tei, and Sham Shui Po) with population densities of more than 48,930 persons per square kilometre. The first of these partial lockdowns centred on several housing blocks in Jordan, a district in which high proportions of the residents have lower socio-economic status and are members of ethnic minority groups. On 23 January 2021, more than 3,000 government staff – including 1,600 so-called "disciplinary workers" – locked down an area of around 70 buildings in Jordan, Kowloon, and conducted more than 7,000 COVID-19 tests (Hong Kong Government, 2021a). Numerous other community-level lockdowns have since been implemented in residential blocks spread around the city that were suspected of having clusters of COVID-19 cases. Given that these small COVID-19 outbreaks across various parts of the city were indeed brought under control, it is clear that these policy actions helped to stem the spread of the virus in the most cramped housing blocks.

The relatively low mortality and case fatality rates due to COVID-19 in Hong Kong are remarkable given the territory's large older population and the high proportion of its residents living in residential care homes, as studies have shown that there is a strong relationship between having an older population age structure and high COVID-19 mortality (Hoffmann and Wolf, 2020, 2021). As the results of our previous analysis suggested, one key, yet often overlooked factor in these relatively low mortality rates is the distribution of confirmed cases during the first few months of the COVID-19 pandemic, which were concentrated among the younger age groups in Hong Kong (Cruz et al., 2020) However, by the third and fourth waves of the pandemic in Hong Kong, the CFR in the city was clearly exhibiting the expected pattern: i.e., it was increasing with age, and was especially high among older men. Nonetheless, the CFR in Hong Kong remained lower than the rates in most other territories. A second important set of factors in the relatively low mortality and case fatality rates in Hong Kong are, most likely, the city's effective health care system and its coordinated management of residential facilities from the start of the pandemic. Based on the lessons the city learned during the 2003 outbreak of severe acute respiratory syndrome (SARS), the Hong Kong Department of Health directed all residential care homes at the start of the COVID-19 pandemic to assign a staff member to manage infection control and implement preventive measures. These staff members were expected to implement measures such as the limitation/suspension of family visits, the restriction of the movement of residents outside the facility, social distancing, and the wearing of face masks (Chow, 2021; Woo, 2020). Meanwhile, the Hong Kong government also issued guidelines to support residential care homes in preventing infection (Centre for Health Protection, 2020), and offered other forms of support, including the provision of personal protective equipment (PPE) and infection protection services (Hong Kong Government, 2020c), as well as the transition to online care support for individuals who would ordinarily visit day care centres (Xinghui et al., 2020). Research has shown that the implementation of stringent COVID-19 guidelines and prevention measures has been highly effective in preventing the spread of infection (McMichael et al., 2020). Thus, it is likely that the strict preventive measures implemented in Hong Kong care homes from the beginning of the pandemic may have created fewer opportunities for sustained local spread within the older population. In addition, some studies have linked the low mortality and case fatality rates in Hong Kong to the city's strong overall health care system and testing and quarantine regimes (Farzanegan, 2020; Lui et al., 2020). Farzanegan found that the risk of death from COVID-19 has been lower in ageing societies with at least 3.5 hospital beds per 1,000 population (Farzanegan, 2020). Our results appear to support this finding, as based on our estimates of the numbers of beds in public and private hospitals as of May 2019 (Hong Kong Department of Health, 2019) and of the population as of the end of December 2020 (Census and Statistics Department, 2021), the current hospital bed capacity in Hong Kong is approximately 4.5 hospital beds per 1,000 population.

Moreover, even though migrant workers have been identified in other regions as a high-risk population during the coronavirus pandemic, the spread of COVID-19 among migrant workers in Hong Kong has been extremely low. It is likely that government policies in conjunction with community actions among groups of migrant workers have greatly reduced the transmission of COVID-19 in Hong Kong. In terms of government policies since the second wave of the pandemic, the government has advised local employers of FDWs to discourage employees from socialising in public places during periods of social distancing, and has mandated that such gatherings can be broken up by the police, and that the participants can be fined. It is also likely that travel policies and flexible contract and immigration arrangements for FDWs played a very important role in reducing the spread of the virus among this population. To discourage migrant workers from travelling between Hong Kong and their home countries, the government offered to extend the visas of those individuals whose visas were about to expire. In August 2020, the Philippines and Indonesia, the biggest migrant sending countries, were added to the list of high-risk countries, and a two-week hotel quarantine for travellers from these countries was put in place. Employers of FDWs travelling from these countries were required to sign an agreement to pay for a hotel stay and testing for each employee (Hong Kong Government, 2021b). In line with the general tightening of travel restrictions, from December 2020 onwards, FDWs travelling to work in Hong Kong were required to stay in a government-designated hotel for 21 days. In addition to these efforts by the government, community actions among groups of migrant workers may have also contributed the low rates of infection among this group. These actions included mask-wearing, social distancing and taking advantage of the free COVID-19 testing that was made available to FDWs (Hong Kong Government, 2020a).

As well as the policies implemented by the government, community actions appeared to be remarkably successful in preventing the rapid spread of COVID-19, particularly in the initial stages of the pandemic. Citizens of Hong Kong were on high alert as early as in January 2020, when the Chinese government officially reported a cluster of cases of pneumonia in Wuhan, Hubei Province. For example, the general public overwhelmingly started wearing masks at the beginning of the local COVID-19 pandemic (Cheng et al., 2020), despite a lack of government advice to do so. Mask-wearing was already a common practice in Hong Kong, as it had been used to control the community transmission of SARS in 2003, and then the pandemic influenza A-H1N1 in 2009. It is also believed that these experiences contributed substantially to the community's high levels of compliance with many other non-pharmaceutical measures, including social distancing, border controls and quarantine requirements (Cheng et al., 2020). For example, evidence from three cross-sectional, representative telephone surveys during the first and second waves indicates that the vast majority of the population engaged in the rapid uptake of behaviours aimed at preventing the spread of COVID-19. By mid-February, around 20 days after the first case was announced, 97.5% of residents reported using face masks, 92.5% reported washing their hands more often, 90.2% said they were avoiding going to crowded places and 89.3% reported that they had disinfected their home in response to the pandemic (Cowling et al., 2020). Although the proportion of people who said they were avoiding public places had dropped slightly by mid-March, rates of face mask-wearing and hand-washing remained extremely high (Cowling et al., 2020).

5 Conclusion

Research has suggested that places that have an ageing population structure, high population density and cramped living conditions, and a high proportion of migrants in the population are at high risk of experiencing the rapid spread of COVID-19 and high mortality rates from the virus (Goldstein and Lee, 2020; Humanitarian Organisation for Migration Economics, 2020). However, despite fitting all these criteria, the COVID-19 infection rates in Hong Kong have been much lower than those in many global territories, and the mortality rates in the city have been correspondingly low. The collective efforts by the government, the private sector and the public through targeted policies and community actions may have helped Hong Kong overcome its aforementioned significant socio-demographic vulnerabilities to COVID-19. Our analysis has highlighted the importance of travel histories and border restrictions in explaining the shift in the age structure of cases across waves. Border closures, travel bans and quarantine requirements significantly deterred inbound and outbound travel, resulting in lower numbers of imported cases in later waves, which had previously been clustered in the younger age groups. We highlighted the effectiveness of social distancing, testing and tracing, housing management and partial lockdowns in mitigating the local transmission of the COVID-19 virus. In seeking to explain the low COVID-19 mortality rates in Hong Kong despite the city's ageing population, we noted the role of the age profile of cases, but also emphasised the importance of the city's efficient health care system and nursing home management. The combination of all of these efforts proved effective in slowing down or even stopping the spread of infections in Hong Kong.

Furthermore, public health experts see hope in the rollout of safe COVID-19 vaccines around the world (Kasai, 2021). In Hong Kong, the vaccination rollout started at the end of February 2021, and as of 10 August 2021, 51.9% and 40.0% of the total population had been vaccinated with the first and the second dose, respectively (Hong Kong Government, 2021c). However, relative to many other countries, "vaccine hesitancy" is high and the general acceptance of vaccines is low in Hong Kong (Yu et al., 2021). To address this slow uptake, medical experts have recommended that all relevant actors help through "intensive education, provision of more evidence-based information, and public health interventions" (Chan et al., 2021).

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Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 437–457

Rapid changes in birth counts in Brazilian major cities during the COVID-19 pandemic

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Abstract

Since the beginning of the coronavirus pandemic, Brazil has been among the countries that have been heavily affected by this novel disease. From March 2020 onwards, records of deaths in Brazil increased as the number of COVID-19 infections skyrocketed. Consequently, many studies have tried to explain how this illness has affected the overall number of deaths since the start of the pandemic, and have examined the question of whether mortality related to COVID-19 has led to reductions in life expectancy. However, at the time of writing, there have been few empirical analyses of the effects of the pandemic on births. In this study, we sought to investigate whether the COVID-19 pandemic influenced the recent birth counts of six large cities in Brazil by assessing the most up-to-date vital statistics data that are available. Using data from the municipal health departments of these cities, we compared the number of monthly births from October–December 2020 and January–March 2021 with the number of new-borns in similar months and years before the pandemic. Our results show that there was a strong decline in the number of births in some of the cities analysed, and that most of the reductions occurred among women around the age of 30 years old. It appears that because of the uncertainty surrounding the pandemic, women have been postponing or foregoing the realisation of their fertility intentions, which may have led to a temporary baby bust in some cities of Brazil. However, the COVID-19 pandemic was not found to be associated with faster reductions in births in all Brazilian cities. Indeed, in the

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DOI: 10.1553/populationyearbook2022.dat.3

cities of Rio de Janeiro and Belo Horizonte, the decreasing trend in birth counts appears to have slowed down, or even reversed.

Keywords: COVID-19 pandemic; birth count changes; Brazilian cities

1 Context of the COVID-19 pandemic in Brazil

In early 2020, several cases of COVID-19 emerged in different regions of the world, after a number of cases were observed in Europe and the United States (Burki, 2020; Muñoz, 2020; Rodriguez-Morales et al., 2020). The COVID-19 pandemic has profoundly affected many aspects of our daily lives, and, as Settersten et al. (2020) has pointed out, family-related behaviours may have been significantly altered due to the pandemic.

During the pandemic, Brazil has attracted the world's attention, as the country's executive leadership has encouraged people to go out, and has generally advocated for relaxing social-distancing measures. As a result, the numbers of infections and deaths have been high across Brazil, turning the country into the epicentre of the disease, and prompting international media coverage of the pandemic conditions in this South American country (Lima et al., 2021a). At the same time, the tensions caused by poor political and sanitary conditions in Brazil have raised concerns among the scientific community, and have led to the publication of a number of studies on the demographic costs of deaths, excess mortality and potential reductions in life expectancy due to COVID-19 in Brazil (Castro et al., 2021a, 2021b; Lima et al., 2021a, 2021b).

In Brazil, the COVID-19 pandemic started in the country's two largest cities: São Paulo and Rio de Janeiro. Both of these cities are located in the most developed region in the south-east of the country, and they are also the most developed municipalities in Brazil in terms of health care access and the quality of medical facilities (Lima et al., 2021a; see also Figure A.1 in the appendix). Due to tourism traffic and business travel, especially from Europe, these two cities had their first contact with the virus in March 2020 (Lima et al., 2021a). Gradually, however, COVID-19 cases spread to other cities and regions of the country. At the beginning of 2021, the country was setting daily mortality records. In the month of March 2021, the daily average number of deaths from the disease reached values above 3000 (Consórcio de veículos de imprensa, 2021). In the state of São Paulo, for example, the average number of deaths was above 800 per day; while in the city of São Paulo, the average number of deaths was more than 200 per day until the beginning of April (Prefeitura de São Paulo, 2021). In addition, similar surges in COVID-19 deaths were reported in other large cities across the country. As a result of these developments, Brazil's mortality levels were higher in 2020 than in previous years (França et al., 2020; Marinho et al., 2021). According to CONASS (2021), Brazil registered 22% more deaths in 2020 than in previous years, with excess mortality varying across geographical regions, from 38% in the south-east to 9%

in the south. In the first semester of 2021, there were 62% more deaths in Brazil than there were in the same period of the previous years. During this period, the highest excess mortality levels were reported in the south-eastern region (45%), and the lowest levels were reported in the country's mid-western region (9%).

With the pandemic out of control in much of the country, and no prospect of this public health crisis coming to an end over the short term, we may wonder what effects the pandemic has had on other demographic indicators, such as on births and fertility trends. Initial speculations in the media have suggested that the lockdowns could lead to an increased number of births as couples spend more time together in their homes (Sobotka et al., 2021). However, past empirical evidence has shown that exogenous shocks on populations can have negative effects on fertility, including outbreaks of infectious diseases, such as the Zika virus epidemic in Brazil in 2015–2016; and the economic turbulence caused by the global financial crisis of 2007–2008, which affected short-term fertility developments in most developed nations (Comolli, 2017; Marteleto et al., 2020; Rangel et al., 2020; Sobotka et al., 2011). Additionally, some scholars have argued that during uncertain times, couples may be expected to postpone or revise their childbearing plans and intentions (Vignoli et al., 2020).

The literature suggests that the pandemic could have both positive and negative effects on fertility. In terms of the potential negative effects, Sobotka et al. (2021) have argued that the pandemic may directly and indirectly affect the number of births in a population, which would, in turn, reduce fertility rates. The direct effects of the pandemic include an increased likelihood of couples voluntarily deciding to use birth control because they are struggling with economic uncertainties, concerns about the health consequences of the pandemic and increased stress related to lockdowns (Aassve et al., 2020; Kearney and Levine, 2020; Settersten et al., 2020). The indirect effects may include the postponement of unions or relationship disruptions caused by long periods of social distancing measures, which might reduce the frequency of sexual intercourse among young people (Lehmiller et al., 2020) because they have fewer chances to meet; the increased opportunity costs of families who are having to adjust to homeschooling and providing other forms of care to their children who are staying at home; and the loss of contact with grandparents, and of their availability to provide childcare. All of these factors may have reduced the chances of pregnancy during the pandemic.

On the other hand, Coutinho et al. (2020) have argued that there are several factors that could positively affect fertility rates during the pandemic. The authors divided these factors into two groups: first, those related to difficulties and a loss of access to sexual and reproductive health services; and, second, those related to issues of social distancing, such as sexual and gender violence, mental health problems and the evaluation of the costs of parenting. Thus, it is possible that long periods of quarantine in association with greater sexual exposure and the loss of access to contraception could increase fertility rates instead of depressing them, including in countries like Brazil, where half of pregnancies are considered unplanned (Theme-Filha et al., 2016). Moreover, other scholars have posited that being quarantined in stressful environments (with increased alcohol abuse, stress and financial difficulties) may lead to more domestic violence, which could, in turn, lead to more unplanned pregnancies (Ferrero, 2020; Theme-Filha et al., 2016).

In this context of speculative hypotheses about how the pandemic could affect fertility trends in Brazil, we aim to investigate recent birth developments in six Brazilian municipalities for which we have publicly available data. We focus on the association between the numbers of births at the start of the pandemic (23–29 March 2020) and the probable reduction (or increase) in birth counts nine months later and in the following period. Our strategy is to compute the monthly birth counts in the last three months of 2020 and in the first three months of 2021, and to compare them with the numbers of births in the years before the COVID-19 pandemic. Additionally, we give a general overview of some fertility measures, such as total fertility rates (TFR), age-specific fertility rates (ASFRs) and mean age at birth, that we can use to better understand the most recent fertility developments in these selected municipalities before the COVID-19 pandemic started. Moreover, for the pandemic period, we estimate the percentage changes in birth counts by trimester, and then decompose the contributions of different age groups to the changes in birth counts during the years 2020 and 2021. Our aim is determine whether women of different ages responded to the pandemic differently.

While the present analysis is addressing a question that might imply causality between the COVID-19 pandemic and changes in birth counts, we are neither assuming nor investigating a such a causal relationship; instead, we are evaluating whether there was an association between the two phenomena. Indeed, given that the birth counts in Brazil have been declining in recent years, it could be argued that any reductions (or increases) in birth counts nine months after the onset of the pandemic are simply the result of the natural course of fertility decline in the country, and cannot be attributed to the effects of the COVID-19 pandemic. However, in this study, we argue that the pandemic may have accelerated (or slowed down) these normal developments in birth rates.

2 Data sources and methodological approach

2.1 Description of birth data sources and their availability

In Brazil, birth records are made available to the public by the Ministry of Health and the National Brazilian Statistical Office (IBGE). Both provide online access to birth records, including information from birth registries on age and sex, as well as other demographic information, such as the ages and the educational levels of the mother and the father, the ethnicity of the mother and other socio-economic indicators.

The Brazilian National Statistical Office collects vital statistics from across the country, bringing together all of the records of live births reported by the Civil

Registry of Natural Persons and Notary offices, and publishing this information on the webpage of the IBGE Automatic Recovery System (SIDRA, 2021). Until the end of the first semester 2021, this vital statistical source only provided birth count information for the years prior to 2020 (ibid). Hence, we use this dataset only to verify the consistency of the birth data drawn from other sources.

The Ministry of Health compiles birth count information and makes it publicly available via the Live Birth Information System (SINASC, 2021). The ministry uses a decentralised model, gathering information on births reported by the state health departments. The birth certificates are then distributed by the ministry to the state health departments, which, in turn, distribute them to the municipal health departments. The municipal health departments manage the distribution of these birth certificates to health facilities, civil registry offices, forensic medicine institutes, and so on (Lima et al., 2021c). These departments also compile the initial information on birth counts. Thus, for certain cities and states, it is possible to access information on births in the early months of 2021 (Lima et al., 2021c). This information is mainly available in places where the vital statistical system is locally well organised, and can quickly provide reliable information on births and deaths, even during the pandemic period.

For this study, we use information from municipal health departments[1] to compile monthly birth counts according to the age of the mother for six Brazilian municipalities: Belo Horizonte, Curitiba, Fortaleza, Rio de Janeiro, Salvador and São Paulo (see Figure A.1 in the appendix for the spatial distribution of these cities according to their respective macro-regions). We have chosen to focus on these six cities because they provide a good overview of the effects of the pandemic in the country, as each of them is located in a different region of Brazil, has a different level of socio-economic development and experienced the onset of the pandemic at a different point in time. For example, the cities of Belo Horizonte, Rio de Janeiro and São Paulo are located in the socio-economically developed south-eastern region of the country, which accounts for more than 50% of Brazil's GDP (da Lima and de Ramos, 2010). The city of Curitiba, which is located in the southern region of the country, is considered the city in Brazil that offers the highest quality of life in terms of job opportunities and access to basic health and education services (COMEC, 2012). Meanwhile, Fortaleza and Salvador are located in the historically

[1] The Municipal Health departments linked to the Live Birth Information System of the Ministry of Health (SINASC, 2021) have the follow webpages for each city:
Belo Horizonte: http://tabnet.saude.mg.gov.br/deftohtm.exe?def/nasc/nascr.def.
São Paulo: http://tabnet.saude.prefeitura.sp.gov.br/cgi/deftohtm3.exe?secretarias/saude/TABNET/sinasc/nascido.def
Rio de Janeiro: http://tabnet.rio.rj.gov.br/cgi-bin/dh?sinasc/definicoes/sinasc_apos2005.def
Curitiba: http://www.tabnet.sesa.pr.gov.br/tabnetsesa/dh?sistema/sinasc99diante/nascido_99diante
Salvador: http://www.tabnet.saude.salvador.ba.gov.br/deftohtm.exe?sivitais/sinasc/nascido.def
Fortaleza: http://extranet.saude.ce.gov.br/tabulacao/deftohtm.exe?sim/nascido.def. Please note that some webpages might not be accessible outside of Brazil.

less developed north-eastern region of Brazil (Chein et al., 2007). Moreover, as all of these urban areas have more than one million inhabitants, and are among Brazil's largest cities, the chances that they will experience fluctuations in births caused by a small number of events occurring in each month are low. In addition to meeting the population size criteria, these cities are the only ones in Brazil that have made publicly available preliminary birth counts for the early months of 2021.

An alternative source of information on vital statistics that has attracted attention and publicity in Brazil during the pandemic is the Civil Registry Transparency Portal[2] (Portal Transparência in Portuguese). Accessible since 2018 and maintained by the National Association of Registrars for Individuals (ARPEN, 2021), this portal is a publicly accessible website that provides vital statistics on births, marriages and deaths. Although this source provides information on monthly birth counts for the years 2020 and 2021, after comparing the three data sources (see Figure A.2 in the appendix), we decided to not use the ARPEN data because we found too many inconsistencies between the portal's birth counts and those of SINASC and SIDRA.

2.2 Methods

First, we estimated general fertility measures for the six municipalities; i.e., TFR, AGFRs and the average age at childbirth broken down by years prior to the pandemic. Second, we compared relative differences in birth counts by quarters for the years 2017 to 2021, while giving special attention to the trimesters of October to December (important for comparisons between 2020 and previous years) and January to March (for 2021 comparisons) of each year, according to the formula: $[B(t+1) - B(t)]/B(t)$. This enabled us to control for the effects of birth seasonality in each year. Finally, we performed a decomposition exercise to better understand the age patterns of the fertility changes.

2.3 Age decomposition of birth counts

We have monthly birth data by the mother's age that give us the opportunity to explore more dimensions of the changes in birth counts in the six cities. This analysis is important, especially considering that before the pandemic, fertility in Brazil was generally concentrated at certain maternal ages (Lima et al., 2018; Rios-Neto et al., 2018). Thus, it could be informative to investigate whether the patterns of

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[2] This data source is not considered an official source of vital statistics, and all information from this source comes from the Civil Registry Information Centre. The information is collected via notary offices, and the informant submits the birth certificates to the Civil Registry Service Unit responsible for registering the event (Lima et al., 2021c). One advantage of this source of vital information that it makes the birth count data available to a broader public relatively quickly. This practice has been criticised, as the raw data may not be cleaned, and could have biases that can lead to wrong interpretations.

changes in birth counts varied according to the mother's age during the COVID-19 pandemic. Hence, we also explore the association between the COVID-19 pandemic and changes in birth counts, but this time by disaggregating our analysis by births into different maternal age groups. In this part of the analysis, we have applied an adaptation of Das Gupta (1991) decomposition model that separates crude births counts in terms of the effects in each maternal age group (in Das Gupta, 1993).

The numbers of monthly births at ages below 15 and above 44 years old are too small, and can thus be disregarded. In its original formulation, we assume that the total monthly births of a population (R) can be separated as the effect of six maternal abridged ages α, β, γ, δ, ε, η, where $\alpha, \beta, \ldots, \eta$ represent the effects of changes in monthly births attributed to the age groups 15–19, 20–24, 25–29, 30–34, 35–39 and 40–44, respectively.

Suppose we have a population in two different time periods (R_1 and R_2), each of which can assume birth count values of $R_1 = F(A, B, C, D, E, F)$ and $R_2 = F(a, b, c, d, e, f)$ in the population during time$_1$ and in the same population in time$_2$, where $A, B, \ldots, F$ and $a, b, \ldots, f$ represent the birth counts for the maternal age groups 15–19, 20–24, 25–29, 30–34, 35–39 and 40–44 in times 1 and 2, respectively.

Thus, if we are interested in knowing what share of the total monthly changes in birth counts between times 1 and 2 can be attributed to the number of births in a specific maternal age group, e.g., the percentage share of births to women aged 15–19 years old (*α-effect*) in the changes in total birth counts between the two periods, we apply the following Das Gupta (1993) decomposition method in its original formulation. As an example, let us consider the number of births to women aged 15–19 years old:

$$\beta\gamma\delta\varepsilon\eta\text{-standardised total : in time}_1 = Q(A), \tag{1}$$

$$\text{in time}_2 = Q(a), \tag{2}$$

so that

$$\alpha\text{-}\mathit{effect} = Q(a) - Q(A) \tag{3}$$

Where:

$$\begin{aligned} Q(A) = Q(A; b, c, d, e, f, B, C, E, F) &= [F(A, b, c, d, e, f) + F(A, B, C, D, E, F)]/6 \\ &+ [F(A, b, c, d, e, F) + F(A, b, c, d, E, f) + F(A, b, c, D, e, f) \\ &+ F(A, b, C, d, e, f) + F(A, B, c, d, e, f) + F(A, B, C, D, E, f) \\ &+ F(A, B, C, D, e, F) + F(A, B, C, d, E, F) + F(A, B, c, D, E, F) \\ &+ F(A, b, C, D, E, F)]/30 + [F(A, b, c, d, E, F) + F(A, b, c, D, e, F) \\ &+ F(A, b, c, D, E, f) + F(A, b, C, d, e, F) + F(A, b, C, d, E, f) \\ &+ F(A, b, C, D, e, f) + F(A, B, c, d, e, F) + F(A, B, c, d, E, f) \\ &+ F(A, B, c, D, e, f) + F(A, B, C, d, e, f) + F(A, B, C, D, e, f) \\ &+ F(A, B, C, d, E, f) + F(A, B, C, d, e, F) + F(A, B, c, D, E, f) \\ &+ F(A, B, c, D, e, F) + F(A, B, c, d, E, F) + F(A, b, C, D, E, f) \\ &+ F(A, b, C, D, e, F) + F(A, b, C, d, E, F) + F(A, b, c, D, E, F)]/60, \end{aligned} \tag{4}$$

Table 1:
Total fertility rates of six selected cities of Brazil, 2017–2020

	Year and TFR Value			
City	**2017**	**2018**	**2019**	**2020**
Belo Horizonte	1.43	1.42	1.38	1.28
São Paulo	1.71	1.69	1.63	1.53
Rio de Janeiro	1.88	1.84	1.72	1.65
Curitiba	1.44	1.41	1.37	1.27
Fortaleza	1.51	1.48	1.45	1.36
Salvador	1.71	1.68	1.66	1.55

Source: Birth data provided by Ministry of Health (SINASC, 2021) and population information based on projections from the Laboratorio de Estimativas e Projeções Populacionais da UFRN - LEPP (Freire et al., 2019).

For $Q(a)$, the same expression as that in (4) with A is replaced by a. Other standardised factor effects (considering other age groups) follow directly from 1–4.

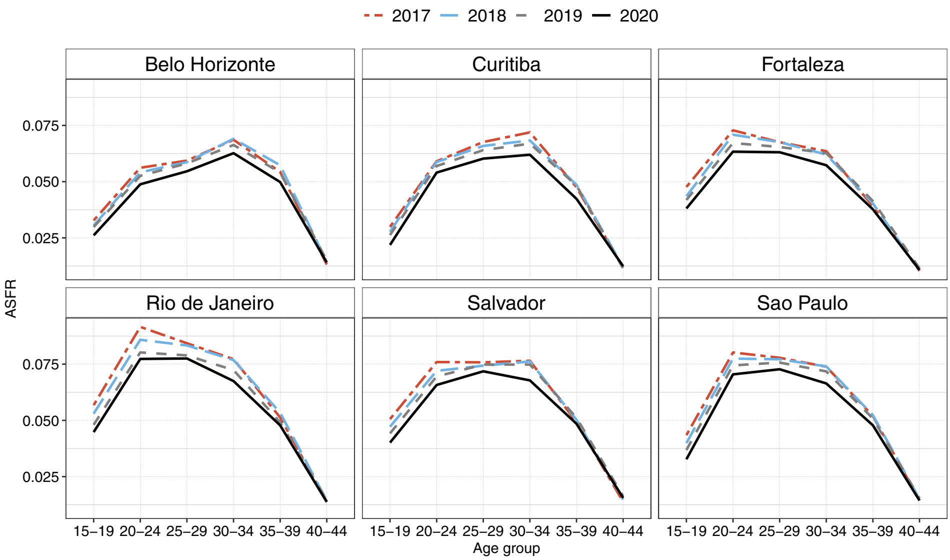
3 Results

First, we present the outcomes of a number of measures of fertility for the analysed cities: namely, the TFR, ASFRs and the mean age at birth. This gives us an overview of how the fertility schedules in these cities were developing before the pandemic started. In addition, we note that these six major cities underwent the fertility transition process relatively quickly, starting in the 1960s (Alves, 1994; Carvalho and Brito, 2005). Thus, in many Brazilian municipalities, the total fertility rates are now below the replacement level (Yazaki, 2003).

As we show in Table 1, the TFR has fallen to very low levels in Belo Horizonte, Curitiba and Fortaleza, to values of 1.28, 1.27 and 1.36, respectively. The total fertility rates in São Paulo, Rio de Janeiro and Salvador are a bit higher, at 1.53, 1.65 and 1.55, respectively. It is important to bear in mind that these values assume that there is no underreporting of births. Nevertheless, the National Brazilian Statistical Office, applying capture-recapture methods and record linkage to the birth datasets from the Ministry of Health and IBGE, have estimated that the rate of underreporting of births was less than 2.5% in the six selected cities between 2016 and 2018.[3]

[3] Estimated percentages of births that are unreported in the six cities for the years 2016, 2017 and 2018, respectively, Fortaleza: 0.89%, 0.66% and 2.49%; Salvador: 0.47%, 0.39% and 0.47%; Belo Horizonte: 0.61%, 0.43% and 0.37%; Rio de Janeiro: 0.73%, 0.16% and 0.21%; São Paulo: 0.04%, 0.02% and 0.04%; and Curitiba: 0.10%, 0.07% and 0.04% (IBGE, 2018).

Figure 1:
Age-specific fertility rates in six major cities of Brazil. 2017–2020



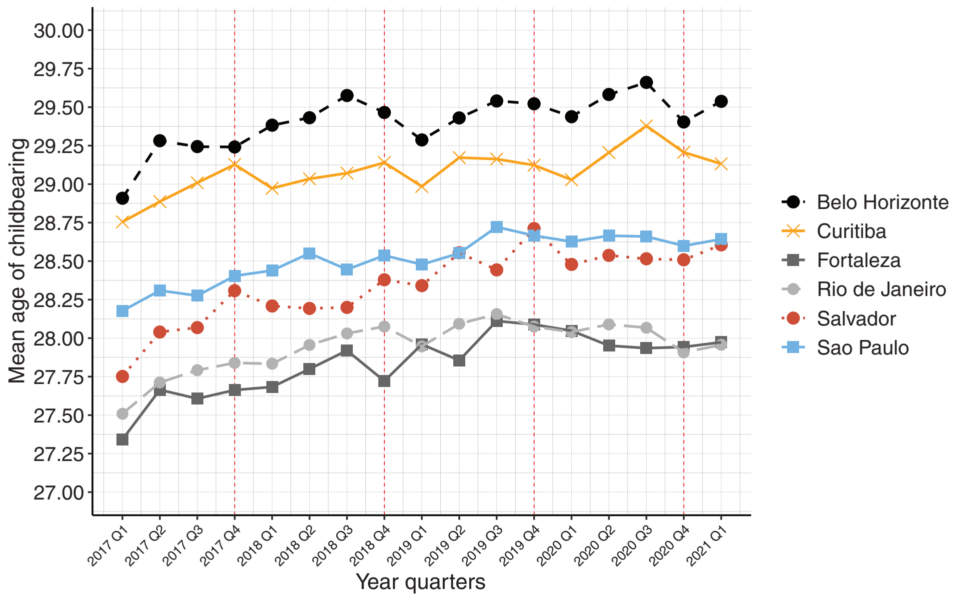
Source: Birth data provided by Ministry of Health (SINASC, 2021) and population information based on projections from the Laboratório de Estimativas e Projeções Populacionais da UFRN - LEPP (Freire et al., 2019).

Between 2017 and 2018, the age-specific fertility rates (ASFRs) in all of the selected cities changed, but not as much as they did in 2020 (in Figure 1). For example, in the cities of Belo Horizonte and Curitiba in 2019, fertility was highest around the ages of 30–34 years old. However, in 2020, the highest ASFRs were at earlier ages in these cities. This means that if we want to get a clearer picture of the effects of the pandemic on birth numbers, we need to consider the mother's age in our further analysis.

In Figure 2, we also illustrate the relative changes in the mother's age by looking at the evolution of the mean age of childbearing (MACB)[4] in periods before the pandemic. The developments in the MACBs are shown by trimesters from years 2017 to 2021. Hence, we can see that in a period of three years, the mean age of childbearing has increased in all of the analysed cities, with the values increasing by 0.37 (in Curitiba) to 0.86 (in Salvador) years from the first quarter of 2017 (2017.Q1) to the first quarter of 2021 (2021.Q1). Thus, in these cities, the mean

[4] As defined by United Nations, the mean age of mothers at the birth of their children if women were subject throughout their lives to the age-specific fertility rates observed in a given year. (https://www.un.org/en/development/desa/population/publications/dataset/fertility/age-childbearing.asp).

Figure 2:
Quarterly mean age at childbearing between age groups 15–44 in six major cities of Brazil. 2017–2021



Source: Birth data provided by the Ministry of Health (SINASC, 2021) and the population information is based on projections from the Laboratório de Estimativas e Projeções Populacionais da UFRN - LEPP (Freire et al., 2019).

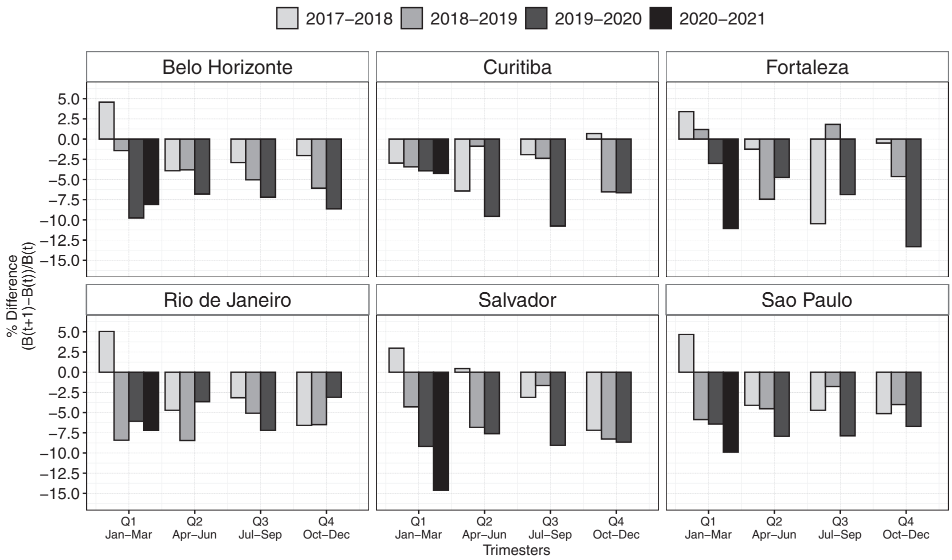
age of childbearing increased by almost half a year to nearly one year in a very short period of time.

While we analyse the associations between the COVID-19 pandemic and the recent changes in birth counts, an overview of the outcomes of these three fertility measures in the six cities is needed us to help us better understand past fertility developments. In particular, it is important to keep in mind that before the start of the COVID-19 crisis, these municipalities were experiencing changes in the shape of their fertility trends, and had below-replacement fertility.

Figure 3 shows the percentage relative differences in birth counts for the selected cities. This time, we compare the number of births in the trimesters of the years affected by the COVID-19 pandemic (2020 and 2021) with the corresponding quarters of the previous years, which were not affected by this public health crisis. The main aim here is to investigate whether there was a substantial change in relative birth counts, especially eight to nine months after the onset of the pandemic; i.e., in Q4 2019–2020 and Q1 2020–2021.

With a few exceptions these results show a decline in birth counts in all of the analysed cities. If we compare the relative differences in the most recent years, i.e.,

Figure 3:
Relative differences in monthly births in six major cities of Brazil. 2017–2021



Source: SINASC (2021). See Footnote 1 for details.

Q1 in 2019–2020 (grey bars) and Q1 in 2020–2021 (light blue bars), with the first trimester of 2021, we see that the number of new-borns has decreased in Curitiba, Fortaleza, Salvador and São Paulo. This decline was especially pronounced in the north-eastern cities of Fortaleza and Salvador. In the case of Salvador, there were 15% fewer births in the first trimester of 2021 than there were in the same period of previous years.

In Fortaleza, the decreasing trend in birth counts further accelerated during the pandemic. When we compare the first trimesters, we observe that birth counts went from declining by 2.5% in 2019–2020 to decreasing by more than 10% in 2020–2021. In addition, when we compare the fourth quarters, we see that birth counts went from decreasing by 5% in 2018–2019 to declining by more than 12% in 2019–2020. This pattern appears to indicate that between the months of October to December 2020 and January to March 2021, the onset of the pandemic was associated with an acceleration of the process of the decline in birth counts that was already underway in this city.

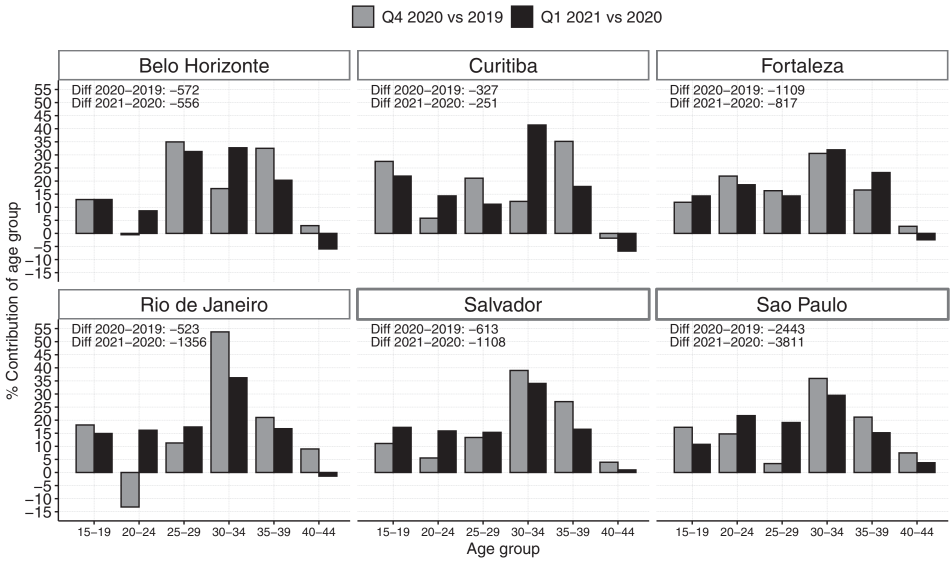
On the other hand, when we look at the differences between the cities only in the first quarter of the years, we see that Rio de Janeiro and Belo Horizonte represent exceptions, as in these cities the decreasing trend in birth counts was more modest, or even slowed down during the pandemic. In Rio de Janeiro, for example, we see that the decline in birth counts went from 6% to 7.5% (grey and light blue bars, respectively); however, if we follow the trend back to previous periods, we find that a bigger drop in birth counts occurred in Q1 2018–2019 (dark blue bar). In Belo Horizonte, we even see a slowdown in the process of the decline in birth counts when we consider the differences between the two last periods.

In the south-eastern region, São Paulo is the only city in which we observe a slight acceleration of the process of the decline in birth counts, especially in the first trimester of 2021. When we compare the Q1 differences across all periods, we see that birth counts went from increasing by 5% in 2017–2018 (red bar) to decreasing by 6% between 2018–2019 and 2019–2020 (dark blue and grey bars), and to declining by 10% in 2020–2021 (light blue bar). In Curitiba, the city located in the southern region, we observe decreases in the birth counts in the first trimester of all the years considered, although this decline was more gradual than it was in the other municipalities. We also find that in Curitiba, the onset of the pandemic did not seem to be associated with any large changes in birth counts. In other words, it appears that the COVID-19 crisis did not alter the natural fertility decline that was already underway in this city. As a final analysis, Figure 4 presents the results of the Das Gupta decomposition of total birth counts for mothers aged 15–44 years old. This time, we decompose the percentage share differences of each maternal age group to the total decline in births during the period affected by the pandemic. The main idea here is to see whether the changes in the number of births in each period varied by maternal age group. Or, in other words, we investigate whether the share of the changes in birth counts varied according to the maternal age. If this was indeed the case, then it is possible that some groups of women have been (in)voluntarily changing their reproductive behaviour during the pandemic period.

As we can see in Figure 4, the differences between birth counts (comparing Q4 in 2020 with Q4 in 2019 and Q1 in 2021 with Q1 in 2020) were negative in all of the cities, which probably indicates that the process of the decline in birth counts was already underway in these locations. In addition, we find that the relative share of the fertility decline varied across age groups, but that in all of the cities, the biggest contribution in percentage differences is found around the age of 30 years old. For example, if we consider the differences in the first trimesters of 2021 and 2020, we see that 30–40% of the reduction in the number of new-borns was attributable to women aged 30 to 34, and that this age group contributed the most to the decrease in the number of births during this period in all of the cities studied.

In addition, when we compare the percentage contributions of age groups to the birth count differences from Q4 (2020–2019) to Q1 (2021–2020), we find small fluctuations in these numbers in the municipalities of Fortaleza, Salvador and São Paulo. However, in the cities of Salvador and São Paulo, we see marked increases in these percentage contributions, especially for the 20–24-year-olds (in Salvador, the contribution of this age group increased from 5% in Q4 to 16% in Q1) and the 25–29-year-olds (in São Paulo, the contribution of this age group increased from 3% in Q4 to 19% in Q1). Meanwhile, in Rio de Janeiro, we find that most of the variations in birth counts are attributed to 30- to 34-year-old mothers, but also that the contribution of this age group declined from 55% in Q4 to almost 35% in Q1.

Figure 4:
Decomposition of absolute differences in total births of mothers aged 15–44 from Q4 2019 to Q4 2020 and from Q1 2020 to Q1 2021 by age group contribution in Brazil's six major cities



Source: SINASC (2021). See Footnote 1 for details.

On the other hand, in Belo Horizonte and Curitiba, the contribution of the 30–34-year-old mothers to the absolute differences in total births increased, respectively, from 16% to 32% and 10% to 35% between Q4 (2020 vs. 2019) and Q1 (2021 vs. 2020). We further note that Belo Horizonte is the only city where the group of 25–29-year-olds also played an important role in the variations in birth counts.

4 Discussion

During the coronavirus pandemic, countries around the world have faced considerable social challenges, with most countries being forced to adapt to a new set of circumstances due to the effects of COVID-19. Worldwide, the number of deaths has increased considerably since the start of the pandemic, and from the beginning of 2020 until the first months of 2021, Brazil became one of the world leaders in numbers of COVID-19 cases and deaths. In response to this health crisis, many studies have investigated the patterns of deaths by region and by age, and have tried to determine which socio-economic groups have been most affected by this pandemic.

Recently, researchers have been devoting more attention to another demographic component of the crisis: i.e., the effects of the pandemic on women's fertility (Marteleto et al., 2020). It is generally assumed that birth numbers have been negatively affected by the economic uncertainties and health issues associated with the pandemic, as well as by the stress related to lockdowns and quarantines (Aassve et al., 2020; Kearney and Levine, 2020; Settersten et al., 2020). In addition, the postponement of unions or relationship disruptions, a reduction in the frequency of sexual intercourse among young people (Lehmiller et al., 2020) and the consequences of many other pandemic-related restrictions may have directly or indirectly affected people's reproductive plans.

In this context, using the available data from municipal health departments, we examined the effects of the pandemic on the numbers of births in six cities of Brazil representing the main regions of the country. We compared monthly birth counts from the end of 2020 until the beginning of 2021 in the selected municipalities with the birth counts from periods before the start of the pandemic. It is also important to bear in mind that especially in Brazil's largest cities, women have had below replacement level fertility since the middle of the 2000–2010 period (Berquó and Cavenaghi, 2014; Castanheira and Kohler, 2015), and more and more women are postponing childbearing (Lima et al., 2018; Rios-Neto et al., 2018). Hence, we did not assume that the recent observed changes in birth counts were caused by the pandemic. Instead, we evaluated whether there was an association between the two phenomena; in other words, whether the existing fertility trends in these cities accelerated (or slowed down) during the COVID-19 pandemic.

Our findings suggest that in the north-eastern cities of Salvador and Fortaleza, the fertility rates are likely to decline even further. Moreover, given the declines we found, we expect fertility in these cities to reach levels close to the lowest-low rates in 2021 and in the upcoming years. However, we also observed that during the pandemic period, the decline in birth counts in Rio de Janeiro and Belo Horizonte slowed down or even reversed its course relative to the previous decreasing trend. Although the decline in birth counts in São Paulo accelerated in 2021, an association between the COVID-19 pandemic and a speeding up of the process of fertility decline was not found throughout the country. In addition, we showed that during the first trimester of 2021, 30- to 34-year-old women contributed the most out of all age groups to the reproductive changes we observed in all six cities.

While there are other issues that could be analysed, we faced some barriers to addressing these questions. First, there is a lack of good quality educational data that would enable us to disentangle the effects of inequality on reproduction among different socio-economic groups. Thus, we were unable to verify whether women with fewer years of education have been more affected by problems related to the supply of contraceptive methods during the pandemic, and have therefore had more unplanned pregnancies over the short term. Additionally, we could not determine whether better educated women have been controlling and postponing fertility more than their less educated counterparts during the COVID-19 pandemic. We may speculate that young women from low socio-economic backgrounds are especially likely to rely on contraception methods provided by public health services (Gonçalves et al., 2019; Martins et al., 2006; Trindade et al., 2021), and thus that the number of births among this group will increase in the near future, as they have difficulties accessing reproductive health services during the pandemic. Additionally, previous studies have found inequalities in the age distribution of first births, with the fertility curve showing two peaks at the ages of 20 and 30 years old: the first for the lower socio-economic group and the second for the higher socio-economic group (Lima et al., 2018; Rios-Neto et al., 2018). We also assume that these fertility inequalities have been accentuated during the COVID-19 pandemic. Second, these preliminary data are still subject to revision, even though the variations in birth numbers are not large enough to change the overall trends. To address this issue, we used data from the first three months only, while leaving room for additional data quality assessment. Updated data are always necessary in these studies.

Acknowledgments

We are thankful for the helpful comments of the editors and the reviewers in preparing the manuscript. Camila Soares would also like to acknowledge the financial support from the Coordination for the Improvement of Higher Education Personnel – Brazil (CAPES) – Finance Code 001. Dr. Lima receives a productivity scholarship from CNPq (number 308219/2019-8).

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Appendix

Figure A.1:
Localisation of the six selected cities distributed according to the five Brazilian macro-regions in 2021. The date when the first COVID-19 death was reported is in parentheses

Figure A.2:
Comparison between monthly births by three data sources. Municipalities of São Paulo and Rio de Janeiro, 2017–2019

Source: ARPEN (2021), SIDRA (2021) and SINASC (2021).

Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 459–476

Pregnancies and contraceptive use in four African countries during the COVID-19 pandemic

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Abstract

The COVID-19 pandemic and the public health measures adopted in response to it have triggered plenty of speculation about the potential impact on fertility in different regions of the globe. This study provides evidence on the fertility response in four sub-Saharan African countries during the first year of the pandemic. Using harmonized data on women of childbearing age from the Performance Monitoring for Action (PMA) data series, this study compares pregnancy rates at the turn of the year 2020/21 to a pre-pandemic baseline. There is no indication of a general increase in pregnancy rates after the beginning of the pandemic. In some of the sample countries, pregnancy rates during this phase of the COVID-19 pandemic instead fell significantly among the youngest and the least educated women of childbearing age, respectively. The findings also indicate that over this period, rates of modern contraceptive usage rose significantly among the surveyed female populations in several sample countries.

Keywords: fertility; pregnancy; COVID-19; sub-Saharan Africa

1 Introduction

Understanding the potential impact of the COVID-19 pandemic on human fertility is of great importance for demographic science and for the formulation of demographically oriented policies in the coming years. This issue is particularly relevant in the context of developing countries, as reducing fertility has been deemed essential for advancing education and economic development in these countries, while a stalling of fertility declines had already been observed in some sub-Saharan African

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The views expressed in this paper do not necessarily reflect the views of the Federal Institute for Population Research.

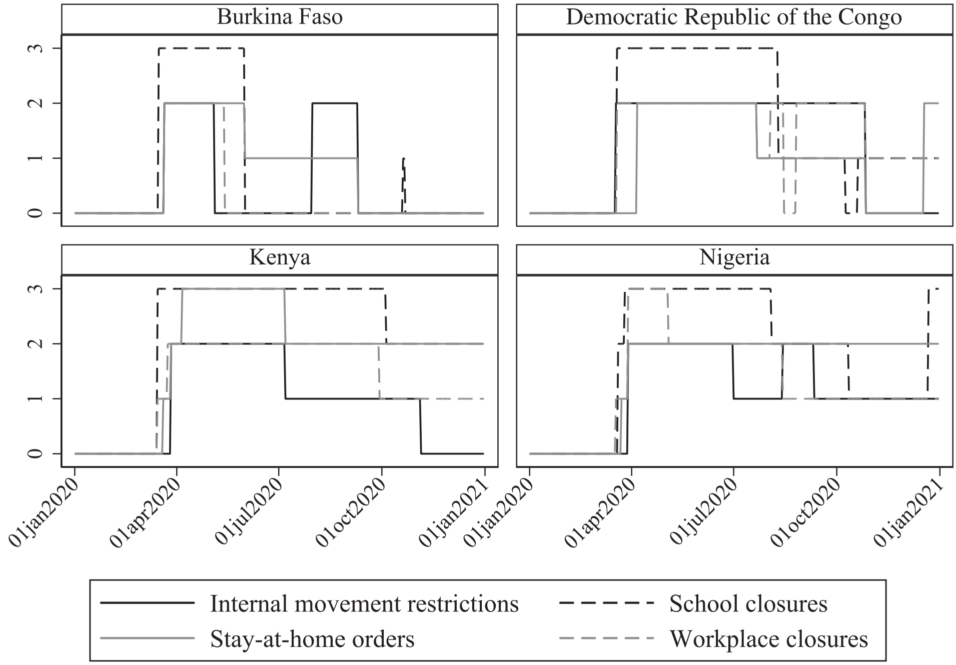
DOI: 10.1553/populationyearbook2022.dat.4

countries prior to the pandemic (Kebede et al., 2019; Schoumaker, 2019; Tabutin et al., 2020). If the pandemic caused the fertility declines in these countries to remain stalled or even to reverse, it could have lasting demographic consequences beyond the pandemic's actual duration. However, up to now, there has been very limited evidence on the actual effects of the COVID-19 pandemic on fertility in sub-Saharan Africa. Consequently, Beaujouan (2021) called for replacing speculation about these effects with cross-national evidence.

This study provides evidence on the fertility response in four sub-Saharan African countries during the first year of the pandemic. Using harmonized data from the Performance Monitoring for Action (PMA) data series, the following analysis compares pregnancy rates among women of childbearing age at the turn of the year 2020/21 to a pre-pandemic baseline in Burkina Faso, the Democratic Republic of the Congo (DR Congo), Kenya and Nigeria. The available data allow for an analysis that is differentiated by the women's age and educational background. Furthermore, a particular concern in the context of developing countries during the COVID-19 pandemic has been that the pandemic and the wide-ranging measures implemented to contain it may have restricted women's access to family planning services and modern contraceptives. Therefore, in addition to providing evidence on pregnancy rates, this study also examines rates of modern contraceptive usage among women in the four sample countries before and during the COVID-19 pandemic.

For context, it is important to note that the populations of the four sample countries were subject to substantial restrictions to public life during the first year of the pandemic, as indicated in Figure 1, which presents information on the relative stringency of four different COVID-19-related non-pharmaceutical interventions (NPIs) over the course of 2020. The governments of all four countries mandated school closures and restricted movements within each country for several months in the spring and summer of 2020. While Kenya further mandated stay-at-home orders, the other three countries at least recommended them. Nigeria, in turn, briefly mandated workplace closures, a measure which the other countries only recommended. While the underlying data assembled by Hale et al. (2020) and Ritchie et al. (2020) do not provide information on the degree of compliance with the various COVID-19-related measures that were implemented, the plots are at least indicative of the extent to which sub-Saharan African countries were subject to restrictions that had the potential to interrupt social and economic life to a similar extent as was occurring in Europe and in other regions of the world. The pandemic clearly had a detrimental impact on the economies of the four African countries, as they all experienced negative GDP per capita growth in 2020, according to The World Bank (2022). Thus, the pandemic may have had a negative impact on fertility via economic channels, as highlighted by Aassve et al. (2020): i.e., rising poverty may have caused the demand for unpaid child labor within households to rise while also increasing parents' reliance on their children to provide them with economic security in old age. In addition, both rising poverty and COVID-19-related restrictions may have limited women's access to contraception and family planning services, which might, in turn, have led to an increase in fertility. However, Aassve et al. (2020) also noted that past pandemics and other large-scale shocks

Figure 1:
Government policy responses to COVID-19 by country in 2020



Notes: Each panel displays four indicators of government policy responses to the COVID-19 pandemic in one of the four sample countries. The indicators refer to restrictions on internal movements, school closures, stay-at-home orders and workplace closures. With the exception of the indicator on internal movement restrictions, each of the indicators is scaled between zero and three, with level zero indicating that no restrictions are in place, level one indicating that restrictions are recommended, level two indicating that restrictions are mandatory to some extent, and level three indicating that restrictions must be followed to the greatest possible extent. The indicator on internal movement restrictions is scaled between zero and two, with level zero indicating that there are no restrictions, level one indicating that restrictions on movement are recommended, and level two indicating that movement is restricted.
Source: Author's own depictions based on Hale et al. (2020) and Ritchie et al. (2020).

were associated with falling fertility in the short run, and that births did not rebound or recuperate until after these disasters were over.

What still remains unclear at present is how severe the spread and the death toll of COVID-19 have been on the African continent. Highly constrained testing capacities have limited the detection of COVID-19 cases, and possibly also of COVID-19-related deaths. Thus, it has been difficult to assess to what extent COVID-19 itself has affected sub-Saharan African societies beyond the impact of the NPIs, by, for example, imposing a burden of disease on the population. It has also been hard to determine to what extent voluntary behavioral adjustments of the populations in these countries to the perceived threat from the disease may have affected their reproductive outcomes.

This study contributes to the fast-growing literature on the demographic impact of the COVID-19 pandemic, particularly with regard to the pandemic's potential effects on human fertility. In an analysis of high-income countries, Luppi et al. (2020) reported that in Italy, Germany, France, Spain and the UK, individuals aged 18–34 negatively revised their fertility plans during the early stage of the pandemic, while Naito and Ogawa (2021) found that pregnancies decreased more in areas of Japan where stricter containment measures had been imposed. Sobotka et al. (2021) analyzed births in 19 European countries, two East Asian high-income countries and the United States up to late 2020, and found evidence that a birth recession was occurring in many countries. However, the existing evidence on the impacts of the pandemic on fertility in low- and middle-income countries is much more sparse due to the lack of timely data. Lima et al. (2022) observed a large decline in the number of births in some Brazilian cities in late 2020 and early 2021 compared to previous years. Dasgupta et al. (2020) prospectively considered a scenario of the potential impact of the COVID-19 pandemic on contraceptive use in which the proportion of the need for family planning satisfied by modern methods is expected to decrease particularly sharply in sub-Saharan Africa. This projection is based in part on evidence indicating that short-term methods of contraception are widely used in sub-Saharan Africa, and that these forms of contraception are especially vulnerable to supply chain disruptions. Notably, Dasgupta et al. (2020) pointed out that while their scenario assumes that fertility preferences, sexual behavior and total demand for family planning remain constant during the pandemic, in reality, women and couples may actually postpone childbearing until after the pandemic is over. Also using data provided by IPUMS PMA, Karp et al. (2021) found that most women at risk of unintended pregnancy in Burkina Faso and Kenya did not change their contraceptive use status between the pre-COVID-19 surveys and the special COVID-19 surveys conducted in mid-2020, while Wood et al. (2021) found no evidence of either a broad increase in the need for contraception or a decline in its usage among women in union in the four sub-Saharan African countries surveyed during the pandemic. The present study complements and extends their findings by focusing on pregnancy as an outcome that is strongly predictive of future births, while also considering changes in modern contraceptive usage as a potential channel for changes in fertility.

2 Data

The data used in this study have been provided by IPUMS PMA (Boyle et al., 2022). IPUMS PMA processes the Performance Monitoring for Action (PMA) data series to provide harmonized variables on family planning, water and sanitation, and health. While IPUMS PMA regularly collects data from 11 countries, nine of which are located in sub-Saharan Africa, harmonized datasets are currently only available for four sub-Saharan African countries since the outbreak of the COVID-19 pandemic: Burkina Faso, the DR Congo, Kenya and Nigeria.

This study uses data from the IPUMS PMA survey rounds which have been collected since 2014 in Burkina Faso, since 2015 in the DR Congo and Kenya, and since 2016 in Nigeria. In late 2019, PMA launched a new phase of longitudinal data collection. The baseline round collected in late 2019 and early 2020 represents the latest available data before the beginning of the pandemic, while the first follow-up round of the longitudinal surveys, which was collected in late 2020 and early 2021, provides the earliest available data after the outbreak of the pandemic. In order to obtain a broader pre-pandemic baseline from all available survey rounds, this study does not exploit the longitudinal character of the two most recent rounds, but instead treats all rounds as cross-sectional data. Prior to the launch of the longitudinal surveys, the timing of each survey round within a given year varied substantially across countries and rounds. However, as the dates of the interview collection are available in the data, adjustments for seasonal fluctuations in pregnancies can be made in the following analysis.

Geographically, the IPUMS PMA survey covers all 13 regions of Burkina Faso, and it covers 11 of Kenya's 47 counties, including the capital city of Nairobi. In the case of Nigeria and the DR Congo, the earlier sample rounds cover more subnational geographical units than the more recent longitudinal sample rounds. Observations collected in the additional subnational units are removed from the earlier sample rounds in order to increase comparability. As a result, the data from the DR Congo solely cover the capital city of Kinshasa, while the data from Nigeria only cover the capital city of Lagos and the state of Kano. A round of COVID-19-specific PMA surveys is not utilized in the following analysis, as the surveys were collected in June and July of 2020, and thus only a few months after the outbreak of the pandemic, which might be too early to detect whether pregnancy rates in 2020 deviated from those in previous years.

Table 1:
Observations per PMA survey round

Round	(1) Burkina Faso	(2) DR Congo	(3) Kenya	(4) Nigeria
1	2033	0	3715	0
2	2078	0	4289	0
3	3202	0	4351	3042
4	3104	2711	4869	3171
5	3489	2567	5722	3290
6	3316	2498	5826	0
7	0	2579	5638	0
8	6545	2604	9431	2551
9	6350	2352	9293	2587
Total	30117	15311	53134	14641

Notes: The table reports the number of women surveyed by PMA in each round in the four sample countries.
Source: Author's own compilation.

Table 2:
Observations per PMA survey year

Year	(1) Burkina Faso	(2) DR Congo	(3) Kenya	(4) Nigeria
2014	1996	0	0	0
2015	2115	2705	8004	0
2016	6089	2573	9220	3042
2017	3702	2498	5722	3171
2018	3107	2579	5826	3290
2019	237	987	5635	1966
2020	9325	3697	9434	3093
2021	3546	272	9293	79
Total	30117	15311	53134	14641

Notes: The table reports the number of women surveyed by PMA in each year in the four sample countries.
Source: Author's own compilation.

Table 1 displays the number of observations that are available in each sample country per survey round, while Table 2 displays the number of observations available per survey year.

Every round of the IPUMS PMA survey records the pregnancy status of each female respondent. However, as this individual pregnancy status is self-reported, it is possible that pregnancies that recently occurred have not yet been noticed by the respondent and/or been medically confirmed yet. In addition, information

Table 3:
Summary statistics

	(1) Burkina Faso	(2) DR Congo	(3) Kenya	(4) Nigeria
Pregnancy rate	0.085	0.054	0.054	0.073
Age	28.60	28.04	28.54	29.56
Share never attended school	0.618	0.016	0.041	0.196
Share w. primary/middle school	0.171	0.148	0.468	0.139
Share w. secondary/post-primary school	0.194	0.676	0.358	0.439
Share w. tertiary/post-secondary school	0.018	0.160	0.133	0.226
Rate of modern contraceptive usage	0.271	0.246	0.469	0.170
Observations	30098	15292	53096	14635

Notes: The table reports summary statistics on women surveyed by PMA in the four sample countries. Statistics for modern contraceptive usage are computed while excluding non-pregnant women from the sample. Sampling weights are applied.
Source: Author's own computations.

on the female respondents' age, educational background and usage of modern contraceptives is available. Table 3 reports summary statistics on the women of childbearing age included in the sample.

3 Empirical strategy

The availability of data for periods both before and since the beginning of the pandemic makes it possible to empirically test whether the frequency of the pregnancies and the usage of modern contraceptives reported by the surveyed women changed during the pandemic relative to earlier periods. For this purpose, data from the pre-pandemic periods are pooled in order to form a baseline group to which the observations collected during the pandemic can be compared. This approach boils down to first regressing the binary female pregnancy status $Pregnant_i$ on a binary indicator $SincePandemic_t$ that is equal to one if a woman was surveyed after the outbreak of the pandemic, and to zero otherwise, as expressed by Equation (1):

$$Pregnant_i = \alpha + \beta SincePandemic_t + \gamma X_i + \delta SincePandemic_t \times X_i + \epsilon_i, \quad (1)$$

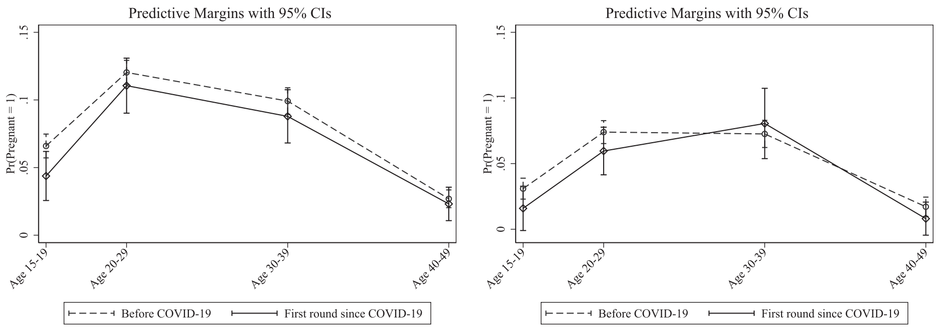
The vector X_i contains controls for the surveyed women's ages, which are organized into four groups (ages 15–19, 20–29, 30–39, 40–49); and for the women's educational levels, which are also grouped into four categories (never attended, primary/middle school, secondary/post-primary, tertiary/post-secondary). In addition, the vector contains indicators for the calendar months of the women's interviews. Elements of the vector X_i can also be interacted with the $SincePandemic_t$ indicator in order to allow for age group- and education-specific deviations from the baseline of the pregnancy status after the outbreak of the pandemic. ϵ_i is an error term. Equation (1) is estimated as a linear probability model using OLS, and separately for each sample country in the following. As well as enabling the study of changes in pregnancy rates during the pandemic, the available data also allow for the examination of changes in the usage of modern contraceptives. For this analysis, the binary pregnancy outcome in Equation (1) will then be substituted for a binary indicator that is equal to one if a non-pregnant woman uses modern contraceptives, and is otherwise equal to zero.

4 Results

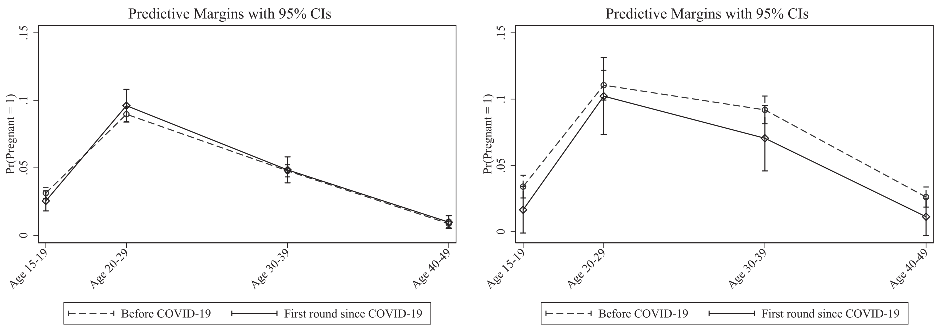
The results of the empirical analysis are presented in two different ways: First, plots for each country display the predicted probabilities of being pregnant and of using modern contraceptives, respectively. These plots differentiate by the $SincePandemic_t$ indicator in Equation (1); i.e., they allow for the visual comparison of the predicted probabilities for the pre-pandemic baseline periods to the predicted probabilities for the period after the outbreak of the pandemic. Second, tables report marginal effects computed from the underlying regressions, as well as baseline rates of the outcome variable for the pre-pandemic periods. These marginal effects, together with their reported standard errors, indicate whether the pregnancy rates and the rates of modern contraceptive usage estimated for the period since the outbreak of the COVID-19 pandemic differ statistically and in quantitatively relevant magnitudes from those in the baseline periods.

Figure 2 displays the predicted probabilities of being pregnant before and after the start of the pandemic across the four age groups. In Burkina Faso and Nigeria, the predicted probabilities of being pregnant for the period after the outbreak of the pandemic are lower than the baseline across all age groups, but

Figure 2:
Pregnancy rates by age group and country



(a) Pregnancy rates by age group in Burkina Faso (b) Pregnancy rates by age group in DR Congo



(c) Pregnancy rates by age group in Kenya (d) Pregnancy rates by age group in Nigeria

Notes: Each panel displays the predicted probabilities of being pregnant in an individual sample country. Predicted probabilities are displayed for four different age groups. The dashed line indicates the predicted probabilities of being pregnant in the baseline period 2014–2020. The solid line indicates the predicted probabilities of being pregnant in the period affected by the COVID-19 pandemic.
Source: Author's own computations. Sampling weights are applied.

the overlapping confidence intervals do not yet indicate any statistically significant deviations. In the DR Congo, only the predicted probability for the 30–39 age group during the pandemic slightly exceeds the baseline probability. In Kenya, the gaps between the predicted probabilities are very small to non-existent across age groups. Similarly, Table 4 reports that in the youngest age group of 15–19, the pregnancy rates are lower after the outbreak of COVID-19 in all four countries, while the marginal effect is statistically significant only in Burkina Faso, indicating a decrease in pregnancy rates of 2.2 percentage points. This is a large decrease, as it represents a decline of one-third relative to the pre-pandemic baseline rate of 6.6%. All marginal effects in the higher age groups are statistically insignificant at the 5% level in all four countries.

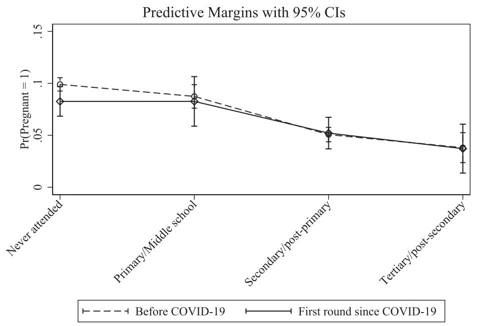
Figure 3 displays the predicted probabilities of being pregnant across different female educational background levels, while controlling for the four age groups. In Burkina Faso, the predicted probability of being pregnant is visibly lower among

Table 4:
Marginal effects on pregnancy rates by age group

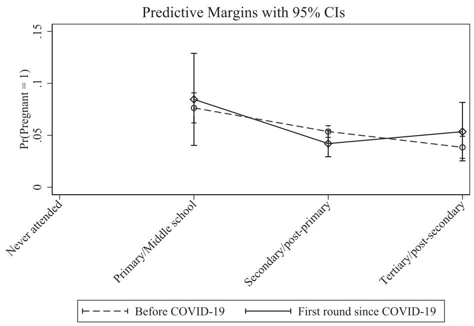
	(1) Burkina Faso	**(2) DR Congo**	**(3) Kenya**	**(4) Nigeria**
Since COVID-19				
Age 15–19	−0.022**	−0.015	−0.006	−0.018
	(0.01)	(0.01)	(0.00)	(0.01)
Age 20–29	−0.010	−0.014	0.006	−0.008
	(0.01)	(0.01)	(0.01)	(0.02)
Age 30–39	−0.011	0.008	0.001	−0.021
	(0.01)	(0.01)	(0.01)	(0.01)
Age 40–49	−0.004	−0.009	0.001	−0.015*
	(0.01)	(0.01)	(0.00)	(0.01)
N	30117	15311	53134	14641
Interview month FE	Yes	Yes	Yes	Yes
Baseline rates				
Age 15–19	0.066	0.030	0.031	0.033
Age 20–29	0.120	0.073	0.090	0.110
Age 30–39	0.099	0.071	0.048	0.091
Age 40–49	0.027	0.016	0.009	0.025

Notes: The table reports the marginal effects from linear regressions of the pregnancy status on an indicator for the survey round during the COVID-19 pandemic, age group indicators, and interactions of the two. Results for Burkina Faso are reported in column 1. Results for the DR Congo are reported in column 2. Results for Kenya are reported in column 3. Results for Nigeria are reported in column 4. Interview month fixed effects are included in all regressions. Sampling weights are applied. Robust standard errors are reported in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
Source: Author's own computations.

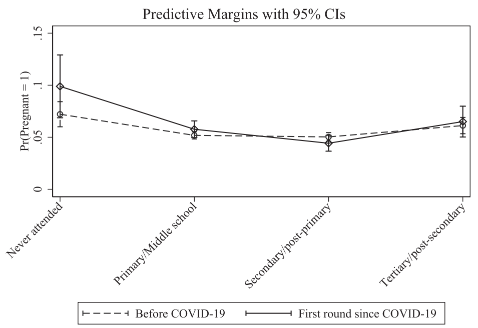
Figure 3:
Pregnancy rates by educational background and country



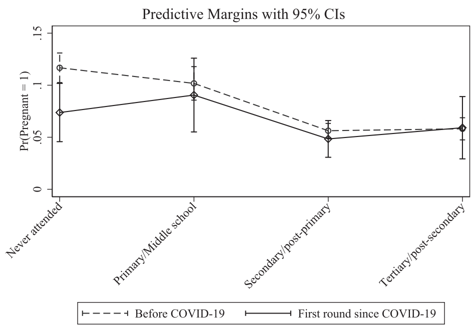
(a) Pregnancy rates by education in Burkina Faso



(b) Pregnancy rates by education in DR Congo



(c) Pregnancy rates by education in Kenya



(d) Pregnancy rates by education in Nigeria

Notes: Each panel displays the predicted probabilities of being pregnant in an individual sample country. Predicted probabilities are displayed for four different levels of education. The dashed line indicates the predicted probabilities of being pregnant in the baseline period 2014–2020. The solid line indicates the predicted probabilities of being pregnant in the period affected by the COVID-19 pandemic.
Source: Author's own calculations. Sampling weights are applied.

women who have never attended school after the outbreak of the pandemic, while there are no notable differences among women with higher levels of educational attainment. In the DR Congo, the number of women who have never attended school is very small due to the urban focus of the surveys there; thus, the lowest level of educational attainment is omitted for that country. Across the remaining three levels, the predicted probabilities of being pregnant after the outbreak of the pandemic deviate somewhat from the baseline, but the directions and magnitudes are alternating. Among women who have never attended school, the predicted probabilities of being pregnant after the start of the COVID-19 pandemic rise in Kenya but fall in Nigeria. In both countries, the predicted probabilities of being

Table 5:
Marginal effects on pregnancy rates by educational background

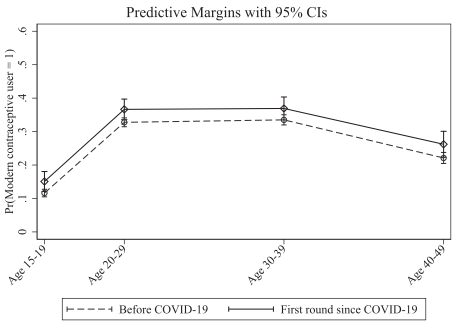
	(1) Burkina Faso	(2) DR Congo	(3) Kenya	(4) Nigeria
Since COVID-19				
Never attended	-0.016^{**}	omitted	0.027	-0.043^{***}
	(0.01)	(.)	(0.02)	(0.02)
Primary/middle school	–0.005	0.008	0.006	–0.011
	(0.01)	(0.02)	(0.00)	(0.02)
Secondary/post-primary	0.001	–0.012	–0.006	–0.008
	(0.01)	(0.01)	(0.00)	(0.01)
Tertiary/post-secondary	–0.001	0.015	0.004	0.001
	(0.01)	(0.02)	(0.01)	(0.02)
N	30101	15062	53128	14635
Age group FE	Yes	Yes	Yes	Yes
Interview month FE	Yes	Yes	Yes	Yes
Baseline rates				
Never attended	0.099	.	0.073	0.116
Primary/middle school	0.087	0.072	0.053	0.102
Secondary/post-primary	0.050	0.051	0.051	0.056
Tertiary/post-secondary	0.037	0.046	0.062	0.058

Notes: The table reports marginal effects from linear regressions of the pregnancy status on an indicator for the survey round during the COVID-19 pandemic, indicators for educational background, and interactions of the two. Results for Burkina Faso are reported in column 1. Results for the DR Congo are reported in column 2. Results for Kenya are reported in column 3. Results for Nigeria are reported in column 4. Age group and interview month fixed effects are included in all regressions. Sampling weights are applied. Robust standard errors are reported in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
Source: Author's own computations.

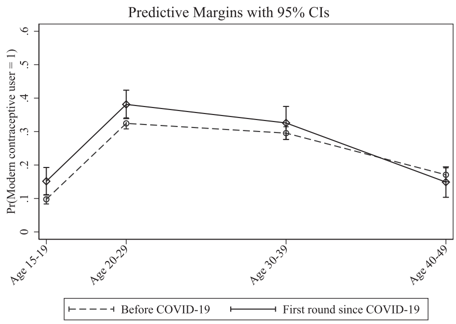
pregnant vary little among women with higher levels of educational attainment. Turning to the marginal effects reported in Table 5, pregnancy rates indeed decline significantly among women with no formal education, by 1.6 percentage points in Burkina Faso and by 4.3 percentage points in Nigeria after the outbreak of the pandemic. Again, these declines are large, constituting 16% and 37% of the pre-pandemic baseline levels, respectively. Among women with higher levels of education, all marginal effects are insignificant in all four countries.

Next, the binary pregnancy indicator in Equation (1) is substituted for the binary indicator that is equal to one if a woman uses modern contraceptives, and is equal to zero otherwise, with pregnant women now being excluded from the estimation sample. Figure 4 displays the predicted probabilities of modern contraceptive usage differentiated by the four age groups. Notably, in the period after the start of the COVID-19 pandemic, the probabilities of usage shift upward across most

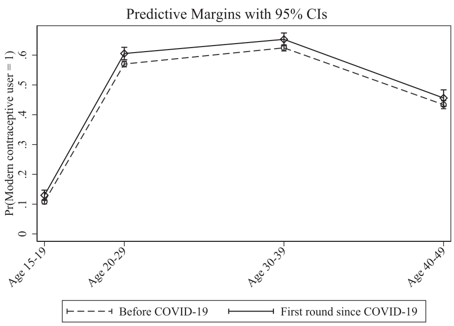
Figure 4:
Rates of modern contraceptive usage by age group and country



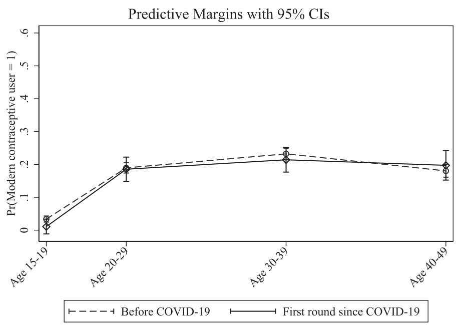
(a) Rates of modern contraceptive usage by age group in Burkina Faso



(b) Rates of modern contraceptive usage by age group in DR Congo



(c) Rates of modern contraceptive usage by age group in Kenya



(d) Rates of modern contraceptive usage by age group in Nigeria

Notes: Each panel displays the predicted probabilities of using modern contraceptives in an individual sample country. Predicted probabilities are displayed for four different age groups. The dashed line indicates the predicted probabilities of using modern contraceptives in the baseline period 2014–2020. The solid line indicates the predicted probabilities of using modern contraceptives in the period affected by the COVID-19 pandemic.
Source: Author's own computations. Sample is restricted to non-pregnant women. Sampling weights are applied.

age groups in Burkina Faso, the DR Congo and Kenya, while they change in varying directions in Nigeria. According to the marginal effect estimates presented in Table 6, the rates of modern contraceptive usage among the 15–19 and 20–29 age groups increase significantly by more than three percentage points in Burkina Faso and by more than five percentage points in the DR Congo. In comparison to the pre-pandemic baseline rates, these are large increases. Among the 15–19, 20–29 and 30–39 age groups, the rates of modern contraceptive usage during the COVID-19 pandemic increase significantly by more than two percentage points in

Table 6:
Marginal effects on modern contraceptive usage by age group

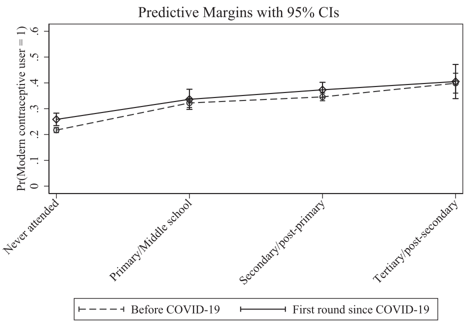
	(1) Burkina Faso	(2) DR Congo	(3) Kenya	(4) Nigeria
Since COVID-19				
Age 15–19	0.035**	0.054**	0.022**	−0.023*
	(0.02)	(0.02)	(0.01)	(0.01)
Age 20–29	0.039**	0.057**	0.035***	−0.004
	(0.02)	(0.02)	(0.01)	(0.02)
Age 30–39	0.034*	0.030	0.029**	−0.018
	(0.02)	(0.03)	(0.01)	(0.02)
Age 40–49	0.041*	−0.022	0.022	0.017
	(0.02)	(0.03)	(0.02)	(0.03)
N	27885	14462	50327	13551
Interview month FE	Yes	Yes	Yes	Yes
Baseline rates				
Age 15–19	0.113	0.095	0.108	0.029
Age 20–29	0.323	0.322	0.568	0.186
Age 30–39	0.330	0.293	0.623	0.229
Age 40–49	0.218	0.169	0.432	0.177

Notes: The table reports marginal effects from linear regressions of the modern contraceptive usage status on an indicator for the survey round during the COVID-19 pandemic, indicators for age groups, and interactions of the two. Results for Burkina Faso are reported in column 1. Results for the DR Congo are reported in column 2. Results for Kenya are reported in column 3. Results for Nigeria are reported in column 4. Interview month fixed effects are included in all regressions. Sample is restricted to non-pregnant women. Sampling weights are applied. Robust standard errors are reported in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
Source: Author's own computations.

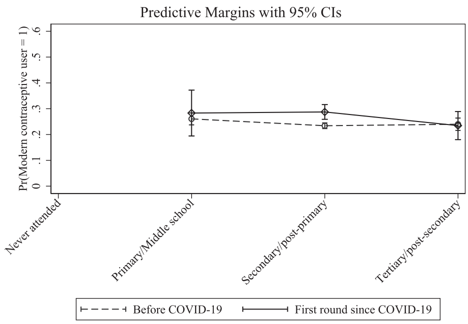
Kenya. However, in Nigeria, the changes in the rates of modern contraceptive usage are insignificant at the 5% level.

Finally, Figure 5 displays the predicted probabilities of using modern contraceptives among women with different levels of education, while controlling for the four age groups. The plots indicate that in Burkina Faso, the DR Congo and Kenya, the probabilities of using modern contraceptives are higher after the outbreak of the COVID-19 pandemic for women with educational attainment below the tertiary/post-secondary level, while the predicted probabilities move in varying directions across the different levels of female education in Nigeria. According to the marginal effect estimates presented in Table 7, the usage of modern contraceptives increases significantly among the least educated women in Burkina Faso, while it increases significantly among women with secondary or post-primary education in the DR Congo. Again, these increase are large relative to

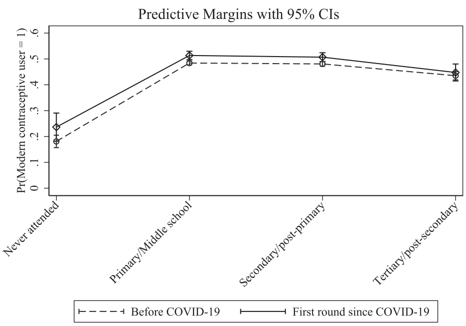
Figure 5:
Rates of modern contraceptive usage by education and country



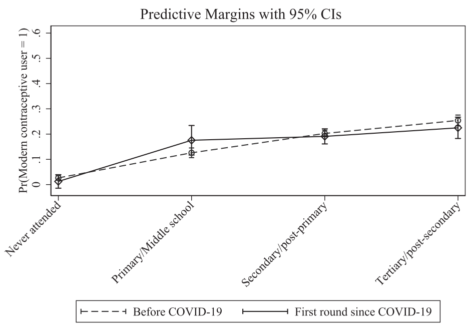
(a) Rates of modern contraceptive usage by education in Burkina Faso



(b) Rates of modern contraceptive usage by education in DR Congo



(c) Rates of modern contraceptive usage by education in Kenya



(d) Rates of modern contraceptive usage by education in Nigeria

Notes: Each panel displays the predicted probabilities of using modern contraceptives in an individual sample country. Predicted probabilities are displayed for four different levels of education. The dashed line indicates the predicted probabilities of using modern contraceptives in the baseline period 2014–2020. The solid line indicates the predicted probabilities of using modern contraceptives in the period affected by the COVID-19 pandemic.
Source: Author's own computations. Sample is restricted to non-pregnant women. Sampling weights are applied.

the pre-pandemic baseline rates. In Kenya, women with primary or secondary/post-primary education are significantly more likely to use modern contraceptives after the outbreak of the pandemic, while in Nigeria, there are no significant changes in the predicted probabilities of using modern contraceptives at any level of education.

Table 7:
Marginal effects on modern contraceptive usage by educational background

	(1) Burkina Faso	(2) DR Congo	(3) Kenya	(4) Nigeria
Since COVID-19				
Never attended	0.041***	omitted	0.055*	−0.014
	(0.01)	(.)	(0.03)	(0.02)
Primary/middle school	0.014	0.023	0.029***	0.050
	(0.02)	(0.05)	(0.01)	(0.03)
Secondary/post-primary	0.027*	0.053***	0.026***	−0.012
	(0.02)	(0.02)	(0.01)	(0.02)
Tertiary/post-secondary	0.006	−0.005	0.012	−0.029
	(0.04)	(0.03)	(0.02)	(0.02)
N	27869	14230	50321	13545
Interview month FE	Yes	Yes	Yes	Yes
Baseline rates				
Never attended	0.234	.	0.246	0.038
Primary/middle school	0.303	0.243	0.494	0.129
Secondary/post-primary	0.281	0.226	0.431	0.175
Tertiary/post-secondary	0.446	0.281	0.520	0.278

Notes: The table reports marginal effects from linear regressions of the modern contraceptive usage status on an indicator for the survey round during the COVID-19 pandemic, indicators for educational background, and interactions of the two. Results for Burkina Faso are reported in column 1. Results for the DR Congo are reported in column 2. Results for Kenya are reported in column 3. Results for Nigeria are reported in column 4. Age group and interview month fixed effects are included in all regressions. Sample is restricted to non-pregnant women. Sampling weights are applied. Robust standard errors are reported in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
Source: Author's own computations.

5 Conclusions

By the end of the first year of the global COVID-19 pandemic, the pregnancy rates in the four sub-Saharan African countries examined in this study had barely deviated from their pre-pandemic baselines, and in the few cases in which they did deviate significantly, they appear to have decreased. In Burkina Faso and Nigeria, the pregnancy rates of the least educated women have fallen significantly below their pre-pandemic baselines by the turn of the year 2020/21. Moreover, in Burkina Faso, the pregnancy rates of the youngest surveyed women had also decreased significantly. The relative magnitudes of these specific declines in pregnancy rates were large. By contrast, in the DR Congo and Kenya, the pregnancy rates had neither risen nor fallen to a statistically notable extent.

Taken together, these results may seem surprising given that the youngest and least educated women of childbearing age can be presumed to have been particularly vulnerable to the effects of the economic downturn triggered by the pandemic, which may, in turn, have activated the economic channels toward higher fertility highlighted by Aassve et al. (2020). However, the evidence presented in this study does not contradict the timing of fertility effects that have been observed during and after past pandemics, as discussed by Aassve et al. (2020) and Ullah et al. (2020): i.e., the short-term effects of a pandemic on fertility tend to be negative, while any positive effects may occur only in the aftermath of a pandemic. Collected by the turn of the year 2020/21, the most recent IPUMS PMA survey data included and analyzed in this study clearly do not cover the late phase of the COVID-19 pandemic or the post-pandemic period. Thus, it remains to be seen how fertility evolves in the sub-Saharan African region as the pandemic burden eases. If the results of this study are complemented with analyses that focus on other sub-Saharan African countries, a more comprehensive picture of the impact of the COVID-19 pandemic on fertility in sub-Saharan Africa will emerge, which will, in turn, allow for further assessments of how the pandemic has interacted with the fertility stalls observed in some countries prior to the pandemic.

Interestingly, the findings of this study show that after the start of the pandemic, the usage of modern contraceptives increased significantly among women of various age groups and educational backgrounds in all sample countries except Nigeria. First, this result does not point to women having more limited access to modern contraceptives as a consequence of the pandemic. Second, the study found that the increase in the usage of modern contraceptives coincided with a decrease in pregnancies among the youngest and the least educated women of childbearing age in Burkina Faso. Third, while a broad decrease in pregnancies was not observed among women of all the age groups and educational strata whose usage of modern contraceptives increased, this does not imply that there was no association between the two outcomes, as this study did not control for other factors that may have been associated with both contraceptive usage and fertility during the pandemic. For example, while the economic downturn triggered by the pandemic may have exerted an upward pressure on fertility, women of childbearing age may have increasingly relied on modern contraceptives to counteract this pressure, which could have resulted in a net effect on fertility that cannot be statistically differentiated from zero. Further research on the potentially elevated role of contraceptives as a potential means of regulating fertility during the pandemic is warranted.

It is worth recalling that in some of the four African countries in the study sample, the IPUMS PMA surveys cover only particular states or other subnational entities; hence, the findings presented here cannot be interpreted as being nationally representative for these countries. Other data sources typically used in fertility research, such as birth registries and census waves, provide more comprehensive coverage of the population. However, as these kinds of sources are not yet available for sub-Saharan African countries during the COVID-19 pandemic, the IPUMS PMA surveys provide researchers with a valuable opportunity to obtain early insights into pandemic-related fertility changes in developing countries.

Acknowledgements

The author thanks Elke Loichinger, the Editor, and two anonymous reviewers for helpful comments and suggestions.

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Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 477–498

Exploring psychological vulnerability and responses to the COVID-19 lockdown in Greece

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Abstract

This study explores the psychosocial impact of the COVID-19 pandemic on the population in Greece during the general lockdown period. Specifically, depression, anxiety and stress scores, as well as the factors associated with vulnerability to developing mental health conditions during this period, were investigated. A total of 911 adults participated in an online survey by completing a self-reporting questionnaire that included demographic questions, DASS-42 items (anxiety, stress and depression scales) and other questions related to personal experience. Regression modelling uncovered a significant relationship between gender and DASS scores, with women having significantly higher scores than men for all mental health problems. Participants aged 20–39 years were especially vulnerable to experiencing poor mental health. Unemployed participants reported having worse mental health than others. Having more perceived psychosocial support during the pandemic was associated with lower overall scores. Thus, women, young adults and the unemployed exhibited particularly high levels of vulnerability, while individuals who received social support from relatives and friends during the lockdown were more resilient to the effects of social isolation.

Keywords: COVID-19; lockdown; pandemic consequences; mental health; DASS-42 score; anxiety; depression; stress; digitalisation; teleworking

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DOI: 10.1553/populationyearbook2022.dat.5

1 Introduction

The coronavirus (COVID-19) outbreak had a major impact not only on people's physical health, infection risk and fatality rates, but also on people's social interactions due to the implementation of drastic protective measures, including social distancing requirements and forced lockdowns.

The recent literature on the negative psychological effects of these measures found that the impact varied based on the quarantine duration, infection fears, boredom levels, lack of adequate supplies and/or information, financial losses and concerns about stigma. While some researchers have found that these effects were brief, others have suggested that they may be long-lasting (Brooks et al., 2020). A research study conducted during the lockdown period in Greece showed that the overall well-being of the population was poor, and that people experienced mild to moderate levels of anxiety, with women being especially burdened (Argyropoulos et al., 2021). The term "coronaphobia" has been used in recent studies to refer to the mass fear of COVID-19. This fear has been shown to be associated with a wide range of psychiatric symptoms and manifestations in multiple social and cultural contexts (Dubey et al., 2020). Moreover, there is evidence that levels of resilience in the Greek population during the first lockdown varied depending on social factors, such as on people's working conditions, gender, age and educational background (Kalaitzaki, 2021). Additionally, many scientists have questioned the effectiveness of forced lockdowns in preventing disease transmission. It has also been argued that individual rights and public health interventions related to compliance had an impact on people's mental health (Kochhar et al., 2020).

In March 2020, several weeks after the first case of COVID-19 was registered, the Greek government imposed the first general lockdown. The lockdown period lasted for 42 days. During the lockdown, non-food stores, educational institutions, bars and restaurants were closed. Moreover, travel restrictions were imposed, and individuals were ordered to stay indoors. People were allowed to leave their homes only if they had official permission to do so based on one of six specific reasons. Residents were obliged to send an SMS to the government informing them of their reason for going out. The six permitted reasons for leaving home were: going to a medical appointment; going to a store to purchase essential goods (supermarket, mini market) or to a bank; going out to assist people in need or to accompany minor students to or from school; attending a funeral; visiting one's children as a divorced parent; and engaging in physical exercise outdoors or walking a pet, individually or in pairs. Furthermore, multiple proactive controls were put in place by police authorities to monitor the use of public space by residents (Ntikouli, 2021).

As the Greek state was dealing with major challenges before the start of the pandemic, including a refugee crisis, an economic crisis and high levels of unemployment, the capacity of the Greek medical system to cope with pandemic was very limited (Moris and Schizas, 2020). Thus, the Greek government's policy decision to impose lockdown measures early in the pandemic was seen as the most appropriate way to prevent the spread of COVID-19 (Moris and Schizas, 2020).

While the implementation of these measures has been characterised as a success story by most mass media outlets and some scholars (Moris and Schizas, 2020), other authors have found that the lockdown measures led to increases in mental health problems and socio-economic difficulties (Saurabh and Ranjan, 2020).

The aim of this paper is to explore the psychosocial effects of the first COVID-19 lockdown period on the Greek population, with a particular focus on the experiences of vulnerable population groups more prone to developing mental health symptoms. Mental health scores are assessed and reported; and potential vulnerability factors, such as demographic characteristics, social factors, social relationships and emotional experiences, are investigated. This study contributes to the emerging literature on the impact of the pandemic on well-being by identifying several vulnerability factors. The findings can be used by policy-makers to design more sensitive policies for dealing with the consequences of the pandemic.

2 Background

Extensive academic research has shown that the lockdown restrictions imposed around the world in response to the COVID-19 pandemic had significant negative effects on people's social and personal lives, and on their economic and financial well-being. In Asia, lockdown measures mandated extreme forms of social distancing, which kept even healthy individuals isolated from each other (Poudel and Subedi, 2020). This isolation led people to experience a variety of mental health problems, including feelings of fear, anger, anxiety, panic and boredom; and, in some cases, feelings of loneliness and guilt for not being able to provide and receive social support (Chatterjee et al., 2020). Moreover, during lockdown periods, many people experienced financial losses, unemployment and various forms of economic precarity (Kochhar et al., 2020) that led them to report symptoms of severe anxiety. Isolation was found to be the key factor that connected all aspects of people's lockdown experiences, as all social activities were cancelled, and people were threatened with monetary losses (Kochhar et al., 2020). The citizens of European countries seemed to experience similar difficulties. In Germany, the financial insecurity and changes in employment status or working conditions people experienced during lockdowns were found to have major psychosocial effects. These effects have been related to the experience of precarity, a term that is widely associated with mental health difficulties (Ahrens et al., 2021).

The long-term isolation and the shift towards increased domestic work demands and home-schooling during the pandemic were associated with a higher incidence of common mental health disorders (CMD) (Chandola et al., 2020). Spatial distancing in combination with financial uncertainty contributed to people feeling a sense of helplessness and negative emotions (Khan et al., 2020). Loneliness has been shown to be the major determinant of CMD among adults in the UK (Chandola et al., 2020). There is evidence that loneliness is as damaging to long-term health as smoking and obesity and is an important risk factor for suicidal behaviour (Townsend, 2020).

High stress levels, depression, irritability and insomnia have been identified as significant consequences of isolation (Rossi et al., 2020).

Thus, a large number of studies have found that the COVID-19 lockdown and quarantine measures negatively affected the mental health of the general population. Nonetheless, certain population groups in European countries were particularly sensitive to the challenges that arose during these periods. Individuals who had previously experienced traumatic events were especially negatively affected by the isolation and the lack of social activities during the lockdowns (Ahrens et al., 2021). Moreover, mental health patients were among the most vulnerable population groups during these periods (Rodriguez-Jimenez et al., 2020).

There is also evidence that changes in people's working conditions, such as having more precarious working conditions and being required to telework (including remote working, home office), led to new challenges. Previous research has shown that teleworking has a negative emotional impact on employees, as it can lead to feelings of loneliness, irritability, worry and guilt (Mann and Holdsworth, 2003). The findings of a study conducted during a lockdown period found that teleworkers reported having lower levels of well-being than other employees after the lockdown, and that unemployed and furloughed individuals reported having even lower well-being levels than their counterparts in every kind of employment (Escudero-Castillo et al., 2021). In another study conducted in Italy during a lockdown period, employees reported high levels of depression and anxiety due to a lack of free time and concerns about exposure to the virus (Rossi et al., 2020).

Furthermore, research conducted in Western countries has shown that there were large gender-based differences in the mental health symptoms reported during lockdown periods. In Italy, women experienced higher levels of psychological distress than men during lockdowns (Rossi et al., 2020). In line with the above findings, research conducted in the US found that the mental health effects of stay-at-home orders were highly negative for women in particular, and that these effects could not be explained by increases in financial uncertainty, childcare responsibilities or fear of dying from COVID-19 (Adams-Prassl et al., 2020).

Findings for Greece indicated that during the pandemic, symptoms of depression, stress and anxiety increased among the general population (Dragotis et al., 2021). Moreover, studies have reported that younger people aged 18–24 had relatively high scores on measures of anxiety and stress (Dragotis et al., 2021), while less educated younger individuals had relatively high rates of post-traumatic stress during the pandemic. The prevalence of suicidal ideation was found to be elevated during the lockdown period in Greece, especially among individuals with a history of poor mental health, poor perceived physical health or impaired family functioning (Papadopoulou et al., 2021). Research has also shown that health care workers were among the most vulnerable groups in the pandemic, as being on the frontlines of a pandemic crisis has been characterised as an extremely traumatic experience that may lead workers to experience secondary traumatic stress (Kalaitzaki et al., 2021).

Other studies have argued that the severe mental health consequences observed during the pandemic may be linked to gender differences

(Argyropoulos et al., 2021), and are more common among individuals who are experiencing financial uncertainty (Zavras, 2021). Individuals with precarious working conditions, such as seasonal workers, the unemployed, the underemployed and lower income workers, had especially poor mental health during the pandemic (Argyropoulos et al., 2021; Zavras, 2021). Moreover, women had significantly worse mental health than men (Argyropoulos et al., 2021). In the Greek context, gender roles may help to explain these differences, as women tend to have more housekeeping and parenting responsibilities than men. Finally, pregnant women reported having significantly increased levels of anxiety during the early stages of the lockdown (Dagklis et al., 2020).

School and university students in Greece were also very negatively affected by the pandemic (Giannopoulou et al., 2021; Sazakli et al., 2021). Restrictions on social life and the digitalisation of the educational process were found to have negatively affected the mental health scores of students (Giannopoulou et al., 2021). An online survey of 1000 university students in Greece showed that there was a horizontal increase in levels of anxiety, depression and suicidal thoughts (Kaparounaki et al., 2020). Another study conducted in Greece found that 12.43% of the university students (N = 1104) surveyed had major depression symptoms, and that women were more affected than men (Patsali et al., 2020). Finally, the school lives of younger children and adolescents were affected in various ways by social distancing and lockdown measures, online schooling and decreased engagement in physical activities. Socio-economic inequalities were also found to be associated with these effects (Magklara et al., 2020).

Based on the previous literature, the research questions of the current study are focused on the relationship between potential vulnerability factors and mental health outcomes during the 2020 lockdown period in Greece. Among the potential vulnerability factors we investigate are demographic and socio-economic variables related to age, sex, employment status, educational background, health status, family status, cohabitating status, levels of socialising (defined as meeting and communicating in person with other people), perceived psychosocial support, preference for digitalised ways of working and dominant emotional states (defined as the dominant emotional condition each individual experienced while completing the questionnaire). Mental health outcomes are based on the participants' scores on the Depression Anxiety Stress Scale-42 items questionnaire (DASS-42), which measures depression, anxiety and stress levels.

3 Data and methods

The present investigation is based on the results of a survey that focused on the psychological impact of the 2020 COVID-19 general quarantine on the mental health of the Greek population. A total of 911 adult participants living in Greece completed an online survey entitled "Social and Psychological Impacts of Quarantine during the COVID-19 Pandemic Period". The survey, which was distributed via free online software from Google Forms (https://bit.ly/3hsAgKN), collected self-reported data on the participants' depressive and anxiety symptoms, health status, the quality of their social support networks, and other demographic and social information. The questionnaire was prepared by a research team led by the Department of Statistics of the Athens University of Economics and Business. The team included Prof. Anastasia Kostaki, who is one of the authors of the current paper. The survey remained online as a Google Form for four consecutive weeks during April and May 2020.

The sample was collected through a convenient sampling procedure. The sampling frame was comprised of anyone who had access to the questionnaire via social networking and who wanted to respond. As the collection method lacked the features of a probabilistic sampling approach, the composition of the sample did not reflect the demographic and social characteristics of the total population of the country. In the sample, females, people of early adult ages and employed people were overrepresented in comparison to the composition of the total population of Greece according to the latest available census data from 2011. Compared to the general population, such people tend to have easier access to the internet, to be more familiar with social networking, and to be more willing to respond to surveys. Given this limitation, caution should be used in extending the results to the total population. However, comparisons between groups of people with different characteristics, like comparisons based on gender, statistical testing and modelling, are not affected by this limitation.

A 100-item questionnaire was used to collect demographic data; information on the participants' social, financial, psychosocial and mental health status; and information on the participants' attitudes towards digitalised ways of communicating and working (examples of questions: "If you work from home during the quarantine, how do you experience the digital way of working?" and "How do you experience the digital way of communicating in general?"), and on their emotional states (examples of questions: "What emotions have been dominant during the lockdown period?"; "Which emotion has been most prevalent during the last month?"; and "What is your main concern at the moment?"). The questionnaire was distributed in seven sections: 1. Demographic data; 2. Psychosocial status during lockdown; 3. Health; 4. Mental health; 5. Social contacts/relationships during lockdown; 6. General social perceptions; and 7. Attitudes towards pandemic and lockdown measures. The questionnaire included explorative questions related to each section category. Answers were given via multiple choice or written responses. Data from the sixth and seventh sections were not included in the current analysis.

The participants' mental health was measured using the Greek translation of the psychometric material DASS-42 scale (DASS; Lovibond and Lovibond, 1995), a self-administered, 42-item questionnaire that principally measures anxiety, stress and depression in the general population (Lyrakos et al., 2011). The 42-item self-reported scale was used to measure each of the negative emotional states of depression, anxiety and stress. According to existing research on the DASS-42 methodology (Lovibond and Lovibond, 1995), the three scales of the questionnaire have high levels of internal consistency and yield meaningful scores in a variety of settings. The sum of all 42 items represents an index of the participants' overall negative emotional states, defined here as the overall mental health condition.

The principal role of the DASS-42 scale in a clinical setting is to clarify the locus of emotional disturbance as part of a broader clinical assessment. The essential function of the DASS-42 is to assess the severity of the core symptoms of depression, anxiety and stress. Answers were given via a four-item Likert scale with a range that varied from "Does not apply to me" (0) to "Does apply to me very much, most of the time" (3) (Dragotis et al., 2021). A detailed description of the DASS-42 has been provided by Parkitny and Mcauley (2010). The survey participants' DASS-42 scores were then analysed according to the standard guidelines. A scoring guide of the DASS-42 values for each of the negative emotional states of depression, anxiety and stress is given in Table A.1 in the appendix. There is no corresponding information for the overall score.

Information on the study and a consent form were presented to the participants on the first webpage of the survey. This page included all of the relevant information on the participation procedures. It also described the purpose of the study and provided assurances of anonymity and confidentiality. The researchers' contact information was given in case the participants wanted more information about or explanations of the study's aims and design. Long-lasting effects or high levels of distress due to participation in the DASS-42 have not been previously reported. After the participants completed the questionnaire, they were presented with a debriefing text with further information.

As was mentioned above, our analysis was based on the responses of 911 participants. The mean age of the participants was 42.99, with a standard deviation (hereafter SD) equal to 13.9 and a median age of 42. Broken down by gender, 69.6% of the participants were women and 30.4% were men. The mean age of the women was 41.32 (SD 13.6, median age 41). The mean age of the men was 46.8 (SD 13.9, median age 47). Of the participants, 24.8% were single, 53.1% were married, 51.3% had children, 46.8% had a tertiary degree and 25.9% had a postgraduate degree. Furthermore, 48.2% of the participants were living with a partner, 32.2% were living with their children and 19.6% were living with their parents. Most of the participants were employed (70.7%), while 17.5% of them had lost their job during the lockdown. Most of the participants were living in an urban area (69.3%). Of the participants, 13.1% reported having a chronic disease, while 46% said they had a family member with health difficulties. Almost half of the participants (57.6%) indicated that they liked digital communication. When asked about their fears, 31.9% of the participants said they were afraid of getting ill, 30.5% reported feeling afraid of financial loss and 29.6% said they were experiencing general uncertainty. Of the participants, 62% reported feeling close to loved ones and 78.5% reported feeling close to members of their family. The mean depression score was 7.77 (SD 7.38), with a median value of six; the mean anxiety score was 4.76 (SD 5.13), with a median value of three; and the mean stress score was 9.26 (SD 7.03), with a median value of eight. The mean value of the overall DASS-42 scores was 21.79 (SD 17.7), with a median value equal to 18. Supplementary Figure S1 provides the distribution of the depression, anxiety and stress scores, as well as the overall DASS-42 scores differentiated by sex (available at https://doi.org/10.1553/populationyearbook2022.dat.5). Table A.2 in the appendix provides information about the composition of the sample according to various characteristics. It also provides for each category the percentages of people suffering from each of the three psychological distortions according to the DASS-42; i.e., the percentages of people whose scores were not normal according to the DASS-42 scoring guide, as presented in Table A.1 in the appendix. However, Table A.2 does not display the corresponding percentages for the overall scores, as there is no limit provided in the literature on DASS-42 psychometric scaling for classifying the scores as normal or distorted, as is provided for the each of the three distinct psychological distortions. Table A.2 also shows bivariate comparisons between the percentages. To assess the association between two categorical variables, the χ^2 test was used. Respondents with missing values in the variables of interest were excluded from the analysis. However, missing values were very rare for all of the variables of the dataset.

It should again be emphasised that because the sample was collected using a convenience sampling technique, it did not have the same composition as the target population. This would, of course, be a serious limitation if the aim was to extend the results on the psychological effects of the lockdown to the total population. However, this was not the scope of our research.

4 Results

Multiple regression modelling using a GLM Univariate procedure was performed to assess the association between the overall DASS-42 scores, as well as the specific scores for each of the three separate mental health problems (depression, anxiety, stress), and a variety of explanatory variables representing all of the main demographic characteristics of the individuals (e.g., age, sex, family status, education, employment status, living conditions, number of children), as well as variables related to social relationships and reported emotional experiences. Applying forward and backward elimination stepwise procedures, we used the optimal models for the description of each of the three psychological distortions, according to statistical goodness-of-fit criteria such as R-square, adjusted *R*-square and mean square errors and partial *F* hypothesis testing. The significance level *p* was set at 0.05. All of the statistical analyses were performed with the IBM SPSS Statistics 25 package.

Table 1 below presents the results of the regression modelling of the overall DASS-42 scores, and provides the parameter estimates of the variables included in the model and the standard errors of the estimates. In all models, higher scores indicate a more negative mental health status.

Table 1:
Statistical modelling of the overall DASS-42 scores; parameter estimates, standard errors and *p*-values of their significance in the model

	Overall score		
	b	***p*-value**	**SE**
Intercept	31.113	0.000	6.4640
Women	5.149	0.000	1.1985
Age			
0–19	3.01	0.459	4.1427
20–29	7.374	0.001	2.1540
30–39	4.01	0.042	1.9384
40–49	2.697	0.114	1.8025
50–59	0.241	0.849	1.8868
60+	*ref.*		
Education			
Secondary school	*ref.*		
High education (Bachelors)	−0.205	0.499	1.6268
Postgraduate (Master)	−1.398	0.951	1.8216
Ph.D.	−2.808	0.266	2.1092
Unemployed	3.456	0.022	1.4914
Living with parents	2.834	0.077	1.6653
Living with a partner	1.657	0.139	1.2044
Living with children	−1.953	0.188	1.2746
Health difficulties	5.075	0.001	1.5927
Family member with health difficulties	1,830	0.125	1.0735
Fear of illnesses	6.985	0.048	2.8658
Fear of financial loss	6.038	0.072	2.8702
Fear of socializing	9.891	0.017	3.7581
Feeling of general uncertainty	7.563	0.028	2.8906
Like digital communication	1.579	0.200	1.1175
Like digitalization of work	2.719	0.034	1.2518
Feeling close to the people you hold dear	−2.823	0.063	1.2387
Feeling close to the people that you are living with	−8.026	0.000	1.4423
Perceived psychosocial support within the pandemic			
Not at all	14.835	0.001	4.4056
Little	10.803	0.000	1.9586
Some	5.344	0.000	1.4455
Much	4.450	0.002	1.5873
Very much	*ref.*		
N			906
R^2			0.243

There was a highly significant relationship between gender and the overall score, as women had a significantly higher mean score than men ($p = 0.000$). Of the age groups, the 20–39 age group was the most vulnerable ($p = 0.001$), while the 30–39 age group was also significantly more affected ($p = 0.042$) than the 60+ age group. As expected, unemployed people had higher scores than employed ($p = 0.022$). Living with parents had a marginally negative impact on psychological health ($p = 0.077$). People who reported having health difficulties had significantly higher scores than people who did not ($p = 0.001$). People who expressed a feeling of general uncertainty had significantly higher scores than people who did not ($p = 0.028$); while people who were afraid of getting ill, experiencing a financial loss or socialising had higher scores than people who were not ($p = 0.048$, 0.072 and 0.017, respectively). People who liked the digitalisation of work had higher scores than people who did not ($p = 0.034$).

Furthermore, people who were feeling close to loved ones and to the people they were living with had lower scores than people who were not ($p = 0.063$ and 0.000, respectively). Finally, the higher the level of psychosocial support during the pandemic people reported receiving, the lower their overall scores (all p-values < 0.01).

Table 2 presents the results of the regression modelling of the DASS-42 scores of each of the three separate mental health problems: depression, anxiety and stress. It also provides the parameter estimates of the variables included in each model and the standard errors of the estimates. Note that due to the model selection method, the three models did not necessarily include the same number of independent variables.

The overall score indicated that there was a highly significant relationship between gender and depression scores, with women having a significantly higher mean depression score than men ($p = 0.008$). People in the 20–39 age group had significantly higher depression scores than people in the 60+ age group, while people in the 30–39 age group had marginally higher scores than people in the 60+ age group ($p = 0.061$). Regarding marital status, married people had significantly lower mean depression scores than people in all other categories, who had significantly higher mean depression scores ($p = 0.011$ for singles, $p = 0.011$ for people in a relationship and $p = 0.025$ for divorced people). In terms of educational level, highly educated people (post-graduate degree or PhD) had marginally lower scores than people with less education ($p = 0.159$ and $p = 0.089$, respectively). As expected, people who had lost their job during the lockdown period had higher depression scores than people who did not ($p = 0.105$). An interesting finding was that people who were living with their parents also had higher depression scores than others ($p = 0.051$). People who were living with a partner had higher depression scores than people who were not ($p = 0.039$). In addition, people who were living with their children had marginally lower scores than people who were not ($p = 0.111$). People with health difficulties and people who had family members with health difficulties had marginally higher scores than others ($p = 0.123$ and 0.114, respectively). People who reported being afraid of illness, financial loss or socialising had higher depression scores than those who

Table 2:
Statistical modelling of depression, anxiety and stress; parameter estimates, standard errors and *p*-values of their significance in the model

	Depression			Anxiety			Stress		
	b	*p*-value	SE	b	*p*-value	SE	b	*p*-value	SE
Intercept	13.960	0.000	4.0307	7.851	0.000	1.7921	19.580	0.000	3.8131
Women	1.345	0.008	0.5015	1.395	0.000	0.3576	2.416	0.000	0.4746
Age									
0–19	1.806	0.312	1.7912	−0.204	0.923	1.2175	4.034	0.019	1.6780
20–29	2.666	0.005	0.9512	1.939	0.002	0.5952	3.437	0.000	0.8380
30–39	1.588	0.061	0.8426	1.022	0.086	0.5752	2.094	0.013	0.7626
40–49	1.134	0.142	0.7841	0.805	0.160	0.5214	1.207	0.096	0.6983
50–59	0.281	0.653	0.7959	−0.188	0.678	0.5475	0.465	0.534	0.7395
60+	*ref.*			*ref.*			*ref.*		
Marital status									
Single	1.313	0.011	0.9120						
Relationship	2.446	0.011	0.9629						
Married	*ref.*								
Divorced	2.122	0.025	0.9743						
Education									
Secondary school	*ref.*			*ref.*					
High education (Bachelors)	−0.134	0.793	0.6765	−0.490	0.263	0.4882			
Postgraduate (Master)	−0.850	0.159	0.7498	−0.938	0.277	0.5433			
Ph.D.	−1.364	0.089	0.8679	−1.301	0.127	0.6285			
Lost job during lockdown	1.031	0.105	0.5945	0.851	0.052	0.4410			
Living with parents	1.473	0.051	0.7075				1.042	0.010	0.6425
Living with a partner	1.487	0.039	0.7305						
Living with children	−0.962	0.111	0.5812						
Health difficulties	1.590	0.123	0.6667	1.392	0.003	0.4779	1.748	0.004	0.638
Family member with health difficulties	0.722	0.114	0.4489	0.676	0.031	0.3209			
Fear of illnesses	2.052	0.109	1.2152	1.447	0.000	0.3871	4.082	0.010	1.1686
Fear of financial loss	2.737	0.051	1.2165				3.485	0.022	1.1732
Fear of socializing	3.301	0.046	1.6016	1.138	0.097	0.8391	4.994	0.002	1.5519
Feeling of general uncertainty	3.292	0.011	1.2241	0.693	0.094	0.3963	4.293	0.007	1.18
Like digital communication	0.926	0.039	0.4519	0.506	0.154	0.3216	0.770	0.159	0.4516
Like digitalization of work							0.968	0.032	0.5000
Feeling close to the people you hold dear	−1.293	0.014	0.5198				−0.997	0.131	0.5013
Feeling close to the people that you are living with	−3.009	0.000	0.6077	−2.412	0.000	0.3871	−2.320	0.000	0.5622
Perceived psychosocial support within the pandemic									
Not at all	5.106	0.008	1.8353	3.528	0.008	1.3077	5.909	0.001	1.7748
Little	4.136	0.000	0.8165	2.524	0.000	0.5657	4.153	0.000	0.7874
Some	2.379	0.000	0.6063	0.723	0.067	0.4229	2.367	0.000	0.5823
Much	1.768	0.011	0.6649	0.708	0.098	0.4744	1.824	0.004	0.6439
Very much	*ref.*			*ref.*			*ref.*		
N			897			897			897
R^2			0.203			0.179			0.213

did not ($p = 0.109$, $p = 0.051$ and $p = 0.046$, respectively). People who reported having a feeling of general uncertainty also had significantly higher depression scores than those who did not ($p = 0.011$). People who said that they liked digital communication had higher depression scores than others ($p = 0.039$). Furthermore, people who indicated that they were receiving low levels of social support from their friends or their family members had higher depression scores than people who said they were receiving high levels of support ($p = 0.008$ and 0.000, respectively). Finally, the higher the levels of social support people reported receiving during the pandemic, the lower their depression scores.

Turning now to anxiety scores, there was a highly significant relationship between gender and anxiety, with women having a much higher mean anxiety score than men ($p = 0.000$). People in the 20–29 age group had significantly higher anxiety scores than people in the 60+ ($p = 0.002$) age group, while people in the 30–39 age group had marginally significantly higher scores than people in the 60+ age group ($p = 0.086$). Individuals who lost their job during the lockdown had higher anxiety scores than others ($p = 0.052$). People who had family members with health difficulties and people who had their own health difficulties had significantly higher anxiety scores than people who did not ($p = 0.031$ and 0.003, respectively). Furthermore, people who were feeling afraid of getting ill had significantly higher anxiety scores than others ($p = 0.000$). Individuals who were feeling afraid of socialising with other people in person or were feeling general uncertainty about the future had marginally significantly higher anxiety scores than people who were not ($p = 0.097$ and 0.094, respectively). An interesting finding was that those people who reported liking digital communication had marginally significantly higher scores than others ($p = 0.154$). People who said they were feeling close to the people they were living with had significantly lower anxiety scores than people who reported feeling distant from the people they were living with ($p = 0.000$). Finally, the higher the levels of psychosocial support people reported receiving from friends and family members during the pandemic, the lower their anxiety scores.

Finally, there was also a large gender gap in the stress scores, with women having significantly higher stress scores than men ($p = 0.000$). People under age 40 had significantly higher stress scores than people aged 60+, while people in the 40–49 age group had marginally significantly higher scores than people in the 60+ age group ($p = 0.096$). People who were living with their parents and who had health difficulties had significantly higher stress scores than others ($p = 0.010$ and $p = 0.004$, respectively). People who reported a feeling of general uncertainty also had significantly higher stress scores than those who did not ($p = 0.007$). Likewise, people who were afraid of getting ill, experiencing financial loss or socialising had higher stress scores than others ($p = 0.010$, 0.022 and 0.002, respectively). Additionally, people who reported liking the digitalisation of work or digital communication had higher stress scores than others ($p = 0.032$ and 0.159, respectively). People who said they were feeling close to the people they were living with had highly significantly lower stress scores than others ($p = 0.000$). Likewise, people who said they were feeling close to the people they hold dear had marginally lower stress scores than others ($p = 0.131$). Finally, the higher the level of social support people reported receiving during the pandemic, the lower their stress scores ($p < 0.004$).

5 Discussion

As the present study was conducted at a time when COVID-19 lockdowns were still taking place across the globe, we were unable to track all of the new research that was published internationally on the mental health effects of lockdown restrictions. Thus, the current paper was written during a dynamic situation that was continuously changing based on the reach of the pandemic and the development of coping strategies. Due to our use of a convenience sample, our limited recruitment procedures and our short period of data collection, we could only present a short quantitative analysis of the data we collected during an unprecedented period of time.

The most important factors we found to be associated with vulnerability to negative mental health outcomes during the first lockdown period included being a woman, being young (20–39 years old), experiencing uncertain/precarious financial conditions and having limited social support.

Our results regarding the differences in the lockdown experiences of men and women are in line with recent findings from the European and Greek contexts. In a study conducted in Germany, Bäuerle et al. (2020) reported that women and younger people experienced more stress during the pandemic. In addition, most of the research conducted in Greece has confirmed that men and women had unequal burdens during the pandemic (Argyropoulos et al., 2021; Dagklis et al., 2020; Dragotis et al., 2021; Kalaitzaki, 2021). According to Power (2020), the COVID-19 pandemic added to the care burdens of women and families because the amounts of unpaid care work being performed, such as housekeeping and parenting, increased as schools were closed, the care needs of older family members grew and health care services were overwhelmed.

Our observation that younger age groups were especially vulnerable during the pandemic confirmed the findings of previous studies conducted in Western countries. According to the literature review of Kowal et al. (2020) that covered 26 countries, people in the 20–40 age group had more depression symptoms during the pandemic because they tend to have a greater need for outdoor and social activities than people in other age groups. The pandemic era and the impact of social distancing measures radically changed the daily lives of these younger adults, as they were “violently” forced to change their ways of life and their habits, and to move away from other people and from their social and recreational habits. These disruptions burdened them psychologically, while the intense pressure to achieve pushed them to the brink of depression. In addition, the literature review by Kowal et al. (2020) found that the highest levels of anxiety were experienced by younger people mainly between the ages of 20 and 40, but also by people who were living alone during the quarantine.

Moreover, financial uncertainty, unemployment and a sense of precarity were found to be important vulnerability factors mainly for depression and anxiety. As the pandemic revealed that the Greek health care system had significant deficits, the unequal distribution of the risks and the negative psychological and social outcomes of the pandemic-related threats became more obvious. Thus, the socio-economic aspects of the dangers of exposure and infection must be taken into account (Zissi and Chtouris, 2020).

The perception of having psychosocial support seems to have been a key factor in well-being during the pandemic, as individuals who reported receiving higher levels of social support from family and friends were found to be more resilient.

In line with the findings described above, the results of the present study indicated that reduced social support from friends and family was an important vulnerability factor that was associated with negative mental health symptoms. Recently conducted studies in the US identified loneliness as the greatest threat to mental health during and after the COVID-19 era (Saltzman et al., 2020). It has been argued that the social isolation and loneliness people experienced due to the pandemic measures had a broader impact on behavioural health, since the loss of social contact can elicit a fear of death.

This latter finding could be also associated with people's levels of engagement with digital forms of communication, as the participants in our study who reported having a more favourable view of digital communication also reported having more mental health symptoms. Although age could play a role in this finding, given that adolescents seem to have more addictive behaviours related to forms of digital communication (Dávideková, 2016), it was previously shown that extensive use of digital communication, especially during periods when embodied social life was highly restricted, had significant consequences for the psychosocial lives of younger individuals, including reduced levels of social skills, self-motivation, emotional intelligence and empathy; and increased levels of conflict with others, ADHD symptoms and depression (Scott et al., 2016).

According to Zissi and Chtouris (2020), the pandemic acted as an accelerator of social inequalities. Dealing effectively with the current social and financial crises presupposes that social institutions and social subjects are resilient, and are able to address the negative effects of the pandemic, such as the widespread social atrophy and social implosion, with creative solutions and collective action (Zissi and Chtouris, 2020). Studies conducted before the start of the pandemic found that the depression, anxiety and stress scores in the Greek population had already increased, and that the most vulnerable groups included women, the unemployed and low-income individuals who had seen their income levels decrease due to pressures associated with the Greek economic crisis, chronic patients and refugees (Economou et al., 2019; Fanakidou et al., 2017; Kokaliari, 2016; Latsou and Geitona, 2018; Stathopoulou et al., 2018). Recent findings have confirmed that the population groups who were facing challenges before the pandemic were even more burdened during the lockdowns (Ahrens et al., 2021; Adams-Prassl et al., 2020). Such findings can be used to craft new policies that take these pre-existing inequalities into account, and thus to construct socially equitable strategies that promote the development of coping skills and psychosocial resilience.

Supplementary Material

Available online at https://doi.org/10.1553/populationyearbook2022.dat.5

Supplementary file 1. DASS-42 depression, anxiety, stress, and total scores distribution by sex

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Ethical considerations

Information about the study and a consent form were presented to the participants on the first webpage of the survey. It included all of the relevant information on the participation procedures. It also described the purpose of the study, while assuring anonymity and confidentiality. The researchers' contact information was given in case the participants wanted more information about or explanations of the study's aims and design. After the participants completed the questionnaire, they were presented with a debriefing text.

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Appendix

Table A.1:
Scoring guide for DASS-42

DASS (42) Scoring	Depression	Anxiety	Stress
Normal	0–9	0–7	0–14
Mild	10–13	8–9	15–18
Moderate	14–20	10–14	19–25
Severe	21–27	15–19	26–33
Extremely severe	28+	20+	34+

Source: Lovibond and Lovibond (1995).

Table A.2:
Sample composition according to various characteristics (absolute numbers) and percentage of respondents suffering from depression, anxiety and stress according to the DASS-42 scale by sample composition, with χ^{2-} statistics (n = 911)

		Depression		Anxiety		Stress	
Variable	***N***	**%**	***p*-value**	**%**	***p*-value**	**%**	***p*-value**
Gender							
Women	613	34.7	0.008	26.8	0.000	21.4	0.005
Men	276	25.7		12.7		13.4	
Missing values	22						
Age							
0–19	21	28.6	0.000	23.8	0.009	23.8	0.000
20–29	173	46.2		32.9		30.6	
30–39	175	34.3		23.4		21.7	
40–49	236	28.8		20.8		15.7	
50–59	175	25.1		17.1		13.1	
60+	131	25.2		18.3		13.7	

Continued

Table A.2: Continued

		Depression		Anxiety		Stress	
Variable	***N***	**%**	***p*-value**	**%**	***p*-value**	**%**	***p*-value**
Marital status							
Single	226	43.4	0.000	25.2	0.006	21.7	0.000
Relationship	103	38.8		33.0		34.0	
Married	484	24.8		18.4		14.5	
Divorced	95	32.6		24.2		18.9	
Missing values	3						
Education							
Secondary school	134	33.6	0.000	29.9	0.002	19.4	0.095
High education (Bachelors)	426	38.0		25.1		21.6	
Postgraduate (Master)	236	26.3		19.1		18.2	
Ph.D.	115	19.1		12.2		11.3	
Location							
Athens	560	32.8	0.261	21.9	0.975	19.5	0.457
Rest of Greece	265	28.5		21.8		17.1	
Missing values	86						
Have children							
No	444	39.9	0.000	26.4	0.009	24.1	0.000
Yes	467	24.4		19.1		14.3	
Employment status							
Employed	644	29.5	0.001	20.7	0.008	17.4	0.012
Unemployed	183	43.2		31.1		26.8	
Missing values	84						
Like digital communication							
No	386	37.3	0.003	26.7	0.012	23.3	0.006
Yes	525	28.0		19.6		16.0	
Like digitalization of work							
No	252	34.9	0.233	21.4	0.597	21.4	0.269
Yes	659	30.8		23.1		18.2	
Fear of illnesses							
No	620	34.7	0.010	20.6	0.038	19.5	0.641
Yes	291	26.1		26.8		18.2	
Fear of financial loss							
No	633	31.9	0.976	25.4	0.002	19.9	0.351
Yes	278	32.0		16.2		17.3	

Continued

Table A.2: Continued

		Depression		Anxiety		Stress	
Variable	***N***	*%*	***p*-value**	*%*	***p*-value**	*%*	***p*-value**
Fear of socializing							
No	874	31.5	0.132	22.3	0.291	18.3	0.003
Yes	37	43.2		29.7		37.8	
Feeling of general uncertainty							
No	641	29.0	0.004	21.5	0.228	18.4	0.414
Yes	270	38.9		25.2		20.7	
Lost job during lockdown							
No	745	30.1	0.008	21.1	0.020	18.7	0.541
Yes	159	40.9		29.6		20.8	
Missing values	7						
Living with parents							
No	725	29.1	0.000	20.8	0.011	16.8	0.001
Yes	186	43.0		29.6		28.0	
Living with a partner							
No	454	37.2	0.001	25.6	0.035	21.4	0.083
Yes	457	26.7		19.7		16.8	
Living with children							
No	605	36.7	0.000	24.5	0.060	21.3	0.016
Yes	306	22.5		19.0		14.7	
Health difficulties							
No	792	30.9	0.092	21.1	0.004	18.1	0.039
Yes	119	38.7		32.8		26.1	
Family member with health difficulties							
No	492	28.0	0.006	19.5	0.015	16.7	0.043
Yes	419	36.5		26.3		22.0	
Feeling close to the people you hold dear							
No	346	43.4	0.000	30.1	0.000	26.3	0.000
Yes	565	25.0		18.1		14.7	

Continued

Table A.2: Continued

		Depression		Anxiety		Stress	
Variable	***N***	**%**	***p*-value**	**%**	***p*-value**	**%**	***p*-value**
Feeling close to the people that you are living with							
No	195	53.3	0.000	35.9	0.000	31.3	0.000
Yes	715	26.0		19.0		15.8	
Missing values	1						
Perceived psychosocial support within the pandemic							
Not at all	15	40.0	0.000	46.7	0.001	33.3	0.006
Little	116	49.1		34.5		27.6	
Some	381	35.4		22.3		21.0	
Much	208	27.4		19.2		15.4	
Very much	191	18.8		17.8		13.1	

Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 499–526

Why did care home residents face an elevated risk of death from COVID-19? A demographic perspective using data from Belgium and from England and Wales

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Abstract

In many countries, deaths from COVID-19 were highly concentrated among care home residents during the initial wave of the pandemic. Care home residents may have faced higher risks of exposure and infection than the general population of older people. Once infected, residents may have been more likely to succumb to this disease as they were both older and frailer than the general population of older people. This study presents a quantified assessment of these factors in Belgium and in England and Wales. In doing so, this paper applies the Das Gupta decomposition method to explain the contributions of these three factors to the observed differences in mortality rates from COVID-19 between older people residing in care homes and older people living at home. According to these estimates, older people residing in care homes were 36 times more likely to die in Belgium and were 23 times more likely to die in England and Wales from COVID-19 than older people living at home during the initial wave of the pandemic. Decomposition of the differences in the mortality rates of these populations in Belgium and in England and Wales showed that the two key determinants were the greater underlying frailty of older people in care homes (accounting for 46% of the differences in Belgium and 66% of the differences in England and Wales) and the higher infection prevalence of older people in care homes (accounting for 40% of the differences in Belgium and 26% of the differences in England and Wales).

Keywords: COVID-19; care home/nursing home; infection prevalence; decomposition

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The views expressed in this paper are those of the author and do not necessarily reflect the views of the United Nations.

DOI: 10.1553/populationyearbook2022.dat.6

1 Introduction

In much of Europe, North America and Australia, the COVID-19 epidemic disproportionately affected care home residents (Comas-Herrera et al., 2020; ECDC, 2020; Fisman et al., 2020; Ladhani et al., 2020; Petretto and Pili, 2020). Deaths among care home residents accounted for more than one-half of all COVID-19 deaths in Australia (75%), Belgium (57%), Canada (59%), the Netherlands (51%) and Slovenia (56%); and for more than one-third of deaths in Austria (44%), France (43%), Spain (40%), Sweden (47%) and the USA (39%) by January 2021 (Comas-Herrera et al., 2020). Why did care home residents face such an elevated risk of death from COVID-19?

This paper explores three causal factors: the older ages, the greater underlying frailty and the higher exposure to infection of care home residents. Among the general population, age and underlying health conditions were the key determinants of the risk of dying from COVID-19 (Panagiotou et al., 2021; Williamson et al., 2020). Older people were at much higher risk of dying from COVID-19 than any other age group (Dowd et al., 2020; Dudel et al., 2020; Goldstein and Lee, 2020; Kashnitsky and Aburto, 2020; Riffe et al., 2021; Williamson et al., 2020; Zhou et al., 2020). A large cohort study in the United Kingdom using the primary health care records of 17 million patients, including of 11,000 individuals who died from COVID-19, found that patients over age 80 were at least 20 times more likely to die from the disease than those in their fifties, and hundreds of times more likely to die than those under age 40 (Williamson et al., 2020). Furthermore, individuals with comorbidities such as cardiac disease, pulmonary disease, kidney disease, cancer or obesity have an increased risk of COVID-19 mortality (Williamson et al., 2020). Older people living in care homes tend to be older and frailer than older people living at home. Therefore, both age and underlying frailty would be expected to contribute to the higher rates of COVID-19 mortality observed in care homes.

A third contributing factor is the high risk of exposure to COVID-19 among care home residents. Studies have highlighted the key role of staff in the transmission of infection in care homes, especially when the staff are temporary or work across multiple locations (Ladhani et al., 2020; ONS, 2020; Shallcross et al., 2021). The high rates of COVID-19 transmission in care homes have also been linked to crowded conditions, shared bedrooms and bathrooms, low staff-to-resident ratios and high community prevalence of COVID-19 infections (Abrams et al., 2020; Brown et al., 2021; He et al., 2020; Li et al., 2020; ONS, 2020; Shallcross et al., 2021; Stall et al., 2020).

To date, there have been few studies that examined the causal factors behind the marked differences in COVID-19 mortality between older adults living in care homes and those living elsewhere. This is due in part to a lack of published data on counts of COVID-19 deaths by both age and place of residence (i.e., living in a care home or living at home). Three studies that did examine this relationship are Hardy et al. (2021), Fisman et al. (2020) and Schultze et al. (2022). Using data from the Wallonia region of Belgium, Hardy et al. (2021) compared the care home population to the general population (of all ages) living outside of care homes. They found that the COVID-19 mortality rate of care home residents was 130 times higher than that of non-residents. Using the Miettinen (1972) method, they decomposed this relative risk into three multiplicative effects of differences in the residents' age and sex structure (11 times greater risk), in health frailty (3.8 times greater risk) and in infection risk (3.5 times greater risk). Studying the first wave of the pandemic, Fisman et al. (2020) compared the COVID-19 mortality rates in 627 long-term care facilities with those in the general older population in Ontario, Canada. They found that mortality from COVID-19 was 13 times higher among long-term care residents than it was among community-living adults over age 69. Schultze et al. (2022) studied the age-standardised risks of death due to all causes and to COVID-19 among adults aged 65 and older in England between 1 February 2019 and 31 March 2021. They found that the relative risk of death among care home residents compared to that among non-residents was 17 times higher among older women and was 18 times higher among older men during the first wave, but did not change during the second wave.

Can the observation that COVID-19 death rates were higher among care home residents than among non-residents be explained by the residents' advanced ages, their greater underlying frailty (at every age) or their higher levels of exposure to and subsequent infections with COVID-19? This paper seeks to compare the COVID-19 mortality of older people in care homes with that of older people not living in care homes, and to assess the impact of the differences in the age composition, the age-specific underlying frailty and the infection rates of these two groups. In doing so, this paper applies the Das Gupta (1993) decomposition to quantify the contributions of these three key factors in Belgium and in England and Wales.

2 Data

For the analysis of the COVID-19 mortality risk factors of care home residents presented in this paper, data are needed on the numbers of deaths linked to COVID-19 by age for both care home residents and non-residents. Such data are not widely available. This paper uses data from Belgium and from England and Wales.

Data from Belgium on the number of COVID-19 deaths disaggregated by age and place of usual residence were provided by Sciensano, the Belgian institute for health (Appendix Table A.1). The COVID-19 death numbers for care home residents include the deaths of residents that occurred in hospitals. The data include both confirmed cases (by molecular testing for COVID-19 or radiological results) and possible cases[1] of COVID-19. Detailed information on the COVID-19 data and

[1] At least one of the following major symptoms of acute onset, with no other obvious cause: cough, dyspnoea, thoracic pain, anosmia or dysgeusia. Or two or more of the following minor symptoms, with no other obvious cause: fever, muscle pain, fatigue, rhinitis, sore throat, headache, anorexia, watery diarrhea, acute confusion, sudden fall. Or exacerbation of chronic respiratory symptoms (COPD, asthma, chronic cough...), without any other obvious cause (Peeters et al., 2021).

methodology can be found in Bustos Sierra et al. (2020), Peeters et al. (2021) and Renard et al. (2021).

There were two major waves of the COVID-19 epidemic in Belgium: a first wave that lasted from 1 March 2020 until 21 June 2020, and a second wave that lasted from 31 August 2020 until 1 February 2021 (Bustos Sierra et al., 2020; Peeters et al., 2021). The data provided by Sciensano for this analysis are for the period from week 11 of 2020 (14 March 2020) until week 39 of 2020 (28 September 2020), which allows for the analysis of the first wave of the epidemic in Belgium. This period was prior to the start of the nationwide mass vaccination campaign in early 2021. The data on the number of deaths from all causes by age and place of death for the year 2018 were obtained from STATBEL, the Belgian statistical office (Appendix Table A.2). The annual data on the number of people by age and place of residence (residents of collective housing vs. non-residents) as of 1 January 2019 (Appendix Table A.3a) and 1 January 2020 by age were provided by STATBEL, the Belgian statistical office (Appendix Table A.3b). The population of older people in collective housing is a good but imprecise measure of the population of older people in care homes, as the category of collective housing also includes older people living in prisons and religious communities. In addition, the population registry may include some care home residents who continue to be listed under their previous residence (usually a private home).

All data for England and Wales were provided by the Office for National Statistics of the United Kingdom licensed under the Open Government Licence (https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/datasets/carehomeresidentdeathsregisteredinenglandandwalesprovisional). The numbers of COVID-19 deaths are based on any mention of COVID-19 on the death certificate, and thus include both confirmed and possible cases.[2] The numbers of deaths of care home residents include the deaths of residents regardless of their place of death. That is, the deaths of care home residents refer to both the deaths of residents that occurred in a care home and the deaths of individuals whose place of residence was a care home but who died elsewhere. The obtained data include the number of deaths involving COVID-19 among care home residents and non-residents by age from 14 March 2020 to 2 April 2021 (Appendix Table B.1a and Table B.1b); the number of deaths from any cause among care home residents and the general population by age in 2019 (Appendix Table B.2); and the number of care home residents and non-residents by age in 2020 (Appendix Table B.3). Unlike the data for Belgium, these data allow for the analysis of two major waves in England and Wales: the first wave that lasted from 14 March 2020 to 11 September 2020, and the second wave that lasted from 12 September 2020 to 2 April 2021.

[2] The definition of COVID-19 includes some cases in which the certifying doctor suspected the death involved COVID-19, but was not certain. For example, a doctor may have clinically diagnosed COVID-19 based on symptoms, but this diagnosis may not have been confirmed because no test was available, or the test result was inconclusive (ONS, 2020).

Table 1:
Data sources

	Belgium	England and Wales
COVID-19 deaths	By age and place of usual residence for the period of 14 March 2020 to 28 September 2020. Source: Sciensano, the Belgian institute for health (Appendix, Table A.1)	By age and place of usual residence for the period of 14 March 2020 to 2 April 2021. Source: Office for National Statistics of the United Kingdom (Appendix, Table B.1a and Table B.1b)
All-cause mortality rates	By age and place of death for the year 2018. Source: STATBEL, the Belgian statistical office (Appendix, Table A.2)	By age and place of usual residence in 2019. Source: Office for National Statistics of the United Kingdom (Appendix, Table B.2)
Population counts	By age and place of usual residence in 2019 and 2020. Source: STATBEL, the Belgian statistical office (Appendix, Table A.3a and Table A.3b)	By age and place of usual residence in 2020. Source: Office for National Statistics of the United Kingdom (Appendix, Table B.3)

3 Methods

Using data on COVID-19 deaths by age and by place of residence (care home vs. non-care home) and similar data for population counts, the COVID-19 mortality rates by age and by residence are calculated using equation (1). These rates are calculated for four age groups: the 65+ age group, which is further sub-divided into the 64–74, 75–84 and 85+ age groups for each population: the care home population and the non-care home population. These sets of rates are calculated for Belgium for the period of March 2020 to September 2020; and for England and Wales for two periods: 14 March 2020 to 11 September 2020 and 12 September 2020 to 2 April 2021.

$$m^r(x) = d^r(x)/k^r(x) \tag{1}$$

where:[3]

m is the COVID-19 mortality rate at age x in population r;
d is the number of reported COVID-19 deaths at age x in population r;

[3] d and k are not annualised rates in this paper since the reference period is irregular. However, this paper reports ratios, and the decompositions are unaffected.

k is the mid-year count of population at age x in population r; and
r refers to the place of residence (1 = lives in care home; 0 = lives elsewhere).

As death from COVID-19 is a two-stage process of infection followed by death, the age-specific mortality rate for COVID-19, $m^r(x)$, can be defined as:

$$m^r(x) = i^r(x) \cdot f^r(x) \tag{2}$$

where:

m is the COVID-19 mortality rate at age x in population r;
i is the infection prevalence at age x in population r, i.e., the number infected divided by the population count;
f is the infection fatality rate at age x in population r, i.e., the number of deaths from COVID-19 of those infected with COVID-19; and
r refers to the place of residence (1 = lives in care home; 0 = lives elsewhere).

If the data were available, the decomposition presented in equation (2) would provide the most straightforward approach to answering the question of why the care home population faced such highly elevated risks. Theoretically, the true number of infected individuals could be estimated through serological testing of a representative random sample of the population (Kritsotakis, 2020; Metcalf et al., 2016). However, serological testing requires investments of time and resources, and there are many situations in which such tests may not be conducted in a timely manner, or even at all (WHO, 2020). Unfortunately, the lack of accurate and timely health information has been a hallmark of the pandemic. Data on the infection prevalence and the infection fatality rates in the care home population are not publicly available. In addition, measuring the proportion of individuals who are infected is a challenge because the infections of those who have mild or no symptoms are often undetected. Thus, some people who are infected may not be aware that they are spreading the disease (Kim et al., 2020; Li et al., 2020; Nishiura et al., 2020; Sharman, 2020). In addition, due to the widespread lack of testing and contact tracing, many cases have gone unreported, especially in the early stages of the pandemic (Ioannidis, 2021; Lau et al., 2020). For example, according to official estimates from the United States Centers for Disease Control and Prevention (CDC), only one in four COVID-19 infections was reported between February 2020 and September 2021 (CDC, 2021). As a result, there are wide disparities in the published estimates of both infection prevalence and infection fatality rates based on different modelling approaches and assumptions (Meyerowitz-Katz and Merone, 2020). Therefore, the analysis presented in this paper is based solely on the observed rates of COVID-19 mortality during the pandemic and of all-cause mortality in a year prior to start of the epidemic.

Since neither the infection prevalence nor the infection fatality rates of equation (2) are observed, the analysis relies on the indirect estimation of these factors. The key assumption is that the risk of succumbing to COVID-19 after being infected is proportional to the risk of all-cause mortality. Indeed, this seems to be the main explanation for the age pattern of COVID-19 mortality and its variation around the world (Demombynes, 2020; Goldstein and Lee, 2020; Promislow, 2020; United Nations, 2020). COVID-19 mortality by age seems to closely follow the same pattern observed for all-cause mortality by age at older ages. That is, it is a fixed proportion b of the age-specific all-cause mortality rate, as seen in equation (3):

$$f^r(x) = b \cdot n^r(x) \tag{3}$$

where:

f is the infection fatality rate at age x in population r, i.e., the number of deaths from COVID-19 of those infected with COVID-19;
b is an unknown proportion, assumed to be a constant across ages and populations (care home residents and non-residents);
n is the all-cause mortality rate at age x in population r during a pre-pandemic year; and
r refers to the place of residence (1 = lives in care home; 0 = lives elsewhere).

If this assumption is true, then data from observations collected in previous years of all-cause mortality by age and care home status can be leveraged to estimate a proxy for the infection fatality rates. In essence, this method assumes that frailer individuals are at greater risk of dying from COVID-19 once infected. Increased age and the presence of co-morbidities are indicators of increased "frailty" or susceptibility to illness and death from a broad range of causes (United Nations, 2020). While all-cause deaths rates are a useful proxy for frailty, they may be imperfect, since deaths from some causes are not closely tied to any physiological vulnerability, such as deaths from violence and some accidents (United Nations, 2020).

Equation (4) re-expresses the age-specific mortality of equation (2) using this proxy from equation (3).

$$m^r(x) = i^r(x) \cdot b \cdot n^r(x) \tag{4}$$

where:

m is the COVID-19 mortality rate at age x in population r;
i is the infection prevalence rate at age x in population r;
b is an unknown proportion, assumed to be constant across ages and populations (care home residents and non-residents); and
n is the all-cause mortality rate at age x in population r during a pre-pandemic year.

Note that the only variables that are measurable in this equation are the mortality rates from COVID-19 during the period of study and from all causes during a pre-pandemic year. Therefore, the infection prevalence rate, $i^r(x)$, cannot be estimated. Only the composite term, $i^r(x) * b$, is estimated.

The ratio of the age-specific COVID-19 mortality rates of the care home population relative to those of the non-resident population can be expressed as the product of two ratios, as shown in equation (5). This equation can be used to derive the relative infection risk of care home residents compared to that of non-residents, as the relative risks of COVID-19 mortality and the relative risks of all-cause mortality in a pre-pandemic year are known quantities

$$\frac{m^1(x)}{m^0(x)} = \frac{i^1(x)}{i^0(x)} \cdot \frac{b}{b} \cdot \frac{n^1(x)}{n^0(x)} = \frac{i^1(x)}{i^0(x)} \cdot \frac{n^1(x)}{n^0(x)} \tag{5}$$

where:

m is the COVID-19 mortality rate at age x in population r;
i is the infection prevalence rate at age x in population r;
b is an unknown proportion, assumed to be constant across ages and populations (care home residents and non-residents); and
n is the all-cause mortality rate at age x in population r during a pre-pandemic year; and
superscripts $1, 0$ indicate the place of residence (1 = lives in care home; 0 = lives elsewhere).

Note that equation (5) is also useful for exploring counterfactual scenarios for the age-specific mortality rates among the care home population. For example, evaluating equation (5) with $i^1(x)$ equal to $i^0(x)$ shows the hypothetical mortality rate among care home residents if they had experienced the same infection prevalence as non-residents.

The COVID-19 mortality rate for care home residents aged 65 and older is the weighted sum of the age-specific mortality rates at ages 65–64, 75–84 and 85+ weighted by the age distribution of the population (see equation (6)). Therefore, the different rates of COVID-19 mortality experienced by these two populations is a result of differences in the three factors: infection prevalence, $i^r(x)$; frailty as measured by all-cause mortality in a pre-pandemic year, $n^r(x)$; and the age distribution of the population, $p^r(x)$.

$$M^r(65+) = \sum_x i^r(x) \cdot b \cdot n^r(x) \cdot p^r(x) \tag{6}$$

where:

$M(65+)$ is the COVID-19 mortality rate for the population aged 65 and older in population r;
i is the infection prevalence rate at age x in population r;
n is the all-cause mortality rate at age x in population r during a pre-pandemic year;
b is an unknown proportion, assumed to be constant across ages and populations (care home residents vs non-residents);
p is the proportion of population r at age x; and
r refers to the place of residence (1 = lives in care home; 0 = lives elsewhere).

To what extent were the higher COVID-19 death rates among care home residents due to their higher infection rates, their higher levels of frailty or to their advanced ages? In demography, the Kitagawa (1955) method for standardisation and decomposition is often used to turn a difference in mortality rates between populations into a component effect attributed to the differences in the age structure, and a rate effect attributed to the differences in the age-specific mortality rates. The age component effect is calculated as the differences in the age distributions of the two populations weighted by the arithmetic mean of the age-specific mortality rates of the two populations. The rate effect is calculated as the differences in the age-specific mortality rates of the two populations weighted by the arithmetic mean of the age distribution in the two populations. The Das Gupta (1993) method is an extension of Kitagawa's decomposition method for more than two effects, following the same logic. Equation (7) presents a decomposition of the differences in the COVID-19 mortality rates of care home residents and non-residents into three effects: differences in the infection prevalence at each age, differences in the infection fatality rate at each age (proxied by the all-cause mortality in a pre-pandemic year) and differences in the age structure. Note that the estimation of the decomposition in equation (7) uses the composite term, $i^r(x) * b$, estimated using equation (3); as was previously noted, the infection prevalence rate, $i^r(x)$, cannot be measured. Equation (7) also shows that the inability to measure the infection prevalence rate does not affect the decomposition estimates, as an equivalent expression for the decomposition in the case in which the infection prevalence rates could be measured shows that all three factors are multiplied by the unknown term "b", and hence that the share of the difference attributed to each factor is unchanged.

$$
\begin{aligned}
&M^1(65+) - M^0(65+) \\
&= \sum_x (i^1(x) \cdot b - i^0(x) \cdot b) \\
&\quad \cdot \left[\frac{n^1(x) \cdot p^1(x) + n^0(x) \cdot p^0(x)}{3} + \frac{n^1(x) \cdot p^0(x) + n^0(x) \cdot p^1(x)}{6} \right] \\
&\quad + \sum_x (n^1(x) - n^0(x)) \\
&\quad \cdot \left[\frac{i^1(x) \cdot b \cdot p^1(x) + i^0(x) \cdot b \cdot p^0(x)}{3} + \frac{i^1(x) \cdot b \cdot p^0(x) + i^0(x) \cdot b \cdot p^1(x)}{6} \right] \\
&\quad + \sum_x (p^1(x) - p^0(x)) \\
&\quad \cdot \left[\frac{i^1(x) \cdot b \cdot n^1(x) + i^0(x) \cdot b \cdot n^0(x)}{3} + \frac{i^1(x) \cdot b \cdot n^0(x) + i^0(x) \cdot b \cdot n^1(x)}{6} \right] \\
&= b \sum_x (i^1(x) - i^0(x))
\end{aligned}
$$

$$\cdot \left[\frac{n^1(x) \cdot p^1(x) + n^0(x) \cdot p^0(x)}{3} + \frac{n^1(x) \cdot p^0(x) + n^0(x) \cdot p^1(x)}{6} \right]$$
$$+ b \sum_x (n^1(x) - n^0(x))$$
$$\cdot \left[\frac{i^1(x) \cdot p^1(x) + i^0(x) \cdot p^0(x)}{3} + \frac{i^1(x) \cdot p^0(x) + i^0(x) \cdot p^1(x)}{6} \right]$$
$$+ b \sum_x (p^1(x) - p^0(x))$$
$$\cdot \left[\frac{i^1(x) \cdot n^1(x) + i^0(x) \cdot n^0(x)}{3} + \frac{i^1(x) \cdot n^0(x) + i^0(x) \cdot n^1(x)}{6} \right] \tag{7}$$

where:

$M(65+)$ is the COVID-19 mortality rate for the population aged 65 and older in population r;
i is the infection prevalence rate at age x in population r;
n is the all-cause mortality rate at age x in population r during a pre-pandemic year;
b is an unknown proportion, assumed to be constant across ages and populations (care home residents vs non-residents);
p is proportion of population r at age x; and
superscripts $1, 0$ indicate the place of residence (1 = lives in care home; 0 = lives elsewhere).

4 Results

Between March 2020 and September 2020 in Belgium, COVID-19 deaths were heavily concentrated in care homes (see Table 2a). The number of deaths among care home residents aged 65+ was 6111, which represents 61% of all COVID-19 deaths in the population aged 65+ (9399). Among the general population, there were 0.9 COVID-19 deaths per 1000 people during this period. But among older people, the mortality rate was four times higher, at 4.3 deaths per 1000 people. And among these older people, the mortality rate of those living in care homes was 57 deaths per 1000, which was 36 times higher than the mortality rate of non-residents (1.6 deaths per 1000).

Similarly, in England and Wales, COVID-19 deaths were heavily concentrated among the care home population, with these deaths accounting for 39% of all deaths during the first wave of the pandemic from 14 March 2020 to 11 September 2020 (see Table 2b). Among the general population, there were 0.9 COVID-19 deaths per 1000 people during this period. But among older people, the mortality rate was four times higher, at 4.1 deaths per 1000 people. And among these older people, the mortality rate of those living in care homes was 55 deaths per 1000, which

Table 2:
COVID-19 deaths and mortality rates for people aged 65 and older by care home status

A. Belgium, 14 March 2020–28 September 2020

	All ages	Ages 65+			
Place of residence	**Total**	**Living in care home (A)**	**Not living in care home (B)**	**Total (A+B)**	**Ratio (A/B)**
COVID-19 deaths	9,975	6,111	3,288	9,399	1.86
Population	11,492,641	107,257	2,097,221	2,204,478	0.05
COVID-19 mortality rate (per 1000)	0.9	57.0	1.6	4.3	36.3

Source: Author's calculations based on COVID-19 deaths by age provided by Sciensano, the Belgian institute for health, and care home residence and estimates of care home residents and non-residents by age provided by provided by STATBEL, the Belgian statistical office.

B. England and Wales, 14 March 2020 to 11 September 2020 (wave 1)

	All ages	Ages 65+			
Place of residence	**Total**	**Living in care home (A)**	**Not living in care home (B)**	**Total (A+B)**	**Ratio (A/B)**
COVID-19 deaths	51,912	20,231	26,132	46,363	0.77
Population	59,867,666	369,483	10,828,745	11,198,228	0.03
COVID-19 mortality rate (per 1000)	0.9	54.8	2.4	4.1	22.7

Source: Author's calculations based on COVID-19 deaths by age and care home residence and estimates of care home residents and non-residents by age provided by the Office for National Statistics of the United Kingdom.

C. England and Wales, 12 September 2020 to 2 April 2021 (wave 2)

	All ages	Ages 65+			
Place of residence	**Total**	**Living in care home (A)**	**Not living in care home (B)**	**Total (A+B)**	**Ratio (A/B)**
COVID-19 deaths	84,762	21,321	53,541	74,862	0.40
Population	59,867,666	369,483	10,828,745	11,198,228	0.03
COVID-19 mortality rate (per 1000)	1.4	57.7	4.9	6.7	11.7

Source: Author's calculations based on COVID-19 deaths by age and care home residence and estimates of care home residents and non-residents by age provided by the Office for National Statistics of the United Kingdom.

was 23 times higher than the mortality rate of non-residents (2.4 deaths per 1000). The figures for England and Wales are strikingly similar to those for Belgium in terms of the overall COVID-19 mortality rate and the rates for the older population and for the care home population. Data for England and Wales are available for the second wave of the pandemic, which took place from 12 September 2020 to 2 April 2021 (see Table 2c). In this second wave, care home residents experienced COVID-19 death rates similar to those in the first wave (57.7 per 1000 compared to 54.8 per 1000), but they did much better in comparison to other population groups. Whereas the mortality rate of people living in care homes was 23 times higher than that of non-resident older people in the first wave, the ratio fell to 12 times higher in the second wave (57.8 per 1000 compared to 4.9 per 1000). Accordingly, the concentration of COVID-19 deaths among the care home population declined from 39% of all COVID-19 deaths in the first wave to 25% of all COVID-19 deaths in the second wave.

The care home residents were older than the non-residents. The average age of care home residents was about 86 in Belgium and 83 in England and Wales, while the average age of non-residents was about 76 in both Belgium and England and Wales based on the age distribution data from Table 3. Compared to non-residents, older people living in care homes were about 10 years older in Belgium and were about seven years older in England and Wales. As age is a known risk factor for COVID-19 mortality (Dowd et al., 2020; Dudel et al., 2020; Kashnitsky and Aburto, 2020), these age differences partly explain the higher levels of mortality experienced by care home residents.

Furthermore, at every age, care home residents had a much higher COVID-19 mortality rate than non-residents. For example, in Belgium, the COVID-19 death rates for care home residents were 31 per 1000 for those aged 65–74, 53 per 1000 for those aged 75–84, and 65 per 1000 for those aged 85+, as shown in Table 3a. Non-residents had much lower rates, at 0.6 per 1000 for those aged 65–74, 2.0 for those aged 75–84, and 4.6 for those aged 85+. England and Wales displayed the same pattern, with COVID-19 death rates being higher for residents than for non-residents at every age in both waves, as shown in Tables 3b and 3c.

The age-specific mortality data in Table 3 are expressed as ratios of COVID-19 mortality among care home residents relative to that among similarly aged non-residents in Table 4. As was previously noted, as a group, the care home population experienced substantially higher COVID-19 mortality than non-residents. In addition, a very strong age gradient is observed. The gap in COVID-19 mortality rates between the two groups was largest in the youngest age group (ages 65–74) and was smallest in the oldest age group (ages 85+). For instance, compared to non-residents, care home residents in Belgium had death rates that were 51 times higher for those aged 65–74, 26 times higher for those aged 75–84 and 14 times higher for those aged 85+.

As COVID-19 mortality is the product of the infection prevalence and the infection fatality rate, the much higher risk of dying from COVID-19 of care homes residents relative to that of non-residents was due to differences in the infection prevalence as well as differences in the infection fatality rate. As was discussed in the methods section (see equation (3)), the infection fatality rates from COVID-19

Table 3:
COVID-19 mortality rates and population counts by age and care home status

A. Belgium, 14 March 2020–28 September 2020						
	Living in care home			**Not living in care home**		
		Population			**Population**	
Age	**COVID-19 mortality rate (C) (per 1000)**	**Count**	**Distribution (%)**	**COVID-19 mortality rate (D) (per 1000)**	**Count**	**Distribution (%)**
65–74	31.23	13,771	13	0.60	1,156,628	55
75–84	52.51	29,402	27	1.99	669,538	32
85+	64.56	64,084	60	4.64	271,055	13
Total 65+	56.98	107,257	100	1.57	2,097,221	100

Source: Author's calculations based on COVID-19 deaths by age provided by Sciensano, the Belgian institute for health, and care home residence and estimates of care home residents and non-residents by age provided by provided by STATBEL, the Belgian statistical office.

B. England and Wales, 14 March 2020 to 11 September 2020 (wave 1)						
	Living in care home			**Not living in care home**		
		Population			**Population**	
Age	**COVID-19 mortality rate (C) (per 1000)**	**Count**	**Distribution (%)**	**COVID-19 mortality rate (D) (per 1000)**	**Count**	**Distribution (%)**
65–74	45.54	34,451	9	1.03	5,943,094	55
75–84	55.71	112,274	30	2.93	3,601,514	33
85+	55.70	222,758	60	7.39	1,284,137	12
Total 65+	54.75	369,483	100	2.41	10,828,745	100

Source: Author's calculations based on COVID-19 deaths by age and care home residence and estimates of care home residents and non-residents by age provided by the Office for National Statistics of the United Kingdom.

C. England and Wales, 12 September 2020 to 2 April 2021 (wave 2)						
	Living in care home			**Not living in care home**		
		Population			**Population**	
Age	**COVID-19 mortality rate (C) (per 1000)**	**Count**	**Distribution (%)**	**COVID-19 mortality rate (D) (per 1000)**	**Count**	**Distribution (%)**
65–74	36.40	34,451	9	2.08	5,943,094	55
75–84	49.58	112,274	30	5.72	3,601,514	33
85+	65.10	222,758	60	16.02	1,284,137	12
Total 65+	57.70	369,483	100	4.94	10,828,745	100

Source: Author's calculations based on COVID-19 deaths by age and care home residence and estimates of care home residents and non-residents by age provided by the Office for National Statistics of the United Kingdom.

are assumed to be proportional to all-cause mortality. Hence, the estimates of the ratio of the COVID-19 infection fatality rates for care home residents relative to those for non-residents (reported in column F of Table 4) are based on the ratio of the all-cause mortality rates for care home residents relative to those for non-residents, which are drawn from pre-pandemic years (2018 for Belgium and 2019 for England and Wales). At every age, care home residents had much higher all-cause mortality than non-residents, reflecting their greater frailty. However, this disadvantage declined with age. For instance, in Belgium in 2018, the all-cause mortality rates were nine times higher at ages 65–74, seven times higher at ages 75–84 and four times higher at ages 85+ for care home residents than for non-residents. Similar results have been reported for England and Wales. The greater health frailty of the care home residents is an important factor in the higher COVID-19 mortality experienced by this population, and it underlies the strong age gradient observed in COVID-19 mortality. That is, care home residents were at higher risk of dying from COVID-19 than other older people because they are generally at higher risk of death than other older people at every age.

The ratio of the infection prevalence of care home residents to non-residents, $(i^1(x)/i^0(x))$, reported in column G of Table 4, was estimated using equation (5), which divides the observed ratio of COVID-19 mortality $(m^1(x)/m^0(x))$ by the observed ratio of all-cause mortality $(n^1(x)/n^0(x))$ in a pre-pandemic year. The results indicate that care home residents aged 65+ in Belgium were 3.8 times more likely to become infected with COVID-19 than other older people. In England and Wales, care home residents aged 65+ were 1.79 times more likely to become infected with COVID-19 than other older people during the first wave. During the second wave, this difference was reversed, with care home residents being less likely to become infected than the general population (i.e., residents had 0.9 times the prevalence of non-resident older people).

Table 4 shows that the age-specific infection prevalence was nearly constant across ages. This finding lends support to the hypothesis that this factor is measuring infection risk (which is unlikely to have much of an age gradient within care home facilities). This assumption is consistent with evidence from Akhtar-Danesh et al. (2022) indicating that, among long-term care residents in Ontario, the infection prevalence was nearly constant by age. Therefore, the results displayed in Table 4 suggest that care home residents experienced higher death rates from COVID-19 in part because they were more likely to be exposed to COVID-19 than the general population of older people during the first wave of the pandemic. That is, the infection spread more rapidly within and between care home facilities than it did in the general population. As other respiratory viruses such as the seasonal flu also appear to spread more rapidly among care home residents, it is likely that a similar pattern of transmission occurred during the COVID-19 pandemic (Anderson et al., 2020; CDC, 2020; Chen et al., 2020). In addition, a lack of resources, such as testing and personal protection equipment for care home staff, meant that there were likely vectors of spread within and between care home facilities (Shallcross et al., 2021).

The examination of the age pattern of COVID-19 mortality has shown that care home residents faced a much higher risk of death than non-residents, but that this disadvantage declined with age. The estimates indicate that this declining disadvantage with age was likely due to decreasing differences between the two

Table 4:
Ratios of mortality, infection fatality and infection prevalence: comparing older people living in care homes to older people not living in care homes

A. Belgium, 14 March 2020–28 September 2020			
Age	**Ratio: COVID-19 mortality (C/D) = E**	**Ratio: infection fatality rate (estimated) (F)**	**Ratio: infection prevalence (estimated) G = (E/F)**
65–74	51.74	9.01	5.74
75–84	26.38	7.23	3.64
85+	13.92	3.74	3.72
All 65+	36.34	9.56	3.80

Source: Author's calculations based on COVID-19 deaths by age provided by Sciensano, the Belgian institute for health, and care home residence and estimates of care home residents and non-residents by age provided by provided by STATBEL, the Belgian statistical office.

B. England and Wales, 14 March 2020 to 11 September 2020 (wave 1)			
Age	**Ratio: COVID-19 mortality (C/D) = E**	**Ratio: infection fatality rate (estimated) (F)**	**Ratio: infection prevalence (estimated) G = (E/F)**
65–74	44.34	20.97	2.11
75–84	19.04	9.46	2.01
85+	7.54	4.48	1.68
All 65+	22.69	12.71	1.79

Source: Author's calculations based on COVID-19 deaths by age and care home residence and estimates of care home residents and non-residents by age provided by the Office for National Statistics of the United Kingdom.

C. England and Wales, 12 September 2020 to 2 April 2021 (wave 2)			
Age	**Ratio: COVID-19 mortality (C/D) = E**	**Ratio: infection fatality rate (estimated) (F)**	**Ratio: infection prevalence (estimated) G = (E/F)**
65–74	17.50	20.97	0.83
75–84	8.66	9.46	0.92
85+	4.06	4.48	0.90
All 65+	11.67	12.71	0.92

Source: Author's calculations based on COVID-19 deaths by age and care home residence and estimates of care home residents and non-residents by age provided by the Office for National Statistics of the United Kingdom.

populations in frailty by age. That is, among the youngest age group (ages 65–74), people who were living in care homes were much frailer than those who were living outside of care homes, whereas among the oldest age group (ages 85+), this frailty difference – though still large – was much reduced. Therefore, the larger gap in COVID-19 mortality rates between the care home population and the population at large in the 65–74 age group was likely attributable to the care home population in that age group being far more selected for frailty than the population in the 85+ age group. Finally, the age patterns show that the higher infection prevalence of care home residents relative to that of non-residents did not vary much by age.

The large differences in the COVID-19 mortality rates observed between residents and non-residents can be decomposed into three components: (1) the component due to different age structures (age composition); (2) the component due to different infection prevalence rates at each age; and (3) the component due to different infection fatality rates at each age, which reflects underlying frailty. The Das Gupta method (1993) is applied using equation (6), and the results are reported in Table 5. During wave 1 in Belgium, 13% of the differences in mortality between care home residents and non-residents could be attributed to the older ages of the care home residents (age composition effect). The greater frailty of the care home population accounted for 46% of the differences in mortality. Finally, an estimated 40% of the differences in mortality were likely due to the higher infection levels among the resident population. The fourfold greater risk of infection among care home residents in Belgium during wave 1 was a second major factor, accounting for about two-fifths of the elevated COVID-19 mortality rates experienced by this population during wave 1. These results are not directly comparable to those of Hardy et al. (2021), who examined the Wallonia region (rather than all of Belgium, as in this study), and compared care home residents to the general population of all ages (rather than the older population, as in this study). Nevertheless, in line with the results of this study, they identified higher infection rates among care homes residents as an important explanatory factor that likely had nearly the same impact as underlying frailty.

Similarly, in England and Wales during the first wave, the 1.79 times higher infection rate (estimated) observed among care home residents was a second major factor that accounted for 26% of the elevated COVID-19 mortality rates experienced by this population. However, by the second wave, the infection rate was estimated to be slightly lower among care home residents, accounting for −6% of the elevated mortality rates experienced by this population. The better outcomes of the care home population during the second wave might be attributed to the higher immunisation rates among this population, and/or to better infection control procedures within care homes (ONS, 2020; Schultze et al., 2022).

Having identified infection prevalence as a significant contributor to the large differences in COVID-19 mortality experienced by the care home populations in Belgium and England and Wales, it is useful to construct a counterfactual: What would have happened if care home residents had experienced the lower infection rates observed among non-residents? Using equations (5) and (6), we calculate the hypothetical COVID-19 mortality rate of care home residents given their population age structure and their underlying frailty, but with the lower infection rate of non-residents. In this hypothetical scenario, if the infection prevalence of the care home

Table 5:
Decomposition of the differences in the COVID-19 death rates between older people living in care homes and older people living at home

	Belgium, 14 March 2020–28 September 2020		England and Wales, 14 March 2020–11 September 2020 (wave 1)		England and Wales, 12 September 2020–2 April 2021 (wave 2)	
	Deaths per 1000 persons	**Distribution**	**Deaths per 1000 persons**	**Distribution**	**Deaths per 1000 persons**	**Distribution**
Differences in COVID-19 mortality rates between care home residents and non-residents	55.4	100%	52.3	100%	52.8	100%
Contributions of age compositional differences	7.5	13%	4.3	8%	10.0	19%
Contributions of differences in age-specific frailty	25.6	46%	34.3	66%	46.2	88%
Contributions of differences in age-specific infection rates	22.3	40%	13.7	26%	−3.4	−6%

Source: Author's calculations based on COVID-19 deaths by age in Belgium provided by Sciensano, the Belgian institute for health; care home residence and estimates of care home residents and non-residents by age in Belgium provided by STATBEL, the Belgian statistical office; and COVID-19 deaths by age and care home residence and estimates of care home residents and non-residents by age in England and Wales provided by the Office for National Statistics of the United Kingdom.

population had been as low as that of the non-resident population in Belgium, the COVID-19 mortality rate among the care home population would have fallen from 57 deaths per 1000 to 15.5 deaths per 1000. Note that relative to the non-resident population, they still would have experienced death rates that were 10 times higher due to the underlying frailty of the population. Overall, the COVID-19 mortality rate would have fallen by 49% from 4.3 deaths per 1000 to 2.2 deaths per 1000 among the population aged 65 and older, as presented in Table 6. That is, the number of COVID-19 deaths among people aged 65 and older would have fallen from the observed 9399 deaths to 4955 deaths. For England and Wales, the COVID-19 mortality rate for the care home population would have fallen from 54.8 deaths per 1000 to 30.4 deaths per 1000. Note that as was the case for Belgium, the care home population still would have experienced a death rate that was much higher than that of the non-resident population (13 times higher) due to the greater underlying frailty of this population. Overall, if the infection prevalence of the care home population had been as low as that of the non-resident population, the COVID-19 mortality rate for the population aged 65 and older would have fallen by 20% from 4.1 deaths per

Table 6:
COVID-19 deaths and mortality rates as observed and under an alternative scenario in which nursing home residents had the same infection prevalence as non-residents

A. Belgium, 14 March 2020–28 September 2020

		Total	Residents	Non-residents	Ratio
Baseline	Deaths	9,399	6,111	3,288	1.9
	Rate	4.3	57.0	1.6	36.3
Alternative scenario	Deaths	4,955	1,667	3,288	0.5
	Rate	2.2	15.5	1.6	9.9

B. England and Wales, 14 March 2020–11 September 2020 (wave 1)

		Total	Residents	Non-residents	Ratio
Baseline	Deaths	46,363	20,231	26,132	0.8
	Rate	4.1	54.8	2.4	22.7
Alternative scenario	Deaths	37,357	11,225	26,132	0.4
	Rate	3.3	30.4	2.4	12.6

1000 to 3.3 deaths per 1000 in wave 1. That is, the number of COVID-19 deaths among those aged 65 and older would have fallen from the observed 46,363 deaths to 37,357 deaths.

5 Limitations

A key limitation of this analysis is the inability to directly observe infection prevalence and infection fatality rates. An indirect method had to be used to measure these rates based on the strong assumption that the unobserved COVID-19 infection fatality rates for care home residents relative to those for non-residents were closely approximated by the all-cause mortality rates for care home residents relative to those for non-residents (observed in the years prior to the epidemic). Support for this assumption is provided by the growing body of evidence that age-specific COVID-19 mortality rates seem to closely approximate the age-specific all-cause mortality rates in most countries. However, to the extent that this approximation has understated the true infection fatality rate differences between care home residents and non-residents, the analysis would have overstated the role of infection prevalence in explaining the differences between these populations.

A second limitation in the case of Belgium is the use of all-cause mortality data based on the place of death rather than on the place of usual residence. Since some care home residents died in hospitals, the true mortality differences between care home residents and non-residents in the pre-pandemic year were underestimated in Belgium. The use of data by the place of death rather than by the place of usual residence would have led to an understatement of the mortality differences between care home residents and non-residents in the pre-pandemic year. This would, in turn, have led to an underestimation of frailty and an overestimation of infection prevalence (see equation (5)).

A third limitation stems from the fact that COVID-19 deaths are underreported. The level of underreporting may differ between countries as well between population groups within countries. Similarly, caution is warranted in interpreting international comparisons of COVID-19 mortality, as the potential for underreporting also applies to the within-country differences examined in this study. A priori, it is difficult to know if the underreporting of COVID-19 deaths was more or less severe among care home residents than it was among non-residents.

A fourth limitation is the measurement of the care home population. For Belgium, data on the number of people in collective housing at ages 65 and older were used. These data provide a close approximation of the number of people in care homes. In addition, for England and Wales, the study used population data for care home residents in 2020 for the denominator in calculating mortality rates in both waves of the pandemic. Thus, population change over the course of the epidemic was not accounted for. To the extent that the care home population declined over time due to reduced entrants as well as increased deaths (due to COVID-19), the rates for care home residents in the second wave would have been too low.

A fifth limitation is that this paper aimed to analyse the significance of the three factors of age composition, infection prevalence and underlying frailty within each country, but not across countries. Conducting international comparisons with the available data would be difficult due to the different approaches countries use in recording deaths, and because different countries have different definitions of what constitutes a care home (Comas-Herrera et al., 2020). There are several data issues to be considered when conducting international comparisons of COVID-19 mortality, including: the time lag between the occurrence of a death and its publication; the coverage of different places of death; the criteria for attributing the cause of death to COVID-19; the start date of the epidemic; the magnitude and the dynamics of the death curve; and the age and the gender structure of the population (INED, 2020).

A sixth limitation is that sex differences in COVID-19 were not considered in this paper due to data limitations. Women have a lower risk of dying from COVID-19 than men (Ng et al., 2020), and care homes tend to have more women than the general population in European countries (United Nations, 2017). Therefore, sex differences between these populations would tend to lower COVID-19 mortality among care home residents relative to that among non-residents. But this effect was small relative to the other factors analysed in this study, such as age, frailty and increased exposure, which is why nursing home residents faced risks that were more than 20 times higher than those of non-nursing home residents.

A seventh limitation is that in computing the mortality rate for all-cause mortality in 2018 in Belgium, population by age and place of usual residence in 2019 was used instead of in 2018 due to a lack of available data. However, the 2019 population can be considered a good proxy for the 2018 population given that the annual changes in the population were small.

6 Conclusion and discussion

In much of Europe, Australia and North America, deaths from COVID-19 have been concentrated among care home residents, with deaths among this population accounting for 39% to 79% of all COVID-19 deaths (Comas-Herrera et al., 2020). Why has this been the case? We know that care home residents are older and frailer than the general population of older people. These factors have contributed to their increased risk of death from COVID-19. In addition to being more likely to die once infected, care home residents might have also faced higher risks of exposure and infection relative to the general population. This study has presented a quantified assessment of these factors.

The first key aim of this study was to measure the COVID-19 mortality of care home residents relative to that of non-residents among the population aged 65 and older in Belgium and in England and Wales. In Belgium, older people residing in care homes were 36 times more likely to die from COVID-19 than non-residents (57 deaths vs 1.6 deaths per 1000) between March 2020 and September 2020. In England and Wales, the likelihood was 23 times higher during wave 1 (14 March 2020–11 September 2020) and 12 times higher during wave 2 (12 September 2020–2 April 2021). The improvement in outcomes in the second wave in England and Wales may have occurred because there was delayed access to care services and rapid testing during wave 1; and lower care home occupancy, more vaccine availability and mortality displacement[4] during wave 2 (ONS, 2020). In short, the care home population experiencing the second wave was likely to be more robust to the effects of COVID-19 for two main reasons. First, because of the high mortality levels care home residents experienced in the first wave, the remaining population in the second wave was younger and more robust (Schultze et al., 2022), and was more resistant to infection from COVID-19 due both to acquired immunity and increasing immunisation rates (Krutikov et al., 2021). Second, by the second wave, care homes may have learned how to handle COVID-19 using new guidelines issued by the government that were specifically focused on care homes (Marshall et al., 2021).

The second key finding was that the older age structure of care home residents relative to that of non-residents was only a small factor in the elevated mortality rates among residents. The age-specific mortality rates for COVID-19 were substantially higher at every age for care home residents than for non-residents. These higher rates were the likely result of residents having both a higher risk of becoming infected and a higher risk of succumbing to the disease once infected.

This study attempted to identify and measure these two risks by assuming that the higher relative risks of succumbing to COVID-19 once infected could

[4] Mortality displacement occurs when a high-mortality event is followed a period of below-average mortality. During the high-mortality event, frailer individuals die sooner than expected. In a sense, their deaths are displaced backwards in time. These individuals do not die in the following days, weeks and months when they would have died, which leads to a lower-than-average period of mortality.

be approximated by measuring the higher relative risks of all-cause mortality experienced by care home residents. Pre-pandemic data on age-specific all-cause mortality showed that care home residents were 10 times more likely to die than non-residents in Belgium and were 12 times more likely to die than non-residents in England and Wales. The third key finding of this study was that this underlying health frailty was a major cause of the higher COVID-19 mortality experienced by care home residents. In Belgium, it accounted for 46% of the differences in mortality rates between care home residents and non-residents, while in England and Wales, it accounted for 66% of the differences in the first wave and 88% of the differences in the second wave.

Finally, the fourth key finding was that care home residents likely faced a much higher risk of COVID-19 infection than non-residents during the initial wave of the pandemic. In Belgium, the risk of infection was four times higher among care home residents than among non-residents during wave 1. In England, the risk was about 1.79 times higher in wave 1, but was slightly lower in wave 2 (0.92 times).

This study lends support to the hypothesis that the failure to provide care home residents with the levels of protection against exposure and infection enjoyed by the general population was a significant factor in the tragic concentration of deaths observed in care homes during the initial wave of the COVID-19 pandemic in Belgium and in England and Wales. At the same time, the study provides encouraging evidence of a much improved response in the second wave in England and Wales, with care home populations experiencing infection rates below those of the general population. However, COVID-19 mortality continued to be concentrated among older people in care homes due to the underlying frailty of this population.

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Appendix

A. Belgium

Table A.1:
Number of COVID-19 deaths, Belgium, week 11–week 39, 2020

	Total	Resident	Non-resident
Total	9,975	6,224	3,751
Under 65	576	113	463
65–74	1,128	430	698
75–84	2,877	1,544	1,333
85+	5,394	4,137	1,257
65+	9,399	6,111	3,288

Source: Sciensano, the Belgian institute for health.

Table A.2:
All-cause deaths by age, Belgium, 2018

	Total	Resident	Non-resident
Total	110,645	31,644	79,001
Under 65	16,839	626	16,213
65–74	17,615	1,699	15,916
75–84	29,334	7,190	22,144
85+	46,857	22,129	24,728
65+	93,806	31,018	62,788

Source: STATBEL, the Belgian statistical office.

Table A.3a:
Population by age, Belgium 2019

	Total	Resident	Non-resident
Total	11,431,406	106,381	11,325,025
Under 65	9,266,106	–	9,266,106
65–74	1,147,009	13,425	1,133,584
75–84	690,685	29,702	660,983
85+	327,606	63,254	264,352
65+	2,165,300	106,381	2,058,919

Source: STATBEL, the Belgian statistical office.

Table A.3b:
Population by age, Belgium, 2020

	Total	Resident	Non-resident
Total	11,492,641	107,257	11,385,384
Under 65	9,288,163	–	9,288,163
65–74	1,170,399	13,771	1,156,628
75–84	698,940	29,402	669,538
85+	335,139	64,084	271,055
65+	2,204,478	107,257	2,097,221

Source: STATBEL, the Belgian statistical office.

B. England and Wales

Table B.1a:
Number of COVID-19 deaths, England and Wales, wave 1 (14 Mar 2020 to 11 Sept 2020)

	Total	Resident	Non-resident
Total	51,912	20,664	31,248
Under 65	5,549	433	5,116
65–74	7,673	1,569	6,104
75–84	16,792	6,255	10,537
85+	21,898	12,407	9,491
65+	46,363	20,231	26,132

Source: Office for National Statistics of the United Kingdom licensed under the Open Government License.

Table B.1b:
Number of COVID-19 deaths, England and Wales, wave 2 (12 Sept 2020 to 2 Apr 2021)

	Total	Resident	Non-resident
Total	84,762	21,677	63,085
Under 65	9,900	356	9,544
65–74	13,613	1,254	12,359
75–84	26,176	5,566	20,610
85+	35,073	14,501	20,572
65+	74,862	21,321	53,541

Source: Office for National Statistics of the United Kingdom licensed under the Open Government License.

Table B.2:
All-cause deaths by age, England and Wales, 2019

	Total	Resident	Non-resident
Total	527,234	137,998	389,236
Under 65	81,410	3,176	78,234
65–74	87,492	9,484	78,008
75–84	149,651	34,082	115,569
85+	208,681	91,256	117,425
65+	445,824	134,822	311,002

Source: Office for National Statistics of the United Kingdom licensed under the Open Government License.

Table B.3:
Population by age, England and Wales, 2020

	Total	Resident	Non-resident
Total	59,867,666	442,888	59,424,778
Under 65	48,669,438	73,405	48,596,033
65–74	5,977,545	34,451	5,943,094
75–84	3,713,788	112,274	3,601,514
85+	1,506,895	222,758	1,284,137
65+	11,198,228	369,483	10,828,745

Source: Office for National Statistics of the United Kingdom licensed under the Open Government License.

Vienna Yearbook of Population Research 2022 (Vol. 20), pp. 527–542

Comparing the loss of life expectancy at birth during the 2020 and 1918 pandemics in six European countries

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Abstract

The COVID-19 pandemic that reached Europe in 2020 has often been compared to the Spanish flu pandemic of 1918. In this article, we compare the two pandemics in terms of their respective impacts on the loss of life expectancy at birth in six European countries (France, Italy, the Netherlands, Spain, Sweden, Switzerland) by estimating life expectancy in 2020 using Eurostat data. We found that the loss of life expectancy at birth was up to 20 times larger between 1917 and 1918 than between 2019 and 2020. A decomposition of these losses clearly shows that in all six countries, the main contributors were older age groups in 2020 and younger age groups in 1918. These observations are consistent with evidence indicating that most COVID-19 fatalities were among the elderly, while a majority of Spanish flu fatalities were among the young.

Keywords: all-cause mortality; COVID-19; Europe; life expectancy decomposition; period life expectancy; Spanish flu

1 Introduction

The COVID-19 pandemic that reached Europe in 2020 is considered by many to be the health event that had the greatest impact on all-cause mortality since the Spanish flu of 1918 (e.g. Morens et al., 2021). As of early 2021, several studies had been published that attempted to estimate the loss of life expectancy in 2020 in various countries around the world (e.g. Aburto et al., 2021a; Andrasafay and Goldman, 2021; Heuveline and Tzen, 2021; Locatelli and Rousson, 2021). For example, Locatelli and Rousson (2021) estimated that in Switzerland, life expectancy at birth

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DOI: 10.1553/populationyearbook2022.dat.7

declined between 2019 and 2020 by 5.3 months for women and by 9.7 months for men. Although losses of this magnitude had not previously been observed since 1962 for women and since 1944 for men, the authors of the Swiss study noted that the Spanish flu pandemic had a far greater impact, with life expectancy decreasing between 1917 and 1918 by more than eight years for women and by more than 10 years for men. In the following analysis, we will further compare levels of all-cause mortality between the two pandemics in six European countries. Our approach is to compare the loss of life expectancy at birth in 2020 and in 1918, and to decompose the losses into the contributions of different age groups, following the method used in United Nations (1982, 1985), as reported in Ponnapalli (2005).

2 Data

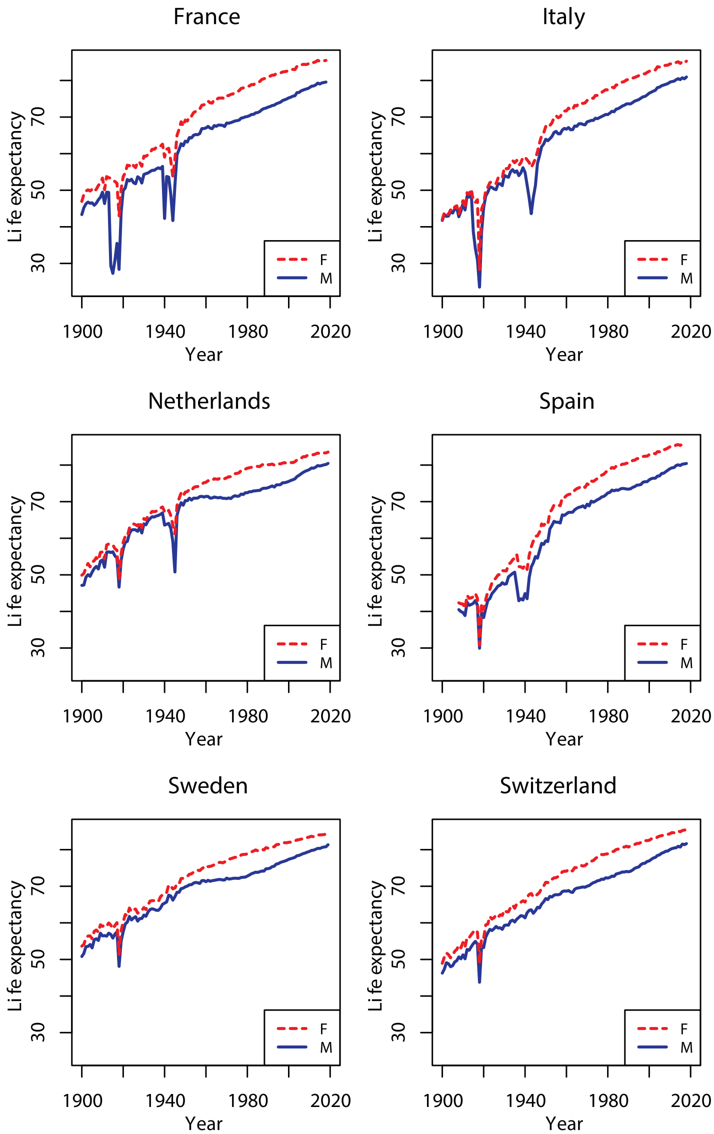
The countries included in this study were chosen primarily on the basis of available data. Period life tables for 1917 and 1918 were taken from the Human Mortality Database (HMD, https://www.mortality.org/). As these data were not available for all European countries, we had to exclude a number of countries, including Austria, Belgium, Germany, Greece, Ireland, Luxembourg, Portugal, the United Kingdom and the Eastern European countries. We also excluded countries that experienced (almost) no loss of life expectancy in 2020, such as Denmark, Finland, Iceland and Norway (Aburto et al., 2021b). This left us with six countries – namely France, Italy, the Netherlands, Spain, Sweden and Switzerland – that were all affected (to varying degrees) by the two pandemics, as seen below.

Figure 1 displays estimates from the HMD of life expectancies at birth for women and men in these six countries from 1900 (1908 for Spain) to 2018 (2019 for the Netherlands and Sweden). The figure shows that there was a dramatic drop in life expectancy in 1918, and thus during the largest wave of the Spanish flu, both in countries that were actively participating in the First World War (France and Italy) and in countries that were not directly involved (the Netherlands, Spain, Sweden and Switzerland). Note that during the First World War, special methods for obtaining estimates of death and population numbers were used to include the military population in France and in Italy (see the HMD country-specific documentation).

For these six countries, the number of deaths (from all causes) for the years 2010–2020 and the population size on January 1 for the years 2010–2021 by age and sex (with a last open age group of 100+) were obtained from the Eurostat website (https://ec.europa.eu/eurostat/fr/web/main/data/database, last accessed on April 29, 2022).[1] Age- and sex-specific mortality rates in each year were calculated by dividing the number of deaths in that year by the average of the population size of the corresponding year for a given age and sex.

[1] Population size on January 1, 2021 is still provisional in France.

Figure 1:
Life expectancy at birth between 1900 (1908 for Spain) and 2018 (2019 for the Netherlands and Sweden) for women (F) and men (M) in six European countries



Source: Human Mortality Database, University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at https://www.mortality.org.

3 Methods

For a given country and sex, the probabilities l_x^y of surviving to age x for each year y ($y = 2010, \ldots, 2020$) were obtained using a piecewise exponential model (Friedman, 1982) until the age of 110. This was done by letting $l_0^y = 1$ and calculating (for $x = 1, \ldots, 110$):

$$l_x^y = \exp\left(-\sum_{t=0}^{x-1} m_t^y\right).$$

In this formula, m_x^y denotes the mortality rate at age x for year y obtained above using Eurostat data, assumed to be constant in the last open age group (100+). Life expectancy e_x^y at age x in year y was estimated using the l_x^y by means of classical mortality table calculations. This was done by calculating (for $x = 0, \ldots, 109$):

$$e_x^y = \frac{\sum_{t=x}^{109}(l_t^y + l_{t+1}^y)/2}{l_x^y}.$$

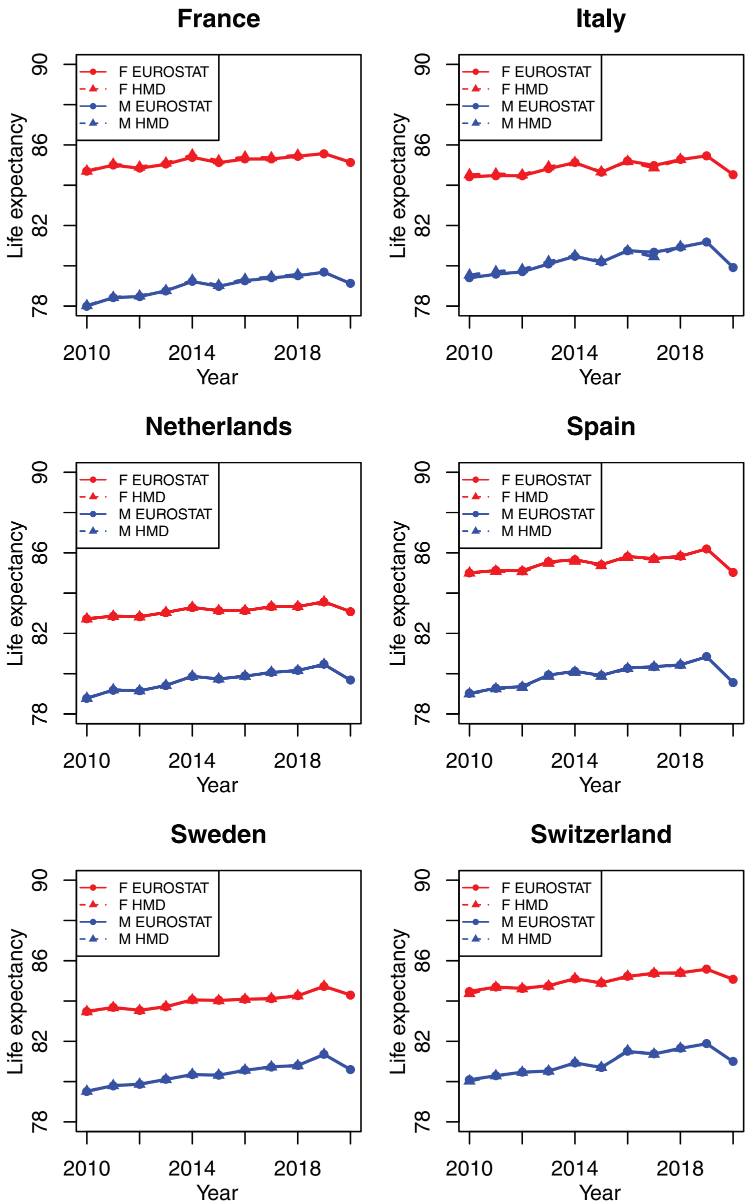
Thus, we implicitly assumed that everybody died before the age of 110. Corresponding estimated life tables for 2020 are provided as Supplementary Material (available at https://doi.org/10.1553/populationyearbook2022.dat.7). Figure 2 shows life expectancies at birth obtained for men and women in the six countries between 2010 and 2020. To check the validity of the method and the reliability of the data, these estimates could be compared with those provided in the HMD for the years 2010–2018 (2019 for the Netherlands and Sweden), which are considered to be the gold standard. As can be seen in Figure 2, the two estimates were very close to each other, with the absolute differences between the two estimates averaging 0.03 years (0.4 months), and with 89% of them being less than one month and 99% of them being less than two months. Similar percentages were found (93% and >99%) when the two estimates of life expectancies at any age between zero and 85 years were compared (no life expectancies at ages over 85 are used in this paper).

For each country and sex, we calculated losses of life expectancy at birth between 2019 and 2020 (based on Eurostat data), and between 1917 and 1918 (based on HMD data). The contributions of the different age groups to these losses between years y_1 and y_2 were calculated using the United Nations (1982, 1985) decomposition method, as advocated by Ponnapalli (2005), which is a compromise between the decomposition methods introduced by Lopez and Ruzicka (1977) and by Arriaga (1984). The contribution of age group $(x, x + n)$ to the total loss was thus calculated as:

$$(e_x^{y_2} - e_x^{y_1})(l_x^{y_2} + l_x^{y_1})/2 - (e_{x+n}^{y_2} - e_{x+n}^{y_1})(l_{x+n}^{y_2} + l_{x+n}^{y_1})/2.$$

The contribution of the last open age group was obtained by the first term of this formula, without subtracting any second term. As an example, we had for Italian women in $y_2 = 1917$ and $y_1 = 1918$ (according to HMD period life tables)

Figure 2:
Life expectancy at birth between 2010 and 2020 estimated using Eurostat data (solid lines) or provided by the Human Mortality Database (HMD, dashed lines) for women (F) and men (M) in six European countries



$e_0^{1917} = 47.41, e_0^{1918} = 28.34, e_5^{1917} = 56.24$ and $e_5^{1918} = 38.10$ while we had $l_0^{1917} = l_0^{1918} = 1, l_5^{1917} = 0.770$ and $l_5^{1918} = 0.646$. The loss of life expectancy at birth in 1918 was thus 47.41 − 28.34 = 19.07 years, and the contribution of age group 0-5 to that loss was:

$$(47.41 - 28.34)(1 + 1)/2 - (56.24 - 38.10)(0.770 + 0.646)/2 = 6.23.$$

Of note, this example shows that it is possible for the contribution of an age group to be greater than the length n of the corresponding age interval.

4 Results

Distributions of the number of deaths by age for the different years in each country (the d_x of the life tables, which refer to a population size of 100,000) are shown in Figure 3 for women and in Figure 4 for men. As expected, the deaths in 2019 and 2020 were concentrated in the older ages in all countries, with almost no deaths occurring in the younger ages. By contrast, there were many deaths at very young ages in 1917 and 1918, as well as a non-negligible number of deaths among young adults, especially in 1918. In 1917, we can also see the impact of the First World War in the high number of deaths among French and Italian young men.

Our estimates of the decomposition of the loss of life expectancy at birth between 2019 and 2020 and between 1917 and 1918 for women and men in the six countries are provided in Table 1, along with the estimated life expectancies at birth for those years. In all countries and for both sexes, the loss was much larger in 1918 than in 2020. In 2020, it ranged from 0.4 years (for French and Swedish women) to 1.3 years (for Italian and Spanish men). The loss in 2020 was generally slightly larger for men than for women, and averaged 0.8 years over both sexes and the six countries. By contrast, the loss of life expectancy at birth in 1918 ranged from 7.1 or 7.5 years (for French and Italian men) to 12.8 or even 19.1 years (for Spanish and Italian women), with an average of 10.0 years.

Since life expectancy was very different in 1917 and 2019, it might also be sensible to express and compare these losses in terms of percentages. For example, Woolf et al. (2021) used percentages to compare the losses of life expectancy due to COVID-19 in different sub-populations of the USA. In the six countries, the loss in 2020 represented between 0.5% and 1.6% (averaging 0.95%) of life expectancy at birth in 2019. By contrast, the loss in 1918 represented between 14% and 40% (averaging 21%) of life expectancy at birth in 1917. Thus, if we express these losses in years, 1918 (with the Spanish flu) was, on average, 13 times more deadly than 2020 (with COVID-19) in these countries. If we express these losses in percentages, 1918 was as much as 22 times more deadly than 2020. Note that these figures are similar if we exclude from the calculation French and Italian men who actively took part in the First World War.

The contributions of different age groups to the loss of life expectancy at birth in 2020 and 1918 for both sexes in each country are provided in Table 2, using the same

Figure 3:
Distribution of deaths by age (the d_x of the life tables) in 1917, 1918, 2019 and 2020 for women in six European countries

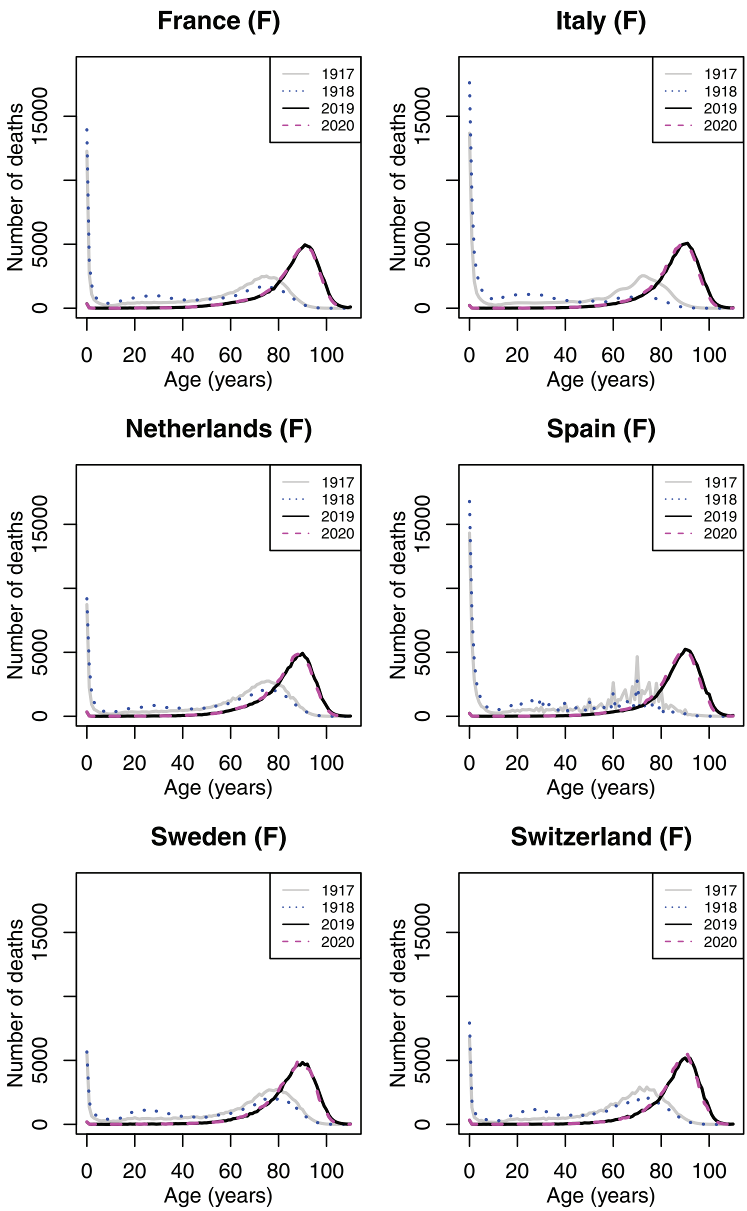


Figure 4:
Distribution of deaths by age (the d_x of the life tables) in 1917, 1918, 2019 and 2020 for men in six European countries

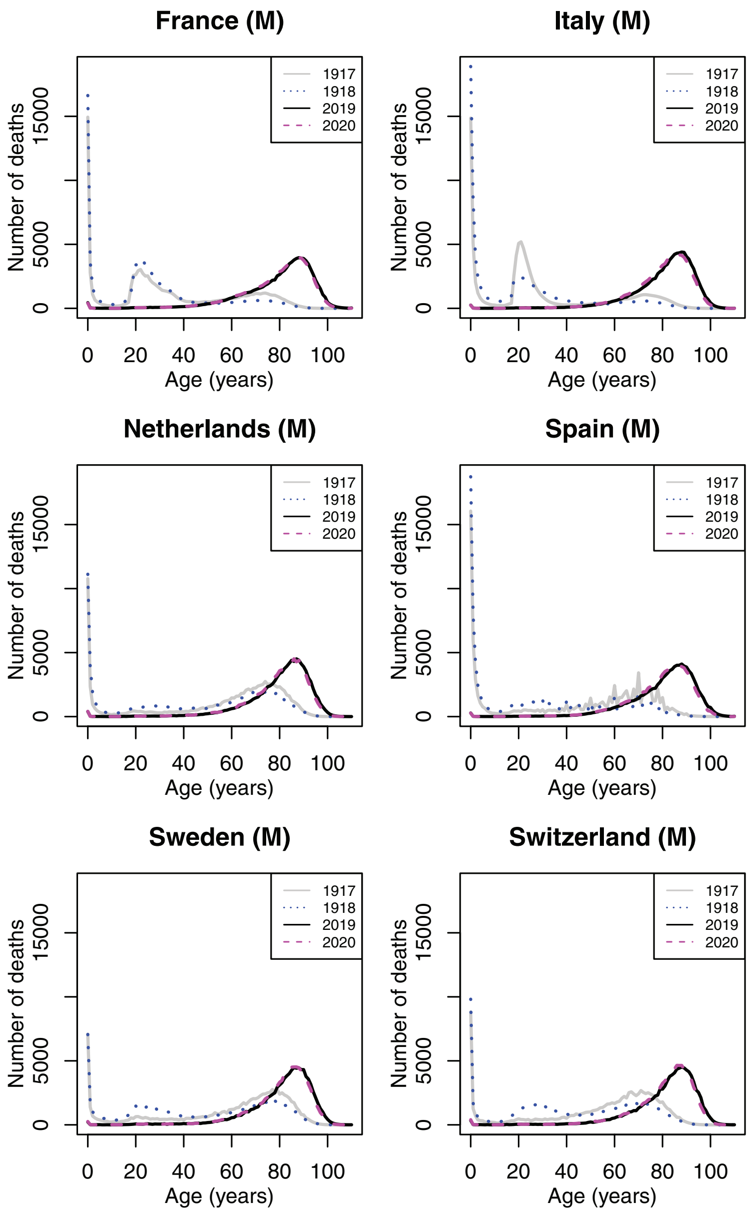


Table 1:
Life expectancy at birth estimated in 1917, 1918, 2019 and 2020, and the corresponding loss (in years and in %) between 1917 and 1918 and between 2019 and 2020 for women (F) and men (M) in six European countries

		Life expectancy				Life expectancy			
				Loss				Loss	
		1917	1918	Abs.	%	2019	2020	Abs.	%
France	F	51.9	43.0	**8.9**	**17.2**	85.6	85.1	**0.4**	**0.5**
	M	35.5	28.4	**7.1**	**20.1**	79.7	79.1	**0.6**	**0.7**
Italy	F	47.4	28.3	**19.1**	**40.2**	85.5	84.5	**0.9**	**1.1**
	M	31.0	23.5	**7.5**	**24.1**	81.2	79.9	**1.3**	**1.6**
Netherlands	F	56.7	48.6	**8.1**	**14.2**	83.6	83.1	**0.5**	**0.6**
	M	54.6	46.6	**8.0**	**14.6**	80.5	79.7	**0.8**	**1.0**
Spain	F	43.6	30.8	**12.8**	**29.3**	86.2	85.0	**1.2**	**1.4**
	M	41.7	29.9	**11.7**	**28.1**	80.8	79.6	**1.3**	**1.6**
Sweden	F	60.1	51.4	**8.7**	**14.5**	84.7	84.3	**0.4**	**0.5**
	M	57.5	48.1	**9.4**	**16.4**	81.3	80.6	**0.8**	**0.9**
Switzerland	F	57.4	48.9	**8.5**	**14.8**	85.6	85.1	**0.5**	**0.6**
	M	54.1	43.8	**10.4**	**19.1**	81.9	81.0	**0.9**	**1.1**

age groups as in Table 4 of Ponnapalli (2005). All but one of these contributions were positive or equal to zero (when rounded to one decimal), meaning that mortality in 2020 was higher than (or equal to) mortality in 2019, and mortality in 1918 was higher than (or equal) mortality in 1917 in all age groups considered. The only exception was the age group 15–25 for Italian men, who made a negative contribution (−1.5 years) to the 1918 loss; which means that among the men in that age group, mortality was lower in 1918 than in 1917 (probably due to different wartime circumstances). The magnitudes of these positive contributions and their distributions across age groups were, however, very different in 2020 than in 1918. In line with Figures 3 and 4, we find that most of the contributions to the 2020 loss came from the older age groups (65–85 and 85+), and that there were almost no contributions by the age groups below 45. In contrast, we observe that most of the contributions to the 1918 loss came from the age groups below 45, and that there was almost no contribution by the age group 85+. We also find that this general pattern was largely repeated for both sexes in each country.

5 Discussion

The COVID-19 pandemic has often been compared to the Spanish flu. For example, He et al. (2020) discussed the epidemiological similarities between the two pandemics in the UK, whereas Agrawal et al. (2021) noted similar trajectories at

Table 2:
Contributions of different age groups to the loss of life expectancy at birth between 1917 and 1918 and between 2019 and 2020 for women (F) and men (M) in six European countries, using the United Nations (1982, 1985) decomposition method. Values rounded to 0.0 are represented with a dot

		Loss 1918–1917								Loss 2020–2019							
		0–5	**5–15**	**15–25**	**25–45**	**45–65**	**65–85**	**85+**	**Total**	**0–5**	**5–15**	**15–25**	**25–45**	**45–65**	**65–85**	**85+**	**Total**
France	F	2.3	1.0	1.9	3.2	0.6	.	.	**8.9**	.	.	.	.	.	0.2	0.2	**0.4**
	M	1.4	0.5	1.6	3.4	0.3	.	.	**7.1**	.	.	.	.	0.1	0.4	0.2	**0.6**
Italy	F	6.2	3.1	3.3	4.8	1.2	0.4	.	**19.1**	.	.	.	.	0.1	0.5	0.4	**0.9**
	M	4.2	1.6	−1.5	2.2	0.8	0.1	.	**7.5**	.	.	.	.	0.2	0.8	0.2	**1.3**
Netherlands	F	2.3	1.1	1.5	2.7	0.5	.	.	**8.1**	.	.	.	.	.	0.3	0.2	**0.5**
	M	2.2	0.8	1.4	3.0	0.6	.	.	**8.0**	.	.	.	.	0.1	0.5	0.2	**0.8**
Spain	F	3.9	1.7	2.2	3.9	0.8	0.2	.	**12.8**	.	.	.	.	0.1	0.6	0.4	**1.2**
	M	3.7	1.2	2.0	3.9	0.8	0.1	.	**11.7**	.	.	.	0.1	0.2	0.8	0.3	**1.3**
Sweden	F	0.9	1.0	2.4	3.6	0.7	0.1	.	**8.7**	.	.	.	.	.	0.3	0.2	**0.4**
	M	0.7	0.8	2.6	4.7	0.6	0.1	.	**9.4**	.	.	.	.	0.1	0.4	0.2	**0.8**
Switzerland	F	1.5	0.7	2.0	3.6	0.5	0.1	.	**8.5**	.	.	.	.	.	0.2	0.3	**0.5**
	M	1.1	0.5	2.7	5.5	0.5	.	.	**10.4**	.	.	.	.	0.1	0.4	0.3	**0.9**

the beginning of each outbreak. It has been estimated that the Spanish flu killed 50–100 million people around the world (2.3 million in Europe) between 1918 and 1920 (Johnson and Mueller, 2002), and thus up to 5% of the global population at that time (0.5% of the population in Europe). By contrast, at the time of writing (according to https://www.worldometers.info/coronavirus/, accessed on June 7, 2022), COVID-19 has officially killed about 6.3 million people around the world (1.8 million in Europe), and thus about 0.08% of the global population (0.2% of the population in Europe).

Comparing these numbers is, however, challenging for a variety of reasons, including the different levels of mortality in the two periods; the unreliable reporting of causes of deaths; and the difficulties associated with accounting for both the direct and the indirect effects of the two pandemics, and for the confounding effects of the First World War. Furthermore, the population structures were profoundly different in the two periods: i.e. the populations were smaller in number and much younger in 1918 than in 2020. In this article, we have attempted to tackle some of these challenges. We compared mortality in 2020 and 1918 by calculating the loss of life expectancy at birth (to avoid the problem of the different population structures) based on all-cause mortality data (to capture both the direct and the indirect effects of the pandemics, and to avoid the problems arising from the unreliable reporting of causes of deaths) in six European countries, including in four countries that did not directly participate in the First World War. We found that in all six countries, the loss of life expectancy at birth and the contributions of the different age groups to that loss were very different in 2020 than in 1918.

The loss of life expectancy at birth was, on average, 13 times (when expressed in years) or even 22 times (when expressed in percentages) larger in 1918 than in 2020. The figures are similar if we include only the four countries that did not directly participate in the First World War. Thus, it may not be an exaggeration to say that in the countries we analyzed, the Spanish flu was about 20 times more deadly in 1918 than COVID-19 was in 2020. Other striking differences between the two pandemics became apparent when we explored the contributions of the different age groups to these losses, as we found that older age groups contributed more in 2020 while younger age groups contributed more in 1918. These results were largely consistent across the six countries, and were in line with previous evidence indicating that the majority of COVID-19 fatalities were among the elderly, while the majority of Spanish flu fatalities were among very young children and young adults (see e.g. Collins, 1931; Simonsen et al., 1998; Taubenberger and Morens, 2006). Thus, the age structure of fatalities was a key difference between the two pandemics.

Our observations are based on period life expectancy at birth, which is one of the indicators that is most frequently used in demography to summarize mortality (Luy et al., 2019). It has the particular feature of giving more weight to deaths at younger than at older ages, and thus reflects the larger number of years lost when a young person dies. As it is a synthetic measure of the mortality that occurs in a given year, it offers a convenient way to compare different calendar years without having to choose an (arbitrary) reference population for standardization. Moreover, using this indicator, a loss of life expectancy observed between two years can also be decomposed into the contributions of different age groups. This exercise would be more difficult using another summary indicator. However, as is the case for other indicators calculated from period life tables, it does not provide information about a "real" cohort of individuals followed from birth to death, but rather about a hypothetical cohort of individuals who lived their entire lives under the mortality conditions observed in a given calendar year. Thus, if a pandemic occurs in that year, period life expectancy at birth will inform us about what would happen if a similar pandemic occurred in each year of these individuals' lives (Goldstein and Lee, 2020). Hence, unlike analyses using cohort life tables, estimates of loss of life expectancy using period life tables are based on specific assumptions that are not directly transferable to the underlying real populations.

On the other hand, using other indicators to compare mortality across years, such as a standardized mortality rate or a percentage of excess deaths compared to some robust baseline (Ansart et al., 2009; Davies, 2020), can provide another, and often more dramatic picture. For example, Ansart et al. (2009) reported an 86% increase in excess mortality in Europe during the Spanish flu period, which represents an even more dramatic decrease in life expectancy than our estimates indicated. Locatelli and Rousson (2021) reported that in Switzerland, the standardized mortality rate increased 8.8% from 2019 to 2020, which corresponds to a 0.7% decrease in life expectancy at birth. Thus, life expectancy tells only part of the story. See Leser (1955) or Keyfitz and Golini (2009) for further discussions on such mortality comparison measures. This reminds us that the choice of the indicator used to measure the impact of a pandemic is not insignificant. For example, Goldstein and Lee (2020) concluded, in relation to the COVID-19 epidemic in America, that "it is possible to portray the epidemic as unimaginably large – the biggest killer in American history – or small, reducing our remaining life by less than 1 part in 1000." The results presented in this paper could therefore be challenged by other researchers using other indicators.

While such comparisons might not be relevant in countries not significantly affected by the two pandemics, this was not the case for the six European countries included in this study. According to recent estimates, the share of the respective national population that was killed by the Spanish flu was 0.59% in Sweden, 0.61% in Switzerland, 0.71% in the Netherlands, 0.73% in France, 1.07% in Italy and 1.23% in Spain (Johnson and Mueller, 2002). Moreover, at the end of 2020 – and despite the different protective measures adopted by their respective governments – all of these countries belonged to the first quintile of countries in the world in terms of COVID-19 mortality, with Italy ranked fifth, Spain ninth, France 15th, Switzerland 24th, Sweden 26th and the Netherlands 37th among the 220 countries considered in the Worldometer website (https://www.worldometers.info/coronavirus/, accessed on December 27, 2020). These deaths represented between 0.12% (for Italy) and 0.06% (for the Netherlands) of the population. In the present study, Italy and Spain were also found to be the two countries with the largest life expectancy losses in both 1918 and 2020.

To date, a few mortality analyses for the year 2020 have been fully published in the scientific literature. Based on provisional data, Locatelli and Rousson (2021) reported a loss of life expectancy at birth in Switzerland of 5.3 months for women and 9.7 months for men between 2019 and 2020. These findings are just one month less than our estimates of 0.50 years (6.0 months) for women and 0.89 years (10.7 months) for men. For France, our estimates largely match those published on the Statista website (statista.com/statistics/460418/france-life-expectancy-by-gender/, accessed on August 24, 2021), which reported that life expectancy at birth was 85.6 years (the same as our estimate) for women and 79.8 years (our estimate was 79.7) for men in 2019, and was 85.3 years (our estimate was 85.1) for women and 79.2 years (our estimate was 79.1) for men in 2020. Further useful comparisons can be made by examining Figure 2 in Aburto et al. (2021b), who analyzed mortality data from 29 countries in 2020 based on harmonized data produced from initial five age groups. They found that the loss of life expectancy at birth between 2019 and 2020 was about 1.5 years for Spanish men and women and for Italian men; about one year for Italian women and for Swiss men; and between 0.6 and 0.8 years for Swiss women and for men and women in France, the Netherlands and Sweden. As these findings are close to our values, they further validate our method and data.

One limitation of our analysis is that it was restricted to a single year for both pandemics (2020 for COVID-19, 1918 for the Spanish flu). Note, however, that while the Spanish flu lasted until at least 1920 and consisted of three main waves (Patterson and Pyle, 1991), the peak of mortality in Europe occurred in October-November 1918 (Ansart et al., 2009). Indeed, the HMD data show that life expectancy in 1919 had already returned to 1917 levels in most countries (see also our Figure 1). Moreover, as the COVID-19 pandemic that reached Europe in February-March 2020 is not yet over, the analysis provided here gives an incomplete picture of the impact of COVID-19. It would be interesting to conduct a similar analysis in the future using consolidated mortality data for 2021 and beyond.

Finally, and importantly, our analysis did not consider the impact of the public health measures designed to reduce COVID-19 mortality that were put in place in 2020. While it is indeed very difficult to estimate what would have happened if these measures had not been implemented, it is clear that the public health approaches to managing a pandemic were not the same in 2020 as they were 100 years previously. This limits the potential interpretations of our comparison. Thus, our analysis should be seen primarily as descriptive.

Despite these limitations, and although we were unable to analyze more precisely the nature (e.g. societal or medical) of the mortality impacts of the two pandemics, it is fair to conclude that they were quite different, with COVID-19 killing mostly the elderly and the Spanish flu killing mostly young people, and with the loss of life expectancy being about 13 (or even 22) times larger in 1918 than it was in 2020.

Supplementary material

Available online at https://doi.org/10.1553/populationyearbook2022.dat.7

Supplementary file 1. Estimated life tables by sex for the year 2020, France, Italy, Netherlands, Spain, Sweden, Switzerland

Acknowledgements

The authors thank Professor John Braun for carefully reading and correcting our manuscript, and the Editor and three reviewers for their constructive comments and suggestions, which significantly improved the article.

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