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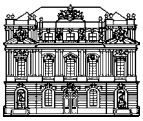
cyberscience

Research in the Age of the Internet

Chapter 12

OVERALL CONCLUSIONS



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> "It will be decades before we see the full effects of the information age. The important effects of the printing press era were not seen clearly for more than 100 years. While things happen more quickly these days, it could be decades before the winners and losers of the information age are apparent. Even today, significant (and permanent) cultural change does not happen quickly."
> (Dewar 1998)

12 OVERALL CONCLUSIONS

This study set out to analyse the rising levels of ICT use in research, to explain the status quo of different levels of diffusion of the new technologies and to get an idea of the likely future developments. In addition, its purpose was to discuss the impact of this pervasive phenomenon and to draw conclusions as a basis for action. Just as academia is no uniform entity, but consists of a multitude of different specialities and varying organisational settings, also the technology under scrutiny here is multifaceted and can be used for different purposes. What is more, both academia and technology are highly dynamic. In this situation, the ambitious targets of this study as just outlined seem impossible to meet in a literal sense and in all detail: too many variables play a role, too much uncertainty persists, and complexity seems simply too high. For instance, the faith of academic publishing is co-determined by a multitude of factors, both intra- and extra-academic, both institutional, economic, cultural, technical and functional – and those factors differ across the various sub-disciplines. In addition, agency plays an important role when it comes to explaining how E-publishing has evolved.

Notwithstanding this sobering statement, the study was without doubt worthwhile. Despite the tentative and partial character of many of my interim conclusions, only such an encompassing approach is able to give an impression of the overall phenomenon. For sure, more focussed research could have led to more precise results in specific narrow fields (and indeed, many of the studies quoted in the preceding chapters are of this type and deserve our respect). What these previous and parallel studies lack, however, is an oversight of the many elements of the phenomenon called "cyberscience". These approaches involve, in particular, the danger of overlooking countervailing or reinforcing developments in neighbouring areas, if only one or two aspects are paid attention to. Furthermore, the pervasiveness of the phenomenon at large remains unnoticed.

The design of this study followed closely the conceptual framework as developed in chapter 1. The various analytical distinctions and operationalisations included in the framework turned out to be highly useful and have informed both the empirical part of this study and the impact analysis. My framework is encompassing enough to grasp all relevant aspects of my object of research. What may at first sight seem a hardly manageable extensive number and a complex web of potential intervening factors, proved to be appropriate. As expected, the technology under scrutiny, while being a relevant driving force, is by far not the only variable determining how academia is moving towards cyberscience – however functional and appropriate the majority of the new tools may sometimes appear. An institutional lens brings to our attention the important constraints of (organisational, disciplinary, science) culture, of the legal and science policy environment, of disciplinary differences in the way research is organised and done, and last, but not

least, of economics. We have also seen that actor-related factors would not only add to our understanding of micro-level developments, but that agency is in many circumstances an important element explaining macro-level phenomena. In addition, my analytical differentiation of elements in the chain of ICT impact on research (cf. 1.2.4) was a useful heuristic tool. Therefore, in retrospective, my inclusive theoretical approach seems highly task appropriate.

To bring to the fore the potentials of this broad-scale study, this concluding chapter integrates (not repeats) the partial conclusions already drawn in the rest of this book. Following my conceptual distinction between the change and the impact model (cf. 1.2.5), I focus separately on the diffusion processes and trends, on the one hand, and the overall impact of the development, on the other. I proceed in the following steps. First, I shall pull together the various scenarios, visions and statements about the likely future development to draw a tentative cyberscience scenario (12.1). Second, I shall go beyond the separate chapter conclusions and discuss a number of insights on a meta-level regarding the impact of ICT on academia (12.2). Finally, in a Coda, I shall mention a number of scope conditions of my results, options for further research and conceptual lessons learned (12.3).

12.1 The cyberscience scenario(s)

> "I am convinced that once scholars have tasted it, they will become addicted for life, as I did."
> (Harnad 1991, 50)

As argued in the section presenting my analytical framework (cf. 1.2.3.5), my trend extrapolation has to be of a qualitative nature, it has to take due account of the various intervening factors and it may use a comparative approach. Throughout this study, I have tried to assess the possible future of particular tools and applications, and this is not the place to repeat these partial assessments. Rather, I shall analyse the results on a meta-level. My material is four-fold: (1) general literature; (2) empirical evidence of the status quo; (3) opinions of interviewees; and (4) results of the impact analysis.

(1) In the literature predating this study, I have found only partial assessments (in particular concerning E-publishing, cf. already 7.3) or very general statements. Many would argue that new technologies tend to supplement rather than replace (substitute) existing forms (e.g. Woolgar 2000; Sumner/Shum 1997, 1; Finholt 2001, 29 f. with regard to collaboratories). While some speak of a gradual evolution instead of substitution (e.g. Stichweh 1989, 21 f.; Interquest 1997, 11), others find areas of rapid development (e.g. regarding online database searching, Davenport/Cronin 1990, 190) and expect simple substitution in some cases (e.g. regarding E-publishing, Odlyzko 2000, 2 f.; regarding hypertext, Davenport/Cronin 1990, 190). Still others argue that the traditional and old technologies are not mutually exclusive (e.g. Guedon 1994, 2; Riehm 1996, 2). As regards E-publishing, for instance, there is the notion of an orthogonal relationship to the existing print domain (Guedon 1994, 2), meaning that print and E-publishing are not parallel in the sense that they follow the same direction, but that E-publishing departs "orthogonally" as it has different properties. Another important insight is that disciplinary differences play an important role in the evolution and shaping of E-publishing in the re-

spective communities (Kling/McKim 2000). Furthermore, there is the observation that the new media can also have a reinforcing effect for the old media or ways of doing. For instance online versions of academic articles may lead to an increase in subscriptions, and electronic communication may stimulate greater worldwide travel (Woolgar 2000; Hiltz 1984, quoted by Stichweh 1989).

(2) My own empirical research on the status quo (cf. 3.3) showed, first, that there are considerable differences between the various research fields. Second, I found that online bibliographic databases already have largely replaced traditional means; that E-mail is already very wide-spread and is about to attain dominance; that the same seems to be true for E-prints in those fields where working papers have always been important; that digital libraries and online disciplinary databases are already standard or spreading and amending traditional ways of researching; that E-journals as well as E-lists tend, so far, to enhance rather than to replace the traditional technologies; that E-conferencing, groupware, hyper/multimedia and virtual institutes/collaboratories as yet have largely no significant effect in most fields, but are considered of growing importance; and that some advanced technologies, such as knowbots, play no role so far.

(3) As regards the opinions of my interviewees[937], the arising picture is not clear cut as regards the future of particular tools, in particular concerning E-publishing.[938] This underlines that the trend will not be the same for all academic fields. Most experts were, however, rather convinced that most of the cyber-tools would actually have a bright future and that the development would be step-by-step and slow rather than revolutionary. Many refrained from looking into the future more than just a few years. As regards E-conferencing, the opinions converged in so far as most experts do not believe that they will ever replace traditional face-to-face meetings, but that they would certainly gain in importance as travel budgets continue to decrease. As regards the online availability of data and publications, the large majority expected it to improve considerably over the next few years with the likely end result that practically everything necessary for daily research routines will be available on the Net.

(4) In the framework of my impact analysis in Part Three, I came to the conclusion that there are a number of social institutions which are, for various reasons, probably resistant to change, in particular face-to-face meetings at conferences (4.2.3) and core peer review (8.3.2). In the area of E-publishing, I ventured the prediction that P-only- as well as P+E-journals are likely to be replaced by E-only journals (7.3.3). By contrast, as regards the more fundamental changes of knowledge representation (hypertext, hyperbases etc.), I was rather cautious and argued that we shall probably witness a gradual move from a linear to a hypertext culture. This is, however, not likely to take place too soon (6.5.4).

Summarising the above discussions and evidence, a productive way of looking at the future of ICT use in academia is not to go at once for an overall trend assessment, but to first differentiate among the various tools. We learned that the simple dichotomy (Carley/Wendt 1991, 411ff.) of the replacement hypothesis (the new technology will replace traditional modes of communication) versus the enhancement hypothesis (the new technol-

[937] Remember the caveats voiced in 1.2.3.5.

[938] While the experts included in the Swiss Delphi study (Keller 2001b) sustained the substitution thesis in the medium run, my interviewees were split with some still predicting paper a long life, but expecting a fully E-publishing system for journals (cf. 7.3.4).

ogy complements traditional modes) is too simple. Rather, we have to distinguish the following five possible relationships[939] between the traditional tools and the cyber-tools:

1. *Substitution* means a more or less complete replacement of the old ways of doing things (the old media, the old tools) by the new cyber-tools;
2. *Superposition* means that the old and new media or tools continue to co-exist, but that the new ones become dominant in the sense that the old ones only play a marginal role in the future;
3. *Amendment* means that the traditional tools remain by and large intact but new elements are a welcome supplement to them and are changing (perhaps: improving) them and, consequently, enhancing traditional practices;
4. *Expansion* means that the old media not only remain dominant, but that they are even used more intensively due to the use of new media in other contexts; and
5. *Insignificant effect* means that the new media have not (yet) the power to change the use of old media, but that they are simply an add-on and present only in niches.

Besides the relationship between old and new tools, the second important element to consider is time. It is understood that both substitution (1) and superposition (2) of old by new media do not necessarily mean that the new tools go unchanged over time. Amendment is also taking place here. While the new media fulfil the same functions, but in a different way, they nevertheless often deploy traditional symbols and interfaces (Hrachovec 1999, 127). In addition, such an assessment will have to take into account that the effects may change over time, as technologies becomes increasingly important, or perhaps decrease in importance.

On the basis of the above five categories, and subdividing the time horizon into short, medium and long term[940], I come to a 5x3 matrix as presented in the following Table 12-1. The dotted lines indicate that the boundaries between both periods and categories are not strict, but that there are grey areas (in particular, as disciplinary differences are not depicted in this matrix). The categorisation of effects in this table is for the cross-disciplinary level, i.e. for cyberscience in general.

Interpreting Table 12-1, note first that I am not expecting any of the cyber-tools to have no effect at all on traditional tools, at least in the medium and long term. While hypertext, for instance, plays practically no general role in the short term[941], it seems likely that it may be an important enhancement in the medium term, and perhaps the dominant way of knowledge representation in the long run. More generally speaking, I hypothesise an "upward" movement over time, that is, in principle, from "no effect" and "expansion" towards "amendment", "superposition" and finally "substitution" in many cases. A particular tool does, however, not necessarily move up the ladder step-by-step in this particular order, but "steps" can be jumped over. For instance, it seems likely that some of the tools in the "insignificant effect" box of the short term range will not be found in the "expansion" box in the medium term, but rather in the "amendment" box already.

[939] This distinction is based on the above review of my results and extends what Hiltz proposed in 1984 (quoted by Stichweh 1989, 22); Hiltz distinguished between substitution, add-on, and expansion.

[940] Without, however, explicitly giving a more precise indication of how many years make up each period, which may in fact differ between various sub-fields. As a general background, note that short term for many authors refers to 0-5 years, and medium term to 5-10 years.

[941] Except, however, for a few specialities, such as in history; as this matrix aggregates at the cross-disciplinary level I have to list hypertext (as well as most of the other entries there) in the "insignificant effect" box.

Furthermore, the "upward movement" may come to a halt at some point. It is not implied that all cyber-tools will eventually end up substituting their traditional counterparts. For instance, E-conferencing is likely to be an amendment[942], but probably never a substitute for face-to-face meetings. While within specialities, some steps may be considered revolutionary (for instance, if the core journal moves from P+E to E-only), there will be probably no big leaps at the general level, but rather small steps on an evolutionary path, since particularistic developments cancel each other out.

Table 12-1: Effects of cyberscience tools on traditional tools in the short, medium and long term

Relationship to traditional tools	Short term	Medium term	Long term
Substitution	• Online bibliographic databases	• Online bibliographic databases • E-mail • E-prints	• Online bibliographic databases • E-mail • E-prints • E-journals
Superposition	• E-mail • E-prints	• E-journals • Disciplinary databases • Digital libraries • Groupware • E-lists	• Disciplinary databases • Digital libraries • Groupware • E-lists • Hypertext
Amendment	• E-journals • Disciplinary databases • Digital libraries • Groupware • E-lists • Multimedia	• Open peer review • Multimedia • Hypertext • Knowbots • Collaboratories	• Open peer review • Multimedia • Knowbots • Virtual institutes • Collaboratories • E-conferences
Expansion	• P+E-journals	• E-conferences • Virtual institutes	
Insignificant effect	• Open peer review • Hypertext • Knowbots • E-conferences • Virtual institutes • Collaboratories		

Some of the new tools will probably never reach a state of superposition or even substitution because, as I observed above, the more traditional ways seem resistant (face-to-face conferences, peer review). For the rest, there may be a forceful trend towards more "pervasiveness" as the technology in question is interactive and hence its diffusion rates

[942] E-conferencing is likely to be used for preparatory meetings or special first phases of conferences (cf. 4.1 (2.)).

tend to become self-sustaining (1.2.3.5). For instance, web-cams are simply not yet widespread enough to trigger video-conferencing at any significant level. As new PCs increasingly tend to come with these tools ready for use, it is not unlikely that the threshold for a sharper increase in the levels of E-conferencing will be reached soon. Similar arguments may hold for groupware where there is not enough experience yet.

It remains, however, difficult to say when a particular tool will reach the next level as this depends on a variety of factors. One such factor will be economic constraints (the necessary resources may not be available yet). For instance, as long as the majority of data, texts and instruments have not yet been made available in electronic form, the establishment of virtual institutes is hampered. Another factor may be insufficient technology expertise for quite some time.[943] And there may also be (temporary or lasting) resistance from some actors. For instance, parts of the faculty may resist adopting the new modes (Skolnik 1998, 647; Manicas 1998, 655). Another example are the commercial publishers who will obviously try to resist de-commodification of academic publishing (9.1.3.5). From my discussion of the various factors involved in the transition from traditional P- to E-publishing (7.3.2) and innovative forms of knowledge representation (6.5), we know in addition that deep-seated cultural adjustments need to take place first. Furthermore, technology has to mature, cyber-entrepreneurs have to accelerate the diffusion process and institutional inertia has to be overcome. Hence, while there are some good arguments to consider the various developments towards cyberscience a transitory phase which will ultimately lead to overcoming resistance, it is likely that some of the cyber-tools will not be adopted on a general level.

As an interim result, I hold that Table 12-1 provides us with a good indication of what cyberscience may actually look like in the not so distant future. The underlying dynamics in the sense of driving forces and the various intervening factors influencing the development from the left to the right column and from the bottom to the top row are discussed in the previous chapters and cannot be repeated here. With regard to the timing and the specifics of the developments indicated in Table 12-1, I have to refrain from any more precise trend statements. Given the multitude of intervening variables, there can be no conclusive, overall answer.

Another way of looking at the issue is to focus on the main crucial forks on the road to cyberscience as they have emerged from this study:

a. to what degree the working relationships between academics go virtual, that is whether it will become standard to "meet" online for the purpose of bilateral co-operation or multilateral workshops or even conferences;
b. to what extent advanced E-publishing (hyperbases, multimedia) will become standard;
c. whether or not the scholarly publication system will enter phase III, that is become essentially de-commodified; and
d. to what degree free access to scholarly results will be accepted as a general rule (this includes a copyright regime compatible with the needs of academia).

While a) and b) may be summarised in the common dimension of the "degree of innovativeness", c) and d) are two aspects of the "degree of independence from the extra-academic world". These two dimensions lead me to the following 2x2 matrix of four ideal-typical cyberscience scenarios:

[943] Finholt (2001, 27) speaks of "collaboration technology readiness" referring to both the presence of sufficient technology infrastructure and to the availability of local technology expertise, both explicit and implicit.

Table 12-2: Ideal-typical cyberscience scenarios

		Degree of innovativeness	
		low	high
Degree of independence	low	(1) Updated status quo	(3) Technically advanced cyberscience
	high	Open & de-commodified cyberscience (2)	Fully-fledged cyberscience (4)

In the scenario "updated status quo" (1), the used cyber-tools are not very advanced. E-mail is widespread; academic publishing is increasingly electronic, but is rather traditional as linear texts are enhanced with links to other articles; multimedia plays no significant role; only traditionally peer-reviewed journals enjoy a good reputation; commercial publishers dominate the academic journal and book market with a number of growing, but limited niches for free-to-all publications. It is this latter aspect, which distinguishes the first scenario from the second, labelled "open and commodified cyberscience" (2). Here, E-publishing has paved the way to a largely de-commodified scholarly communication system; open access to all resources necessary for research is guaranteed. Scenario (3), called "technically advanced cyberscience", differs from the first by a much more intense and innovative use of cyber-tools. Groupware, hypertext, multimedia and E-conferencing are widespread. The scenario "fully-fledged cyberscience" (4), finally, combines the features of the second and third scenarios. Note that "fully-fledged" does not necessarily mean that all elements listed, for instance, in Table 12-1, will be present. Some of them, as noted above, may be blocked or overtaken by further developments unforeseen at the moment. While the concrete combination of features cannot be foreseen, "fully fledged" means, by contrast, that it is both technologically advanced and "shielded" from the extra-academic world.

It is very likely that not all of the various academic fields will be found in the same box, and will probably not stay in the same box over time. Furthermore, these are ideal-types so that some academic specialities may be placed in grey area in-between these four scenarios.

In any case, while I can discuss the various factors favouring one or the other scenario for any particular field at a particular point in time (and I tried to do this at various occasions throughout this study), I cannot be more precise on the overall level. In the frame of this study, I must leave it up to the readers to assess which path their respective academic field will take at the four forks outlined above. Note, however, that even the "conservative" scenario (1) is characterised by a significant extent of ICT use. This is because, as revealed in my empirical work above, the status quo today is quite distinct from what the standard way of academic work in a pre-cyber world was like. That the first steps towards cyberscience have been taken almost unnoticed may indicate that the gradual evolution towards scenario (4) may be so slow that a fully-fledged cyberscience also comes almost unnoticed.

12.2 Meta-level conclusions

Similar to the previous one, this section will also not repeat what has already been said in the concluding sections of all chapters of this encompassing study. Many detailed conclusions regarding the impact of ICT on academia have already been drawn. Rather, I attempt to pull together these partial conclusions with a view to drawing special conclusions on a meta-level. Some of them directly follow from my analysis, whereas others are more speculative.

To begin with, *cyberscience is not utopia*. It is neither utopia in the sense of an ideal state of affairs, nor is it something far in the future, beyond imagination. By contrast, cyberscience is already a fact. For sure, there are considerable differences among the various academic fields, and many potential cyber-tools are by far not yet used widely spread. Furthermore, we are witnessing only the beginning of a longer development. However, *all* elements of a truly innovative environment for doing research in the 21st century are already available and already applied, at least in one or the other speciality or in some proto-form. There is no denying that E-mail and the WWW have already changed the scholarly communication system to a considerable degree (and this study has pulled together the evidence). Whether cyberscience will be utopian in the sense of "ideal" remains an open question. Ubiquitous and universal access to all necessary resources, for instance, sounds just great in the ears of any researcher. It is, however, not yet clear whether cyberscience will have this particular feature, as there is also an alternative plausible scenario of a commodified and closed publication system.

My next overall conclusion relates to the initial hypothesis that potentially *all types of scholarly activities and framework conditions are affected* by this forceful trend towards cyberscience. I could indeed show that while information and communication technologies primarily impact on academic communication (knowledge processing), communication understood in a broad sense is so central to academia (cf. 1.2.2) that it also affects knowledge production and knowledge distribution, as well as the institutional setting. There is enough evidence to claim that not only the academic publication system is currently being reorganised and that this is, to a large degree, due to the advent of the option of E-publishing. However, even how academic knowledge is produced is not exactly the same as a few years back.

An important observation in this context is that the impact of ICT on academia has *not been only superficial*. This will be the case even more so in the future. At first sight, the main impact seems to be an overall acceleration and simplification of communication and a welcome improvement of access to information. My deeper look, however, revealed that cyberscience goes well beyond this. I hold that the increasing use of ICT in academia impacts on the very substance of what science and research produces. It does so via changes in methodology, in work modes and in knowledge representation (cf. 1.2.4.3). Cyberscience also concerns some structural aspects of the scholarly system, such as the relationship between peripheral and central researchers; the constitution of scientific communities and invisible colleges; the notion of an academic library; and the division of labour and roles of various academic actors. Even the economic foundations of academia are affected, by both the financial crisis of the academic libraries and the E-publishing challenge to the commodified publishing system. In addition, cyberscience offers new ways of quality control that may well redefine what academics understand by quality in the future.

Networks have always been important characteristics of academia. The scientific community, scholarly associations and conferences are essentially all networks. Also the individual researcher establishes his/her network of peers, colleagues and collaborators. Academic publications are equally nodes in the network of disciplinary knowledge, interlinked via a myriad of citations and bibliographic lists. In all of these dimensions, cyberscience provides very important support tools and, at least as regards the web of knowledge, can be regarded a quantum leap. Cyberscience essentially *is* networked communication. It facilitates the establishment of networks between researchers, both at the individual and the macro level. In particular, ICT removes spatial barriers to the establishment and maintenance of the social networks. In the area of knowledge representation, however, cyberscience goes well beyond facilitating and improving. In fact, E-publishing is realising the knowledge web *in practice*. While in pre-cyberscience this web was only potential and the interconnections (the "strings" of the net) mainly in the heads of the researchers, it has now become real. This is more than simply providing for handy clickable links as it makes transparent the cognitive connections, the relationships, the intellectual "links". Present day E-publishing is only the beginning; fully-fledged cyberscience brings about innovative and sophisticated media for knowledge representation that even have the potential of enhancing connectivity, that is the interlinking and embedding of research.

Another general observation is that cyberscience is not only affecting formal structures and institutions, but that some of its elements also interact with the *informal, social structures* of academia. Scholarly discourse "goes E-mail". That is, it will be more written than ever, at least for a longer, transitory phase. Researchers have already started knitting a worldwide net of colleagues, but travel and time budgets are not increasing. Therefore, they are bound to uphold these contacts and to communicate via electronic means. It is not unlikely that, from a certain point onwards, "computer-mediated face-to-face" communication, i.e. via E-conferencing, will replace the dominantly written culture of social relationships. For the time being, however, there is a forceful trend towards "keyboard-based" informal communication. In any case, the reach of these informal structures is enhanced considerably as spatial limitations do not play the important role any longer that they used to play before the advent of advanced ICT (cf. 4.4).

One further conclusion is that the *distinction between "rural" and "urban" disciplines* (Becher 1989) has begun to blur. Similar to the impact of the telephone, of television and recently of mobile phones in the small villages and rural areas, the pace of research in the slower fields is considerably accelerated by the new cyber-tools. Competition is growing practically everywhere. While this has not only to do with ICT (cf. Coda below), it is certainly co-determined by cyberscience, in particular as the new working environment is much more transparent and open, thus making it more difficult to uphold niches "in a different time frame". In this context, we may ask whether there might be further convergence among the various disciplines in the way scholarly communication is processed and in the way information gathering works, due to the widespread use of similar cyberscience applications. While certainly not all cyber-tools are similarly functional in all fields, a few of them are likely to turn out to be pervasive. As adaptation (reinvention) is necessarily limited to highly sophisticated tools, they may pre-structure communication processes and, hence, lead to similar ways of doing research despite disciplinary differences.

While information and knowledge was traditionally stored in material artefacts, such as books, journals, catalogues and card files, the advent of the computer, the digital net-

works, the online databases and E-publishing have led to what may be called *de-materialisation* of academia. This process is, however, only partial in the sense that academia is very unlikely to go virtual as a whole (cf. 4.4). As we have seen, some academic institutions are resistant to change. In particular, face-to-face contacts still seem indispensable. Therefore, complete virtualisation is not to be expected. Nevertheless, a new balance of material and immaterial elements is emerging.

In many ways, academia on the path to cyberscience may be seen as a *test-bed for the information society* at large. Intra-academic developments anticipate what will be important outside as well. The Internet in general and particularly the WWW, which forms the basis of practically everything forming cyberscience, have been invented inside academia. Many enhancements, services and tools have been developed here and now trigger to the general world outside. In particular, the beginning virtualisation of working relationships can be observed. Telework, although first discussed and experimented with in the commercial sector, has become widespread practice in research. Furthermore, the digitisation of the resources necessary for academic work, well under way by now, heralds a new way of interacting with information that is likely to be part of the future society. This is, certainly, not to say that all elements of the so-called information society have been or will be developed and tested first by researchers. Videoconferencing and groupware, for instance, seem to be much more important already in the business world. However, as academia is an important supplier of information and knowledge, the ways how it is presented and represented will be of great influence on society at large.

The meta-level conclusions just drawn, finally confirm that the path towards cyberscience was (and is) a worthwhile research topic. My study revealed that it is indeed an encompassing and pervasive phenomenon touching upon the core as well as the periphery of what science and research is about. The initial observation (reported in the Foreword) that ICT has become omnipresent in research in a matter of only years and that it seems to affect important parameters of the daily routine of a researcher, proved fruitful and shed an interesting light upon the changing inner workings of academia.

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12.3 Coda

Concluding this final chapter, I should put my results as well as my conceptual framework in perspective. I shall mention a number of scope conditions of my results and list options for further research.

This research is a piece of technology-induced technology assessment. Starting with communication technology led me to focus on scholarly communication. This is, however, certainly *not the only factor* influencing the dynamics of academia today. When it comes to explaining changes in the outcomes of research, certainly thinking, analysing and applying methodologies are crucial. Therefore, all impact of scholarly communication is limited from the outset: we could not expect a great direct impact, but nonetheless found considerable effects. Even more important is probably the impact of new instruments, of new methods and of academic geniuses. Nevertheless, I largely excluded "research tools", even if computer-related, such as artificial intelligence, simulation and modeling, from my analysis, for this would need a further challenging study of its own. Further important factors determining academia today, but outside the realm of this study, are the increasing commercialisation of research (as well as of teaching) that has triggered increasing competition among researchers and universities; budgetary constraints; targeted research policy programmes at various levels; and the overall expansion of academia over the last decades. This study takes a particularly important perspective, but has to be taken for what it is: one among many perspectives on the future of academia.

Another limit of this study is *timing*. Technology assessment is bound to focus on new technologies where experience is necessarily limited. While some of this research concerns the status quo, the major part is devoted to future developments and impacts. Although I found out that ICT-related impact on academia is already visible in some respects, it is certainly still too early to draw definitive conclusions. Consequently, many of my observations are but a snapshot of an ongoing process and have to be handled with care.

In this study, I have largely refrained from impact *evaluation*, which goes beyond impact identification and assessment (cf. 1.2.4). What I have done is to analyse, as objectively as possible, the evaluations of others, including my interviewees, and to measure impact against the yardstick of whether particular important functions can also be performed using cyber-tools. True evaluation, however, would have to be done in a discursive process rather than by the individual author of an impact study, quasi as a meta-assessor. I would propose participatory TA methods, such as scenario workshops and focus groups, as appropriate tools to arrive at legitimate meta-individual evaluations that could feed into politics at various levels.

Based on my results, *further research* may follow four main routes. First, one may seek to enhance the empirical evidence of the status quo and of the dynamics of ICT use in academia. A much broader survey among researchers in as many fields as possible, perhaps at regular intervals, together with a quantitative analysis of network effects could complement and advance my findings. Second, further research may aim at deepening our understanding of particular aspects of cyberscience. To name but a few, it would be highly interesting to know more about the effects of new kinds of knowledge representation on research; to analyse the likely impact of digital rights management on academia; to study digital archiving for the purposes of academia; to analyse the functioning and prospects of new models of quality control and of innovative publishing; and to study, in more depth, the impact of ICT on university teaching and its potential feed-

back to the research system. The third route of useful further research could be called fine-tuning of my overall results. For instance, what I have just addressed above, namely participatory evaluation of my results seems worthwhile, as it would present us with a much clearer basis for the evaluation of policy options. Furthermore, the relationship of ICT-related impacts and the effects of other factors, that is the integration of my results in an overall analysis of the state and the future of academia, could lead to interesting insights on a meta-level. Finally, cyberscience research could be expanded to also include IT-related changes, that is "research tools". In particular, artificial intelligence, virtual reality, simulation, computer modelling and revolutionary "number crunching" potentials are worthwhile study objects when we aim at understanding the overall impact of technology on science and research.

While my *conceptual framework* linking a model of ICT diffusion with an analysis of impact on a societal sub-system is obviously shaped and elaborated with academia in mind, it should nevertheless be flexible enough to be applied to other cases, too. In principle, a focus on the respective communication system is important for any study on the diffusion of communication technologies. In particular, the types of intervening factors would be helpful in elaborating the relevant variables in another context, as would be the categories of the impact chain. The conceptual framework will, however, be most fruitful when studying other aspects of academia. For instance, those study objects proposed above for further research could be embedded and analysed in the same framework.

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