On the integration of the Internet into informal science communication

Barjak, Franz

University of Applied Sciences, Northwestern Switzerland

May 2004

Series A: Discussion Paper DPW 2004-02

On the integration of the Internet into informal science communication

Franz Barjak

Mai 2004

University of Applied Sciences Solothurn Northwestern Switzerland

In the Department of Management of the University of Applied Sciences Solothurn Northwestern Switzerland the following majors are offered in Economics: Controlling, Human Resource Management, Marketing, and Information and Knowledge Management. In addition, the department offers both a full-time and part time course in Information Systems. The Department of Engineering offers majors such as "IT and Telecommunications", "Electronics and Automation" (with possible specialisations in "Electronic/Signal Processing" or "Control Engineering/Automation") and "Operations and Production Engineering" (with possible specialisations in Organizational Theory, options: "Design of Production Facilities and Plant" or "Logistics and IT for the Manufacturing Industry"). The Department of Social Work offers a degree course in Social Work (with possible specialisations in "Counselling", "Prevention and Social Learning", "Social Planning and Social Management").

The University is well known for its further education activities which range from conferences, seminars, and examination preparation to fully-fledged graduate studies. The Department of Management offers graduate programs in Non-Profit Organisation, Logistics, Corporate Design Management, Corporate Communications Management and Personnel Management.

The University of Applied Sciences Solothurn Northwestern Switzerland is active in diverse areas of economics research. The most noteworthy research topics are in the areas of Industry, Innovation and Strategic Management, Human Resource Management, Social Work, Electronics and Automation as well as Information and Knowledge Management. The results of this research are presented in our publication series and research seminars.

Publication Series

In this series, the University of Applied Sciences Solothurn Northwestern Switzerland publishes the results of this research, with the aim of ensuring that colleagues as well as the broader public are informed about research activities and their results. To order any of these publications, please refer to the order form at the end of this brochure.

Acknowledgements

I thank my colleague, Prof. Najib Harabi, for guiding the SIBIS research on Internet use in public science. The present paper draws on the evidence collected within the SIBIS (Statistical Indicators for Benchmarking the Information Society) project and is indebted to the European Commission and the Swiss Federal Office for Education and Science who funded the project under the IST programme (IST-2000-26276). Furthermore, I gratefully acknowledge the support of the following organisations: British Computer Society, European Association of Experimental Social Psychology, European Economic Association, German Informatics Society, Italian Chemical Society and the Swiss Association for Research in Information Technology. I also thank all the other colleagues from the SIBIS project team and the external experts who critically reviewed the work and provided comments which also influence this paper.

Author

Franz Barjak currently works as a Research Fellow at the FHSO Department of Management. After graduating from the Technical University in Munich, Germany, with a diploma in geography, he was a member of the research team on regional and urban economics at the Institute for Economic Research Halle (IWH), Germany. His current research focuses on the use of the Internet in science and technology transfer.

Abstract

The present analysis looks at how scientists use the Internet for informal scientific communication. It investigates the relationship between several explanatory variables and Internet use for social communication, information retrieval and information dissemination in a cross-section of scientists from seven European countries and five academic disciplines (astronomy, chemistry, computer science, economics, and psychology). The analysis confirmed some of the results of previous US-based analyses. In particular, it corroborated a positive relationship between scientific productivity and Internet use. Furthermore, the relationship was found to be non-linear, with very productive (non-productive) scientists using the Internet less (more) than would be expected according to their productivity. Also, being involved in collaborative R&D and having large networks of collaborators is associated with increased Internet use, again with a non-linear relationship for the latter variable. In contrast to older studies, the analysis did not find an equalizing effect of higher Internet use rates for potentially disadvantaged researchers. Obviously, everybody who wants to stay at the forefront of research and keep up-to-date with developments in their research fields has to use the Internet. This also applies to renowned academics who are very well integrated into invisible colleges, and to social scientists – in our analysis economists and psychologists – who do not have lower usage rates than their peers from the natural sciences when it comes to the most common tools such as e-mail and the World Wide Web.

Keywords

Science communication, Internet

Table of contents

1 Introduction

Scientific research is a social rather than isolated undertaking which is heavily dependent on social interactions such as communication and collaboration. Garvey (1979) called communication the " essence of science" . Scientific communication has been pictured in the form of flow models (Garvey and Griffith 1972, pp. 123-136; Hurd 1996, pp. 9-33) and cycles (Lievrouw and Carley 1990, pp. 457-477): a new scientific finding is disseminated to the research community via a process of communication, evaluation by fellow scientists, publication in different media, corroboration through repetition and comparison with other results, citation and integration into the knowledge body of a research field.

Essentially two different types of science communication can been distinguished: formal and informal communication. Formal communication is impersonal and it takes place in scientific journals, books and to some extent at conferences. The journal article is expected to be a robust and reliable piece of information. Informal communication is personal and social. The communication partners know each other, and in many cases they are friends. The entire range of one-to-one communication channels, from face-to-face discussions through to e-mail exchanges is used, as well as one-to-many channels for reaching larger groups of people (for instance postal or computer-based mailings). The information which is communicated informally is very diverse and can range from a mere thought, hypothesis or measurement result through to more elaborate draft papers, preprints and finished articles. Scientific information communicated informally is less robust and more redundant than information communicated formally (Garvey 1979, pp. 23-26).

Both formal and informal communication are important for the advancement of scientific knowledge and both had become increasingly inefficient in the past. For the majority of scientists the situation before the onset of the Internet age was rather depressing: Current information could be accessed only by a fraction of all scientists working in a field. In particular younger and less established scientists, scientists in developing countries or at less renowned institutions participated in informal information flows in a manner which was partial at best (Crane 1972, p. 117; Mulkay 1977, p. 112). Their work was also frequently hampered by poorly stocked libraries and limited resources for acquiring current literature. The growth of the knowledge producing system and the increasing specialization of individual academics, research institutes and national communities (Ziman 1994, p. 65) increased the distance between scientists working in a field and made personal encounters and face-to-face discussions more difficult and expensive (Hiltz and Turoff 1993, pp. 213-215). Communication costs were high: subscription fees for scientific journals devoured library budgets; travelling to research meetings and conferences cost a lot of time and money; joint research centres, where scientists could meet and collaborate, required considerable investment at national and international levels. And yet scientists were still largely ignorant of what was happening in other fields outside their own, and when they needed a piece of information from another field they often had to undertake time-consuming searches which produced incomplete results (Crane 1972, pp. 115-128).

Some of these problems still persist, such as the high subscription prices for scientific journals. However, the dissemination of computer networks and the Internet might have alleviated others in particular. We can even assume that the demand for efficient means and tools of communication and collaboration in science itself contributed significantly to the development of computer networks: the developers of the Internet and its predecessors were driven by the search for an efficient medium for long-distance communication (Leiner et al. 2003, http://www.isoc.org/internet/history/brief.shtml). It is therefore no wonder that e-mail usage rates have nearly reached 100% in science: Walsh et al. (2000, p. 1298) reported 95-100% for American biologists, mathematicians, physicists, and sociologists. Barjak and Harabi (2004) reported 99.7% for European astronomers, chemists, computer scientists, psychologists and economists. They also found a WWW usage rate of close to 99% for the same dataset.

The spread of the Internet has been accompanied by considerable hopes and fears in regard to the effects on scientists' communication practices. For instance, researchers like Paul Ginsparg (1994), Stevan Harnad (1991, 1997) and Andrew Odlyzko (2001) have contributed to the view that the Internet will revolutionize formal academic communication. Others are more critical about how eager scientific communities are to change the established communication conventions (e.g. Kling and McKim 2000; Kling and Callahan 2001, http://www.slis.indiana.edu/csi/WP/wp01-04B.html). Several academics assumed that computer networks improve and increase informal communication among non-collocated colleagues and shrink the "communication gap" (Tibbo 1991, p. 281; see also Carley and Wendt 1991, p. 412; Clark 1995, p. 194; Noam 1995, pp. 247-249; Van Alstyne and Brynjolfsson 1996, pp. 1479-1480). Moreover, they feared that local science networks, interdisciplinary communication and the cross-fertilisation of scientific disciplines might be disrupted. However, somewhat more optimistically, it has also been proposed that the Internet might help to integrate disadvantaged scientists – such as those from less renowned organisations and developing countries, as well as younger and less established scientists – into the communication flows (Lievrouw and Carley 1990, pp. 468-469; Hurd 1996, p. 14; Liebscher, Abels and Denman 1997, p. 496; Nentwich 2003, pp. 250-255).

Since the early years, researchers have carried out empirical analyses on Internet use in science and monitored the intensity of Internet use and its possible effects (see chapter 3 for a review). However, the available literature has three inherent major weaknesses:

- The majority of studies were carried out in the US; there are very few cross-country and comparative analyses.
- The studies are often "technology-driven". They look at the simple use of Internet applications such as e-mail or the WWW but fail to consider the functions for which the applications are needed.
- The studies rarely go beyond mere empiricism and seldom contain frameworks that put the use of computer networks into the general context of scientific communication.

The present investigation sets out to overcome these weaknesses. Also, the present empirical work was carried out after the dramatic period of Internet diffusion in science which in the industrialised countries mainly took place in the 1990s. Due to network effects, the benefits of using the Internet increase with the number of users and we can assume that the spread of Internet applications also changes their role in science. In particular, a comparative analysis of Internet use is carried out for different activities of informal scientific communication. Formal communication will not be considered in detail. How the new information and communication technologies might affect formal communication in science has been discussed to a considerable extent. New models of formal communication processes have been proposed (Hurd 1996, pp. 20-33). Electronic publishing as a new form of computer-supported scientific publishing has been debated widely. In particular, the problems of peer review, authors' disapproval of e-journals, reliable identification and sustainable archiving of electronic documents have triggered considerable controversy (see e.g. Butterworth 1998; OECD 1998; Stevens-Rayburn and Bouton 1998; Tenopir and King 2000; Kling and Callahan 2001; The Journal of Electronic Publishing; Nentwich 2003, chapters 7 and 8). Scientific databases have been discussed as a new type of publication (see for instance Hilgartner 1995).

The present paper will therefore concentrate on the role that computer networks play in informal scientific communication. The role of informal scientific communication in two important theories of scientific knowledge production is briefly debated in chapter 2. Chapter 3 gives an overview of the empirical literature concerning the use of computer networks for informal science communication. In chapter 4 the data of the SIBIS R&D survey is presented; this constitutes the empirical basis of this contribution. Chapter 5 elaborates on the results and in chapter 6 some conclusions are drawn.

2 Scientific communication in two theories of scientific knowledge production

In science studies various models of scientific knowledge creation have been developed (see Zuckerman 1988 and Callon 1995 for overviews). Two of these, perhaps the most important, are known as the *sociology of science* and the *sociology of knowledge*; they differ in regard to the role of communication.

2.1 Sociology of science

The sociology of science model is characterized by treating scientific information as a commodity with a particular value for both the producers and the users (Lievrouw 1990, pp. 8-11). The producers of new scientific knowledge receive prestige and social recognition (Hagstrom 1965, p. 13; Ravetz 1971, p. 283) and the accompanying personal promotion and resources for further scientific work. The users benefit from new knowledge because scientific knowledge production is to some extent a cumulative undertaking and it can be incorporated by users in their own work (Kuhn 1962/1996; Garvey 1979, p. 14; Callon 1995, p. 37). In their flow model of scientific communication, Garvey and Griffith (1972, pp. 123-136) distinguished between several forms of formal and informal communication and pointed out the stage of the research process and the point in time in which they are used.

Formal communication fulfils several functions. New findings become publicly available information through their publication in scientific journals and books and presentations at scientific conferences. Whether a scientific result qualifies as new knowledge and the producer deserves recognition is evaluated in the process of formal communication, *ex-ante* through reviews of submitted papers and *ex-post* through citations and the inclusion in reviews, yearbooks, and abstract books (Crane 1972, p. 116; Garvey 1979, pp. 21, 28). Also, formal communication serves an archiving function, preserves knowledge and makes its subsequent retrieval possible (Garvey and Griffith 1972, p. 132). It is governed by certain norms which on the one hand are technical: a piece of information that is communicated has to appear in a certain form with a certain content. On the other hand, the norms can also be social: universalism, communism, disinterestedness and organised scepticism rule the communication process (Merton 1942, pp. 550-561).

Informal communication takes place through discussions with close co-workers, talks and reports to small colloquia, working papers and presentations to conferences. At each stage of this process the audience increases. Depending on the phase of research, it helps to identify suitable topics, focus the research approach, refine the findings and put them into the context of other current research. Two different groups of researchers which communicate informally have been distinguished (Hagstrom 1965, p. 112; Price and Beaver 1965, p. 1015; Crane 1972, pp. 34-35): The first is the team of researchers and collaborators which jointly work on a project; the second is the invisible college, i.e. the *"power group of everybody who is really somebody in a field"* (Price and Beaver 1965, p. 1011). An invisible college controls research resources and decides on the research strategies in its field. It serves as a channel for the dissemination of research ideas and research results which it has evaluated positively. It also represents a regulator that matches the volume of information with the absorptive capacities of the researchers (Mulkay, Gilbert and Woolgar 1975, p. 189).[1] Last but not least, invisible colleges might be viewed as exchanges for skills and access to costly research apparatus, where for one reason or another researchers seek each other out in order to collaborate (ibid.).

Though informal scientific communication is deemed to be important at all stages of a research project, the major focus is laid on the communication and dissemination of (intermediate) results to fellow scientists in the invisible college. For this communication the status of a scientist becomes important: usually it is only established scientists who have access to the network and who are accepted as equivalent communication partners. Scientific recognition, professional status and reputation of the university are important factors which determine the extent to which scientists communicate informally with the invisible college. Also, the existence of something that can be communicated – a new research result or theory – is necessary. Informal communication is not a pastime but serves to announce new knowledge, evaluate and refine it, and test its acceptance by fellow scientists. Therefore, a relationship between informal communication and productivity can be expected: the more output scientists produce, the more they must communicate and the more visible they will be to their fellow scientists.

2.2 Sociology of knowledge

This sociology of science model was contrasted by what has become known as the sociology of knowledge model. In particular, this approach deviates from the understanding of scientific information and knowledge as a commodity and instead describes it as socially constructed (Lievrouw 1990, p. 14). This means that scientific knowledge is not taken from nature or reality, but it is constructed in discussions between scientists from often contradictory evidence, previous findings, and theories (Latour and Woolgar 1979, p. 37).

> *"Laboratory studies display scientific products as emerging from a form of discursive interaction directed at and sustained by the arguments of other scientists." (Knorr-Cetina 1983, p. 128)*

Also, the results of this knowledge production through discussion are highly contingent on local circumstances (Latour and Woolgar 1979, p. 239; Knorr-Cetina 1983, p. 123). This includes the products of research such as the scientific paper which should not be considered as a one-to-one report of the research, but rather as a particular performance which can only be completely understood and repeated in another context if additional, tacit knowledge is provided (Knorr-Cetina 1981, pp. 94-133).

Informal communication is therefore already a salient feature of scientific knowledge production and not only of the dissemination of results. In particular, in the sociology of knowledge model all types of informal communication are much more relevant to the production of scientific

[1] Mulkay, Gilbert and Woolgar (1975, p. 189) use the term "research network" to describe a "relatively intensive concentration of interest ties".

knowledge than in the sociology of science model. Furthermore, the relevant group of people that affects knowledge production is transepistemic, including scientists and external agencies such as funding bodies, firms and other stakeholders (Knorr-Cetina 1983, pp. 132-133). The increased importance of informal communication in the production of knowledge points again to the productivity of a scientist as a determinant of their communication activities. In addition, by emphasising the discoursive character of scientific research, the constructivists also stress the importance of scientific collaboration. Besides being a tool for realising the division of labour and integration of differing capabilities, scientific collaboration serves to carry out the interpretations, negotiations, and discussions that characterise knowledge production (Latour and Woolgar 1979; Knorr-Cetina 1981, 1983).

The constructivist approach to science has been criticized from various angles. For instance, Zuckerman (1988, pp. 546, 556) questions whether the fact of multiple discoveries can be reconciled with the local contingency postulated by the constructivist approach. Whitley (2000, p. 10) proposes that the organization and control of activities of knowledge production remain rather obscure and it does not become clear how different types of knowledge are obtained.

3 State of knowledge on the use of computer networks for informal communication in science

In the previous chapter it was deduced that the professional status of a scientist, their productivity and participation in collaborative R&D are factors which should determine informal communication activities. Various analyses on the use of computer networks for informal scientific communication have included variables for these factors. Moreover, they have presented evidence on further relevant issues. The review in this chapter pools the variables found in the literature into seven groups: country, network-related infrastructure, academic discipline, scientific status, collaboration activities, productivity, and attitude and skills.

Country: Science is probably one of the areas where national differences in communication habits are not particularly pronounced. In many social situations, communication is subject to more national peculiarities and idiosyncrasies than it is in science. Science is very much a global undertaking, and research teams and science communities are often multinational. English is predominantly the language of choice, due to the dominance of scientists from the USA and English-language journals in many fields. However, in some countries a sizable proportion of academic communication takes place in the national language(s), in particular in countries with large national research systems. Also, the systems of higher education and research and their funding differ at the national level. Careers are also to some extent national. A strong argument for national differences in scientific communication is the notable variation of *per capita* publications between countries: For instance, according to the latest European Report on Science and Technology Indicators, from 1996-99 a researcher in Switzerland published on average 2.24 scientific articles, a researcher in the UK 1.65, in Germany 0.99, in the US 0.86 and in Japan 0.46 (European Commission 2003, p. 283). These differences have been attributed partially to the differing specialisations of the national research and innovation systems (European Commission 2003, p. 282) and to a bias of the data towards the English language which affects in particular larger non-English speaking countries (Van Leeuwen et al. 2001, pp. 335-346).

To the best of our knowledge, the use of informal communication media in general and computer-based communication in particular has not yet been analysed from a cross-country perspective.

Network-related infrastructure – computers, network connections, access to electronic libraries, archives, databases and others – is the material basis for using computer networks. Infrastructure is costly and therefore its quality varies according to the funding available. Few studies have assessed the importance of network-related infrastructure for scientific communication. In the second half of the nineties, infrastructure-related problems did not receive high priority in the US (Holmquist 1997, http://www.eso.org/gen-fac/libraries/lisa3/holmquistj.html; Lenares 1999, http://www.ala.org/ala/acrl/acrlevents/lenares99.pdf), whereas they were still highlighted as problems in European countries. In particular, problems of electronic access such as time consuming searches (Day and Bartle 1998, http://sosig.ac.uk/iriss/papers/paper06.htm) and high access costs and low access speeds (Stevens-Rayburn and Bouton 1998, http://www.eso.org/gen-fac/libraries/lisa3/stevens-rayburns.html) were highlighted. The lack of standardisation of electronic sources was also deplored (Brockman et al. 2001, p. 29).

The *academic discipline* or research field to which scientists belong can affect their communication behaviour in various ways and consequently their use of computer networks for communication. The size of academic disciplines, the possibilities of exploiting research results commercially and the locus of critical information differ (Walsh and Bayma 1996b, pp. 689-691). For instance, in the mid 90s in some disciplines a part of the empirical data was moved to on-line databases; this included genetic sequencing in molecular biology and digital space images in astronomy (OECD 1998, pp. 28-29). Research costs, the necessity to collaborate, and the visibility of the work performed by other scientists can vary (Kling and McKim 2000). There are also differences in communication conventions, e.g. at what time and in what media new findings are announced, what informal communication media are used, and how academic societies deal with previous informal publications (Kling and McKim 2000). Work is organized differently in different academic disciplines (Whitley 2000); in particular interdependence of work organization – such as the "*extent to which a person's daily tasks depend on the actions of others in the collaboration*" (Walsh et al. 2000, p. 1302) – varies. The importance of collaboration also differs (Walsh and Bayma 1996a, p. 347). Michael Nentwich (2003, pp. 148-181) explores a long list of hypotheses on the relationship between scientific disciplines/specialties and the use of several Internet applications. He finds that no single factor can explain the overall differences between the disciplines. Factors which can support the use of certain Internet tools in an academic discipline are a high importance of collaborative research, an existing pre-print culture, high time pressure, a cumulative tradition, and an extensive use of data and models; whereas a closeness of the field to a commercial exploitation and a tradition of book-publishing rather work against using the Internet.

The effects of these differences on the use of computer networks were analysed in the past: Persistently higher Internet usage rates were found for scientists than for social scientists, humanists and physicians (Abels et al. 1996; Cohen 1996, p. 49; Lazinger et al. 1997, pp. 508-518; Kling and Callahan 2001, http://www.slis. indiana.edu/csi/WP/wp01-04B.html). Mathematicians and computer scientists have the highest computer network and computer-mediated communication (CMC) usage rates (Abels et al. 1996; Walsh and Roselle 1999, p. 51; Walsh et al. 2000, p. 1298). Only more recent results suggest that social scientists have caught up with the sciences and even by-passed them in some aspects (Walsh et al. 2000, p. 1298; Nentwich 2003, pp. 129-147; 164).

Status and peripherality: Seniority, position and age can determine to what extent scientists benefit from using the Internet: Firstly, it can be assumed that less established researchers use computer networks more often, as they make up for the lack of the personal information flows derived from invisible colleges at which they participate to a lesser extent; also, computer networks might help to provide access to an invisible college (Nentwich 2003, p. 251). Secondly, more senior scientists are involved with more tasks and in particular with more ambiguous tasks. Ambiguous tasks require the use of information-rich media (Trevino, Daft and Lengel 1990, p. 82; Fulk, Schmitz and Steinfield 1990, p. 130).[2] As face-to-face communication is more information-rich than computer-based communication, status and seniority should be negatively correlated with CMC use. Thirdly, younger scientists may show more affinity to new technologies, accumulate more benefits from learning how to use them, and therefore be more skilled than older scientists. Fourth, another incentive for scientists of lower status to use computer networks for communicating with higher ranked peers stems from the absence of status cues on electronic networks (Dubrovsky, Kiesler and Sethna 1991, pp. 122-124; Walsh and Roselle 1999, p. 61). Thus, the Internet contributed to creating more equal communication situations. However, more recent work has not been able to corroborate this finding, which it attributed to the increasing use of inserted status cues such as addresses, biographies and photos into Internet sites (Walsh and Roselle 1999, p. 61; Nentwich 2003, p. 253). Moreover, network use may itself simultaneously increase status, through providing access to scarce resources, increasing productivity and visibility of the networks users. However, the empirical results are anything but clear. The findings of Hesse et al. (1993, pp. 94-96) support a positive relation between network use and status; Walsh and Roselle (1999, pp. 61-66) report rather inconclusive findings.

Empirical analyses over the last decade have largely confirmed a negative relationship between Internet use and the degree of establishment in science: More senior scientists have lower Internet use (Lazinger et al. 1997, p. 512) whereas younger scientists use CMC more often (Cohen 1996, pp. 50-51; Mitra et al. 1999, http://www.ascusc.org/jcmc/vol4/issue3/mitra.html). E-journal readers tend to be younger than non-readers (Kling and Callahan 2001, http://www.slis.indiana.edu/csi/WP/wp01-04B.html). A 'lower' professorial status (assistant versus associate and full professors) also corresponded to a higher use of computer networks for communication (Cohen 1996, pp. 50-51). Only the findings on gender differences between scientific CMC users were inconclusive: Whereas Cohen (1996, pp. 50-51) reports higher CMC use by women, Mitra et al. (1999, http://www.ascusc.org/jcmc/vol4/issue3/mitra.html) and Walsh et al. (2000, p. 1301) did not find any gender-related differences regarding e-mail.

Collaboration and integration into scientific networks: Being involved in R&D collaboration should also increase the use of computer networks for communication as e-mail can be used to coordinate work more efficiently (Kling et al. 1996, http://www.slis.indiana.edu/kling/pubs/CTCT97B.htm). It is asynchronous, fast, leaves a permanent record, and simplifies communication between people in different time zones or with irregular desk-based work hours (Walsh and Bayma 1996a, p. 348; Nentwich 2003, pp. 189-192). Also, written messages permit greater reflection and non-native English speakers are more at ease communicating in the written form (Sanderson 1996, pp. 106-107). Moreover, e-mail can be used to exchange documents, data, information and software quickly among individual collaborators or groups. However, the range and level of selectivity of network applications can vary. For instance, we may assume that somebody with a large collaboration network can distribute his or her work via e-mail to selected peers, whereas somebody without this kind of network may choose the World Wide Web, which represents a less defined audience.

[2] "Richness" is understood as the information-carrying capacity of a medium consisting of (1) the availability of instant feedback, (2) the capacity to transmit multiple cues (voice tone, facial expression, body language), (3) the use of natural language compared for instance to numbers, and (4) the personal focus of the medium (Daft and Lengel 1984, p. 196-197; Trevino, Daft and Lengel 1990, p. 75).

More sophisticated technologies such as video conferencing are more information-rich than previously available telecommunications media and facilitate the transfer of a broader range of knowledge. Remote access and shared working spaces on computer networks facilitate the collaborative work of non-collocated research teams (Herbsleb et al. 2000, http://www-2.cs.cmu.edu/~jdh/collaboratory/research_papers/cscw_delay.pdf). Some collaborations depend to such a large extent on the electronic transmission of information that they are even considered as a new type of collaboration, called *extended research groups* (Carley and Wendt 1991, pp. 406-440) or *collaboratories* (Hurd 1996, pp. 29-31; OECD 1998, pp. 44-46; European Technology Assessment Network 1999, pp. 40-42; Finholt, T.A. 2001, http://www.crew.umich.edu/Technicalreports/Finholt_Collaboratories_03_07_01.pdf).

However, not all the high expectations can be fulfilled. For instance, case studies and descriptions of different tools for on-line meetings and remote collaboration suggest that there are still several technical shortcomings relating to hardware and software and that the technical staff and users' proficiency with the new technologies is rather limited (Sanderson 1996, pp. 103-105, 110; Finholt et al. 1998, pp. 66-69; Mark et al. 1999, pp. 159-178; Olson and Olson 2002, pp. 139-179). Moreover, the utility of computer-mediated communication tools for collaborative research depends on the phase of the research: At the beginning, intensive conceptual work requires face-to-face discussions. When the research is being performed, telecommunications media are used and at the end face-to-face meetings are again more important (Kraut, Egido and Galegher 1990, pp. 161-162; Walsh and Bayma 1996a, p. 349; Merz 1998). Face-to-face meetings are essential for discussing and orienting the collaborative research, demonstrating expertise, solving disagreements and making decisions (Sanderson 1996, p. 108).

All in all, empirical research has indeed shown that scientists who collaborate use the Internet more frequently: Scientists involved in collaborations have higher e-mail usage rates and in particular remote collaborations are correlated with e-mail use (Walsh et al. 2000, pp. 1303-1304). Computer-mediated communication users publish more co-authored articles than non-users (Cohen 1996, p. 53; Walsh et al. 2000, p. 1303). The quality of the collaborations can also affect communication: The stronger the ties between collaborators, the more they communicate and the more media they use for this communication (Carley and Wendt 1991, pp. 426-435; Koku, Nazer and Wellman 2001). The evidence on the relationship between the size of collaboration networks and the use of CMC is mixed: Hesse et al. (1993, p. 96) state that computer network users know more colleagues whereas Walsh et al. (2000, p. 1303) did not find a strong relationship between the size of collaborative workgroups and e-mail use. However, this might be explained by a U-shaped relationship: poorly connected scientists do not use CMC much because they do not communicate much, and very well connected scientists use CMC less due to time constraints. Early evidence (Hiltz 1984, p. 48) also points into this direction.

Furthermore, some authors assume that computer-mediated communication is not only the result but also a cause of collaboration (Brockman et al. 2001, p. 12). However, a deterministic stance should be avoided in this context. As Sanderson (1996, p. 102) notes:

> *"The communication technologies may make it easier to sustain collaboration, but it is the researchers themselves who initiate and create the collaboration."*

Productivity effects: The relationship between scientific output and the use of computer networks may be twofold: (1) Use of computer networks may affect the scientists' productivity and the quality of output produced (scientific articles, other publications). In general, more information is available over computer networks and the search and retrieval of information is faster (Rusch-Feja and Siebeky 1999, http://www.dlib.org/dlib/october99/rusch-feja/10rusch-feja-full-report.html; Brockman et al. 2001, p. 31, Nentwich 2003, p. 210). Access to remote instruments and data sets is also easier and faster (Walsh et al. 2000, p. 1296). Research may become better connected and more modular (Kircz 1998, http://www.science.uva.nl/projects/commphys/papers/nicem.htm; Nentwich 2003, p. 210). E-mail threads and groupware may help groups to memorize discussions and decisions and increase the efficiency of group interactions (Steinmueller 2000, pp. 366-370).

However, computer networks may also reduce productivity. First of all, the time spent on becoming familiar with a technology and learning how to use it is nothing else but learning costs (Nentwich 2003, p. 211). Complaints of information overload and too many and excessively broad hits on web-based information searches are documented (Stevens-Rayburn and Bouton 1998, http://www.eso. org/gen-fac/libraries/lisa3/stevens-rayburns.html; Day and Bartle 1998, http://sosig.ac.uk/iriss/papers/paper06.htm; Nentwich 2003, p. 212). In addition, SPAM – unsolicited e-mail not related to work issues – clutters mailboxes and wastes time, whilst viruses distributed over the Internet can erase hard drives and files. The possibilities of accessing information on computer networks might have a distracting effect and could increase "*the amount of time spent fooling around*" (Bishop 1994 cited in Walsh and Roselle 1999, p. 66). More efficient information searches may lead to the inclusion of more information overall, with decreasing marginal gains.

(2) The second effect would run counter to this. More productive academics are more visible to their peers. Therefore, we should expect that they also receive more comments, requests for publications or further explanation via computer-mediated communication media. In addition, they have been found to be more aware of electronic information sources such as e-journals (see the evidence cited in Kling and Callahan 2001, http://www.slis.indiana.edu/csi/WP/wp01-04B.html).

Empirical evidence supports a positive relationship between productivity and the use of computer networks (Hesse et al. 1993, pp. 95-96). Various authors have found positive correlations between publication rates and the use of CMC tools (Cohen 1996, p. 52; Walsh et al. 2000, p. 1304). But the use of other, non-communication applications is also related to publication rates: Kaminer and Braunstein (1998, p. 727) found a correlation between the use of remote login software, ftp and Kermit (file transfer, management and communication software) and the number of average annual publications.

Attitude: When use of computer networks and specific applications is voluntary and not required by the organisation of work, scientists' attitudes may influence their usage patterns. These attitudes may be generally their openness to technology and interest in trying out new ways of working. More specifically, attitudes can also reflect expectations about the functionality of networks for getting work tasks done, or the understanding of the organisation's culture, tradition and climate (Mitra et al. 1999, http://www.ascusc.org/jcmc/vol4/issue3/mitra.html). However, the use of computer networks may also shape attitudes towards their usefulness by reconfirming and rationalising the decision to adopt them (Brown 2001, http://informationr.net/ir/6-2/paper99a.html).

Empirical evidence on this aspect is scarce: E-mail users were more positively predisposed towards the use of computers and had higher expectations in regard to their functionality for their work (Mitra et al. 1999, http://www.ascusc.org/jcmc/vol4/issue3/mitra.html). The lack of willingness to use new information sources has been found as one factor that determines the use of electronic journals (Day and Bartle 1998, http://sosig.ac.uk/iriss/papers/paper06.htm). In surveys of variables reflecting aspects of an academic's capacity for innovation, such as knowledge of e-journals and acceptance of the properties of electronic media versus traditional media, a high proportion preferred not to use electronic journals (Holmquist 1997, http://www.eso.org/

gen-fac/libraries/lisa3/holmquistj.html; Lenares 1999, http://www.ala.org/ala/acrl/acrlevents/lenares99.pdf).

Another determinant of the use of computers and Internet applications are the *skills of the users* A skills gap may represent an important barrier to the effective use of computer/Internet applications, particularly if the person is familiar with other methods of carrying out the task (Brockman et al. 2001, pp. 20-23). Learning and improving the skills for using computer networks to perform research takes time. Also the acquisition of skills is an investment which must be made before an application can be used efficiently. Older academics have less incentive for learning how to use computer networks because they expect lower cumulated returns in the future. It is difficult to measure skills and therefore empirical investigations very rarely include this. One attempt by Mitra et al. (1999, http://www.ascusc.org/jcmc/vol4/issue3/mitra.html) finds that e-mail users rated their computer skills higher than non-users. However, it is not clear whether this self-disclosure regarding skills level is really valid.

4 Operationalisation, data basis and methods of the analysis

4.1 Operationalisation

Dependent variables

The use of computer networks was assessed for different R&D-related activities: social communication on R&D issues, the search and retrieval of information for R&D projects, and the dissemination of R&D results. Each of these activities was assessed using different variables.

The most important and widely used new communication tool is e-mail. Chat room applications and video conferencing are other markedly less common tools. Based on the responses to a question which assessed the use of these computer-based and various 'off-line' communication media for R&D during an average working week, two hybrid indicators were constructed:

- A computer-mediated communication (CMC) index reflects the ratio of CMC to all R&D communication. The higher the index, the larger the proportion of a respondent's communication that is transmitted via computer networks.
- The second indicator used the same question and built three clusters in a hierarchical cluster analysis which were labelled 'silent researchers', 'e-mail communicators' and 'communicators' according to their overall communication behaviour in general and e-mail use in particular.

The extent to which the Internet is used for retrieving scientific information was also assessed using two types of indicators:

- Simple usage rates of on-line information sources (Internet sites of libraries and archives, e-journals and full text databases, peers' websites, websites of other institutions, others) were the most basic indicators.

- A compound indicator, based on the relationship of on-line sources to all on-line and off-line sources (existing collections of information items, off-line electronic sources, libraries, colleagues, conferences and other off-line sources) was constructed to obtain a more condensed picture.

Scientists not only require information for their work, they are also suppliers of information. Traditionally this was achieved through the publication of research results in working papers, scientific journals, books and other publication media. Most of these media have set up sites on the Internet. However it is not always transparent for scientific authors in what form and to what degree their research findings are available on the Internet. Two indicators were therefore included on information dissemination over the Internet, which to a large extent are controlled by the scientists themselves:

- A simple and straightforward indicator is binary and measures only whether scientists have a personal homepage outlining their professional activities.
- The most important content for readers with a background in science are the results of scientific work reported in scientific publications. The second indicator is again binary and assesses whether scientists have working papers, full text articles, other forms of R&D output, or hyperlinks pointing to these on their website.

Independent variables

The seven groups of independent variables were operationalised for the analysis:

Country: The address data collected for the survey included the country of the scientist. However, in order to obtain more reliable data and control for multiple affiliations, the respondents were also asked for the country of their main organisation. Dummy variables were constructed for the countries in the sample.

Network-related infrastructure: Issues related to infrastructure were covered in the analysis by means of two types of variables: the first related to the scientists themselves and the second related to their organisation. The respondents were asked for their computer hardware. Based on the answers a hybrid indicator was constructed consisting of the type of computer available (standalone PC, workstation, mainframe, supercomputer/cluster) and the age of the computer used most often (as an indicator of its computing power). In addition, another indicator was constructed from a question which asked the respondents whether they had access to the most important network-based information sources in their discipline. The organisation-related variables include a categorical variable for the number of persons working for it and the type (university, university of applied sciences, non-university research institute and others).

The *academic discipline* of the respondent was determined by assessing their main field(s) of research. The analysis aimed at juxtaposing the Internet use of five academic disciplines, a basic science (astronomy), a more applied science (chemistry), an engineering discipline (computer science) and two social sciences (economics and psychology). For the five disciplines, dummy variables were constructed. All respondents who performed research outside the core fields of one of these disciplines were included in the category ‘others’. According to the findings of previous studies it was expected that academics from the science and engineering disciplines would have higher Internet usage rates than the social scientists.

Four different *status dimensions* were included in the analysis: (1) The position of a scientist in regard to R&D (junior researcher, senior researcher, R&D manager), (2) the academic recognition measured as an index of the four nominal variables scientific awards, membership of a professional committee, service on the editorial board of a scientific journal, and membership of an advisory committee, (3) the respondent's age, and (4) gender. A higher reliance on computer networks was expected for the more 'disadvantaged' groups in terms of status (junior researchers, little academic recognition, young and female).

Four different concepts in regard to *scientific collaboration* were used in the analysis:

- The occurrence of a collaboration is a binary variable that is based on the question whether a respondent has been involved in collaborative R&D during the previous two years or not.
- Network size was assessed as the (estimated) number of collaborators. A more limited concept of network size included only the external collaborators from organisations other than a respondent's home organisation. In order to account for U-shaped effects – that is decreasing computer network use by scientists with very large collaboration networks, e.g. due to time constraints – the squared size variable was also included.
- Third, the respondents were asked for the typical number of their co-authors.
- A fourth variable was based on the proportion of co-authored journal articles during the previous two years (according to estimates by the respondents).

In accordance with the literature, a positive correlation was expected between all variables which measure the use of computer networks and the collaboration variables, except for the squared network size.

In order to assess the *productivity* of scientists, a question was included in the questionnaire which asked for the number of publications during the years 2001 and 2002, differentiated according to the type of publication (working paper, journal article, book chapter, monograph, conference presentation, report, others). This self-assessment does of course have some inherent weaknesses, in particular in regard to reliability of the responses. However, other than the standard figure of journal publications, it also includes less well-documented and counted types of publication. In particular, working papers and conference presentations are more informal than journal articles and tend to occur at different stages of the research process. A correlation between network use and informal publication but not formal publication forms may be interpreted as a general trend of 'informalisation' in scientific communication. In addition to the regular indicators, squared indicator values were also calculated in order to control for non-linear relationships between productivity and computer network use. These could appear for different reasons, such as decreasing returns on Internet use, time constraints of very productive scientists or validity problems of the data.

The aspect of a scientist's *attitude* towards the Internet can be deduced from a set of questions targeted at the importance of the Internet for selecting R&D topics. The questions referred to WWW and e-mail communication as sources for new research ideas, the Internet as a tool for supporting the performance of R&D, and as an application which helps to keep researchers up-to-date and focus their R&D on the hot topics in the field.

Scientists' *computer skills* were included with a rather general indicator based on the number of computer applications used and their sophistication. The more types of software a respondent used, and the more sophisticated this software was judged to be, the higher the assumed computer skills level.

4.2 Data basis

The data basis for the present analysis was gathered in a postal survey among higher education organisations (universities, polytechnics), as well as private not-for-profit R&D institutions and government-funded research institutes. The basic unit of observation was the individual scientist themselves. Scientists were defined as research managers, senior researchers and junior researchers. The latter category also includes PhD students who in some countries (e.g. Germany or Switzerland) are often simultaneously junior researchers.

Five academic disciplines were selected for which differing Internet usage patterns were expected according to the results of previous research: astronomy and astrophysics, chemistry, computer science, economics and psychology. For practical reasons seven European countries were included in the analysis: Denmark, Germany, Ireland, Italy, the Netherlands, Switzerland and the UK.[3] In order to obtain a sufficient representation of all disciplines and countries included in the analysis, we set out to build an address data set of at least 150 scientists per academic discipline in the smaller countries (Denmark, Ireland, the Netherlands and Switzerland) and 200 scientists in the larger countries (Germany, Italy, and the UK). However, this was not always possible; in Denmark and Ireland it was not possible to find enough addresses in the smaller disciplines. The addresses were gathered from academic associations at European and national level (either from their published membership records or from their internal address databases). Any gaps were closed by using address searches via the World Wide Web which employed the following procedure:

- Step 1: random selection of research organisations (based on national or international lists of web links for an academic discipline);
- Step 2: random selection of individual researchers from the staff lists of these organisations as published on their homepages.

The questionnaire was mailed twice to all participants between April and July 2003 with a covering letter and a postage-paid return envelope (except for the UK). Overall 1,602 out of the 6,518 respondents replied to the questionnaire. 183 letters were returned because the respondent had died or left the organisation. This leads to an overall net response rate of 25%. The 1,602 responses resulted in 1,482 questionnaires which could be included in the empirical analysis. Descriptive statistics for all variables are provided in the annex tables A-1 and A-2.

The address collection via academic organisations and the Internet left some doubt as to the actual academic discipline in which the respondents carried out their research. The questionnaire also included a question on the three major research disciplines of each respondent and it was decided to use the responses to this question to determine the academic discipline relevant to the researcher.

4.3 Analysis of the data

In addition to frequency distributions, cross-classified tables and variance analyses, several multivariate methods were employed. These served on the one hand to condense the data and on the other hand to relate dependent and several independent variables.

[3] These were the countries of the seven SIBIS partners which provided considerable help in the administration of the empirical work.

In order to condense the data, mainly cluster analyses were carried out using the statistics package SPSS. The social communication groups 'silent scientists', 'e-mail communicators', and 'communicators' are based on such a clustering of variables that reflect the use of different computer-based and traditional communication media for R&D.

The relationship between variables for Internet use and country, infrastructure, academic discipline, status, collaboration, productivity, attitude and skills were estimated by means of various types of models.

- For binary dependent variables (such as the existence of a personal web page and the inclusion of full text on the web page) binary logit and probit models were used.
- Dependent variables with more than two possible values (e.g. the social communication groups) were estimated by means of multinomial logit models.
- Ordinal dependent variables, such as the use of e-journals and peers' websites for obtaining information, were estimated using ordered probit models.
- Last but not least, two indexes were constructed which reflected the relation between the use of on-line and off-line information sources or on-line and off-line communication media. These indexes were standardised on the value range 0-100. In order to estimate the relationship between the explanatory variables and the indexes, the tobit model was employed.

The estimates were performed with the LIMDEP software. Since our main goal was to analyse the existence and direction of relations, marginal effects were not calculated. The results of the estimates are included in the tables in chapter 5. Regarding the technical results of the estimates c.f. the annex table A-3. In each case, the best performing model is presented.

5 Discussion of the results

The picture of *country differences* that emerges is very fuzzy. Overall, only scientists in Germany show a markedly different – lower – use of computer networks for R&D than scientists in Switzerland. The results for all the other countries varied around the Swiss values, which were chosen as the reference group. In particular, the use of the Internet for social communication and for obtaining information is less common in Germany. Swiss, Italian and British scientists use the Internet particularly often for obtaining information compared to scientists in the other countries. Scientists from the UK also carry out a large percentage of their social communication via computer-based media. In Denmark the Word Wide Web is more important than in the other countries for disseminating scientific information: a higher than average proportion of Danish scientists have personal web pages and include full text documents, probably the most important content on a scientist's website.

[Table 1]

The *network-related infrastructure* variables are only important for information retrieval and dissemination. They do not have any influence on the used communication variables. It would seem that infrastructure deficits continue to limit the use of Internet applications by some scientists. The higher the quality of computers and the better the access to information sources, the higher the use of computer networks for information retrieval and dissemination. However, according to the respondents' remarks to an open question, the limiting factor in the use of computer networks for R&D is not so much inadequate hardware but rather expensive licenses for journals, databases and other electronic sources. There were no clear correlations between the type or size of an organisation and its use of Internet applications.

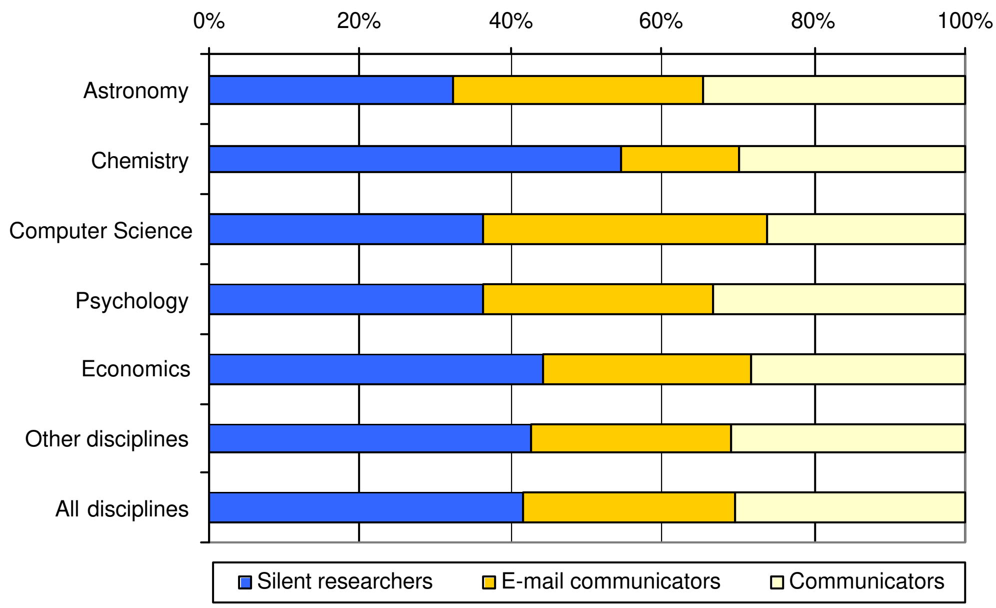
[Table 2]

Academic disciplines: The use of computer networks varies between academic disciplines. However, the expected general difference between scientists and social scientists which emerged in older analyses was not repeated (Abels et al. 1996; Cohen 1996, p. 49; Lazinger et al. 1997, pp. 508-518; Walsh and Roselle 1999, p. 51; Kling and Callahan 2001, http://www.slis.indiana.edu/csi/WP/wp01-04B.html). The use pattern is more varied. Economists and computer scientists are more reliant than scientists from other disciplines on the WWW for obtaining and disseminating information. Computer scientists depend predominantly on personal web sites when searching for information; astronomers do not use personal web pages very often, but rely mostly on impersonal electronic information sources (libraries, archives, databases, and e-journals). Economists use all types of electronic sources. Psychologists and chemists source less information from the Internet than scientists from other disciplines.

[Table 3]

In the social communications domain it is notable that psychologists are the most active communicators (see also figure 1). Though computer scientists communicate less overall, CMC media (e-mail, video and chat tools) nevertheless have a higher relative importance (also documented in the positive and significant coefficient for the CMC index estimation). Chemists, on the other hand, communicate less and use computer-based media to a lesser extent.

Figure 1: Respondents by academic discipline and communication groups



Source: SIBIS R&D survey.

The *status differences* found were mostly not as expected. First, senior researchers and R&D managers had largely similar computer network usage rates which are markedly higher than those of junior researchers. This runs counter to our expectation – and some previous findings (see e.g. Cohen 1996, pp. 50-51; Lazinger et al. 1997, p. 512) – that less renowned researchers use the Internet more often. Academic recognition is very poorly correlated with computer network use. A greater proportion of renowned scientists have their own web page, but this is probably either an automatism brought about by the public relations policy of the institution, or a necessity resulting from the larger information demands which prominent academics encounter. Gender differences are not very marked and are contrary to expectations: male respondents were more likely to have their own web page and these featured full text documents more often. Also, they communicate more than female respondents. The only variable that supports the hypothesis of disadvantaged scientists using the Internet more often is age: younger respondents consistently had higher values for the network use variables. However, a competing interpretation would be that it is not only academic status but also technological competence and the size of the acquired knowledge base which vary with age. Hence the necessity and the willingness to source information externally and from the Internet also vary.

All in all, we cannot conclude that the less integrated and, in terms of off-line information flows, disadvantaged groups of scientists – young, female, and less established – make more use of computer networks in order to overcome the disadvantages. The consistently high use of networks by established scientists for social communication and for retrieval and dissemination of information suggests the use of these computer networks for performing such tasks are dominant - to such an extent that any scientist, regardless of whether they are established or not, has to use the available tools and applications in order to carry out their work effectively.

[Table 4]

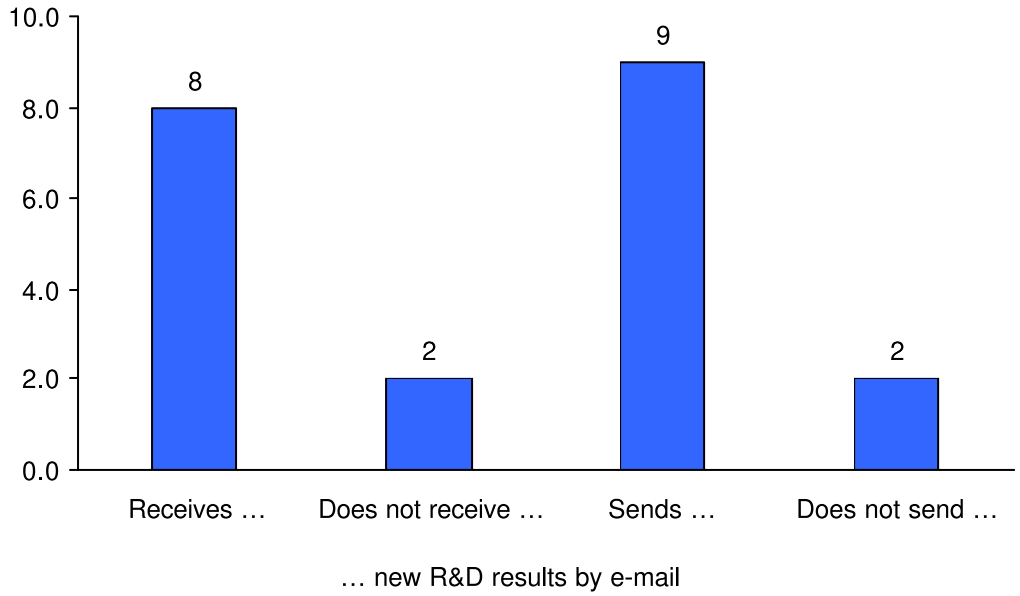
Collaboration and integration into scientific networks: Collaboration was very common in the dataset: Some three out of four scientists were involved in collaborative R&D in 2001 and 2002. A large majority (70%) collaborated with partners from other organisations. On average, every respondent had seven collaborators and two co-authors for their scientific publications (median values).[4] More than 80% of all journal articles were denoted as co-authored.

There are marked differences between collaboration and scientific network variables: neither of the two variables on co-authorship suitably reflects the effects of collaboration on network use. They are therefore omitted from the following discussion. The collaboration variable and the network size variables, however, show a consistent picture: Collaborating scientists communicate more over the Internet and use it more for sourcing and disseminating information than non-collaborating scientists. This is consistent with previous findings (Walsh et al. 2000, pp. 1303-1304). The size of the collaboration network exerts a U-shaped effect, as expected: Scientists with very large collaboration networks use computer networks less than scientists with moderately sized collaboration networks. This could be due to an upper time limit for computer network use which is not exceeded even if a scientist has many colaborators. Considering only external collaborators returns similar results with slightly increased coefficients (not shown in the table). It is also interesting to note that the larger the collaboration network, the smaller the volume of information obtained from electronic sources, with a correspondingly lower importance of the WWW for disseminating research findings. Well-connected scientists obviously have more efficient ways of disseminating information than using impersonal computer networks, for instance by exchanging e-mail attachments with their collaborators (see figure 2).

[Table 5]

[4] The distribution of R&D collaborators is notably skewed to the right. The arithmetic mean is 14.8 collaborators per respondent (see table A-2 in the annex).

Figure 2: Median number of R&D collaborators as a function of e-mail use for exchanging R&D results



Source: SIBIS R&D survey.

Scientific productivity: The respondents to the SIBIS survey published an average of 4.0 articles in journals, 2.2 working papers, 1.0 book chapters, 0.25 monographs, 1.2 reports and 0.2 publications in other media (such as edited books, brochures, articles in professional journals and general outreach). They also gave on average 4.4 presentations at scientific conferences. However, a comparison of the journal data from the SIBIS survey and the publication data from the Institute of Scientific Information (ISI) shows a difference of an order of magnitude. The ISI data lead to an average of 0.4 publications per researcher for the year 1999 for the seven European countries included in the SIBIS survey (calculations based on data published in the US by National Science Board 2002, vol. 2, table 5-41 and Frank 2003, p. 5). SIBIS covers two calendar years, and the respondents stated that they published 4.0 journal articles, or ten times more than according to the ISI figure. There are of course various systematic differences between the two data series,[5] but we cannot exclude the possibility of an overestimation by the SIBIS respondents.

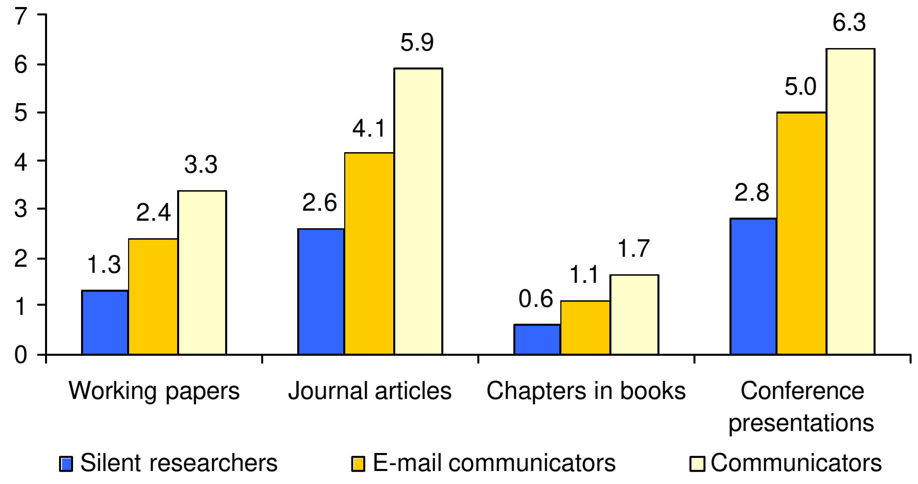
[Table 6]

The relationship between productivity and computer network use is positive (see table 6, figures 3 and 4), as in most previous analyses (Hesse et al. 1993, pp. 95-96; Cohen 1996, p. 52; Kaminer and Braunstein 1998, p. 727; Walsh et al. 2000, p. 1304). Journal articles are clearly the most stable predictor of computer network use among the different publication forms considered. For journal articles, positive coefficients were found for the use of e-mail, the existence of a personal website and the use of e-journals to obtain information. In addition, evidence of a weak but significant non-linear effect was found. As already stated above, this could be due to three reasons: first, decreasing returns on Internet use may be responsible for less pronounced differences in internet use than would be expected from productivity differences alone; second, an alternative explanation would be a certain upper limit of time that scientists are willing to invest for communication and information

[5] These systematic differences are due to different sets of disciplines (only five in SIBIS versus all disciplines in ISI), the sets of journals included (scientists' own judgment in SIBIS, selected journal list in ISI), and counting procedures (fractional counting of co-authored articles in ISI and full counting in SIBIS).

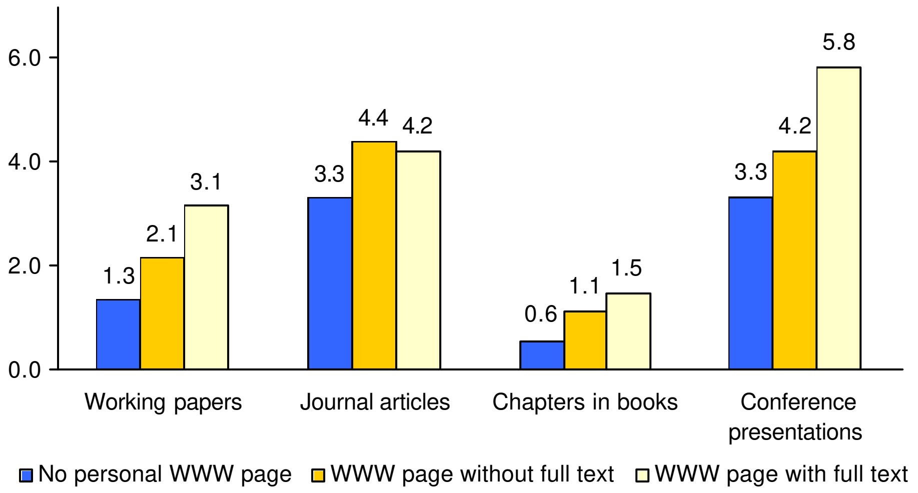
obligations, and therefore for the use of computer networks for these purposes; third, the result could be an artefact of the measurement of publications: in particular, the publication activity of researchers with many co-authored articles is overestimated because of the full counting method. Their Internet use, however, is measured correctly. Given the available information, it is not possible to determine which explanation is valid. Unfortunately, our data does not permit any conclusions about the direction of the relationship between Internet use and productivity either. Last but not least, in our view it is interesting to note that the use of personal websites (both as author/producer and as user) is correlated with the number of conference presentations (see figure 4). This points to an electronically enhanced communication model and the greater importance of self-publishing for some scientists.

Figure 3: Publications in 2001 and 2002 by type and communication group



Source: SIBIS R&D survey.

Figure 4: Publications in 2001 and 2002 by type and use of the WWW



Source: SIBIS R&D survey.

Attitude and skills: The respondents were asked about the relevance of the Internet in general, and the WWW and e-mail in particular, for selecting R&D topics. Positive statements about the WWW and the Internet as a tool for staying up-to-date correlate particularly well with the use of Internet tools for obtaining information. The statement about the usefulness of e-mail communication for obtaining new research ideas correlates with e-mail use. Hence, we find that the previously established relationship between attitudes and use schemes still holds (see e.g. Holmquist 1997, http://www.eso.org/gen-fac/libraries/lisa3/holmquistj.html; Day and Bartle 1998, http://sosig.ac.uk/iriss/papers/paper06.htm; Mitra et al. 1999, http://www.ascusc.org/jcmc/vol4/issue3/mitra.html; Lenares 1999, http://www.ala.org/ala/acrl/acrlevents/lenares99.pdf).

[Table 7]

Whenever it was significant, the computer skills variable also showed the expected positive relationship. The higher the computer skills of a respondent, i.e. the more sophisticated the software they use, the more they use e-mail for social communication, the more likely they are to have a personal website and the more often they use peers' web pages for obtaining information.

6 Summary and conclusions

The empirical analysis showed that Internet use has become a ubiquitous feature of European science. Some of the results which were based on previous, mainly US-based research were corroborated and others were not. This might be attributable to country idiosyncrasies: the intensity of Internet use also differs across the countries of the dataset. However, we prefer a different explanation: The widespread diffusion of the Internet in industrialised countries has also changed its role in scientific R&D in some respects. We therefore have to review some of the older results.

Based on theories of scientific knowledge production, the *ex-ante* expectations are that professional status, productivity and collaboration activities would contribute to explaining the use of computer networks in science. These expectations were partially confirmed: productive scientists use the Internet more than average for all the investigated purposes (social communication, information retrieval and dissemination). Above all journal articles and conference presentations are significant predictors of Internet use. The number of conference presentations correlates in particular with the use of the Internet for disseminating research results. This points toward a computer-based model of self-publication which represents a substantially new mode of communication in science. For the variables journal articles and conference presentations, a slight non-linear effect on Internet use is also evident. Highly productive scientists do not use the Internet as much as their publication activities would suggest. This could be due to decreasing returns on Internet use and/or a certain time limit for communication and information-related activities.

Scientists who collaborate also use the Internet more often than scientists who do not. This applies not only to Internet-based communication tools but also to applications which are essentially used for obtaining or disseminating information. The more collaborators scientists have, the more intensively they use the Internet. However, the relationship is U-shaped: scientists with very large collaboration networks don't use computer networks much more than scientists with moderately sized collaboration networks.

In general, the results support the assumption that invisible colleges have integrated the Internet into their communication practices. Hence, everybody who wants to stay at the forefront of research and keep up-to-date with developments in their research field has to use the Internet. Scientists who belong to rather disadvantaged groups in terms of access to information do not use the Internet more often than established academics. An equalizing effect of the Internet cannot therefore be corroborated. Even the idea that traditional information sources have become less important and that equality of access to on-line sources improves the situation for unknown researchers is not supported in any particular measure: The analysis also shows that the quality of the infrastructure (computers, network access) does affect the use of Internet applications. And it can be assumed that established academics tend to have better computer equipment and network access than their less established co-workers.

Another finding of the analysis is that social scientists have caught up with the sciences in terms of e-mail and World Wide Web use. Academic disciplines differ to some extent in regard to the overall use of Internet applications – in our dataset, computer scientists and astronomers use Internet applications more intensively than chemists, economists and psychologists. Apart from these general differences it becomes clear that different disciplines have integrated the Internet differently into their communication habits: for instance computer scientists rely more heavily on personal sources like their peers whereas astronomers prefer impersonal sources such as libraries or electronic journals for sourcing information.

The analysis was based on a cross-section of nearly 1,500 scientists from seven European countries and five academic disciplines. In order to better understand the use of Internet applications in science it is worth broadening the scope, both in terms of countries and disciplines. Moreover, it would also be beneficial to incorporate time series and panel analyses in the future. These are necessary in order to reliably determine the effects of Internet use which are often – and also in the present analysis – beyond the scope of the available empirical data.

References

Abels, E.G.; Liebscher, P.; Denman, D. W. (1996): Factors that influence the use of electronic networks by science and engineering faculty at small institutions. Part I: Queries, in: Journal of the American Society for Information Science, vol. 47, pp. 146-158.

Barjak, F; Harabi, N. (2004): The Internet in public science. Deliverable 5.2 of the SIBIS project in the topic area of the Internet in R&D (unpublished report at (http://www.empirica.biz/sibis/files/WP5_No2_R_and_D_II.pdf, prior registration required).

Brockman, W. S.; Neumann, L.; Palmer, C. L.; Tidline, T. J. (2001): Scholarly Work in the Humanities and the Evolving Information Environment. Digital Library Federation: Washington D.C. (available at: http://www.clir.org/pubs/reports/pub104/contents.html).

Brown, C. D. (2001): The role of computer-mediated communication in the research process of music scholars: an exploratory investigation, in: Information Research, vol. 6, no. 2. (http://informationr.net/ir/6-2/paper99a.html).

Butterworth, I. (1998): The impact of electronic publishing on the academic community an international workshop org. by the Academia Europaea and the Wenner-Gren Foundation. London [etc.]: Portland Press.

Callon, M. (1995): Four models for the dynamics of science, in: Jasanoff, S.; Markle, G.E.; Petersen, J.C.; Pinch, T. (eds.): Handbook of science and technology studies. 2nd edition. Sage: Thousand Oaks, London, New Delhi, pp. 29-63.

Carley, K.; Wendt, K. (1991): Electronic mail and scientific communication. A study of the SOAR extended research group, in: Knowledge: Creation, Diffusion, Utilization, vol. 12, no. 4, pp. 406-440.

Clark, B. R. (1995): Places of inquiry: research and advanced education in modern universities. University of California Press: Berkeley.

Cohen, J. (1996): Computer mediated communication and publication productivity among faculty, in: Internet Research: Electronic Networking Applications and Policy, vol. 6, no. 2/3, pp. 41-63.

Crane, D. (1972): Invisible colleges. Diffusion of knowledge in scientific communities. Chicago and London.

Daft, R.L. and Lengel, R.H. (1984): Information richness: A new approach to managerial behaviour and organisational design, in: Cummings, L.L., Staw, B.M. (Eds): Research in Organizational Behavior, vol. 6, pp. 191-233.

Day, J.; Bartle, C. (1998): The Internet as an Electronic Information Service: Its Impact on Academic Staff in Higher Education. Proceedings IRISS'98 International Conference: 25-27 March 1998, Bristol, UK. (http://sosig.ac.uk/iriss/ papers/paper06.htm).

Dubrovsky, V.; Kiesler, S.; Sethna, B. (1991): The equalization phenomenon: Status effects in computer-mediated and face-to-face decision making groups, in: Human-Computer Interaction, vol. 6, no. 1, pp. 119-146.

European Commission (2003): Third European Report on Science & Technology Indicators 2003 - Towards a knowledge-based economy. European Commission: Brussels.

European Technology Assessment Network (ETAN) (1999): Transforming European science through information and communication technologies: challenges and opportunities of the digital age. Final version.

Finholt, T.A. (2001): Collaboratories, in: B. Cronin (Ed.): Annual Review of Information Science and Technology, vol. 36. (also available at: http://intel.si.umich.edu/crew/technical_reports_alphabetical.htm).

Finholt, T.A.; Rocco, E.; Bree, D.; Jain, N.; Herbsleb, J.D. (1998): NotMeeting: A field trial of NetMeeting in a geographically distributed organization, in: SIGGROUP BULLETIN, vol. 20, no. 1, pp. 66-69. (http://www.bell-labs.com/org/11359/colab_prod/).

Frank, S. (2003): R&D expenditure and personnel in Europe: 1999-2001, in: Statistics in focus, Theme 9, no. 3/2003.

Fulk, J.; Schmitz, J.; Steinfield, C.W. (1990): A social influence model of technology use, in: Fulk, J.; Steinfield, C. (eds.): Organizations and communication technology. Sage: Newbury Park, London, New Delhi, pp. 117-140.

Garvey, W. D. (1977): Communication: the essence of science. Facilitating information exchange among librarians, scientists, engineers and students. Pergamon Press: Oxford.

Garvey, William D.; Griffith, Belver C. (1972): Communication and information processing within scientific disciplines: empirical findings for psychology, in: Information Storage and Retrieval, vol. 8, pp. 123-136.

Ginsparg, P. (1994): First steps towards electronic research communication, in: Computers in Physics, vol. 8, no. 4, pp. 390-396.

Hagstrom, W.O. (1965): The scientific community. Basic books: New York.

Harnad, S. (1991): Post-Gutenberg galaxy: the fourth revolution in the means of production of knowledge, in: Public-Access Computer Systems Review, vol. 2, no. 1, pp. 39-53 (also available at: http://cogsci.soton.ac.uk/harnad/Papers/Harnad/harnad91.postgutenberg.html).

Harnad, S. (1997): The Paper House of Cards (And Why It is Taking So Long to Collapse), in: Ariadne, vol. 8, pp. 6-7. (also available at: http://www.ukoln.ac.uk/ariadne/issue8/harnad).

Herbsleb, J.D.; Mockus, A.; Finholt, T.A.; Grinter, R.E. (2000): Distance, Dependencies, and Delay in a Global Collaboration, in: Proceedings of CSCW 2000, Philadelphia, PA, Dec. 2-7, 2000. (http://www-2.cs.cmu.edu/~jdh/collaboratory/research_papers/cscw_delay.pdf).

Hesse, B. W.; Sproull, L. S.; Kiesler, S. B.; Walsh, J. P. (1993): Returns to science: Computer networks in oceanography, in: Communications of the ACM, vol. 36, no. 8, pp. 90-101.

Hilgartner, S. (1995): Biomolecular database - new communication regimes for biology?, in: Science communication, vol. 17, no. 2, pp. 240-263.

Hiltz, S. R. (1984): Online communities. A case study of the office of the future. Alex Publishing Corporation: Norwood.

Hiltz, S.R.; Turoff, M. (1993): The Network Nation: Human Communication via Computer. 2nd edition, Cambridge, Mass.: MIT Press.

Holmquist, J. E. (1998): Survey on the Use of Electronic Journals at Princeton (1997), in: Grothkopf, U.; Andernach, H.; Stevens-Rayburn, S.; Gomez, M. (eds.): Library and Information Services in Astronomy III. ASP Conference Series, Vol. 153. (http://www.eso.org/gen-fac/libraries/lisa3/holmquistj.html).

Hurd, J.M. (1996): Models of scientific communication systems, in: Crawford, S.Y.; Hurd, J.M.; Weller, A.C. (eds.): From print to electronic: the transformation of scientific communication. Information Today Inc.: Medford NJ, pp. 9-33.

Kaminer, N.; Braunstein, Y.M. (1998): Bibliometric analysis of the impact of Internet use on scholarly productivity, in: Journal of the American Society for Information Science, vol. 49, no. 8, pp. 720-730.

Kircz, J.G. (1998): Changing Presentations! Changing Science? Colloquium “L'écrit de la science/Writing Science” organised by the journal “Alliage” for The European Science & Technology Forum of the European Commission (DG XII), Nice 12-14 March 1998. (http://www.science.uva.nl/projects/commphys/papers/nicem.htm).

Kling, R.; Callahan, E. (2001): Electronic Journals, the Internet, and Scholarly Communication. (http://www.slis.indiana.edu/csi/WP/wp01-04B.html).

Kling, R.; Kraemer, K. L.; Allen, J. P.; Bakos, Y.; Gurbaxani, V.; Elliott, M. (1996): Transforming Coordination: The Promise and Problems of Information Technology in Coordination. (http://www.slis.indiana.edu/kling/pubs/CTCT97B.htm).

Kling, R.; McKim, G. (2000): Not just a matter of time: Field differences and the Shaping of Electronic Media in Supporting Scientific Communication, in: Journal of the American Society for Information Science, vol. 51, no. 14, pp. 1306-1320. (also available at: http://xxx.lanl.gov/ftp/cs/papers/9909/9909008.pdf).

Knorr-Cetina, K. (1981): The Manufacture of Knowledge. An Essay on the Constructivist and Contextual Nature of Science. Pergamon Press: Oxford et al.

Knorr-Cetina, K. (1983): The ethnographic study of scientific work: towards a constructivistic interpretation of science, in: Knorr-Cetina, K.; Mulkay, M. (eds.): Science Observed. Perspectives on the Social Studies of Science. Sage: London, pp. 115-140.

Koku, E.; Nazer, N.; Wellman, B. (2001): Netting Scholars: Online and Offline, in: American Behavioral Scientist, vol. 44, no. 10, pp. 1752-1774.

Kraut, R.E.; Egido, C.; Galegher, J. (1990): Patterns of contact and communication in scientific research collaboration, in: Kraut, R.E.; Egido, C.; Galegher, J. (eds.): Intellectual teamwork. Social and technological foundations of cooperative work. Lawrence Erlbaum Associates: Hillsdale, pp. 149-171.

Kuhn, T.S. (1996): The structure of scientific revolutions. 3rd edition, University of Chicago Press: Chicago and London.

Latour, B.; Woolgar, S. (1979): Laboratory life. The social construction of scientific facts. Sage Publications: Beverly Hills and London.

Lazinger, S.S.; Bar-Ilan, J.; Peritz, B.C. (1997): Internet use by faculty members in various disciplines: a comparative case study, in: Journal of the American Society for Information Science, vol. 48, no. 6, pp. 508-518.

Leiner, B.M. et al. (2000): A Brief History of the Internet. (http://www.isoc.org/internet/history/brief.shtml).

Lenares, D. (1999): Faculty use of electronic journals at research institutions, in: Proceedings of the ACRL Ninth National Conference. (http://www.ala.org/ala/acrl/acrlevents/lenares99.pdf).

Liebscher, P.; Abels, E: G.; Denman, D. W. (1997): Factors that influence the use of electronic networks by science and engineering faculty at small institutions. Part II: Preliminary use indicators, in: Journal of the American Society for Information Science, vol. 48, no. 6, pp. 496-507.

Lievrouw, L. (1988): Four programs of research in scientific communication, in: Knowledge in Society, vol. 1, no. 2, pp. 6-22.

Lievrouw, L. A.; Carley, K. (1990): Changing patterns of communication among scientists in an era of "telescience", in: Technology in Society, vol. 12, pp. 457-477.

Mark, G; Grudin, J.; Poltrock, S. E. (1999): Meeting at the Desktop: An Empirical Study of Virtually Collocated Teams, in: Proceedings of ECSCW'99, The 6th European Conference on Computer Supported Cooperative Work, 12-16 September 1999, Copenhagen, Denmark, pp. 159-178. (http://research.microsoft.com/users/jgrudin/)

Merton, R. (1942): Social Theory and Social Structure. Free Press: New York.

Merz, M. (1998): 'Nobody Can Force You When You Are Across the Ocean' - Face to Face and E-Mail Exchanges between Theoretical Physicists, in: Crosbie Smith and Jon Agar (eds.): Making Space for Science: Territorial Themes in the Shaping of Knowledge. Macmillan: London, pp. 313-329.

Mitra, A.; Hazen, M. D.; LaFrance, B.; Rogan, R. G. (1999): Faculty Use and Non-Use of Electronic Mail: Attitudes, Expectations and Profiles, in: Journal of Computer-Mediated Communication, vol. 4, no. 3. (http://www.ascusc.org/jcmc/vol4/issue3/mitra.html).

Mulkay, M. (1977): Sociology of the scientific research community, in: Spiegel-Rösing, I.; Price, D. de Solla (eds.): Science, technology and society. A cross-disciplinary perspective. Sage: London and Beverly Hills, pp. 93-148.

Mulkay, M.J.; Gilbert, G.N.; Woolgar, S. (1975): Problem areas and research networks in science, in: Sociology, vol. 9, pp. 187-203.

National Science Board (2002): Science & engineering indicators 2002. Arlington, Va. (http://www.nsf.gov/sbe/srs/seind02/pdfstart.htm).

Nentwich, M. (2003): Cyberscience – Research in the age of the Internet. Vienna: Austrian Academy of Sciences Press.

Noam, E. M. (1995): Electronics and the Dim Future of the University, in: Science, vol. 270, pp. 247-249.

Odlyzko, A. (2001): The rapid evolution of scholarly communication. (http://www.dtc.umn.edu/~odlyzko/doc/rapid.evolution.pdf).

OECD (1998): The Global Research Village: How Information and Communication Technologies Affect the Science System, Paris. (http://www.oecd.org/dataoecd/9/30/2754574.pdf).

Olson, G.M.; Olson, J.S. (2002): Distance matters, in: John M. Carroll (ed.): Human-Computer Interaction in the New Millennium. Addison-Wesley, pp. 139-179.

Price, D. J. de Solla; Beaver, D. (1965): Collaboration in an invisible college, in: American Psychologist, vol. 21, no. 11, pp. 1011-1018.

Ravetz, J. (1971): Scientific knowledge and its social problems. Clarendon Press: Oxford.

Rusch-Feja, D.; Siebeky, U. (1999): Evaluation of Usage and Acceptance of Electronic Journals: Results of an Electronic Survey of Max Planck Society Researchers including Usage Statistics from Elsevier, Springer and Academic Press (Full Report), in: D-Lib Magazine, vol. 5, no. 10. (http://www.dlib.org/dlib/october99/rusch-feja/10rusch-feja-full-report.html).

Sanderson, D. (1996): Cooperative and collaborative mediated research, in T. M. Harrison and T. D. Stephen (eds.): Computer Networking and Scholarly Communication in the 21st Century University, New York, pp. 95-114.

Steinmueller, W.E. (2001): ICTs and the possibilities for leapfrogging by developing countries, in: International Labour Review, vol. 140, no. 2, pp. 193-210.

Stevens-Rayburn, S.; Bouton, E. N. (1998): "If it's not on the Web, it doesn't exist at all": Electronic Information Resources - Myth and Reality, in: Grothkopf, U.; Andernach, H.; Stevens-Rayburn, S.; Gomez, M. (eds.): Library and Information Services in Astronomy III. ASP Conference Series, Vol. 153. (http://www.eso.org/gen-fac/libraries/lisa3/stevens-rayburns.html).

Tenopir, C.; King, D.W. (2000): Towards Electronic Journals: Realities for Scientists, Librarians, and Publishers. Washington, D.C.: Special Libraries Association.

Tibbo, H. (1991): Information systems, services and technology for the humanities, in: Annual Review of Information Science and Technology, vol. 26, pp. 287-346.

Trevino, L.K.; Daft, R.L.; Lengel, R.H. (1990): Understanding manager's media choices: a symbolic interactionist perspective, in: Fulk, J.; Steinfield, C. (eds.): Organizations and communication technology. Sage: Newbury Park, London, New Delhi, pp. 71-94.

Van Alstyne, M.; Brynjolfsson, E. (1996): Could the Internet Balkanize Science?, in: Science, vol. 274, no. 5292, pp. 1479-1480.

Van Leeuwen, T. N.; Moed, H. F.; Tijssen, R. J. W.; Visser, M. S.; van Raan, A. F. J. (2001): Language biases in the coverage of the Science Citation Index and its consequences for international comparisons of national research performance, in: Scientometrics, vol. 51, no. 1, pp. 335-346.

Walsh, J. P.; Bayma, T. (1996a): The Virtual College: Computer-Mediated Communication and Scientific Work, in: The Information Society, vol. 12, pp. 343-363.

Walsh, J. P.; Bayma, T. (1996b): Computer networks and scientific work, in: Social Studies of Science, vol. 26, pp. 661-703.

Walsh, J.P.; Roselle, A. (1999): Computer Networks and the Virtual College, in: STI Review No. 24: Special Issue on the Global Research Village. Paris, pp. 49-77.

Walsh, J. P.; Kucker, S.; Maloney, N.; Gabbay, S. (2000): Connecting minds: CMC and scientific work, in: Journal of the American Society for Information Science, vol. 51, pp. 1295-1305.

Whitley, R. (2000): The intellectual and social organization of the sciences. 2nd edition. University Press: Oxford.

Ziman, J. (1994): Prometheus bound. Science in a dynamic steady state. Cambridge.

Zuckerman, H. (1988): The sociology of science, in: Smelser, N. J. (ed.), Handbook of sociology. Newbury Park, pp. 511-574.

Annex

Table A-1: Nominal variables of the analysis

Variable	n	Total valid N	Percentage
Country of the organisation			
Switzerland	232	1482	15.7
Germany	281	1482	19.0
Denmark	183	1482	12.3
Italy	307	1482	20.7
Ireland	154	1482	10.4
The Netherlands	144	1482	9.7
United Kingdom	177	1482	11.9
Other countries	4	1482	0.3
Individual WWW presentation	1003	1455	68.9
Thereof having working papers, articles, hyperlinks included	482	1010	47.7
Clusters of communication media use			
Silent researchers	594	1433	41.5
E-mail communicators	404	1433	28.2
Communicators	435	1433	30.4
Type of organisation			
University or technical university	1206	1481	81.4
Non-university research institute	202	1481	13.6
Polytechnic/university of applied sciences	44	1481	3.0
Other	29	1481	2.0
Discipline of R&D			
Astronomy	191	1475	12.9
Chemistry	284	1475	19.3
Computer Science	261	1475	17.7
Psychology	277	1475	18.8
Economics	307	1475	20.8
Other disciplines	155	1475	10.5
Current position from an R&D perspective			
Research Manager	281	1468	19.1
Senior Researcher	656	1468	44.7
Junior Researcher	493	1468	33.6
Other positions	38	1468	2.6
Gender			
Male	1130	1479	76.4
Female	349	1479	23.6
Involved in R&D collaborations	1116	1451	76.9

Table A-2: Variables of the analysis with ordinal and rational scales

Variable	Total valid N	Arithmetic mean	Standard deviation
Computer-mediated communication (CMC) index (range 0-100)	1431	32.05	10.31
Index of usage of on-line information sources (range 0-100)	1271	46.71	5.89
Internet access to the important information sources (range 1-4)	1465	3.70	0.55
Age	1476	42.88	11.90
Total number of collaboration partners	1408	14.83	30.21
Number of co-authors	1372	1.96	3.24
Percentage of coauthored journal articles (range 0-100)	1031	82.74	31.73
Publications			
Working papers total	1416	2.23	4.16
Journal articles, total	1435	4.01	5.23
Chapters in books	1439	1.06	2.09
Monographs	1438	0.25	0.78
Presentations at scientific conferences	1433	4.48	5.29
Reports	1428	1.26	3.42
New ideas for new research through browsing the WWW (range 1-5)	1473	2.59	1.39
Considers whether the Internet supports realisation of R&D (range 1-5)	1465	2.54	1.43
Internet used to stay up-to-date and focus the R&D (range 1-5)	1473	3.73	1.28
New ideas for R&D through e-mail communication (range 1-5)	1470	3.05	1.27
Use of electronic journals for obtaining scientific information (range 0-3)	1462	2.18	0.82
Use of peers' websites for obtaining scientific information (range 0-3)	1383	1.48	0.88
Computer quality index (range 0-5)	1456	2.49	0.92
Scientific recognition (range 0-4)	1476	1.04	1.18
Level of computer skills (range 0-3)	1473	2.25	0.80

Table A-3: Technical results of the estimations

	Type of model	Number of observations	Log-L(0)	Log-L
Social communication				
E-mail communicators, Communicators	Multinomial logit	1223	-1318.912	-1019.855
CMC Index	Tobit	1255	-	-4575.856
Information retrieval				
On-line information index	Tobit	1111	-	-3452.839
E-journals	Ordered probit	1245	-1395.475	-1206.927
Peers' web pages	Ordered probit	1181	-1439.038	-1318.644
Information dissemination				
Individual WWW page	Logit	1262	-778.7094	-634.6376
Full text articles or links on the web site	Logit	882	-609.7017	-461.8807

Log-L(0): Restricted log likelihood, Log-L: log likelihood

Tables

Table 1: Country parameters from the estimations

	Social communication			Information retrieval			Information dissemination	
	E-mail communicators	Communi-cators	CMC Index	On-line information index	E-journals	Peers' web pages	Individual WWW page	Full text articles or links on the web site
Switzerland	.	.	.	.	.	.	.	.
Germany	–*	+	–*	–‡	–**	–	–	+
Denmark	–	–	+	–‡	–	–*	+	+**
Italy	–	+‡	+	+	–	–*	–**	–
Ireland	–*	–	+*	–	–*	–*	–*	–
The Netherlands	–	–	+	–	–	–**	–**	+
UK	+‡	–	+**	+	–	–*	–	+

Reference groups: respondents from Switzerland, for 'e-mail communicators' and 'communicators' also the 'silent scientists'.
+ Positive coefficient, – negative coefficient; significance levels: ** p < 0.01, * p < 0.05, ‡ p < 0.1 (significant coefficients are bold)

Table 2: Parameters for infrastructure variables

	Information retrieval			Information dissemination	
	On-line information index	E-journals	Peers' web pages	Individual WWW page	Full text articles or links on the web site
Computer quality index	+	**+****	+	**+***	+
Internet access to important information sources	**+****	**+****	**+****	+	+
Organisation of the respondent					
University	.	.	.	.	.
Non-university research institutes	+	+	–	–	–
University of applied sciences	**+***	+	–	**–****	+
Others (multinatl. org., government, business)	–	–	+	**–****	+
Size of the organisation	**+****	–	+	**+ ǂ**	–

Reference group: university scientists

+ Positive coefficient, – negative coefficient; significance levels: ** p < 0.01, * p < 0.05, ǂ p < 0.1 (significant coefficients are **bold**)

Table 3: Parameters for academic disciplines

	Social communication			Information retrieval			Information dissemination	
	E-mail communicators	Communicators	CMC Index	On-line information index	E-journals	Peers' web pages	Individual WWW page	Full text articles or links on the web site
Astronomy	**–***	**–****	+	**+****	**+****	–	**–****	**+***
Chemistry	**–****	**–****	**–****	+	**+****	**–ǂ**	**–***	**–ǂ**
Computer Science	–	**–***	**+****	**+****	**–****	**+****	**+***	**+****
Economics	**–****	**–****	+	**+****	**+****	**+****	**+***	**+****
Psychology	.	.	.	.	.	.	.	.
Other disciplines	**–ǂ**	**–ǂ**	+	+	+	**–***	–	**+ǂ**

Reference groups: psychologists, for 'e-mail communicators' and 'communicators' also the 'silent scientists'.

+ Positive coefficient, – negative coefficient; significance levels: ** p < 0.01, * p < 0.05, ǂ p < 0.1 (significant coefficients are **bold**)

Table 4: Parameters for status groups

	Social communication			Information retrieval			Information dissemination	
	E-mail communicators	Communi-cators	CMC Index	On-line information index	E-journals	Peers' web pages	Individual WWW page	Full text articles or links on the web site
Position in regard to R&D								
R&D manager	+*	+**	+ ‡	+*	+	+ ‡	+*	+
Senior researcher	+**	+**	+*	+**	+ ‡	+ ‡	+*	+
Junior researcher	.	.	.	.	.	.	.	.
Age	–*	–*	–*	–**	–**	–	–	–*
Gender								
Female	.	.	.	.	.	.	.	.
Male	–	+	–	–	–	+ ‡	+*	+**
Academic recognition	+	+**	+	+	+	+	+*	–

Reference groups: junior researchers, females, for 'e-mail communicators' and 'communicators' also the 'silent scientists'.

+ Positive coefficient, – negative coefficient; significance levels: ** p < 0.01, * p < 0.05, ‡ p < 0.1 (significant coefficients are **bold**)

Table 5: Parameters for the collaboration variables

	Social communication			Information retrieval			Information dissemination	
	E-mail communicators	Communicators	CMC Index	On-line information index	E-journals	Peers' web pages	Individual WWW page	Full text articles or links on the web site
Collaborative R&D	–	–	**+****	+	**+***	+	**+****	+
Size of network	**+****	**+****	+	–	**–****	+	**+ǂ**	**–****
(Size of network)^2	**–***	**–****	–	+	**+***	–	**–ǂ**	+

Reference group for 'e-mail communicators' and 'communicators' the 'silent scientists'

+ Positive coefficient, – negative coefficient; significance levels: ** $p < 0.01$, * $p < 0.05$, ǂ $p < 0.1$ (significant coefficients are **bold**)

Table 6: Parameters for productivity

	Social communication			Information retrieval			Information dissemination	
	E-mail communicators	Communicators	CMC Index	On-line information index	E-journals	Peers' web pages	Individual WWW page	Full text articles or links on the web site
Working papers	**+***	**+****	.	.	.	.	.	.
Articles in scientific journals	**+***	**+****	**+ ǂ**	+	**+****	+	**+***	–
(Articles in scientific journals)[2]	–	–	–	.	**–****	.	**–ǂ**	+
Book chapters	+	+	.	.	.	.	**+***	.
Monographs	–	–	.	.	.	.	.	.
Conference presentations	**+***	+	.	.	**+***	**+***	+	**+****
(Conference presentations)[2]	–	–	.	.	**–***	–	.	.
Reports	–	+	.	.	.	.	.	.

Reference group for 'e-mail communicators' and 'communicators' the 'silent scientists'

+ Positive coefficient, – negative coefficient; significance levels: ** p < 0.01, * p < 0.05, ǂ p < 0.1 (significant coefficients are **bold**)

Table 7: Parameters for attitude and skills

	Social communication			Information retrieval			Information dissemination	
	E-mail communicators	Communicators	CMC Index	On-line information index	E-journals	Peers' web pages	Individual WWW page	Full text articles or links on the web site
Get ideas while browsing the WWW	+	+	+	**+***	**+****	**+****	.	.
Consider the Internet in project planning	+	+	–	–	–	**–****	.	–
Use the Internet to stay up-to-date and focus the R&D	+	+	+	**+****	**+****	**+***	.	**+****
Get ideas from e-mail communication	**+****	**+****	**+****	–	–	**+****	**+***	.
Computer skills	**+ǂ**	–	**+ǂ**	+	+	**+***	**+***	+

Reference group for 'e-mail communicators' and 'communicators' the 'silent scientists'

+ Positive coefficient, – negative coefficient; significance levels: ** $p < 0.01$, * $p < 0.05$, ǂ $p < 0.1$ (significant coefficients are **bold**)

Publications to date:

In Series A 'Discussion Papers' of Solothurn University of Applied Sciences Northwestern Switzerland, the following publications have appeared:

DPW	No. 98-01	THOMAS M. SCHWARB (July 1998) «Ich verpfeife meine Firma»... Einführung in das Phänomen «Whistle-Blowing».
DPW	No. 98-02	MATHIAS BINSWANGER (December 1998) Stock Market Booms and Real Economic Activity: Is this Time different?
DPW	No. 98-03	GÜNTER SCHINDLER (December 1998) Unscharfe Klassifikation durch kontextbasierte Datenbankanfragen.
DPW	No. 99-01	MATHIAS BINSWAGER (January 1999) Co-Evolution Between the Real and Financial Sectors: The Optimistic «New Growth Theory» View versus the Pessimistic «Keynesian View».
DPW	No. 99-02	MATHIAS BINSWANGER (June 1999) Die verschiedenen Rollen des Finanzsektors in der wirtschaftlichen Entwicklung.
DPW	No. 99-03	LORENZ M. HILTY (June 1999) Individuenbasierte Verkehrssimulation in Java.
DPW	No. 99-04	ALBERT VOLLMER (June 1999) Mobile Arbeit in der Schweiz – Telearbeit und Desksharing.
DPW	No. 99-05	NAJIB HARABI (July 1999) The Impact of Vertical R&D Cooperation on Firm Innovation: an Empirical Investigation.
DPW	No. 99-06	MAIKE FRANZEN (July 1999) Konstruktives Lernen mit dem E-Book. Entwicklung einer Lernumgebung für konstruktives Lernen.
DPW	No. 99-07	MATHIAS BINSWANGER (December 1999) Technological Progress and Sustainable Development: Different Perspectives on the Rebound Effect.
DPW	No. 2000-01	LORENZ M. HILTY, THOMAS RUDDY, DANIEL SCHULTHESS (January 2000) Resource Intensity and Dematerialization Potential of Information Society Technologies.
DPW	No. 2000-02	LORENZ M. HILTY, ALBERT VOLLMER, DANIEL SCHULTHESS, THOMAS RUDDY (February 2000) Lifestyles, Mobility and the Challenge of Sustainability: A Survey of the Literature.
DPW	No. 2000-03	LORENZ M. HILTY, THOMAS RUDDY (May 2000) The Information Society and Sustainable Development.
DPW	No. 2000-04	ROLF MEYER, NAJIB HARABI (June 2000) Frauen Power unter der Lupe. Geschlechtsspezifische Unterschiede der Jungunternehmerinnen und -unternehmer. Ergebnisse einer empirischen Untersuchung.

Publications to date:

DPW	No. 2000-05	ROLF MEYER, MARION ALT, KERSTIN HÜFFMEYER, NAJIB HARABI (June 2000) Selbständigerwerbende und ihre jungen Unternehmen – 9 Fallbeispiele.
DPW	No. 2000-06	NAJIB HARABI, ROLF SCHOCH, FRANK HESPELER (August 2000) Einführung und Verbreitung von Electronic Commerce. Wo steht die Schweiz heute im internationalen Vergleich? Ergebnisse einer empirischen Untersuchung.
DPW	No. 2000-07	NAJIB HARABI (December 2000) Employment Effects of Eco-Innovations: An Empirical Analysis.
DPW	No. 2001-01	ROLF MEYER, NAJIB HARABI, RUEDI NIEDERER (January 2001) Der Einfluss der Beratung, Weiterbildung und des Beziehungsnetzes auf den Erfolg junger Unternehmen.
DPW	No. 2001-02	NAJIB HARABI (January 2001) Introduction and Diffusion of Electronic Commerce – What is Switzerland's position in an international comparison? Results of an empirical study
DPW	No. 2001-03	NAJIB HARABI, HESPELER FRANK (February 2001) Electronic Commerce in der Schweiz: Lehren aus Einzelfallstudien
DPW	No. 2001-04	BINSWANGER MATHIAS (February 2001) Does the Stock Market Still Lead Real Activity? - An Investigation for the G-7 Countries
DPW	No. 2001-05	ZBINDEN DANIELA, MEYER PETER (February 2001) Wissensrisikomanagement - Ein Vorgehen zur Identifizierung und Bewertung von Wissensrisiken als Problemlösungsinstrument
DPT	No. 2001-06	GÖLDI SUSAN (July 2001) Kommunikative ingenieure - Bedeutung der sozialen Kommunikation im beruflichen Alltag von Ingenieuren und Ingenieurinnen und Folgen daraus für die Ingenieurausbildung (former DPT No. 2001-01)
DPT	No. 2001-07	MUHMENTHALER PETER (July 2001) Möglichkeiten und Grenzen des E-Business Bericht der Phase 1 des Forschungsprojektes (KTI 5212.1 FHS) des Bundesamtes für Berufsbildung und Technologie BBT. Thema: „Welche neuen Anforderungen stellt e-business an die logistische Systemtechnik?" (former DPT No. 2001-02)
DPW	No. 2001-08	NAJIB HARABI (August 2001) Formation of new businesses in Switzerland – An empirical analysis (former DPW No. 2001-06)
DPS	No. 2001-09	CLAUDIA HOFMANN, EVA NADAI UND PROF. DR. PETER SOMMERFELD (NOVEMBER 2001) Verstecktes Leiden unter Armut. Wie betroffene Kinder und ihre Eltern die Situation wahrnehmen und bewältigen (former DPS No. 2001-01)
DPW	No. 2002-01	BINSWANGER MATHIAS (APRIL 2002) Time-saving innovations and their impact on energy use: Some lessons from a household-production-function approach
DPW	No. 2002-02	ROLF MEYER (June 2002) Neue Unternehmen in Liechtenstein: Was machen selbständige Frauen anders als Männer?

DPW	No. 2002-03	BINSWANGER MATHIAS, JOCHEM ANNETTE (December 2002) Nachhaltigkeit auf Kantonsebene am Beispiel der Staatsrechnung Aargau: Bericht für das Baudepartement des Kantons Aargau, Stabstelle Nachhaltigkeit
DPW	No. 2003-01	BINSWANGER MATHIAS (June 2003) Why Does Income Growth Fail to Make Us Happier? – Treadmills Behind The Paradox of Happiness
DPS	No. 2003-02	BAUMGARTNER EDGAR (OCTOBER 2003) **DER NUTZEN BETRIEBLIECHER SOZILABAREIT**
DPW	No. 2003-02	DORNBERGER ROLF (NOVEMBER 2003) **BIOMETRICS** – EIN ÜBERBLICK
DPS	No.2004-01	MEYER ROLF, KRATTIGER BARBARA (FEBRUARY 2004) **ANSTOSSFINANZIERUNG DES BUNDES FÜR FAMILIENERGÄNZENDE KINDERBETREUUNG** - QUO VADIS?
DPW	No. 2004-02	BARJAK FRANZ (MAI 2004) **ON THE INTEGRATION OF THE INTERNET INTO INFORMAL SCIENCE COMMUNICATION**

In Series B 'Reprints' of Solothurn University of Applied Sciences Northwestern Switzerland, the following publications have appeared:

SDW	No. 98-01	NAJIB HARABI (October 1998) Channels of R&D spillovers: An Investigation of Swiss Firms. Reprinted from: Technovation, 17 (11/12) (1997) 627–635.
SDW	No. 98-02	MAX ZUBERBÜHLER (October 1998) Virtualität – der zukünftige Wettbewerbsvorteil. Reprinted from: io Management, 67 (1998), 18–23.
SDW	No. 98-03	NAJIB HARABI (October 1998) Les facteurs déterminants de la R&D. Reprinted from: Revue française de gestion, n° 114, 1997, p. 39–51.
SDW	No. 98-04	NAJIB HARABI (December 1998) Innovation through Vertical Relations between Firms, Suppliers and Customers: a Study of German Firms. Reprinted from: Industry and Innovation, Volume 5, Number 2, pp. 157–178.
SDW	No. 99-01	CHRISTOPH MINNIG, RUEDI NIEDERER, THOMAS SCHWARB (January 1999) Imagestudie Erziehungsdepartement des Kantons Solothurn. A Study by order of Swiss Science and Technology Council and Commission for Technology and Innovation.
SDW	No. 99-02	NAJIB HARABI (January 1999) Der Beitrag von Profit- und Nonprofit-Organisationen zum technischen Forstschritt: Ergebnisse aus der Schweiz. Reprinted from: Wagner, R. (1997). Festschrift zum 60. Geburtstag von Antonin Wagner. Zürich: Turicum.

SDW	No. 99-03	LORENZ M. HILTY, KLAUS TOCHTERMANN, JÖRG VON STEINAECKER (July 1999) The Information Society and the Environment – A Survey of European Activities. Reprinted from: Proc. 1st International Environmental Management Systems Conference, Vienna/Austria 1998.
SDW	No. 99-04	THOMAS M. SCHWARB (August 1999) Das Arbeitszeugnis als Instrument der Personalpraxis. Reprinted from the dokumenation at the conference „Arbeitszeugnis" at Solothurn University of Applied Sciences Northwestern Switzerland, Olten.
SDW	No. 99-05	THOMAS M. SCHWARB, ALBERT VOLLMER (December 1999) Telearbeit Reprinter from: Schwarb Th. M. (ed.) (1999) Erfolgsfaktor Human Resource Management, Zürich: Weka.
SDW	No. 2000-01r	ROLF MEYER (February 2000 and April 2002) Die neuen Selbständigen (revised issue) A Study by order of NEFU (Netzwerk für Einfrau-Unternehmerinnen) Switzerland.
SDW	No. 2000-02	RUEDI NIEDERER, STEPHANIE GREIWE, CHRISTOPH MINNIG, THOMAS SCHWARB (March 2000) Projektmanagement – Praxis und Ausbildung. A Study by order of Universities of Applied Sciences and SwissPM.
SDW	No. 2000-03	THOMAS SCHWARB, STEPHANIE GREIWE, CHRISTOPH MINNIG, RUEDI NIEDERER (March 2000) Olten ist eigentlich schön, aber ... A Study of attractivity and image of Olten by order of the Project Olten Plus.
SDW	No 2000-04	THOMAS SCHWARB, ALBERT VOLLMER, RUEDI NIEDERER (March 2000) TA-Studie „Mobile Arbeitsformen: Verbreitung und Potenzial von Telearbeit und Desksharing" A Study by order of Swiss Science and Technology Council and Commission for Technology and Innovation.
SDW	No 2001-03	THOMAS SCHWARB, STEPHANIE GREIWE, RUEDI NIEDERER (December 2001) Erfolgs- und Kapitalbeteiligung von Mitarbeitenden in der Schweiz Repräsentative Unternehmensbefragung. Final report. A study by the Institute of Interdisciplinary Economic and Social Research (IWS).
SDW	No. 2000-05	THOMAS SCHWARB, STEPHANIE GREIWE, CHRISTOPH MINNIG, RUEDI NIEDERER (NOVEMBER 2000) Olten ist eigentlich schön, aber... A Study of the Attractiveness of Olten as a Residential and Industrial Location and of the Image of Olten under Contract from the Project Olten Plus (POP).
SDW	No. 2000-06	THOMAS SCHWARB, STEPHANIE GREIWE, CHRISTOPH MINNIG (NOVEMBER 2000) Ich gehe nach Olten einkaufen, wenn ... A Study of Shopping in Olten under Contract from the Project Olten Plus (POP).
SDW	No. 2000-07	THOMAS SCHWARB, STEPHANIE GREIWE (January 2001) Zofingen unter der Lupe. Study of the Situation of Shopping in Zofingen.

SDS No. 2001-01 EDGAR BAUMGARTNER, CLAUDIA HOFMANN, PROF. DR. PETER SOMMERFELD (March 2001)
Evaluation der SchülerMultiplikatoren-Kurse Alkohol und Tabak (SMAT) in Grenchen und Umgebung
A Study by order of Swiss Science and Technology Council and Commission for Technology and Innovation

SDS No. 2001-02 PETER SOMMERFELD, FRANZISKA JUNGCK (March 2001)
Beurteilung der Sozialhilfe im Kanton Solothurn durch ihre Klientinnnen und Klienten
A Study by order of the Department of communities and social security, welfare and asylum, Solothurn

SDW No. 2002-01 THOMAS SCHWARB, STEPHANIE GREIWE, ULRICH PEKRUHL (April 2002)
Unternehmensberatungsmarkt in der Schweiz
Final report. IWS-Study by order of Jobindex Media AG

SDW No. 2003-02 THOMAS SCHWARB, STEPHANIE GREIWE (JUNE 2003)
Lohn und Arbeit in der Schweiz
Representative Survey of Swiss Population. Final Report. IWS Study.

In Series C 'Guest Lectures' of Solothurn University of Applied Sciences Northwestern Switzerland, the following publications have appeared:

GVW No. 99-01 PATRIK DUCREY, BARBARA HÜBSCHER (July 1999)
Aktuelle Probleme der Wettbewerbspolitik
Lectured at University of Applied Sciences Solothurn Northwestern Switzerland on May 31st 1999.

GVW No. 2000-01 ANDY STURM (April 2000)
Grundlagen der schweizerischen Geldpolitik
Lectured at University of Applied Sciences Solothurn Northwestern Switzerland on April 14th 2000.

GVW No. 2000-02 PATRICIA SCHULTZ (September 2000)
Von Männern und Frauen in Arbeitswelt und Privatleben
Lectured at University of Applied Sciences Solothurn Northwestern Switzerland on February 22nd 2000.

GVW No. 2000-03 NILS GOLDSCHMIDT (September 2000)
Auf dem Weg zu einem kommunitaristischen Wohlfahrtsstaat. Ethische und ökonomische Anmerkungen zu einem nicht ganz neuen Leitbild
Lectured at University of Applied Sciences Solothurn Northwestern Switzerland on March 3rd 2000.

GVW No. 2000-04 ELISABETH JORIS (September 2000)
History and Herstory
Lectured at University of Applied Sciences Solothurn Northwestern Switzerland on November 30th 1999.

GVW No. 2001-01 URS WEBER (December 2000)
Die Rolle des Mittelstandes im ostdeutschen Transformatio nsprozess

Orders

Price per copy:	See our homepage **www.fhso.ch**
Send orders to:	University of Applied Sciences Northwestern Switzerland Solothurn Secretariate for Research & Development PO Box CH-4601 Olten Telephone: ++41 +848 821 011 Telefax: ++41 +62 296 65 01 E-Mail: ccc@fhso.ch

Bestellungen

Preis für ein Exemplar:	Die aktuellen Preise finden Sie auf unserer Homepage: **www.fhso.ch**
Bestellung bitte an:	Sekretariat Forschung & Entwicklung Postfach CH-4601 Olten Telefon: ++41 +848 821 011 Telefax: ++41 +62 296 65 01 E-Mail: ccc@fhso.ch