The Interrelationship between IPR and Standardisation: Patterns and Policies

Knut Blind and Eric Iversen

April 2004

Dr. Knut Blind
Fraunhofer Institute for Systems and Innovation Research
Breslauer Str. 48
76139 Karlsruhe
Germany
Email: k.blind@isi.fraunhofer.de
Phone: (+49)721 6809 212
Fax: (+49) 721 6809 260

Eric Iversen
STEP, Center for Innovation Research
Hammersborg torg 3,
N-0179 Oslo
Norway
Email: ericiv@step.no
Phone: (+47) 22 86 80 23
Fax: (+47) 22 86 80 49

Abstract

This paper takes a fresh and comprehensive look at how intellectual property rights (IPR) interact with formal standardisation activities. The interaction of these two institutions is integral to the working of the innovation infrastructure. Since the 1980s, this has especially been true for industries involving strong network effects where an increasing level of tension and conflict has been noted. The importance of the relationship and the tendency for the interaction to lead to conflict is however not necessarily confined to information and communication technologies, which has been the focus until now. The paper works from the premise that the interaction between IPRs and standardisation involves a more general strain in the innovation system and that this strain potentially has implications that extend well beyond a single industry.

In this light, the paper extends and broadens the existing analysis of this relationship in several fundamental ways. The paper's major contribution to the mainly theoretical treatment in the current literature is a two-pronged empirical analysis involving a survey and a set of 20 case-studies across a set of industries. This exploratory empirical approach provides an initial look at the potential for conflict in other industries where the balance between the importance of standardisation and the importance of patenting differ. The results from the complementary survey and case study work are then used to categorise the type of problems that emerge in a set of industries. In conclusion the paper discusses a set of policy approaches to the emerging problem in Europe.

1. Introduction

IPR regimes and formal standardisation are key institutions in the changing frame of the innovation system. Although their roles are inherently complementary here, we know that the relationship between them has become increasingly tense as the use— and the conditions of use— of each has changed during the past two decades. The "co-evolution" of these and other factors has brought patenting in particular onto a collision course with formal standardisation activities. This has led to an increasing number of conflicts and to new attempts to resolve them at different levels: at the institutional level (IPR policies), at the policy level (areas of competition, IPR, and standardisation policy), and in other multilateral contexts (patent pooling and other licensing schemes).

This situation represents an emerging area of discordination at a key juncture of the innovation system. However, the treatment of this important issue has by and large been limited in scope and perspective. The literature has first and foremost described and analysed the patent-based conflicts that have emerged in the area of information and communication technologies either in general theoretical (legal or economic) terms or in empirical treatments, mostly on a case to case basis. The issues are however not necessarily limited to the ICT field, although this is obviously an area where the drive towards patenting and towards standardisation are particularly strong. Nor is it necessarily confined to patents although this is the most obvious front for conflict where regards technological standardisation. Nor does it only involve the areas of standardisation, IPR, and competition policy, but may extend to research policy more generally.

This paper works from the premise that the interaction between IPRs and standardisation involves a more general strain in the innovation system, and that this strain potentially has implications that extend well beyond a single industry. This in turn suggests the need to broaden the frame of analysis and to direct increased policy attention to the complicated set of issues. In this context, the paper extends and broadens existing analysis of this relationship in several fundamental ways.[1] The paper is structured in the following way. The paper first takes stock of the issues, extending the exploration of the economic questions to further investigate the implications for public funding of research. The paper goes on to present the results of exploratory empirical work, which combines a survey and a set of 20 case studies based in different national and industrial contexts. This discussion considers lessons about the potential for conflict in different types of industries, while explicating the need to further improve the empirical work in the area. The paper finally discusses

---

1 The paper is based on information collected within a project funded by DG Research (EC Contract No G6MA-CT-2000-02001). See Blind et al. (2002), especially chapter D and E.

policy implications and a broad set of policy approaches while emphasising the need for further empirical analysis before drawing overly strong conclusions.

2. Issues in the interaction of IPRs and formal standardization

The interaction between formal standardization—particularly in standards development organizations—and IPRs— particularly the patent regime— involves fundamental issues in the economics of technological change. This section introduces the relationship in terms of the distinct roles they play in the "innovation infrastructure", presenting the case that a co-evolutionary process is bringing what are initially complementary functions in the innovation process into increased confrontation.

Innovation is a complex evolutionary process involving the sustainable generation, distribution and utilization of new economically-relevant knowledge. This knowledge continuously accumulates and is recombined in the economy[2], contributing significantly to economic growth. The evolutionary economics literature[3] points, in this setting, to the importance of two complementary processes: namely the generation of technological variety on the one hand and the selection process on the other. The interaction between technological diversification and a complementary selection process lays the basis for technological development. The process of diversification drives evolution. In the case of technology, this involves a purposeful search by economic actors to adapt new technologies with performance attributes that are intended to distinguish them from rivals. "Fitness" involves success in this venture, not in terms of survival of the fittest or of the "best technology", but in terms of success in navigating the selection environment.

Formatted: Don't adjust space between Latin and Asian text

To a degree the process of selection can then be said to steer evolution. However selection and diversity do not happen in isolation from one another, but rather in close interaction. The ultimate selection mechanism in market economies is the market, where the fitness of an individual technology comes down to the choice of consumers. In an ideal situation, a technological design may 'speciate' to cater to differentiated niches of heterogenous users. [4] However, many other factors may affect choices in the selection environment—for example network externalities will shape preferences and affect the diffusion of new technologies. The case of launching large technological system, like a cellular telecoms system, provides a special challenge in successfully navigating the selection environment. Coordination in developing and selection is especially needed here to concurrently design and select

Formatted: Don't adjust space between Latin and Asian text

---

2 See David and Foray (1995).

3 For a presentation of the issues and their genealogy see, Saviotti and Metcalfe(eds) (1991). Evolutionary Theories of Economic and Technological Change. Harwood Academic publishers: Switzerland.

4 For an evolutionary explanation of such processes see for example Frenken & Nuvolari (2003).

the large set of design dimensions involved which furthermore interact in complex ways.

This brief evolutionary explanation highlights the processes of search and of choice, both of which are unpredictable especially when one accepts that they interact. This distinction between search and selection processes is apt for appreciating the roles of IPRs and SDOs, since each is a social institution in what can be described as the industrial infrastructure for innovation,[5] that affects the search and the selection processes. In the following, Intellectual property rights regimes will be most closely associated with influencing the search process and fostering diversification of new technologies; institutional standardisation on the other hand will be most closely associated with the selection environment. The roles however overlap, apparently increasingly so. The point is the two central institutions play complementary roles in perpetuating such a balances

Formatted: Don't adjust space between Latin and Asian text

2.1 Understanding the role of IPRs

In this context, the term IPR means the technologically oriented rights used in the context of industrial innovation. This definition primarily includes patents and trade secrets, but in view of the importance of software, also certain applications of copyright protection. The rationale of patenting is the most relevant and most illustrative for standardisation. A patent on an invention is in effect a public contract that grants certain rights to the applicant for the use of a technical invention. The patent system caters to the assignee(s)' basic desire to appropriate profits accruing to the invention, while catering to the public interest in having the details of the invention spread to others so that the system can build on new knowledge.[6] In this view, the motives of the state involve (i) creating an incentive for actors in the economy to undertake inventive activities and (ii) to disseminate detailed information about inventive activities such that future generations can build upon them.[7] The motive usually ascribed to the patent-applicant is on the other hand to use the protection

Formatted: Don't adjust space between Latin and Asian text

5 By "industrial infrastructure for innovation", Van de Ven (1993) understands: "institutional arrangements legitimate, regulate and standardise a new technology, public resource endowments of basic scientific knowledge, financing mechanisms and a pool of competent labour, as well as proprietary R&D, manufacturing, marketing, and distribution functions that are required to develop and commercialise an innovation." (Van de Ven, 1993: 339).

6 For a seminal discussion of patents as an appropriation/distribution regime, see Arrow (1962). Note that a basic premise of the incentive aspect is based on assuring the inventor a chance to recoup the cost of his R&D investment. For a recent empirical and theoretical contribution, see Cohen, Nelson & Walsh. Protecting their intellectual assets: appropriability conditions and why US manufacturing firms patent (or not). NBER Working PAPER No. 7552. Feb 2000.

7 See Scotchmer (1991).

from competition to realize profits from the invention, either through developing it and commercialising it himself or through selling the rights to others who do the marketing of the innovation.

Copyright has also become a large issue in standardisation due to its uneasy association with software.[8] The question about how software should best be protected against imitation by copyright[9] or by patent protection[10] has recently arisen again in the European context. This question suggests one aspect of the changing environment that increasingly brings IPR into conflict with standards development organisations (SDOs) in new ways.

Formatted: Don't adjust space between Latin and Asian text

In general, IPRs have a role to play in organizing knowledge production, in promoting new R&D, in promoting further utilization as well as coordinating use of new knowledge, while avoiding underutilization losses. [11] In terms of the economy as a whole, the way IPRs do this implies both costs and benefits. On the one hand, IPR-protection brings with it social costs in the form of higher prices (monopoly pricing): on the other, IPRs provide the economy with an incentive to innovate (based exactly on the prospects for the innovative firm for monopoly pricing). The monopoly profits provided by IPRs may have the added advantage for the economy as a whole if it is ploughed back into higher levels of production and innovation. David (1993) emphasizes the following dimensions of this role:

Formatted: Don't adjust space between Latin and Asian text

a. The importance of full disclosure of information in patent applications. This allows for dissemination, verification, and application by others engaged in intellectual pursuits;
b. The importance of “allocative efficiency”. The provision of efficient focusing of research effort entails, among other things, the avoidance of over-focusing effort on the same research; the avoidance of “deadweight burden” of monopoly. This is the case where rights become too strong and bar close substitutes and raise royalties, while lowering the benefit to society in general and consumers in particular. It also involves the importance of achieving the coordination of R&D activities. This is topical in facilitating common standardization activities.
c. The importance of avoiding “unproductive competition for monopoly profit” (Kitch, 1977: Beck, 1983) including, wastage of resources on premature invention, duplicative R&D, substitute inventions, and excessively rapid spending on research. The non-disclosure of patents in standardization activities represents a poignant

Formatted: Don't adjust space between Latin and Asian text

8 On copyrights on software, see Besen and Raskind (1991), pp. 11-14.

9 Cf. Common Position concerning the draft of a copyright directive. Official Journal of the EU, no. C 344 of December 1, 2000.

10 Cf for example Blind et al. (2003).

11 For a short presentation of the role of IPRs in the innovation process, see e.g. Iversen (2002) on which this section draws.

example where patenting contributes to unproductive competition for monopoly profits.[12]

Formatted: Font: ZWAdobeF, 1 pt, Font color: Auto

2.2 Understanding the role of Standardisation

IPRs tend to be seen predominantly in terms of their contribution to the 'incentive structure' and less for their role in distributing information about innovation throughout the economy. There are two characteristics we want to mark here:

1) IPR are most often identified as a promoter of a diversity of technological ideas; and,
2) IPRs lay the basis for proprietary technologies.

In contrast, the role standardization, especially in standards development organizations (SDOs) plays in innovation[13] can be associated with a selection process to reduce variety and with the creation of non-proprietary goods; ideally, they work in the collective interest of all actors.

Formatted: Don't adjust space between Latin and Asian text

Standardisation is a process with a surprisingly large range of associations. There are different ways in which to classify standards and the standards process Standards can be differentiated as to *what* is standardised and as to *how* the standard is produced. As for the object dimension, there are product standards, control standards or process standards. As for the way standards are produced, there are again three categories: standards that are set through the market, on a de facto basis, standards that are set by government, through the regulatory process (mandatory standards) and standards that are negotiated through a voluntary consensus process.

In general the economics literature tends to associate the role of formal standardization with the idea of the 'failure' or inefficiency of markets. Schmidt & Werle (1998) indicate that the focus tends either to be on the reduction of transaction-costs, especially related to information, or on associated with network externalities. Standards are associated with, among other things, reducing uncertainty by controlling variety; enhancing competition by clearly defining what is required to serve a market (information); constituting markets by defining the relevant aspects of products (Tirole, 1988); facilitating scale-economies for suppliers, or influencing the distribution of cost and benefits of building and operating large complex technical systems. (Mansell, 1995: 217). Ideally, they work in the collective interest of all

12 See cases such as in Stambler v Diebold, Inc (1988), involving the standards related to ATM cards, an early case of conflict in which a patent holder attempted to assert his patent for what manufacturers believed to be an open and available standard.

13 See Iversen, 2000

actors. Then they provide a type of public good. (Cf. Berg, 1989, and Kindleberger, 1983).

Standards play a particularly important role as ‘selection mechanism’ especially in the case of network technologies, where the importance of narrowing the diversity of network technologies in order that the industry can take advantage of network externalities is highlighted.[14] In short, network technologies are vulnerable to the generation of ‘too much diversity'. These technologies rely on connectivity, and their worth therefore rises in proportion to their user bases. As a result, the unbounded proliferation of different, incompatible versions of an emerging radical technology may lead to a damaging Tower of Babel situation. The fight of individual alternatives to establish dominance in such a situation can be costly both for manufacturers, service providers and customers. In the end, a protracted fight for dominance might undermine the potential market for that emerging technology altogether, and remove it from the technology race. Networks will simply not be created in a sustainable way; the value of the component for the consumer will not be realised. Failing to amass a ‘critical mass' of users, the technology risks missing its fabled window of opportunity. There are many examples of this situation of the type of Betamax or more recently of the CT-2/ Telepoint system.

Formatted: Don't adjust space between Latin and Asian text

2.3 Central aspects of the interrelationship

In general, a complex set of factors induces and promotes the creation of diversity and another affects the complementary and intertwined selection process. The important thing is that there is a complex interrelationship that keeps the virtuous circle of the differentiation and the selection processes in swing. Intellectual property rights regimes and institutional standardisation are closely associated with these processes, although they are not tied to one or the other. A stylized division of labour indicates that IPRs, especially patents, are most closely related as incentive mechanisms to the continuous generation of technical variety while formal standards bodies, especially voluntary SDOs, are most closely related to selection from among the ripening variety of technological solutions. In reality, the roles are not this clear cut. The way IPRs and SDOs are used mixes their roles with regard to the creation of variety and the promotion of selection. On the one hand, the standardization process has moved further and further in front of the market, such that standards activities contribute to creating new solutions not provided for by the market; the semantic web standards are one example. On the other, the increasing strategic use of IPR to create defensive bulwarks against competing technologies for example can serve to mimic a selection mechanism; such strategies can limit the scope

[14] See Katz & Shapiro, 1985, Farrell & Salloner, 1985, David, 1987.

for competing technologies to emerge and therefore reduce the gene pool from which new combinations of emerging technologies can develop and recombine.

Indeed the interaction between variety and selection— and the roles of IPRs and SDOs in it— are much messier. The schematic division of labour does however point to an essential trade-off in the innovation process, it indicates the complementary roles of IPRs and SDOs, and it suggests the essential tension that underlies that relationship. Here it appears that the tension between these mechanisms stems from their opposition: opposition between the private interest of the inventor and the collective interest of the industry and more fundamentally, opposition between a role in promoting technological variety as against that of facilitating a certain uniformity.

In this setting, maintaining balance is important. Too much variety may be bad since, “variety conveys efficiencies in specialization and customization that are offset by the failure to achieve network externalities and other economies of scale” (Steinmueller, 1995). Likewise, the opposite may also be the case since, "in reducing diversity, standardization curtails the potentialities for the formation of new combinations and the regeneration of variety from which further selection will be possible" (David, 1995). Therefore, in the ongoing interaction between the generation of technological variety and its selection, "effective long-term adaptation requires that these two processes be kept in balance" (Carlson & Stankiewicz, 1991).

One implicit side of incorporating the institutional framework systemically with the innovation process is that the different components - technologies, institutions, etc - will tend to ‘co-evolve’ (Nelson, 1994). That is, the rapid change of technologies will also be reflected through a two-way relationship with the institutional framework. Institutions will be forced to change and their changing will also reflect the way technology evolves. The reason that this phenomenon of co-evolution is important here is that both IPR regimes and SDOs are undergoing changes. The OECD report on ICT standardisation in the new global context discusses some of the relevant changes standardisation is facing, including the IPR concern. It appears that it is this changing environment that is translating the inherent tension between these two institutions into conflict (Iversen, 2000).

2.4. Central aspects of the emerging conflict

Since the mid-1990s, it has been observed (e.g. Iversen, 1996) that a set of forces has served to amplify the tension and has begun to threaten the balance. The prospect that the role of IPRs should come into conflict with the complementary role of formal standardization suggests that the way these institutions are each evolving is translating the inherent tension into conflict. (Iversen, 2000)

The potential for conflict between intellectual property rights and standardization arises when the implementation of a standard, by its essence, necessitates the application of proprietary technology. The case of 'essential intellectual property rights'[15] is implicit to the tension between the two institutions. The risk that may emerge during the standardization process is that the codification of the specifications will infringe the proprietary rights described in the IPRs of one or more such agents. The IPR will be considered 'essential' if the standard, by its depth and detail, necessitate the use of the proprietary technical solutions describe in it. Should it do so, the collective interest in the standard confronts the private interests of the IPR holder.[16]

Formatted: Don't adjust space between Latin and Asian text

Formatted: Font: ZWAdobeF, 1 pt, Font color: Auto

A court is ultimately needed to establish whether or not the IPR (patent or software-copyright for example) is really 'essential'. At the same time, a court case would require considerable time and resources[17], and could jeopardize the collective standardization enterprise. So the difference between an IPR that is in reality essential and one that is potentially essential is not that great after all: both cases threaten to tie up the standardization process. Essential intellectual property rights in this sense should be further differentiated from 'Blocking IPRs' which definitively block the process.

Formatted: Don't adjust space between Latin and Asian text

However, the interaction between business and standards increasingly raises the situation of the essential and blocking IPR. A blocking IPR can be a result of two main situations for companies. In the first general set, the IPR holder refuses to license or refuses to on a basis that is considered fair, reasonable and non-discriminatory. The threat to withhold IPRs in this situation may be used as a bargaining chip. A flat refusal would be regarded with extreme suspicion. The existence of essential intellectual property rights among individual rights-holders outside the standardization work is much less predictable. Absent the necessary search processes, such rights may appear at any time during the life of the standard. The willingness of the rights-holder to license at agreeable terms is likewise not a bygone conclusion, especially if added to already agreed upon royalty-schemes.

The second set of cases involves a plurality of rights-holders. The relevance of this case—that more than one right held by more than one rights-holder—is itself testimony to the fact that intellectual property rights and the work of standards development organizations have become much more inter-tangled. A variety of rights-holders complicates the licensing process which is supposed to be fair both for the

---

15 For a description of the possible outcomes, see Lea & Shurmer, 1995. See Iversen, 1999 for the way ETSI IPR Policy addressed such outcomes.

16 See Miselbach & Nicholson (1994) for a description of essential IPRs.

17 Witness the current Rambus case. *Rambus v. Infineon and FTC v. Rambus, Inc., FTC (No. 9302).*

licensee and licensor. What happens when the *cumulative royalty costs*, while fair to the individual rights-holder, become too high for potential licensee? The short answer is that the standard would die. This raises the question of different ways to address cases of conflict, which are becoming more and more common. Finding solutions to new challenges in the interaction however does not happen by itself.

2.5 Summing up

IPRs involve a more proprietary and standards more of a public domain aspect. Consequently, this difference entails a certain tension in their relationship, which may cause a broad scope for conflict and therefore a need for policy attention. Besides this, there has been a rising propensity to use patents, together with a growing reliance on standards activities. Since standardisation has moved more towards the coordination of technologies, it has also taken on a more active role in knowledge-creation process. On the other hand, the pooling of IPR has become an issue relevant for standardisation. This phenomenon is exacerbated by the increasing intensity of patenting in particular areas. The effect on how IPR and standards are being used, combined with some other changing framework conditions (like the internationalisation of markets, the convergence of technologies, and the increasing pace of technological change) has led to a growing tendency to conflict. Consequently, the dynamic balancing of private and public knowledge becomes a constant consideration both for SDOs and for government agencies.

Three constellations illustrate how IPR and standards interrelate:

a) the two are designed to complement each other, which promotes a ‘virtuous circle’ of creation and diffusion of new knowledge
b) in a worst case, IPR, especially patents, can be exercised to block standards, with considerable negative welfare impacts
c) however, in a growing number of cases there is a need to ensure more efficient licensing mechanisms, for example through equitable patent-pool schemes, which do not endanger the IPR regime, but allow their controlled diffusion into standardisation processes.

4. Presentation of new empirical research

This section addresses the substantial lack of systematic empirical study in the literature. It considers the scope for conflict in a variety of industries where the balance between the importance of standardisation and the importance of patenting differ. The empirically based approach combining a survey and a set of 20 case studies presents two new sources of (exploratory) empirical evidence.[18] The results from the complementary survey and case study work are then used to categorise the type of problems that emerge in a set of industries.

Formatted: Don't adjust space between Latin and Asian text

4.1 The explorative survey among a set of industries in different countries

An empirical survey was conducted to assess the problems sketched above in a quantitative manner. More than 150 experts from European manufacturing companies, including R&D managers, IPR managers and standardisation experts, were approached to answer questions about their IPR management, their involvement in standardisation processes, and their experiences concerning the interaction between standardisation and IPR in general.

Among the strategies to protect their innovations, secrecy and related measures such as customer relations management, lead-time advantages and complex product design are most important. As already confirmed by other surveys, patenting is only of medium importance in comparison to other protection tools. The importance of patenting as a protection tool rises with the firm size, but so does the importance of secrecy. This is in particular true for patenting and R&D-intensive companies. The protection of own technology from imitation has the highest importance as a motive to patent. This corresponds with the classical (defensive) use of patents, but also with the economic reasoning behind patenting. Aggressive forms of patenting are a more important issue with big companies. The business-related aspects of patenting such as the generation of licensing income and the acquisition of venture capital are of relatively low importance.

More than 50 % of the responding companies have been involved actively in standardisation in the last three years. The survey results confirm also the increasing importance of European and international standardisation. The most important reason to participate in standardisation is to exert influence and to prevent certain

[18] The empirical evidence draws on Blind et al. (2002) and is extended by Blind and Thumm (2004).

specifications in standards. Companies that are involved in standardisation procedures file much fewer patent applications than those firms that are not involved in standardisation. This might be an indicator that the use of IPR, reflecting the success of own R&D activities, and participation in standardisation are to a certain degree alternative innovation strategies.

The motives for participation in standardisation that assume a close relationship to R&D are rather weak. Both the improvement of the dissemination of own IPR and the reduction of R&D costs reach values below average. Therefore, the question has to be answered, what prevents companies from using the standardisation system and from transferring their research results into formal standardisation. The most important barriers reported are problems in connection with the standardisation process. Firstly, standardisation is too slow, secondly too costly, especially for small companies, and thirdly too inflexible, particularly for large companies. Furthermore, the co-ordination between research and standardisation organisations and the awareness by researchers are insufficient and have to be improved.

In order to improve the transfer of research results into formal standardisation processes, it is vital to raise the awareness of the benefits of standards. Financial incentives are especially suggested by small and medium-sized companies, which have emphasised the high costs as a major barrier to transferring their R&D results into the standardisation processes.

Besides the transfer problem, there are obviously numerous conflicts with IPR in standardisation processes. Most problems arise with patents. Over 30 % of the companies indicate that they had problems with own patents and over 40 % of them had problems with the patents of others within the standardisation process. Concerning the kind of problems, over 40 % of the large companies indicate that their licensing conditions have not been accepted. Over 35 % of the patent-intensive companies have experienced infringements of their IPR. The results also indicate that there is a real problem with IPR in standardisation, because over 50 % of the companies indicate that they have never found a solution to their conflicts. To purchase licenses and circumvent protected technologies are the strategies most often used to overcome this problem.

In order to overcome conflicts with IPR involved in formal standardisation processes, some measures have been proposed. However, both mandatory licensing, reduced terms of patents, and a shift of responsibility for screening of IPR involvement in standards to the IPR-holders are not assessed as being adequate solutions.

4.2 The set of case studies

In order to complement the sometimes puzzling quantitative results of the survey by qualitative information, case studies were performed to elucidate the relationship between IPR and standardisation in more depth.

With respect to the objective of the paper, it is of particular interest to see under which conditions and why conflicts between IPR and standardisation emerge. The analysis performed on the survey gives some answers. We do not present details of the cases, but try to report insights about clusters of several cases.

A high potential of conflict between IPR and standardisation arose in particular in six cases of the presented case studies. All these technologies are highly relevant for IPR activities and most of these case studies showed involvement in formal standardisation procedures. These technologies are not at an early stage of development, but tend to be more mature technologies. Naturally the conflict potential rises with the complexity of the technologies, thus conflicts seem to be more likely with systemic technologies than with non-systemic ones. Conflict potential for the mentioned cases also accompanied a high level of competition, with many participants in the market and with heterogeneous actors involved.

In the interest of a more systematic approach in the comparative analysis of the case studies, a list of categories was developed in order to differentiate the cases and to identify relationship patterns between IPR and standards primarily of a qualitative order.

The fundamental distinction with respect to standardisation processes and standards is between formal and de facto standardisation. Formal standardisation is understood to take place via SDOs, where formal standards, pre-standards or publicly available specifications (PAS) are produced. De facto standardisation is on the other hand driven by closed consortia of companies or even single companies which develop under non-transparent circumstances mostly, but not always, proprietary de facto standards.

From the technological perspective, process standards, including test methods or architectures, and product standards can be differentiated. Furthermore, the technology considered can be at an early stage or can already have progressed to a mature phase. This distinction is closely connected with the R&D intensity, since the investment in R&D declines the more mature a technology is. Finally, technologies can be systemic, like information and communication technologies, or non-systemic and stand-alone, like chemistry. However, there is a clear tendency among all technologies to become more systemic, because technologies become more intertwined with an increasing importance of interdisciplinarity and within a technology the specialisation and therefore the division of labour increase. The dimension of (net-

work) externalities is closely related to the issue of systems technologies. The more intense network externalities are, the more likely it is that standards will be developed.

Besides the technology-intrinsic dimensions relevant for standardisation, market structure may also have an influence on standardisation and IPR. However, in the long run, both IPR and standards have an impact on the development of markets. Therefore, the degree of competition in a market may foster or hinder standardisation and the use of IPR.

In addition to the technological and economic framework conditions, the standardisation process itself differs – besides the general distinction into formal and de facto standardisation – according to several dimensions. First of all, the number of participants actively involved can vary. Second, the composition of the participants can vary between a very homogeneous group consisting of just representatives of large companies and a heterogeneous group, involving not only experts from companies, but also from research institutes and representatives of diverse groups interested in protecting the interests of labour union, of the environment or the consumers. Thirdly, participants may all be of the same nationality, may come from European countries or may be globally located – another dimension of heterogeneity.

The standardisation process focuses on the harmonisation of one technical specification. However, different public policy concerns are also recognised or are even the main cause for a standardisation process. The generation of standards may be a major element of an industrial policy strategy or a main instrument in order to support the protection of the health and safety of consumers or workers. Even ethical dimensions may play a significant role.

Finally, technologies and sectors differ in respect to the usage of IPR and to the degree standards are being developed, caused by both the characteristics of the technologies and the structure of the industries, like the intensity of competition.

These various framework conditions have impacts both on the efficiency of the standardisation processes and their output, measured by standard documents published per year. As we have seen various dimensions of differences between the participants, it is more likely that conflicts in standardisation processes arise the higher the heterogeneity and the more proprietary IPR is involved. On the other hand, the more homogeneous the actors and their preferences, the more cooperation is likely to occur. However, heterogeneous participants may have complementary goals, which do not lead to conflicts but to common efforts to achieve a common standard. Since no one-dimensional or unequivocal causalities exist between the characteristics of the cases and possible conflicts or solutions appearing during the standardisation process, in the following sections exemplary incidents are presented.

The following Table 4.2.1 systematises the cases according to a set of categories. The matrix makes the wide range of constellations and combinations clear. There are almost no cases, which are identical respective to the categories, although similarities exist.[19]

Formatted: Don't adjust space between Latin and Asian text

Formatted: Font: ZWAdobeF, 1 pt, Font color: Auto

19 Rare abbreviations: PCR: Polymerase Chain Reaction; EDM: Essential Drug and Medicines Policy; FTTO: Farmaco Therapeutisch Transmuraal Overleg; BMEcat: Catalogue of the BME Bundesverband Materialwirtschaft, Einkauf und Logistik e.V.; TETRA: Terrestrial Trunked Radio; CAN: controller-area network.

Table 4.2-1: Classification of Cases (NA = not assessable)

Case	Formal/ De facto	Product/ Process	Early/ Mature	High / Low R& D	Sys-temic/ Non-systemic	High/ Low external-ities	High/ Low competi-tion	Many / Few parti-ci-pants	Heterogene-ous/ Homo-geneous actors	Global/ Euro-pean partici-pation	Yes/ No public policy con-cerns	High/ Low IPR involve-ment	Kind of IPR	Coopera-tion/ Con-flict	High/ Low level of standardisa-tion
Ther. Antibody	De facto	Product	Early	High	Non syst.	Low	High	Few	Homo		Yes (health)	High	Patents		Low
Genetic Testing	Formal	Prod-uct/Proces	Early	High	Non syst.	High	High	Many	Hetero	Europ.	Yes (ethics)	High	Patents	Conflict	Low
PCR	Formal	Process	Early	High	Non syst.	High	High	Few	Homo		Yes (re-esearch	High	Patents		Low
Opto-electro.	Formal	Process	Mature	High	Non syst.	Low	Medium	Few	Hetero	Global	No	Medium	Patents	Coop.	Medium
Paral. Opt. Interface.	Formal	Product	Early	High	Sys-temic	High	High	Few	Hetero	Global	No	Medium	Patents	Coop.	Medium
EDM	Formal	Process	Mature	Low	Non syst.	Low	High	Many	Hetero	Global	Yes (health)	Medium	(indirect) Patents	Coop.	Low
FTTO	Formal	Process	Mature	Low	Non syst.	Low	High	Many	Hetero	Global	Yes (health)	Medium	(indirect) Patents	Coop.	Low
VCR	De facto	Product	Mature	High	Sys-.	High	Low	Few	Homo	Global	No	High	Patents	Conflict	High
CD	De facto	Product	Mature	High	Sys-.	High	Low	Few	Homo	Global	No	High	Patents/ TM	Coop.	High
DVD	De facto	Product	Me-..	High	Sys-.	High	Low	Many	Hetero	Global	No	High	Patents/TM	Coop.	High
MP3	Formal	Process	Me-..	High	Sys-.	High	Low	Many	Hetero	Global	Yes	Medium	Patents /TM	Coop.	Medium
GSM	Formal	Process	Mature	High	Sys-temic	High	High	Many	Hetero	Global/ Euro-	Yes	High	Patents	Conflict	High
BMEcat	De facto	Product /Process	Me-dium	Low	Sys-temic	High	Medium	Few	Hetero	National ->	No	Medium	TM	Coop	High (e.g. EDIFACT)
Fieldbus	Formal	Process	Mature	High	Sys-temic	High	High	Many	Hetero	National Global	No	High	TM/ Patents	Conflict	High
TETRA	Formal	Process	Me-dium	High	Sys-temic	High	High	Many	Hetero	Global/ Euro-pean	Yes	Medium	Patents, Copyright	Conflict	High
CAN	Formal	Process	Mature	NA.	Sys-temic	High	Medium	Few	Homogeneous	Global	Yes	Medium	Patents	Coop.	High
Aluminium alloy body	Informal	Product	Me-dium	High	Non syst.	High	High	Many	Hetero	Europ.	Yes (safety)	Low	None	Coop.	Low
Creep-Plastic	Formal	Process	Me-dium	High	Non syst.	High	High	Many	Hetero	Global	Yes (safety)	Low	None	Coop.	Medium
Interna-tional Stand.	Formal	NA	NA	NA	NA	NA	NA	Many	Hetero	Global	Yes	NA	NA		NA
ETSI	Formal	NA	NA	NA	Sys-temic	NA	NA	Many	Hetero	Global/	Yes	NA	All IPR	Conflict	NA

4.3 Conflict Potentials

The results of the questionnaire-based survey above revealed that 40% of the respondents had problems with IPR of others in standardisation processes. This conflicting relationship between IPR and standardisation is also reflected in some of the cases analysed.

The particular sensitivity of biotechnology with respect to intellectual property right protection requires careful treatment by any future regulation. The high level of IPR engagement on the one side and the need for standardisation on the other hand provides a dangerous future minefield. The legal situation of patentability for gene sequences is not conclusively resolved. The official position is that gene sequences are in principle patentable once they are isolated, identified and made practically available, together with a process to develop and apply them to a practical use. Genetic testing services used in clinical diagnosis of genetic disease are neither regulated nor standardised in Europe. There are some indications that the excessive use of IPR in the field of genetics limits the accessibility of competitively priced genetic testing services and hinders test-specific development of national programmes for quality assurance. Since it is a relatively new field of technology, the possibilities for abuse of a dominant market position are large. Monoclonal antibody generation and genetic testing methods are illustrative examples of the dynamism and the complexity of biotechnological production methods.

4.4 Solution Potentials

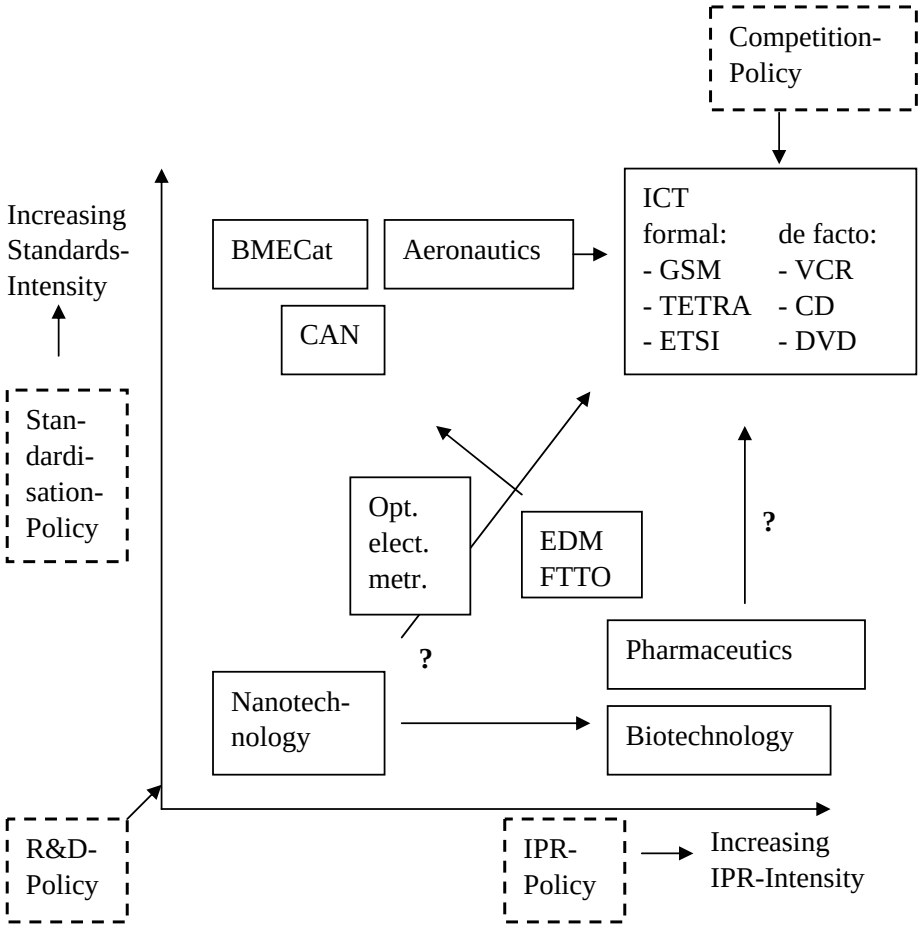
Besides the different lines of conflicts, which have been identified in the questionnaire-based survey and in the case studies, solutions to these conflicts are also presented which may serve as examples for standardisation processes of other technologies.

In general, four quadrants can be distinguished. Technologies which are still at a very early stage of development— like nanotechnology— are both still free of IPR, like patents, and dominated by scientific publications. Due to the emphasis on basic research, applications remain largely in the future, therefore there is no need for standards at the moment. The second cluster of pharmaceutics and biotechnology is characterised by a high density of IPR and a more mature stage in the life cycle of the technology. Only very few sectors have little IPR, like many service related and software based areas. Consequently, little or no problems with standardisation arise. In some cases, like in optical electronical metrology, we observe a simultaneous existence of IPR and standardisation activities on a medium level. In a pre-competitive field of technology, aeronautics, both IPR and standards in form of guidelines coexist beside each other without causing conflicts, since the group of involved actors is small and rather homogeneous. Finally, we have the large and growing field of ICT. The involved companies try to build up strong IPR portfolios. On the other hand, the need to generate positive network externalities requires the

development of common, world-wide accepted standards. Consequently, the conflict potential is most intense. However, the pressure to find a common agreement is also very high, since only in exceptional cases are single companies able to enforce a proprietary de facto standard.

Although we have developed numerous categories to classify the cases, a simple obvious clustering of the cases is not possible. Therefore, we have reduced the dimension down to two, which reflect the core of our paper. In Figure 4.4-1, we have located selected cases according to the involvement of standards and IPR. In addition, four relevant policy areas are depicted. In the following final chapter, recommendations are derived which aim to solve possible conflicts between IPR and standardisation or to optimise their interface.

Figure 4.4-1: Categorisation of Cases by their Standards- and IPR-Intensity and Relevance of Different Policy Approaches



In general, four quadrants can be distinguished. Technologies, which are still at a very early stage, like nanotechnology, are both still free of IPR, like patents, and dominated by scientific publications. Due to the emphasis on basic research, first

applications will be realised in the future, therefore there is no need for standards at the moment. The second cluster of pharmaceutics and biotechnology is characterised by a high density of IPR and a more mature stage in the life cycle of the technology. Only very few sectors have little IPR, like many service related and software based areas. Consequently, little or no problems with standardisation arise. In some cases, like in optical electronical metrology, we observe a simultaneous existence of IPR and standardisation activities on a medium level. In a pre-competitive field of technology, aeronautics, both IPR and standards in form of guidelines coexist beside each other without causing conflicts, since the group of involved actors is small and rather homogeneous. Finally, we have the large and growing field of ICT. The involved companies try to build up strong IPR portfolios. On the other hand, the need to generate positive network externalities requires the development of common, world-wide accepted standards. Consequently, the conflict potential is most intense. However, the pressure to find a common agreement is also very high, since only in exceptional cases are single companies able to enforce a proprietary de facto standard.

5. Discussion of the policy implications and policy approaches

Overall, the literature survey, the results of the questionnaire-based survey and the analysis of the case studies have shown the variety of interrelationships between IPR and standardisation. The review of the literature confirms that the relationship is a relatively new phenomenon, especially virulent in network industries, like telecommunications. The answers of the survey support the relevance of the issue, since conflicts of IPR in standardisation processes are much more likely than the existing literature, especially focused on specific cases, suggests. Furthermore, the IPR issue is indeed predominantly one involving patents, but both the survey and the case studies show that copyright and other rights may also be involved. Finally, the empirical evidence makes clear that many of the numerous conflicts between IPR and standardisation are not adequately resolved.

For the policy dimension it is also notable, that the interface can either be located closer to the research and development area or already in the marketing phase of products. Consequently, the policy approaches have to cover both research and development, the IPR regime, the standardisation regime and competitive issues.

Sometimes, a recommendation concerning one policy area may contradict a proposal made from another policy perspective. For example, stronger IPR regimes may provide companies with additional incentives to perform more R&D. On the other hand, this change may increase the likelihood of IPR-related problems in standardisation processes. A final decision can only be made by regarding the specific framework conditions of the respective technology or market. Therefore, a comprehensive shaping of the interrelationship between IPR and standardisation has to take into account all the policy dimensions. However, since different institutions, like R&D funding organisations, patent offices, standardisation bodies, and institutions regulating competition are addressed by the policy recommendations, there are many difficulties in finding a consensus among their interests and developing coordinated actions.

5.1 Research Policy Recommendations

Although research policies are not directly linked to standardisation, the origin of new standardisation projects can often be found in publicly funded research projects. Furthermore, the direction of research activities can be more easily influenced by the design of public policy than by standardisation activities, which are mostly driven by private interests. The evidence from the results of the survey conducted and some experiences from the case studies allow us to derive the following recommendations concerning future research policies:

- Increase awareness among researchers about the relevance and the implications of standards and standardisation processes by training or exchange of personnel.
- Integrate clear provision for support that may be needed in order to transfer project results into standards in public RTD programmes.
- Make sure that all research to develop test and measurement methods establish the scope for the development of a new standard at the very beginning.
- Identify promoters who are part of research teams as well as a members of relevant standardisation committees, since they may be able to support the transfer of research results into standards more effectively and efficiently.
- Improve the information flows between the public research institutes and the standardisation bodies, by recognising their scientific and technological contribution to standardisation processes in scientific evaluations of these institutions.
- Publish successful case studies of the co-existence of IPR and standards amongst the research community.

5.2 IPR Policy Recommendations

The characteristics of the IPR regime have major impacts on the effectiveness and the efficiency of standardisation processes. Although not only patents have been addressed in the survey and the case studies, they clearly dominate the relationship between IPR and standardisation. Therefore, the following recommendations are focused on changes in the patenting regime or practice:

- Assure a high level of quality of issued patents, thus reducing the risk of conflicts arising from weak patents.
- Promote a world-wide harmonisation of national IPR regimes in order to decrease the likelihood of conflicts caused by cross-border application of technical standards.
- Improve the transparency and accessibility of IPR material in order to make the monitoring activities in the IPR minefield easier.
- Allow for compulsory licensing provisions as last resort in the court system.
- The IPR Helpdesk, funded by the EU, should also provide services concerning the role of IPR in standards.

5.3 Standardisation Policy Recommendations

The following recommendations are addressed to SDOs, which may modify their guidelines according to the suggestions made. However, the existing ISO/IEC directives related to patents, which are implemented by most SDOs, proved to be effective and efficient in most circumstances. Nevertheless, the proposals are mostly directed to general strategic standardisation policies, including licensing and disclosure rules.

- Encourage SDOs to identify promising new technologies in their very early stages and to start new standardisation processes instead of waiting for them to mature, since in the very early pre-competitive stage of technology life cycles there is some pressure on the actors to converge their interests.
- Increase the awareness among participants of standardisation processes of possible inputs from science.
- Prefer standards which do not specify the design of components, but their performance, in order to avoid conflicts with patents protecting these components.
- Limit the duration and the scope of an entire system as well as the level of detail of a standardisation process, in order to restrict the probability for IPR conflicts.
- Change the framework conditions of standardisation in such a way that the incentives of innovative R&D-intensive companies to join standardisation processes become more attractive in general (e. g. allow attractive licensing schemes, see below).
- Standardisation processes should become faster, cheaper and more flexible.

5.4 Disclosure Rules

Disclosure rules enable the SDOs to obtain information about whether technologies under consideration for inclusion in the standard are proprietary and subject to licensing. They thereby reduce the potential for a technology to be included in a standard without the knowledge that a technology owner, with intellectual property that impinges on the standard, may try to extract royalties for the use of his technology.

- Because of differences across industries in the reward afforded by patent protection and in the needs for compatibility and standardisation, no disclosure rule would be optimal for all situations.
- Increase the transparency of IPR relevant for standards by building up publicly available databases with IPR that are potentially ‘essential’ for their standards.

5.5 Licensing Policy

Having learned through disclosure which elements of the standardised technology may be proprietary and subject to royalties, the SDOs are still left with the problem of drafting guidelines for setting licensing fees the technology-owner should charge after the standard is determined. The typical policy mandating that a royalty be "fair, reasonable and non-discriminatory" gives little guidance for royalty determination because "reasonable" can mean different things to a technology-owner and a technology-buyer.

- Make databases available which contain details of exemplary licensing cases, which provide guidelines for the negotiations between the IPR-holders and potential licensees.
- Take into account the IPR-holders´ pre-selection negotiation and conclusion of licenses with individual licensees in the standard selection process.
- Encourage SDOs to set up some means of dispute resolution within the organisation to help resolve royalty disagreements, since this will be quicker and cheaper than resorting to the courts.

5.6 Patent Pools

Since usually not only a single patent has to be considered for integration into a standard, patent pools may represent an organisational model to save transaction cost regarding both disclosure and licensing of IPR, compared to multilateral negotiations. They are also able to resolve conflicts both among IPR-holders themselves and between IPR-holders and standards users. Nevertheless, to establish and run patent pools efficiently, and to promote their general welfare advantages, some conflict potentials and potential disadvantages, like their misuse as a price-fixing mechanism, have to be taken into account and the following recommendations should be considered.

- Pool patents early, in order to avoid constellations with two or more pools driven by different interests.
- Use public non-profit research institutions as key gravitational force for creating patent pools, since they can more easily balance the often controversial interest of the companies.
- Involve companies in patent pools which are successful in distributing new products and technologies, since this may guarantee the successful acceptance of a new standard in the market.

5.7 Competition Policy Recommendations

Both the outcome of the IPR regime, like granting a temporary monopoly via patents, and the results of standardisation processes, like the specifications of a standard causing heterogeneous implementation costs at the user side, may have negative impacts on competition. However, standardisation may also foster competition by levelling the playing field.

In general, competition policy makers have to develop a better understanding of the scope of conflict between IPR and standardisation and its impact on competition policy issues. In general, a more intensive dialogue between all parties involved can be a first step to this better understanding.

Besides this general suggestion, the following proposals focus less on different consequences of the IPR regime for standardisation and competition, but more on the consequences of the interaction of IPR and standards on competition.

- If IPR-protected technologies are integrated in a standard, be very careful about possible negative impacts on competition, since this constellation may increase the monopoly power of the IPR-holder. A remedy could be the prescription of compulsory licenses, although this instrument should be used very restrictively, because of its negative incentive signal to innovative companies interested in standardisation.
- In the case that standards become mandatory via reference in other regulations, solutions have to be found to deal with IPR-holders who refuse to give licenses away for no or very small fees.
- Consider also standardisation as an instrument to solve antitrust problems, since it allows that all interested parties influence both the specifications of a standard and implement it, leading to a common level in the playing field of competition. Therefore, standardisation may also substitute the regulation of competition by governmental institutions.
- Standards are able to devalue the brand loyalty, which is built up during the terms of patents, after the patent protection comes to an end, since standards may speed up the substitution process after the termination of the patent protection period.
- Increase the pro-competitive aspects of patent pools by the involvement of competition policy authorities in laying out allowable licensing arrangements of patent pools. Furthermore, a patent pool notification scheme increases the transparency for these institutions and alleviates and improves their decision-making process.

5.8 Summary

Since the rationales and objectives of the four policy areas differ in general, there are tensions between the recommendations proposed. In addition, the recommendations address different institutions. Consequently, there is a need for coordinated action in order to improve the relationship between standardisation and IPR, also taking research and competition policy aspects into account. A first step towards a comprehensive action is to convoke the responsible authorities and encourage an intensive exchange of ideas. Based on a better understanding, further steps towards an integrated policy approach can be undertaken.

References

Arrow, K. (1962): Economic Welfare and the Allocation of Resources for Invention, in: The Rate and Direction of the Inventive Activity: Economic and Social Factors, edited by R. R. Nelson, Princeton 1962.

Beck, R. L. (1983). The prospect theory of the patent system and unproductive competition. Research in law and Economics 5: 193-209.

Berg, S. V. (1989). The production of compatibility: Technical Standards as collective goods. Kyklos: 42: 361-383.

Besen, S. M. and Raskind, L. J. (1991): An Introduction to the Law and Economics of Intellectual Property, in: Journal of Economic Perspectives Vol. 5 (Winter 1991), pp. 3-27.

Blind, K.; Thumm, N.; Bierhals, R.; Hossein, K.; Iversen, E.; van Reekum, R.; Rixius, B. (2002) Study on the Interaction between Standardisation and Intellectual Property Rights; Final Report to the DG Research of the European Commission (EC Contract No G6MA-CT-2000-02001), Karlsruhe.

Blind, K.; Edler, J.; Nack, R.; Straus, J. (2003): Softwarepatente: Eine empirische Analyse aus juristischer und ökonomischer Sicht, Heidelberg, Physica-Verlag.

Blind, K and Thumm, N. (2004): Intellectual Property Protection and Standardisation, in: Internationl Journal of IT Standards & Standardization Research 2(2), pp. 61-76.

Carlsson, B. and R. Stankiewicz (1991). On the nature, function and composition of technological systems. Journal of Evolutionary Economics. 1, 93 – 118.

Cohen, Nelson & Walsh (2000). Protecting their intellectual assets: appropriability conditions and why US manufacturing firms patent (or not). NBER Working PAPER No. 7552. Feb 2000

Council of the European Union (2000): Common Position on EU Copyright – Directive. In the Official Journal of the EU, nr C 344. December 1, 2000, pp. 1-22.

David, P. A. (1987) Some New Standards for the Economics of Standardization in the Information Age. In P. Dasgupta & P. Stoneman (Eds.) Economic policy and technological performance, Cambridge; Cambridge University Press, 206-234.

David, P.A. & D.Foray (1995), "Accessing and expanding the science and technology knowledge base", STI Review, nr.16.

David, P. A. (1993) “Intellectual Property Institutions and the Panda’s Thumb” in M.B. Wallerstein, M.E. Mogee, and R.A. Schoen (eds). Global Dimensions of Intellectual Property Rights in Science and Technology. Washington DC: National Academy Press.

DIN (1995): Grundlagen der Normungsarbeit des DIN, 6th ed., Berlin, Beuth-Verlag.

Farrell, J. & Saloner, G. (1985). Standardization, Compatibility and Innovation. Rand Journal of Economics, 16:1, 70-82.

Frenken, K. & A. Nuvolari (2003). The Early Development of the Steam Engine: An evolutionary interpretation using complexity theory. Working Paper 03.15 Einhoven Centre for Innovation Studies, The Netherlands.

Iversen, E. J. (1996). Conflicts Between Innovation And Diffusion In New Telecommunications Systems. STEP-Working Paper; 1995. Presented at the ETIC Conference, Maastricht 1996.

Iversen, E. J. (2000): Standardisation and Intellectual Property Rights: Conflicts Between Innovation and Diffusion in New Telecommunication Systems, in: Information Technology Standardisation: A Global Perspective, edited by Kai Jacobs, Idea Group Publishing: Pennsylvania: pp. 80-101

Iversen, E. J. (2001). Raising Standards: Innovation and the emerging global standardization environment for ICTs. 2nd Conference On Standardization And Innovation In Information Technology>> (SIIT), October 3-5, 2001, Univ. Of Colorado, Boulder, Colorado, USA.

Iversen, E. J. (2002). Fundamental and contextual issues involving the strategic use of IPRs. Step Working Paper. http://www.step.no/Notater/A-01-2002.pdf

Katz, M.L. and Shapiro, C (1985). Newtork Externalities, Competition and Compatibility. American Economic Review, (75,3). 424-440.

Kindleberger, Charles P. (1983). Standards as public, collective, and private goods. Kyklos 36: 377-396.

Kitch, E. W. (1977). The nature and function of the patent system. Journal of Law and Economics 20: 265-290.

Lea, G. and Shurmer, M. (1994): ‘Clash of the titans? Intellectual property rights and telecoms standards’, in: Media Law & Practice, Vol. 15, No. 3, 1994, pp. 89-93.

Formatted: Don't adjust space between Latin and Asian text

Formatted: Don't adjust space between Latin and Asian text

Mansell, R (1995) Standards, industrial policy and innovation. in Hawkins, R., R. Mansfield & J. Skea (Eds.). (1995) Standards, innovation and competitiveness: Edward Elgar.Miselbach, R. and Nicholson, R. (1994): Intellectual Property Rights and Standardization. Sec. Update, Sophia Antipolis, France.

Miselbach, R. and Nicholson, R. (1994): Intellectual Property Rights and Standardization. Sec. Update, Sophia Antipolis, FR.

Nelson, R. R. (1994): The co-evolution of technology, industrial structure, and supporting structure, in: Industrial and Corporate Change. 3(1), pp. 47-63.

Saviotti, P and S Metcalfe (eds) (1991). Evolutionary Theories of Economic and Technological Change. Harwood Academic publishers: Switzerland.

Schmidt S and R Werle. (1998) Coordinating technology: Studies in the International Standardization of Telecommunications. MIT: Cambridge, Mass.

Scotchmer, S (1991): Standing on the Shoulders of Giants: Cumulative Research and the Patent Law, in: Journal of Economic Perspectives, Vol. 5, pp. 29-41.

Steinmueller, W. E. (1995) The political economy of data communication standards. in Hawkins, R., R. Mansfield & J. Skea (Eds.). (1995) Standards, innovation and competitiveness. Aldershot: Edward Elgar.

Tirole, J (1988). The Theory of Industrial Organization. MIT Press.

Van de Ven, A. (1993). The Emergence of an Industrial Infrastructure for Technological Innovation. Journal of Comparative Economics 17, 338-365