The Value and Indicator Function of Patents

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1. Introduction

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Patents are one of the most important innovation indicators to assess the technological competitiveness of innovation systems (national, regional, or sectoral), as they are one possible output of R&D processes, among others (see Freeman 1982; Frietsch, Schmoch 2006; Grupp 1997; Grupp 1998). In innovation studies they are used to mirror the present technological profile, but also to take a look at the near future as patents are also an established indicator of future economic activities reflected in production, employment, or exports etc. However, since the beginning of the 1990s, an extreme upsurge of patent filings at the major patent offices (USPTO, JPO, and EPO) took place, and in addition new patent offices – and thereby new markets for technologies – have grown in importance, in particular in South Korea and China (EPO et al. 2006; WIPO 2009). This extreme patent upsurge raised concerns about the value of the applications and therefore about the appropriateness of patent indicators to reflect innovation capabilities. This concern is even more justified, as the input of R&D expenditure did not rise to the same extent in the same period. Many scholars suggested various explanations for this divergence of R&D expenditures and patent filings. These range from an increased R&D productivity, via new and more R&D-intensive technologies, an increased internationalisation, changes of patent systems, to the more frequent strategic use of patent applications by firms (Arundel, Patel 2003; Blind et al. 2006; Janz et al. 2001; Kortum, Lerner 1999). The upsurge faded out at the turn of the new century and R&D expenditures and patents found a new equilibrium. Although the upsurge ended and all the explanations have their justifications and their empirical power, observers of patent systems are still left with the impression that the number of worthless or at least less valuable patents has increased in the last decades. This impression is underpinned by the fact that many examiners at many patent offices complain about an increased number of trivial patent applications, or at least a larger number of patent applications with a low technological content.

Economic research on patents has considered this issue and analysed the values of patent applications and especially of granted patents in recent years (see for example Bessen 2008; Gambardella et al. 2008; Grönqvist 2009; Hall et al. 2005; Hall et al. 2006; Harhoff et al. 1999; Harhoff et al. 2003; Koléda 2005; Sampat, Ziedonis 2004; Stevens, Burley 1997). One of the main findings of this research is that there is indeed an extreme difference between very valuable patents and patents without much economic value. And the distribution between these two extremes is also highly skewed, as the majority of patents are of low value, whereas the number of extremely valuable patents is small.

The task of the underlying research reported here was to check if these imbalances have to be taken into account when the patent profiles of nations are comparatively assessed. Furthermore, an additional task was – given that these imbalances have an impact – to suggest weighting methods to reduce or even overcome these imbalances. Before we enter into the discussion of the valuation of patents and the implications and consequences for international comparisons of the technological competitiveness of nations, a general discussion on how to compare the profiles seems appropriate.

1.1 Which Patents are to Be Valuated?

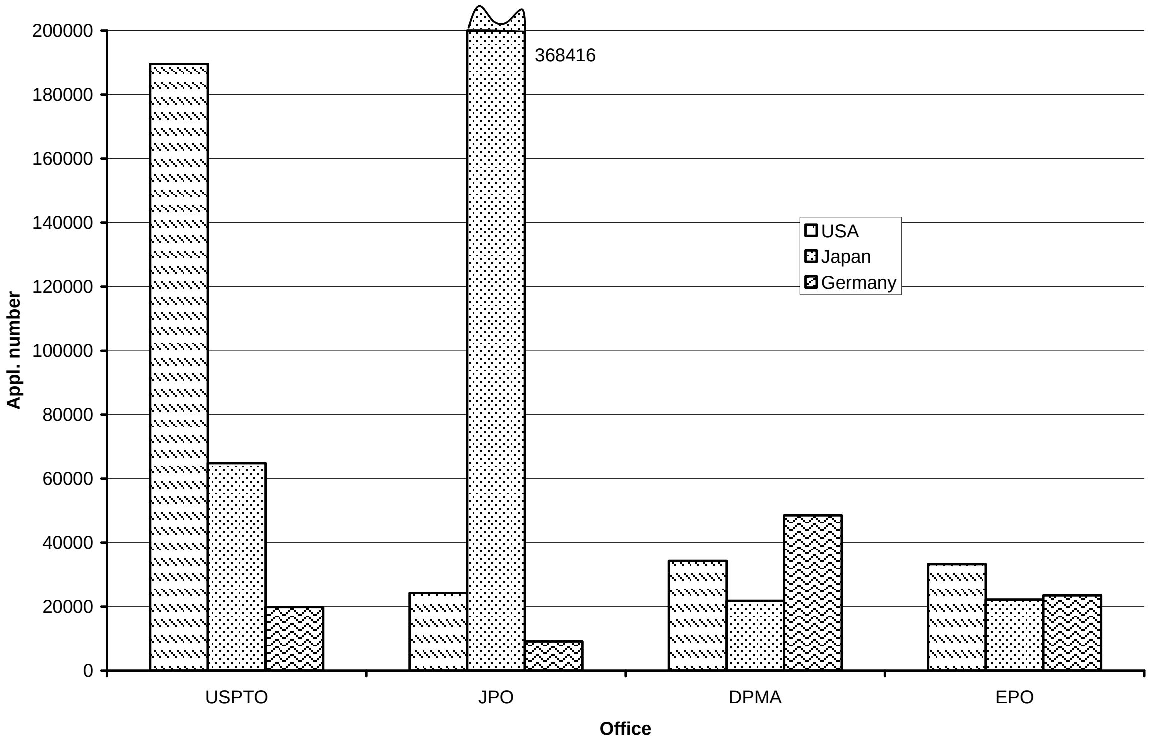
For many years, it has been well known that country comparisons at specific patent offices are biased. The so-called Triadic patents approach was conceived to cope with this problem. In the context of globalisation, this method proves to have increasing shortcomings and is not able to reflect the new world order. Therefore the novel concept of Transnational patents was suggested (Frietsch, Schmoch 2010) and was also introduced into the reporting system on behalf of the Expert's Commission on Research and Innovation.

Patents as an indicator have a dual character: on the one hand, patents provide information on the technological content, but on other hand, the patent filing is – of course – motivated by market interests. In particular, it is important for country comparisons to look at the strategic economic interest of specific countries of origin for specific markets of destination. This general statement will be illustrated by some examples (see also Frietsch, Schmoch 2010).

Many patent analyses are conducted on the basis of patent data at a specific national office, which protect the intellectual property rights in a specific national market. Domestic applicants have a particular economic interest in their 'home' market. In addition, the examination and grant procedure is less complex and costly for these applicants, as they can work with local patent attorneys and the communication costs are reduced. These conditions imply a domestic bias or domestic advantage for domestic applicants in the comparison of application numbers compared to those of foreign ones.

For instance, a comparison of the application numbers of U.S., Japanese and German inventors at the U.S. Patent and Trademark Office (USPTO) leads to a very high number of applications of U.S. origin (see Figure 1-1). Due to the enormous volume of the technological activities in the USA, the very high level of U.S. applications at the USPTO meets the general expectations. However, the relation between the three countries selected is not appropriate compared to other innovation indicators, focusing on a general comparison between the countries and an assessment of their innovative or technological strengths and weaknesses. A balanced assessment is not possible, based on national patent data only. For example, in 2004 the relations between the USA, Japan and Germany (here Germany is the benchmark and is set at 1.0) in terms of applications at the USPTO are 9.6 : 3.3 : 1.0, in terms of industrial R&D 4.7 : 2.2 : 1.0, and in terms of exports with R&D-intensive goods 0.94 : 0.74 : 1.0. The figures for the U.S. exports seem to be quite low, but they reflect that the largest market for R&D-intensive goods is the United States, and most U.S. productions in this segment aim at the U.S. market and less at exports. In any case, the share of applications at the USPTO of U.S. origin is obviously too high with reference to those of Japan and Germany. Even more extreme differences would result from comparisons at the Japanese Patent Office, where the Japanese inventors file about 40 times more patents than German ones, for instance. Vice versa, German inventors file about twice as much patents in Germany than Japanese ones do.

Figure 1-1: Total number of patent applications for selected countries of origin at different patent offices for the priority year 2004



Source: Frietsch and Schmoch (2010).

The European Patent Office (EPO) is a regional office and in consequence all application countries are foreign. This specific structure at the EPO implies a more balanced relation between countries of origin, leading to a relation between the USA, Japan and Germany of 1.4 : 0.94 : 1.0 (see Figure 1-1). Thus the relation between the USA and Japan is largely appropriate, but there is still a regional advantage for Germany, although much less pronounced than the domestic advantage at the German office. The regional advantage of German patent applications is largely due to activities in less R&D-intensive fields. In high-tech fields, in general most applicants file their patents at all large offices, so that the specific market preferences are less relevant. In any case, the calculation of specialisation profiles at the EPO implies adequate results, as no country is really dominant.

The world market in the period of the 1980s and early 1990s was dominated by the production and trade within and between the three big blocks United States, Japan and Europe, the Triad regions. Against this background, Grupp et al. (1996: 279f) proposed the so-called Triad patents. Triad or Triadic patents refer to patents which are applied for at all major offices of the Triad regions, i.e. the USPTO, the JPO, and the EPO. This concept specifies the geographic location of foreign patents more precisely and Grupp et al. (1996) could show a close link of Triadic patents to foreign trade with technology-intensive goods. So Triad patents proved to be an appropriate innovation indicator of international competitiveness.

The Triadic concept has the shortcoming that the numbers for most non-Japanese countries are defined by the applications at the JPO de facto, as this is the office where the lowest number of applications is filed by foreign countries, even if the patents are filed at the USPTO and the EPO. Therefore the outcome largely depends on the economic situation in the Japanese market. As the economic prospects in Japan were less promising during the 1990s, the applications of foreign countries stagnated or even decreased, although the patent trends in most other offices were generally positive. For instance, the German applications at the JPO decreased in the last years, but increased at the EPO.

The Triadic patent approach had its justification at a time when the world economy was less internationalised or globalised. Today, this picture has substantially changed. While in 1993 91.6% of worldwide exports of R&D-intensive goods originated from OECD countries and about 82% from the Triadic regions USA, Japan and EU-15, these shares have decreased and the OECD countries were only responsible for about 85.3% of the worldwide R&D-intensive trade and the Triadic region for about 69% in 2004 (Gehrke et al. 2007). In addition, there was a surge of internationalisation of research activities (Belitz et al. 2006; Döhrn, Edler 2002; Edler et al. 2003), international co-operations (Frietsch, Schmoch 2006; Mattsson et al. 2008; Schmoch 2007; Schmoch, Schubert 2008), international investment (Krawczyk et al. 2007; Patel, Frietsch 2007; UNCTAD 2005), and the number of international branches and affiliations of multinational enterprises (MNEs).

Another possibility for filing international applications is based on the Patent Cooperation Treaty (PCT). The advantage of PCT applications is that patent procedures can be started at the same time in many countries without the direct need of translation. Some selected offices conduct international searches and – if required – preliminary examinations which can be used for information, but which are not legally binding. So in contrast to the EPO, the PCT process implies primarily a central application without final grant. The PCT process ends with a transfer to selected national or regional offices. This transfer must be undertaken within 30 months or 2½ years after the priority year, at the latest. However, according to the standard rules of the so-called Paris Convention, all follow-up applications in foreign countries must be made within the first year after the first application. This requirement is fulfilled by a PCT application within the priority year. But due to late transfer to the final offices of designation, the real decision on foreign applications can be substantially postponed. This latter possibility especially explains the increased interest of enterprises in the PCT procedure, as 2½ years after the first applications, information about the economic potential of inventions in foreign markets is much better than at the end of the first year, so that the decision on the quite costly applications in foreign countries can be substantiated in a much better way.

At the beginning, the PCT applications were not well accepted, due to complex legal requirements and procedures. This is reflected in low application numbers compared to EPO applications in the early years. Due to an improvement of the legal framework, the PCT path became increasingly popular and the application numbers rose sharply in the 1990s. Because of this long transition period, meaningful country comparisons are not possible until about 2000. After 2000, the stagnation linked to the end of the new technology boom was quite short; in 2002 the number of PCT applications exceeded those at the EPO, and then the PCT applications increased much more vigorously than the EPO filings. The reason is a growing interest of newly industrialising countries in PCT applications. For firms from these countries, the ability to postpone decisions on broader foreign patenting is even more important than in advanced industrialised countries. Meanwhile, the patent activities of countries such as China, Korea, India, South Africa, Brazil, or Mexico are so important that they have a clear impact on overall patent statistics. However, country comparisons on the basis of PCT applications are not meaningful until about 2000, due to the very long period of acceptance of this system and the corresponding transition period.

Frietsch and Schmoch (2009) suggested an approach where the applications at the EPO and PCT applications are combined. This approach is called "Transnational Patents" or "World Market Patents". In detail, all PCT applications are counted, whether transferred to the EPO or not, and all direct EPO applications without precursor PCT application.[1] We exclusively include direct EPO applications in order to avoid double counting with transferred Euro-PCT applications. In other words, all patent families with at least one PCT application or an EPO application are taken into account. This combination of EPO and PCT applications leads to a realistic trend in the 1990s and it includes the growing activities of newly industrialising countries in recent years as well. In detail, the relation of Germany, South Korea, China, and India in 2004 in the Triadic approach is 1.00 : 0.10 : 0.03 : 0.02, in the Transnational one 1.00 : 0.16 : 0.07: 0.04. In consequence, the newly industrialising countries are covered much better by the Transnational concept.

The available data are as topical as direct EPO applications and the early publications of PCT applications – 1½ years after the priority date. This lag – regrettable from a statistical perspective – is due to international legal standards of the patent legislation.

Figure 1-2 shows the relations between the three large countries USA, Japan, and Germany according to the Triadic and the Transnational approach. In the Triadic approach, the relation between the USA, Japan, and Germany is 2.7 : 2.3: 1.0, according to the Transnational concept 1.9 : 1.2 : 1.0. Thus, according to the Triadic one, the weight of the USA in comparison to Germany is too high with regard to the weak foreign trade performance of the USA, but primarily, Japan is too strong with reference to the USA. This is due to the factual count of the USA on the Japanese market with less promising economic perspectives and of Japan at the EPO, reflecting an increasing interest of Japanese enterprises in the European market. So the "neutral" concept of Triadic patents includes specific market interests which are not directly visible.

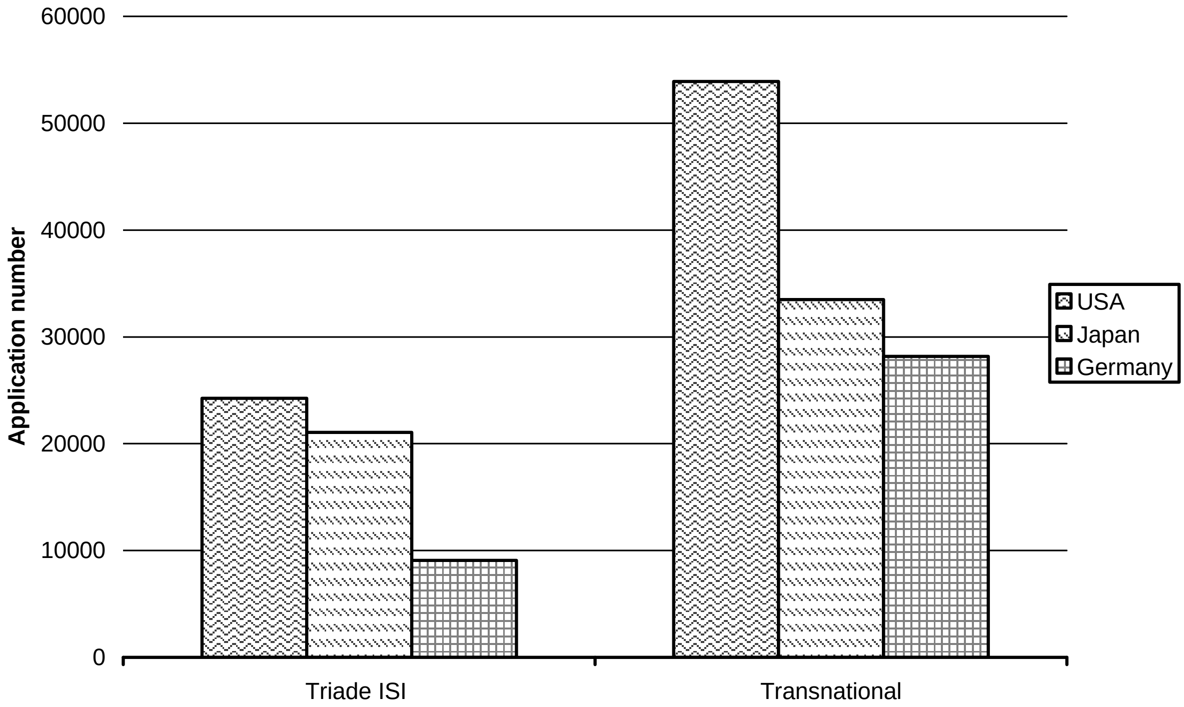
In the Transnational concept, the relation between Germany and the USA seems to be largely appropriate, with a stronger weight on R&D than foreign trade performance. However, the position of Japan is not yet satisfactory. It is better than at the EPO (see Figure 1-1), where Japan is even weaker than Germany, but a Japanese position in the middle between the USA and Germany would be more appropriate. The relatively weak status of Japan is owed to the very late acceptance of the PCT path by Japanese applicants. However, they have detected the advantages of PCT in recent years, and between 2001 and 2004 the share of Japanese applica-

1 However, all direct EPO applications with national precursor applications are included.

tions at the USPTO with precursor PCT applications has doubled from 13 to 26%. So the explanatory power of the Transnational concept will steadily improve in the next years.

A further advantage of the Transnational concept is the significantly higher number of applications considered. It is about twice as high as in the Triadic approach. Therefore a breakdown of analyses by technical fields and countries is statistically more reliable in terms of Transnational patents.

Figure 1-2: Total number of Triadic and Transnational patent applications for selected countries, for the priority year 2004



Source: Frietsch and Schmoch (2010).

1.2 The Obligations of Competitiveness Reports for the Sake of Policy Consultancy

The main intention of patent analysis in the context of national innovation systems is to provide comparative data and a comparative assessment of the technological competitiveness of these innovation systems. In this context, patents are seen as an output of R&D processes, which at the same time provide an input to future market activities, especially in technologically relevant markets. The aim of the reporting system of the Expert Commission – formerly of the Federal Ministry for Education and Research (BMBF) – where these kinds of analyses are regularly conducted, is also to provide a comparative evaluation of the technological performance, especially of industrialised and technology-oriented countries, among them – first of all – Germany, the USA, Japan, the United Kingdom, France, and many more. These reports and these assessments usually address policymakers to allow them to make evidence-based policies. In consequence, the assessments and underlying data have to be as up-to-date as possible, and the mandatory prerequisite of internationally comparable data has to be met.

The main spirit of the reports and analyses provided in the past hardly targeted the absolute numbers, but were much more interested in relative data and information that, on the one hand, allow the evaluation of the development over time. On the other hand, the relations between the countries and their technological competitiveness were the focal point of interest.

Especially when it comes to comparisons across countries and comparative assessments of patent portfolios, a systematic, meaningful and reliable database is required. In the 1990s, this was provided by the concept of Triadic patents, which were able to balance the home advantage of domestic applicants/inventors and – at the same time – to reflect the technological strengths and weaknesses of industrialised countries. The concept of Transnational patents was introduced to adapt to new structures and to new demands. This patent indicator is capable of grasping the new relationships and relative positions between the industrialised, industrialising and emerging countries. It also reflects the strengths and weaknesses of these countries in technology markets also based on other indicators like exports, or R&D activities, by offering data from homogeneous patent systems.

In addition to the focus on Transnational patent applications, an orientation to high-tech patents proved to be reasonable and helpful. Industrialised countries especially specialise in high-tech, where they can succeed in international markets in reaching the economic wealth and prosperity needed to maintain their standard of living. It should not be overlooked companies in industrialised countries are also active in low-tech areas. However, from an international market perspective, as well as from a technological competitiveness point of view, the R&D-intensive goods and commodities are of special interest. Several statistical analyses showed that multi-national applications are of higher economic, and especially technological value than purely national patent applications (Bessen 2008; Dernis, Kahn 2004; Frietsch et al. 2008; Frietsch, Schmoch 2006; Frietsch, Schmoch 2010; Grupp et al. 1996; OECD 2004). For the sake of this obligation, a list of R&D-intensive goods (so-called high-tech goods) was introduced (Grupp et al. 2000; Legler et al. 1992: 27 ff; Legler, Frietsch 2007). A concordance of the patent classification and this list of high-tech goods are regularly used also to restrict the analyses of patent data to high-tech patents.

To compensate the effect of the domestic bias, Soete and Wyatt (1983) suggested the introduction of the so-called Revealed Technological Advantage for the comparison of patent activities in specific fields. This index is defined in the following way:

$$RTA_{ij} = (Pat_{ij} / \sum_i Pat_{ij}) / (\sum_j Pat_{ij} / \sum_{ij} Pat_{ij})$$

Therein, Pat refers to the number of patent applications, i to the field considered, and j to the country. So the RTA sets the share of the patent applications of a country in a specific field in relation to the share of this field within all patent applications at a specific patent office.[2] The RTA index is generally used to determine specialisation profiles of countries, and it partly compensates the bias linked to the domestic advantage due to the normalisation by the total averages. Positive values point to the fact that the field has a higher weight in the portfolio of

2 For further details, see also Nesta and Patel (2004).

the country than its weight in the world. Negative values indicate specialisations below the average, respectively. This indicator allows the assessment of the relative position of a field in a country beyond any size effects. Neither the size of the scientific field nor the size of the country has an impact on the outcome of this indicator.

Applying the concept of Transnational patents as well as the focus on high-tech areas only, is already a kind of quality filter. All those patent applications that were only filed nationally or that are filed in low-tech areas – which demand by definition on average a lower investment in R&D – are already excluded from most of the analyses conducted in the reporting system on behalf of the Commission of Experts for Research and Innovation (EFI). In addition, the use of relative measures like the specialisation index or patent intensities also mitigates the impact of imbalanced value structures.

This report has the following structure. The next chapter (chapter 2) provides a broad literature survey on patent values, where different kinds of values are addressed and thereby the different perspectives taken in this report are defined. Chapters 3 and 4 review the existing literature on patent values. While Bart van Looy (chapter 3) summarises the literature with respect to which methods and results of patent valuation exist, John Walsh (chapter 4) takes a critical perspective on the patent value discussion. Chapter 5 summarises the findings from the literature and provides some basic descriptive statistics, chapter 6 uses renewal fees to estimate a regression model of patent values, and chapter 7 takes a macro-perspective, by valuating national patent portfolios by export data. Chapter 8 applies different weighting procedures to rank the patent profiles of selected countries and summarises and concludes with a suggestion for future treatment of patent data in internationally comparative studies of the technological competitiveness of innovation systems.

2. The Discourse on Patent Value

Rainer Frietsch, Taehyun Jung, Peter Neuhäusler, Yu Meng

2.1 Introduction

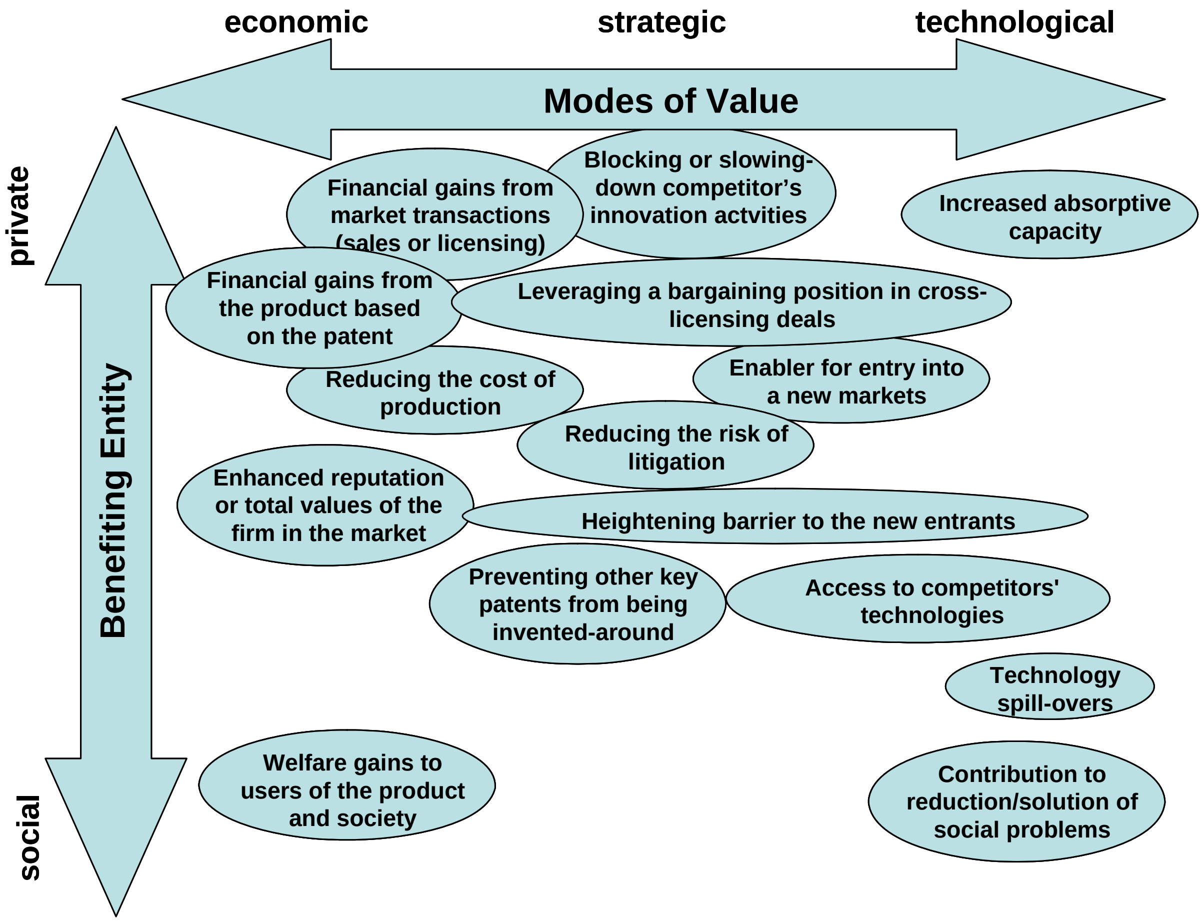
Patents have many different values to different people and parties. First, that a patent system should bestow private economic benefits on the inventors by endowing them with the right to exclude others from using their inventions. Second, catalyzed by these economic benefits accruing to the investment for the inventive activities, society will benefit from the advancement of science and technology. Probably, the latter benefits can be attained not only through the increased R&D investment in specific technologies that the society may need, but also through technology spill-overs occurring during the invention process, as well as technology disclosed in patent documents. Here, we present one important dimension of patent value with the two extreme poles: private and social.

Another important dimension of patent value is whether the benefits from patents are readily transferable into economic benefits. An important reason a society needs to secure inventors the exclusive right to their discoveries and inventions is to provide economic incentives for inventive activities. Furthermore, apart from the pure economic value, many studies focus also on the technological value. Technological value accrues to both inventors and others. Because inventive activities are cumulative and inclusive of tacit elements, research activities of one technology may increase the absorptive capacity of inventors (Cohen, Levinthal 1990). Also, technology disclosed during the process of invention and in patent documents may spill over to other areas of technology or contribute to other persons' developing advanced technologies. In particular, by securing the rights for a limited time, the importance of advancing social value by allowing imitation, improvement and contributing to cumulative innovation by allowing all others to use the invention after the inventor has enjoyed his temporary exclusivity is crucial.

Apart from economic and technological values, patents may create some strategic benefits for inventors exploiting positional advantage in market and technology spaces. This is a rather recent but increasing phenomenon in this era of patent explosion (Blind et al. 2006; Cohen et al. 2002b; Harabi 1995; Sheehan et al. 2003). The strategic value of patents include blocking or slowing-down competitors' innovation capacities, reducing possible future litigation risks, using patents as bargaining chips in cross-licensing deals, gaining access to financial markets, and preventing key technologies from being invented around. A strategic value can be also transferred into or regarded as an economic value ultimately. However, we separate it from the economic value for two practical reasons. First, the strategic value is realized only through the positions of the owner of patents in the market relative to others. Hence, economic gains from this positional advantage are quite sensitive to strategies taken by each participant. Second and foremost, as a consequence, the contingency value of a particular patent is hardly quantifiable at all, especially without knowing the other patents in the bundle and the cost of alternative strategies by the owner of patents as well as by competitors. In general, they are rarely seen in the financial reports of firms.

Figure 2-1 provides a taxonomy of the concepts of patent values and the different motives and incentives for applicants/inventors to file patents. As can be seen, economic and strategic values are closely linked, but there are some wide-spanning values. As a matter of fact, the values of individual patents – or even of patent portfolios – can hardly be separated or isolated.

Figure 2-1: Taxonomy of the concepts of patent value



Source: Own compilation.

2.2 Measures and Predictors of Value

In this section, we elaborate on the different value concepts presented in the taxonomy above. This overview is not comprehensive and does not reflect the totality of existing literature in this area. It aims at giving a brief overview of the discussions of the three dimensions of patent value. It also shows that it is possible to use different approaches to evaluate patents and their various dimensions, but it also shows that no literature exists on the use of patent value indicators as a deflator or balancing indicator of national patent profiles.

2.2.1 Technological Value

Technological value (or the technological significance, importance, or quality) of patents is typically measured by the degree to which a patent contributes to further developing advanced technology. Patent citations are loyal to this concept and widely used as an indicator of technological significance. The validity of this interpretation has been established by several studies examining cross-linkages between forward citation counts and subjective, experts' assessment of technological significance (Albert et al. 1991; Carpenter et al. 1981).

As for the technological value of patents in terms of enhancing absorptive capacity within a firm, Hagedoorn and Cloodt (2003)) show that the number of patents filed by the firm and the average citations received by those patents are significantly correlated with the development of new products. Also, the stock of patents within a firm is known to be positively associated with the absorptive capacity as measured by relevant alliance formations (Rothaermel, Deeds 2004) or sales revenue from new products (Nerkar, Roberts 2004). These findings indirectly support an argument that patents are a means to increase absorptive capacity. Both stock measures (number of patents aggregated at the organizational level) and quality measures (e.g. counts of citations received) are important predictors of this measure of absorptive capacity.

In chapter 1 it was discussed that patent indicators used in the reporting system of the Commission of Experts for Research and Innovation have a special focus on high-tech patents. From a macro perspective, this points to another dimension of technological value, which is defined by its input. The logic behind this approach is not only that the patents or technologies can be valued by the R&D, but that the fact of R&D investments and structured research processes allow the following assumption: R&D is first of all an investment of knowledge, so the technologies are also knowledge-intensive. This makes them harder to replicate or to copy, as not only codified or explicit knowledge enters the process, but also tacit knowledge and experience. An exclusive technology – this is the consequence of the replication or copy threshold – is of higher technological value than a simple or replicable technology. Though even high-tech can sometimes be easily replicated, for example, by reverse engineering. However, it is the role of the patent system to protect the original invention. As long as the criteria of novelty is given and checked by the patent offices, as well as the assumption of high R&D investment (on average) for the technology area is reasonable, then the imputation of a high technological value is justified.

2.2.2 Radical and incremental inventions and innovations

When considering the technological value of patents, it is important to be aware of the link between invention and innovation. In innovation research, it is broadly accepted to distinguish between radical and incremental innovation. Referring to that, a differentiation between radical and incremental inventions is obvious. In this perspective a radical invention is the starting point of a new technology and a new technology cycle. For bringing the radically new technology into the market, it is necessary to elaborate a specific design and to react on requirements of the users. The related improvements are linked to incremental inventions/innovations and are decisive for transforming a radical invention/innovation into a marketable product or process. So technological trajectories are reflected in a series of incremental inventions over a longer period. It may happen that completely new ways of realising a new approach are detected that substantially improve the technology of the basic radical innovation. These substantial improvements are labelled "micro-radical" by Durand (1992). These micro-radical innovations are again refined by a series of incremental innovations.

This typical way of techological developmet was already well described by Tushman and Anderson (1986), based on empirical evidence in cement, aircraft and minicomputers.

"Major product breakthroughs … or process breakthroughs are relatively rare. … These … discontinuities trigger a period of technological ferment. … The technological experimentation and competition persists … until a dominant design emerges. Once a dominant design emerges, technological progress is driven by numerous incremental, improvement innovations. … Technological change is a bit-by-bit, cumulative process until it is punctuated by a major advance". (Tushman, Anderson 1986: 440 f.)

In terms of the technological value of patents, this typical development is reflected in a radical invention/patent with a high technological value and many subsequent incremental inventions with lower value, when they are considered in an isolated way. However they are decisive for bringing the radical invention into the market and for maintaining the competitive advantage achieved by the radical invention. In consequence, not the value of a single patent for an incremental innovation is relevant, but rather the value of many subsequent patents reflecting the stock of knowledge with reference to a radical invention. So it seems to be less appropriate to exclude incremental inventions from the analysis of technological value, as they have a relevant function for economic performance.

As the differentiation between incremental and radical innovations and inventions is highly relevant for assessing patent value, the discussion of these concepts in the literature will be described in more detail. Radical innovations are original products or processes that offer models for imitation, whereas incremental innovations refer to new products and processes where existing ones are slightly improved. Due to their originality, radical innovations are much more profitable than incremental ones and are regarded as the engine of technological evolution and economic growth (Achilladelis, Schwarzkopf 1990).

For innovating firms and their competitors, the relatively greater number of incremental innovations depends on three coherently interrelated factors:

1) product development trajectory;
2) managers' choice between competence exploitation and competence exploration; and
3) a tendency toward specialization.

While a radical innovation signalizes a new "technological paradigm/trajectory" (Dosi 1988), a "technological guidepost" (Sahal 1985), or a new "technology regime" (Nelson, Winter 1982), the original nature also implies its far distance from the market (suppliers, customers, and complementary product suppliers). Therefore, a series of complementary innovations are needed to ensure the familiarization and acceptance of the new innovation. Once a radical innovation is introduced in the market, it has fast increasing profits at its early development stage according to the S-curve theory (Foster 1986; Utterback, Abernathy 1975), which motivates the innovating firm and its competitors to keep refining the new product/process to diffuse its application and fully garner the benefits.

However, an ex ante delineation of a product's trajectory is very tricky, placing managers in a strategic choice dilemma between investing in radical and incremental innovations. Exploiting existing competencies that are associated with incremental innovations may enhance the efficiency and reliability of existing technology, skills, and processes, and therefore yield short-term success. The exploitation strategy, though, will hinder a long-term capability of innovation by crowding out the resources and suffocating creative ideas for the *competence exploration* associated with radical innovations (Atuahene-Gima 2005; Levinthal, March 1993; March 1991). Although managers are making efforts to balance competence exploitation and exploration, considerable complexity and uncertainty that characterize radical innovations (Gibbons, Littler 1979) predict a propensity among them for exploitation over exploration. And the preference towards incremental innovations is especially true for small and medium-sized enterprises (SMEs) given that size is a good predictor of radical innovative activities as a proxy of financial and technical capability (Chandy, Tellis 2000).

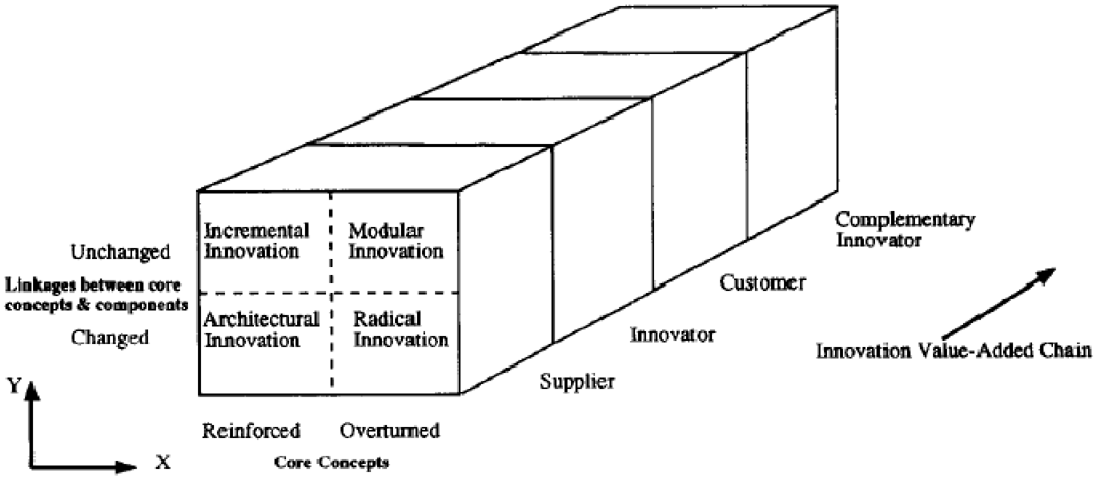
Another force driving managers, including those of innovative firms, to favor incremental innovations is the pursuit of specialization. The seeming paradox between specialization and radical innovation can be compromised by a strong tacit component in knowledge and technology (Polanyi 1967; Tsoukas 2003); Firms tend to accumulate organization-specific competencies that do not solely secure their incumbent position, but strengthen their capacity to grasp the opportunities of innovation (Achilladelis, Schwarzkopf 1990; Chandy, Tellis 2000; Christensen, Rosenbloom 1995; Dosi 1988; Pavitt 1983).

For all entities along the value-added chain, including the innovating firm and its competitors, suppliers, customers, and complementary product suppliers, an innovation has various faces, which is conceptualized as the "hypercube" of innovation by (Afuah, Bahram 1995). According to Henderson and Clark (1990) innovations can be classified as four types based on the degree of change along two dimensions, core concepts and linkages between concepts, and the four types are:

1) *radical* if the core concepts and the linkages overturned the existing ones;
2) *architectural* if the core concepts were reinforced while the linkages between key components were changes;
3) *modular* if the core concepts were overturned but the linkages were unchanged; and
4) *incremental* if the core concepts were reinforced and the linkages were unchanged.

On the basis of this classification, Afuah and Bahram (1995) pointed out that one innovation may be identified as one type of innovation by firms at one stage, but as another type by firms at another stage along the value-added chain (see Figure 2-2). In other words, an incremental innovation at the innovator level may turn out to be radical to customers and architectural to suppliers of complementary products. The hypercube concept of innovation has an important implication for the potentially convertible role of incremental innovations. When an innovation is claimed as incremental in the innovating technology sector, it may be revolutionary in other sectors that are located in different stages relative to the innovating sector along the value-added chain. This deeper analysis of different types of innovation again shows that a premature exclusion of incremental innovations - and incremental inventions - from the assessment of patent value may be misleading.

Figure 2-2: The hypercube of innovation



Source: Afuah and Bahram (1995: 53).

2.2.3 Economic Value

The economic value of patents is not determined solely by the characteristics of a single patent, but by various factors of a technology, firms, competitors, and markets. Thus, the economic or commercial value of individual patents can hardly be derived from information contained in a single patent document. Furthermore, the economic benefits of a technological product can hardly be assigned to one single patent, as this product is usually the result of several technologies – also often protected by several patents – implemented in one device, machine etc. For example, the debate in Japan on employee-inventor compensation centers on this problem of how to assess the contribution of a single patent to the overall economic value of a complex product, with the case of the blue LED as the most famous case (with the final settlement paying millions of dollars to the employee-inventor). However, it is also well established in the empirical literature that some patent indicators predict the economic and social values of patents.

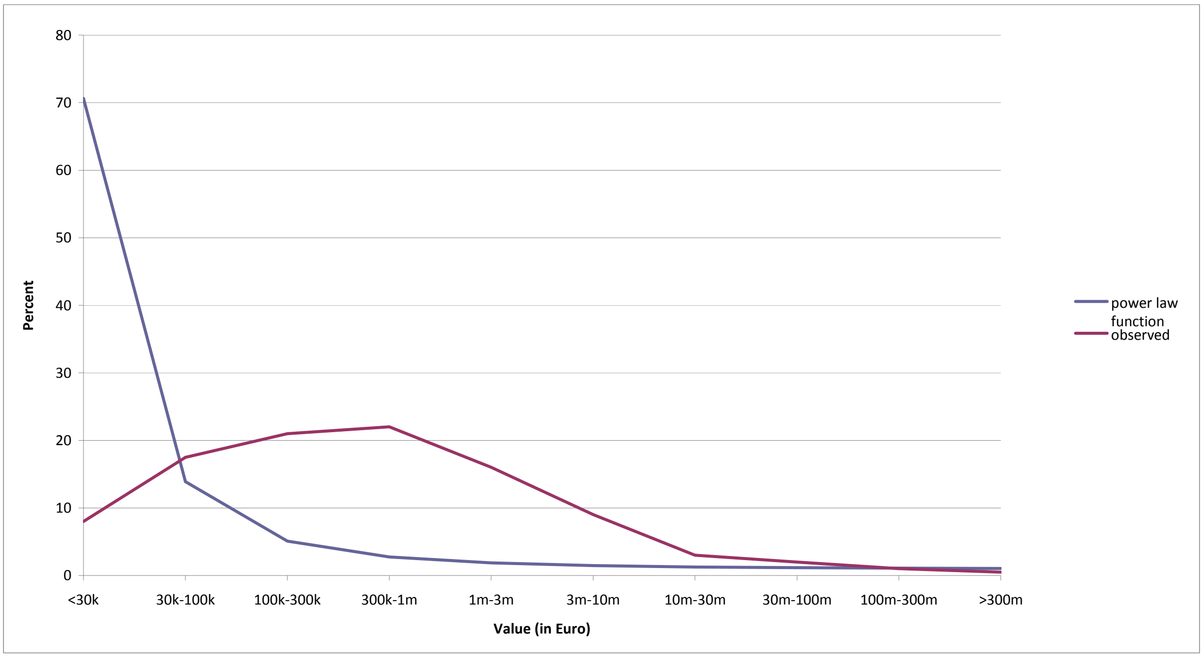
Private economic gains from an individual patent are measured in various ways, including whether the patent is licensed or not (Gambardella et al. 2007; Sampat, Ziedonis 2004), by licensing revenues (Sampat, Ziedonis 2004), by renewal history (Bessen 2008; Harhoff et al. 1999; Schankerman, Pakes 1986; Schankerman 1998), by opposition and litigation history (Harhoff, Reitzig 2004), and by expected sales values of patents (Gambardella et al. 2008; Harhoff et al. 1999; Harhoff et al. 2003). Among these measures, the renewal and opposition history can be acquired directly from patent databases. Other patent indicators that predict these economic values differ across studies. However, the following patent indicators are usually examined in the literature: forward citation counts, backward citations (either to patent documents or non-patent references), the breadth of patents (either as measured by the number of different technology classes or the number of claims), or the size of the patent family.

Several other studies take the stock market value of firms as an aggregated measure of economic value (Hall et al. 2005; Lanjouw, Schankermann 2004; Nagaoka, Kwon 2006) or other financial performance indicators at the firm level (Hagedoorn, Cloodt 2003; Narin, Noma 1987). They examine how these value measures are predicted by various patent indicators including the number of patents, forward citations and others.

A straightforward approach is a survey as described in chapter 2.2 further below. These surveys also confirm the assumption of a skewed distribution of the economic value. However, it is worth it to look at these findings in more detail. In this context, Figure 2-3 shows the value distribution as investigated by Giuri et al. (2007) where the very skewed distribution of values at the area of high values is obvious. However, the observed distribution approximately has the shape of a log normal function, and not of a power law function. The special feature of the log normal function is that the distribution on the side of high value is skewed, whereas the share of patents with very low or no value is rather limited. The majority of patents is situated in the area of low and medium values. In the case of a power function, the share of patents with very low or no value would be quite high. Of course, the distribution is still extremely skewed in terms of concentration on very high values; about 10% of the applications represent about 90% of the value. Nevertheless, the area of low and medium values with the majority of applications refers to the value area from € 300 thousand to € 10 million, thus a level which is not negligible at all.

Linking the values to type of inventions and applicants, most of the low and medium level applications reflect incremental inventions and patents and/or patents of small and medium-sized enterprises (SMEs) with limited markets. In contrast, the patents with very high values are primarily linked to radical inventions of very large enterprises with large markets and some breakthrough inventions of start-up enterprises. Thus a limitation of the analysis to patents with very high value would imply the concentration on some patents of very large enterprises and successful start-ups, and the incremental inventions of all types of enterprises and those of SMEs would be disregarded; thus major parts of economic activity would not be reflected.

Figure 2-3: Distribution of the economic value of patents according to the survey data and an ideal power law function



Source: Giuri et al. (2007).

2.2.4 The Social Value of Patents – Spilling Over

The social economic value of patents has been hardly measured and, hence, hardly studied. One investigation by Trajtenberg (1990) measures the benefits accruing to the users of a medical device and show that citation-weighted patent counts well predict them. Studies at the regional or national level examining the relationship between regional or national financial performance and patenting performance will be further reviewed in the course of this project, with regard to the social value of patents.

Schumpeter (1908) defined social value as the value set by a society or a community instead of any simple individual, which is thus characterized by collectivity and altruism. As a patent is a legal intellectual right granted by an authorized government entity (patent office) to exclusively protect its holder's commercial benefits from unauthorized use for a certain period of time, the patent system offers the temporary monopoly to inventors in exchange for their early disclosure of new technologies. The implications of the patent system are twofold. One is to encourage investments and efforts in inventive activities, but it is less important, given that there are many means to achieve the same goal. The more important implication, from a social point of view, is to force inventors to disclose their newly developed technologies, based on the assumption that the spill-over effects, or externalities, of public knowledge are beneficial for the whole of society.

The crucial role of "knowledge", "technology", or "innovation" in shaping and enhancing economic development has been recognized by many economists and policy-makers (Edquist, McKelvey 2000; Lundvall, Foray 1996; Malecki 1991; Nelson, Romer 1996). Therefore, enlarging the stock of public knowledge is assumed to be critical for both technological and economic development. In sum, the social value of patents, or how society benefits from inventions, is technological advancement and ultimately economic growth. If a new technology contained in a patent is significant, it cannot only advance the field to which it belongs, but also provides new concepts, tools, and ways of production that facilitate innovations in other fields, and gradually update the level of technological capabilities in the whole society.

Patents (and R&D leading to developing the patented inventions) have spill-over benefits. Geographic spill-overs of R&D are well known phenomena (Griliches 1992; Jaffe 1986). Likewise, many studies provide empirical evidences of spill-overs from patented technologies to the technological capacities of companies (Jaffe et al. 1993; Jaffe et al. 1998; Jaffe et al. 2000). A key measure of knowledge spill-overs from patents is the distribution of patent citations, across either regional or technological boundaries. Spill-overs between technologies or technological classes, thereby providing new developments for example by "new combinations" (Schumpeter 1908) has been analyzed by Grupp (1996). In their seminal paper, Jaffe, Trajtenberg, and Henderson (1993) argued that patent citations indicate knowledge flows because citations codify the passage of ideas. From then on, while many studies have employed this indicator to investigate spill-overs (Acs et al. 1994; Almeida 1996; Audretsch, Feldman 1996; Breschi, Lissoni 2004; Maurseth, Verspagen 2002; Thompson, Fox-Kean 2005), a good number of studies have been undertaken to examine the validity of the indicator (Alcacer, Gittelmann 2004; Jaffe et al. 2000; Lemley, Tangri 2003; Meyer 2000; Michel, Bettels 2001; Nelson 2009). A primary concern with patent citations or measures constructed by citations centers on whether all subsequent innovations are built directly upon knowledge contained in a cited patent as assumed. While patent citations are generated by attorneys and/or examiners in addition to inventors, it has been demonstrated that they are, albeit pertinent, a noisy indication of knowledge flows from cited innovations to citing inventors (Alcacer, Gittelmann 2004; Jaffe et al. 2000). Another issue associated with patent citations, due to the scheme of different patent systems, is a redundant or incomplete list of prior arts. Michel and Bettels (2001) found that remotely related work is also cited for fear of running the risk of filing an incomplete list of references, while Lemley and Tangri (2003) discovered applicants are possibly incompletely citing prior arts to reduce the damage from "wilful infringement." Moreover, Nelson (2009) points out patent citations may both under-represent and over-represent spill-overs by neglecting scientific article authors and licensees as downstream users.

Next to the stock of patents and count of citations, several further patent indicators are reported to predict the technological value. They include the numbers of claims, backward citations, and the number of different patent authorities where the patent is filed (see Lanjouw, Schankermann 2004). However, these indicators are shown to be important predictors of technological value in many other studies.

The number of licenses could be considered as an appealing measure of knowledge spill-overs. Given that a licensee has typically to pay 1) an upfront fee and/or 2) an annual fee and/or 3) a percentage of annual revenues on related products, licensing indicators, compared to patent citations, should be able to reflect a more explicit relationship between the licensee and his licensed patent and a stronger impact of the latter on the former. However, it is difficult to collect the licensing data, especially from private firms. Most studies targeting the relationship between licensing and spill-overs were based on licensing data from university technology transfer offices (Nelson 2009; Thursby et al. 2001; Thursby, Thursby 2002), leaving unexamined the patents licensed in industry and other public research institutes. The distinction between two kinds of licensed patents also merits attention, patents containing embryonic and non-embryonic inventions, because the latter ones that are "ready to use" have nothing to do with technology transfer (Colyvas et al. 2002).

Citations of patents in publications have been suggested as a candidate for measuring spill-overs (Nelson 2009). The observed convergence between academia and industry (Hong, Walsh 2009; Powell, Owen-Smith 1998; Slaughter, Leslie 1997; Slaughter, Rhodes 1996) usually refers more to the proximity of academia to industry than the other way around, owing possibly to the commercial emphasis and an ingrained thinking of "linearity" between scientific research and innovation, research on spill-overs predominantly focuses on the diffusion of scientific research results in academia to industry and usually investigates such diffusion by using survey data (e.g. Agrawal, Henderson 2002; Cohen et al. 2002a). However, the relationship between scientific research and innovation is reciprocal and complicated instead of "linear" (Etzkowitz, Leydesdorff 2000; Gibbons et al. 1994; Stocks 1997), publication citations to a patent offer another indication of spill-over effect of a patent, and should reflect a more complete picture of how a patent benefits the whole of society together with patent citation and licensing data.

In addition, the co-patent measure indicating the involvement of different organizations in an innovative project reflects the spill-over effects. As Feldman and Kelley (2006) argued, when different organizations have a project-oriented collaboration, the benefits would spill-over to influence the involved organizations' innovative processes and activities rather than be confined to the collaborative project. Moreover, the social welfare can be enhanced by allowing for more efficient use of expertise and assets (Winter 1987), shortening the innovation cycle and decreasing risks and costs of generating innovations, as well as reducing unnecessary duplicated work, resource waste, and patent races (Reinganum 1989). Although the co-patent measure has become a prevalent variable measuring collaboration (e.g. Guellec, van Pottelsberghe de la Potterie 2001; Hagedoorn et al. 2003; Hicks, Narin 2000), it is seldom treated as an indicator of spill-over effects. One reason is that many enterprises attribute a patent application to one assignee - even in the case of a collaborative invention – and close a license contract, as then the rights of both partners can be defined in a more precise way. In this case, the collaboration is not reflected by multiple applicants.

2.2.5 Strategic value

Besides economic and technological values, patents may create strategic benefits, which is an increasing phenomenon in the era of patent explosion, where it is argued that patent strategies of innovative companies became broader and more complex, thus resulting in an expansion of patent applications. The patent system, whose original purpose was to provide a temporally limited protection for technological knowledge, is more intensively used by companies for various other so-called strategic motives (Blind et al. 2009). The strategic value of patents includes blocking competitors, easier access to financial markets, preventing key technologies from being invented around and the generation of licensing revenues.

This strategic value has frequently been studied in recent years. Several large-scale surveys of inventors or R&D managers clearly provide evidence that a strategic value of patents exists, having several sub-dimensions (Blind et al. 2006; Cohen et al. 2002b; Harabi 1995; Sheehan et al. 2003). Also, more detailed case studies were published recently. They attempt to characterize and examine factors affecting strategic values (Grindley, Teece 1997; Hall, Ziedonis 2001; Reitzig 2004; Reitzig et al. 2007; Ziedonis 2004).

It could clearly be shown that the existence of the patent system offers possibilities to exploit patents for strategic purposes (Blind et al. 2006; Blind et al. 2009). Generally, according to Arundel and Patel (2003), all motives that go beyond the protection of one's own inventions to appropriate benefits in relevant markets based on this inventions are defined as "strategic". The consequence is that the decision to patent has partly uncoupled the technological needs of protection from competitors in the traditional sense or at least the strategic behavior of other market participants is anticipated, and patents serve as new sources of revenue (Blind et al. 2006).

The strategic values do not only cover monetary aspects like access to financial markets, licensing revenues and the like, but also more indirect ones like the motivation of employees. In general, companies' patent portfolios can be seen as a hurdle to deter new potential competitors from entering the market or to establish themselves in a certain sector.

The most common strategic motive is blocking competitors, which can be differentiated in two versions (Blind et al. 2006; Blind et al. 2009). The first is the so-called defensive blockade, where firms use patents to avoid their own technological room to manoeuvre being diminished by patents of others. The second version is the offensive blockade, that exists when firms only patent to prevent competitors using technological inventions in the same or adjacent areas of application that are close to one's own inventions, but not identical. So-called patent thickets (cf. Cockburn, MacGarvie 2009; Shapiro 2000) are built up and firms patent "more broadly" than necessary to directly protect an invention.

In addition, there is a large bandwidth of further strategic motives (Blind et al. 2006; Blind et al. 2009; Cohen et al. 2000). For example, firms may choose to generate licensing revenues or trade with other firms (cross-licensing), or use patents as bargaining chips in negotiations with other companies to gain access to new technologies, which is especially prominent in sectors like ICT (Hall, Ziedonis 2001). Furthermore, patents can be used for international market extension, standardization or to increase the firm's reputation or technological image. Another motive can be seen in the use of patents as a measure of internal performance of a firm's R&D personnel that can also be used for motivational purposes, as the innovative output can easily be assigned to single organizational units.

Especially for SMEs (small and medium-sized enterprises), easier access to the capital market can also be regarded as a strategic motive for patenting. Innovative results are made visible by the use of patents. This can serve as a signal of lower risk for potential investors, which increases their willingness to invest. From this point of view, technological start-ups are largely dependent on patenting.

However, most of the strategic motives are potentially more beneficial for large enterprises (Blind et al. 2006; Neuhäusler 2009). Blocking competitors, for example, is not possible until a firm has some patents at its disposal and has the (financial) capabilities to patent broadly (Blind et al. 2006). The use of patents for cross-licensing negotiations or trade with other firms also tends to be more beneficial for larger companies, as a larger patent portfolio accompanies such "player-strategies" (Cohen et al. 2000; Hall, Ziedonis 2001). Additionally, using patents as an internal performance indicator can also be seen as being far more beneficial with increasing firm size, mainly because larger firms are assumed to have more R&D personnel and more often possess a special in-house patent department that can be evaluated. Additionally, complex product industries, e.g. the electro-technical and automotive industry, where the number of patents per innovation is large, are assumed to show increased strategic use of patents, than discrete product industries, like the chemical sector, where the number of patents per market-exploitable innovation is considerably smaller (Cohen et al. 2000; Cohen et al. 2002b).

Another kind of strategic value of patents lies in their representation of codified knowledge (Grupp 1998). One basic assumption of patent indicators used in the context of national competitive analysis is that they reflect the knowledge capabilities or the knowledge stock of a company and – in a wider perspective – of nations (Frietsch, Schmoch 2006). A patent may have no direct value for the firm or the innovation system, but it is part of a technological trajectory where others will have a high economic, strategic or social value, and these valuable patents build on the (economically) less valuable patents.

Although it is hard to measure the strategic value of patents, the analyses of withdrawal information could serve as a rough estimate. The argument is that, for example, blocking patents which have no direct technological value, are only used as long as they do not create any costs. Payment of maintenance fees at the European Patent Office is not required until three years after filing a patent (European Patent Office 2009). As innovation cycles in many technological fields are rather short and are becoming even shorter, the three-year period suffices to deter market entrants and competitors from patenting in the same field. So patents that are withdrawn shortly before the three-year period ends could at least roughly be seen as an indicator for strategic patenting.

3. Indicators to Assess Patent Value: An Overview and Exploratory Assessment

Bart Van Looy, Robin Devroede, Mariette Du Plessis

3.1 Indicators of patent value

In this section, we provide an overview of the most common indicators of patent value. These indicators will be 'tested' in a second section with a sample of university-owned patents; the actual use of these patents (signalling more or less economic value) will be related to (some) common indicators. This analysis will allow some additional light to be shed on the relevancy of patent value indicators.

3.1.1 Overview of indicators

Renewals

Schankerman and Pakes (1986) introduced the concept of "renewals" as an indicator of patent value. Patent counts as such cannot be considered as fully grasping the notion of innovation 'output'. Indeed, if an assignee pays renewal fees, he/she expects to earn at least the cost of the fee (either by using the technology in a certain product which yields profit, by licensing it out to a third party, and/or as part of a larger patent portfolio which may be exploited commercially as a whole). Hence, renewal fees seem to be better suited to capture the variation in the value of patents. Their analysis reveals that more than half of the patents analyzed were cancelled after 8 years; only 25% survived after twelve years. These figures confirm the skewed distribution of patent value; only a limited number of patents last for 20 years. Of course, renewal data also raise some issues. First, the information on renewal behavior only becomes visible over time, which may imply a disadvantage compared to (some) other indicators. Secondly, renewal data are not readily available for all patent offices in a harmonized manner.

Forward citations

Already in 1984 Narin and Noma (1987) advanced the idea that forward citations might be a relevant value indicator for patents; this concept was made more prominent by Trajtenberg (1990). His results – within the field of tomography (number of patents: 456) – seem to confirm the usefulness of this approach, as patent counts weighted by citations turned out to be highly correlated with value, whereas patent counts per se were not. The forward citations indicator is based on the fact that inventors (have to) mention prior art (patent and non-patent documents); front page references are references withheld or introduced by examiners to qualify the claims of the patent. These processes generate forward citations, as some existing patents are being cited by new patents; the more a patent is cited, the more important it is (cf. also the notion of citations used to qualify scientific papers in terms of quality and impact). The citations indicator is the most frequent indicator used in the literature and has been validated by means of market-based data or events (Hall et al. 2005; Harhoff et al. 1999; Lanjouw, Schankerman 2001) and through surveying inventors (Harhoff et al. 2003).

Also the number of self-citations among the forward citations of a patent has been considered as a potential indicator. It was proposed by Harhoff et al. (2003) and later also used by Hall et al. (2005). The rationale of self-citations is based on the fact that self-citations suggest that a firm has a strong competitive position in the technology under consideration.

Opposition

A third indicator of patent value is opposition. This indicator was introduced by van der Drift (1989) who pointed to the usefulness of this indicator; Harhoff et al. (2003) and Harhoff and Reitzig (2004) confirmed that oppositions and the value of patents are positively related. This indicator is to some extent specific to the EPO system, because of the possibility provided to oppose a patent (within 9 months after grant). In the USA, litigation fees have been used as an indicator (Lanjouw, Schankerman 2001; Lanjouw, Schankermann 2004).

Opposition as an indicator of value stems from the observation that there seems to be a market for the invention and that both the applicant and the opposing party are willing to incur additional costs to safeguard their property rights. In practice, opposing a patent is a relatively rare event. Figures provided by Harhoff et al. (2003) show that only 8% of all EPO patents are opposed. This also implies that for a majority of patents an opposition or litigation does not enable us to infer the patent value.

Family size

This indicator of patent value was introduced by Putnam (1996)[3]; it refers to the number of countries for which a patent has been applied for (or granted). The family size indicator is based on the fact that a patent should be more valuable if protection has been sought in a larger number of countries. This is due to the costs that have to be borne in order to file and enforce a patent in various countries. Therefore it is expected that the owners of the patent only extend their patent abroad if there is a sufficiently large market for the technology protected by their patent. Note that this rationale also applies to so-called 'triadic' patents; i.e. patents that are filed and maintained simultaneously at EPO, USPTO and JPO.

Family indicators can be combined with the renewal indicator in order to measure along the life cycle of the patent the number of countries in which the patent survived This approach was introduced by van Pottelsberghe de la Potterie and van Zeebroeck (2007) through the Scope-Year index.

Grants (versus applications)

This indicator of patent value is very straightforward and the information is directly accessible. The fact that a patent has been granted is a sign of value, as it had to undergo the granting process. This indicator has often been used as a preliminary condition, so researchers consider only granted patents when assessing the technological activities of firms. However, it should

3 It was already suggested by Schmoch et al. (Schmoch et al. 1988) – however in German – and was less visible at that time.

be stressed that pending applications also have value, as patent rights apply retroactively[4], once granted. A disadvantage of grants often is the substantial length of the grant process and thus the delayed availability of the information on grant. This delay is linked to the workload of the patent offices, lengths debates in complex cases and the possibility at various patent offices, to delay the start of the examination process (Harhoff 2009).

Number of claims

The number of claims provides an indication of the legal breadth of patent protection. It is a sign of the complexity of a patent. One could argue that the breadth and complexity it implies should coincide with value. Tong and Frame (1992) have validated this indicator, observing that patents weighted by their claims are positively linked with measures of national research performance, and also Lanjouw and Schankerman (2001) who showed that a patent is more likely to be litigated if it has more claims (using litigations as a dependent variable in their model of patent value).

Number of IPC classes

This indicator of value was introduced by Lerner (1994) and also concerns the scope or breadth of a patent, but this time in terms of technology classes. Lerner showed that the scope of the patents - measured by the number of IPC4 digit classes - had a positive and significant impact on the value of American biotechnology firms. A patent that has a higher technological diversity is seen as broader in scope. As inventions are considered to be a combination of existing ideas, inventions based on a wider set of ideas should be more valuable (Guellec, van Pottelsberghe de la Potterie 2000). At the same time, this indicator has often been regarded as non-significant (see Reitzig (2004), but also Lerner (1994) and Harhoff et al. (2003)).

The number of inventors

This indicator is based on the hypothesis that a patent resulting from the research of several inventors should be more valuable than a patent which was developed by a single inventor (Schmoch et al. 1988). It was found to be positively correlated with the likelihood of being opposed by Reitzig (2004).

Backward citations

Backward citations refer to references to previous patents. This indicator provides information about the technological background of the invention. This information is present in the state-of-the-art mentioned in the patent application. The rationale of backward citation is ambi-

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4 Article 67(1) EPC :"A European patent application shall, from the date of its publication under Article 93, provisionally confer upon the applicant such protection as is conferred [to granted patents] by Article 64, in the Contracting States designated in the application as published"

Article 67(2) EPC: "every State shall ensure at least that, from the date of publication of a European patent application, the applicant can claim compensation reasonable in the circumstances from any person who has used the invention in the said State in circumstances where that person would be liable under national law for infringement of a national patent" guous, as two effects seem to play against each other. On the one hand, backward citations reflect the scope of the patent, as a patent examiner may have to include more references if the scope of the patent is large. On the other hand, a higher number of backward citations causes the content of the patent to be more restricted and therefore limits its possible value (Harhoff et al. 2003).

Backward citations are available much faster than forward citations, as they can be retrieved directly from the patent document and were found to be positively correlated with patent value by Harhoff et al. (2003).

Filing routes

There are different routes available to a patent applicant to file his application at the EPO.

One possibility is to file the patent application directly at a national patent office or at the EPO. From that date – the priority filing – applicants have one year to make their final decision on which countries they want to extend their patent to. A new filing route became available since the Patent Cooperation Treaty (1978) came into force. This PCT route enables applicants to wait 31 months instead of 12 months before a final decision has to be made on the international extension of their patent. This route has become very popular, with 53% of the applicants using it to reach the EPO in 2005.

Whether a patent has followed the PCT route or not can be immediately ascertained from the front page of the patent application. This indicator is, as of now, still unclearly linked with value. This is explained by the fact that the PCT route can be used for very different reasons. On the one hand, applicants aiming at a wide extension of their patent will use the PCT route, on the other hand, applicants who are still unsure of the potential market for their invention and who are applying for a patent at a relatively early stage may want to use the longer delay offered by the PCT route with regards to the international extension (Schmoch 1999; van Pottelsberghe de la Potterie, van Zeebroeck 2008). These two possible uses of the PCT route lead to completely different conclusions as to how valuable the patent is. The former can be associated with a more valuable patent, the latter on the contrary would lead to the opposite conclusion (see in this respect also the findings reported by Reitzig (2004)). Recent work by Stevnsborg and van Pottelsberghe de la Potterie (2007) builds further on this idea and attempts to create a typology of filing strategies, signalling more or less value.

Surveys of patent value

The most direct way to assess patent value and to arrive at an actual monetary value of a patent is through surveying inventors or owners of the patent. Examples of studies adopting this methodology are for instance the PatVal survey and surveys done by Harhoff et al. (2003) and by Harhoff et al. (1999). The main advantage of these types of survey is that a monetary value can be put on a patent, whereas indirect indicators enable potentially valuable patents to be identified from among all the patents in force. Of course, surveys are time-consuming to conduct and require updates. In addition, not all (potential) respondents of surveys are willing to share financial information or able to make a precise estimation of the net financial value that can be contributed to a patent.

Index of patent-value indicators

In the past, indexes of patent value have been designed by various authors, such as Lanjouw and Schankerman (2004) or more recently Gambardella et al. (2008). Lanjouw and Schankerman (2004) built a composite index of patent quality, which is composed of the number of claims, forward citations, backward citations and family size. This index was shown to reduce the variance in patent quality significantly. Gambardella et al. (2008) constructed a similar index (forward citations, backward citations, claims and the number of European countries for which protection is applied). The obtained results signal the incomplete nature of the relationship between indicators and patent value. This is shown by the fact that their index explains 11.3% of the variance observed in terms of patent value. Backward citations and the number of claims had nearly no explanatory power. This last statement confirms that these last two indicators (which have been broadly used) are not very good indicators of patent value, as will be also become clear within our own analysis.

Building an index of patent value is an exercise that is supported by various authors in this field. As a matter of fact, van Zeebroeck (2008) stated that traditional indirect indicators used in the literature (such as families, citations, renewals, oppositions, ...) are only weakly correlated with each other. According to this author, these indicators would actually capture different dimensions of patent value and therefore he insists that it is wise to combine them into a single index. This is a confirmation of the work done by Harhoff et al. (2003), which stressed that the process of valuing patents using citations only is not likely to lead to a good estimation of patent value, or at least to the best possible approximation of patent value. Lanjouw and Schankerman (2004) also proceed in this direction. These authors support the use of multiple indicators. In fact, the index they have developed enables them to reduce the variance in patent quality by between 20 and 73%, depending on the sector considered.

To conclude, the construction of a patent value index can be seen as the ultimate goal of the patent value literature, which hopes to arrive at a reliable approximation of the real value of a patent (Harhoff et al. 2003).

3.2 Different indicators: An empirical assessment.

Within this section, we report on an empirical assessment undertaken by ECOOM to assess the relationship between a number of patent indicators, on the one hand, and the value of patents on the other. The patents being studied are all owned by Flemish universities. Following a request by the Flemish Minister of Economic Affairs and Innovation in 2008, a survey was conducted on the actual use of these academic patents. The reported data on the use of the patents – ranging from no use at all to license agreements with firms (established firms as well as spin-offs) – can be considered as an indication of their value. Relating several indicators to the actual use by means of logistic regressions allows the relevancy of different indicators to be assessed.

The total sample of surveyed patents consists of 192 university patents (grants, both EPO and USPTO). These patents are owned by Flemish universities: Ghent University, K.U. Leuven, University of Antwerp, University of Hasselt and VUB (Brussels). Patents were coded as active (indicating value) or not active. Patents were considered active when they have been licensed out to a spin-off of the university, when they have been licensed out to another company, when they are being used to negotiate research contracts, or when negotiations with a company were on-going.

Next a logit model was developed where the following indicators were introduced (all derived from Espacenet and/or Patstat):

- Forward citations: both with respect to the granted patent and its WIPO (PCT) equivalent within a five-year time window
- The number of countries for which protection is being secured (geographical spread - family size)
- Number of inventors/inventors' nationalities
- Number of years renewal fees are being paid (EPO)
- Number of claims
- Number of IPC classes
- Renewal fees.

The following table provides an insight into the obtained results. The number of countries and whether or not fees are being renewed turn out to be significant at the 5% level. When examining the contribution of both variables in terms of explained variance, both factors contribute 15.81% and 26.97% respectively. Note that several proposed indicators are not significant (at the 5% level): claims, IPC classes, number/nationality of inventors. As such, these findings confirm previous findings with respect to the 'incomplete' nature of value indicators towards predicting the actual use and hence value of patents.

Table 3-1: Logistic Regression

	Coef.	Std.Err.	z	P>z	[95% Conf. Interval]	
fc5	-0.2648971	0.7272745	-0.36	0.716	-1.690329	1.160535
ipc4	0.6521813	0.3374607	1.93	0.053	-0.0092296	1.313592
Claims	0.0237371	0.0325907	0.73	0.466	-0.0401395	0.0876138
Numberofco~s	0.9254125	0.3154813	2.93	0.003	0.3070806	1.543744
Fees	2.333965	1.03204	2.26	0.024	0.3112051	4.356726
Inventors	0.7606867	0.4306044	1.77	0.077	-0.0832824	1.604656
Year	1.798306	0.975274	1.84	0.065	-0.1131961	3.709808
_Cons	-3626.629	1960.563	-1.85	0.064	-7469.263	216.0049

Number of obs = 74; LR chi2(7) = 59.36; Prob > chi2 = 0.0000; Log likelihood = -17.650262; Pseudo R2 = 0.6271

4. Strategic Patenting: Uses, Prevalence and Correlates

John P. Walsh

4.1 Introduction

Recent work on the uses of patents suggests that patenting plays a key role in firms' innovation strategy, but also that the uses of patents are more varied than the traditional uses of exclusion and licensing. So-called "strategic" uses and non-uses of patents – including utilizing patents defensively (prevention of suits)) or to block others from patents to ensure freedom of operation, and for use in cross-licensing – are seen as critical components of firm strategy.

In this report, we summarize recent empirical work highlighting strategic uses of patents, including types of use, prevalence of different uses, and some of the correlates of these strategic uses of patents. While prior work suggests that such strategic uses are associated with firm characteristics, until now, most studies have been limited by either a focus on one technology area or an inability to link firm and patent characteristics to explain the uses of a given patent. However, recently, inventor surveys in Europe, Japan and the USA have provided new insights into the prevalence and correlates of strategic patenting. We will use these new data to supplement the existing literature on strategic patenting. We conclude with some discussion of the policy implications of the prevalence of strategic patenting.

Patents are designed to promote science and the useful arts by giving the owner exclusive rights over an invention for a limited period of time. Traditionally, firms exercised this right through using the technology in their own products and using the patent to enforce market exclusivity, and/or through licensing the patent to others to manufacture in exchange for a share of the rents. However, over the last two decades we have seen a growth in patenting and an increasing emphasis on "strategic" uses of patents, including using patents defensively (prevention of suits) or to block others from patents (to ensure freedom of operation and for use in cross-licensing). Using patents to enhance strategic advantage in the competitive landscape is not a recent phenomenon at all.[5] However, as technology has become more critical in the competitiveness of contemporary firms (Baumol 2002; Jaffe 2000; Kortum, Lerner 1999; Shapiro 2000; Van Zeebroeck et al. 2008) and the filings of patents have exploded, both managers and management theorists have begun to re-examine the uses of patents (Blind et al. 2006; Cohen et al. 2000; Rivette, Kline 2000; Shapiro 2000). Some argue that these strategic uses are key to a well-founded firm strategy (Ziedonis 2004), while others argue that such uses are evidence of a broken patent system (Heller, Eisenberg 1998; Jaffe, Lerner 2004;

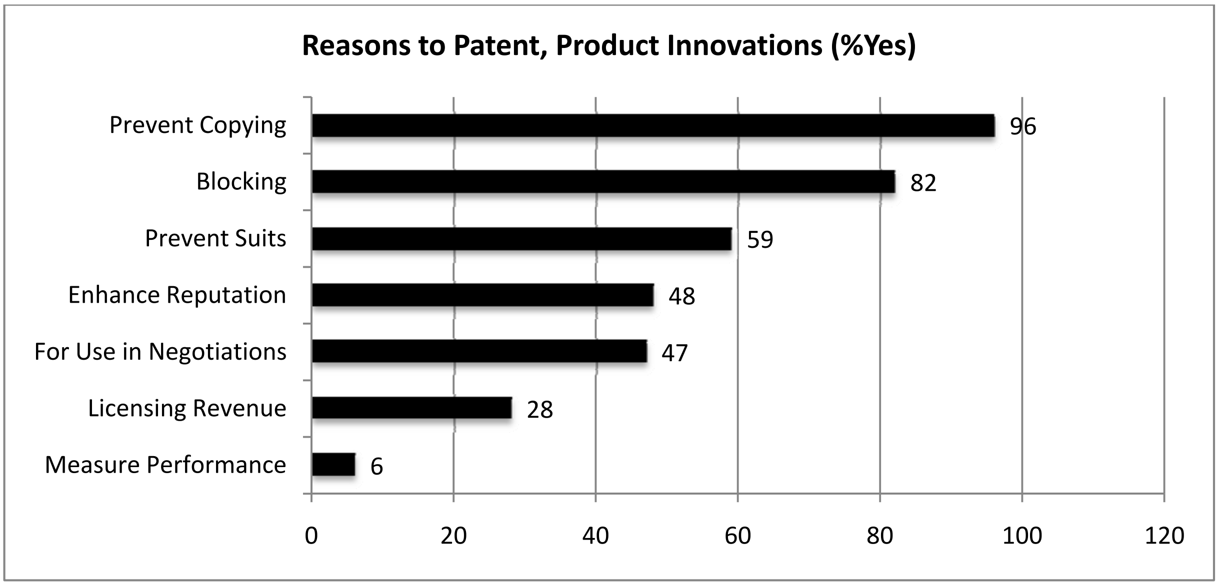
5 A classic example is the "Fleming valve" patent issued in 1905, which stalemated development of radio communication technology (Marconi Wireless & Tel. Co. v. De Forest Radio Tel & Tel. Co., 236 F. 942 (S.D.N.Y. 1916)). Other historical cases are nicely described in the following legal literature: Merges (1994) "Intellectual Property Rights and Bargaining Breakdown: The Case of Blocking Patents." *Tennessee Law Review* 62:75-106, Saunders (2002) "Patent Nonuse and the Role of Public Interest as a Deterrent to Technology Suppression." *Harvard Journal of Law & Technology* 15:389-452, Turner (1998) "Nonmanufacturing Patent Owner: Toward a Theory of Efficient Infringement, The." *California Law Review* 86:179-210.

Saunders 2002; Shapiro 2000). However, in part, the answers to such debates depend on the prevalence and types of uses of such patents. In the next sections, we discuss the types of use, their prevalence, and their correlates.

4.2 Types of Strategic Patenting

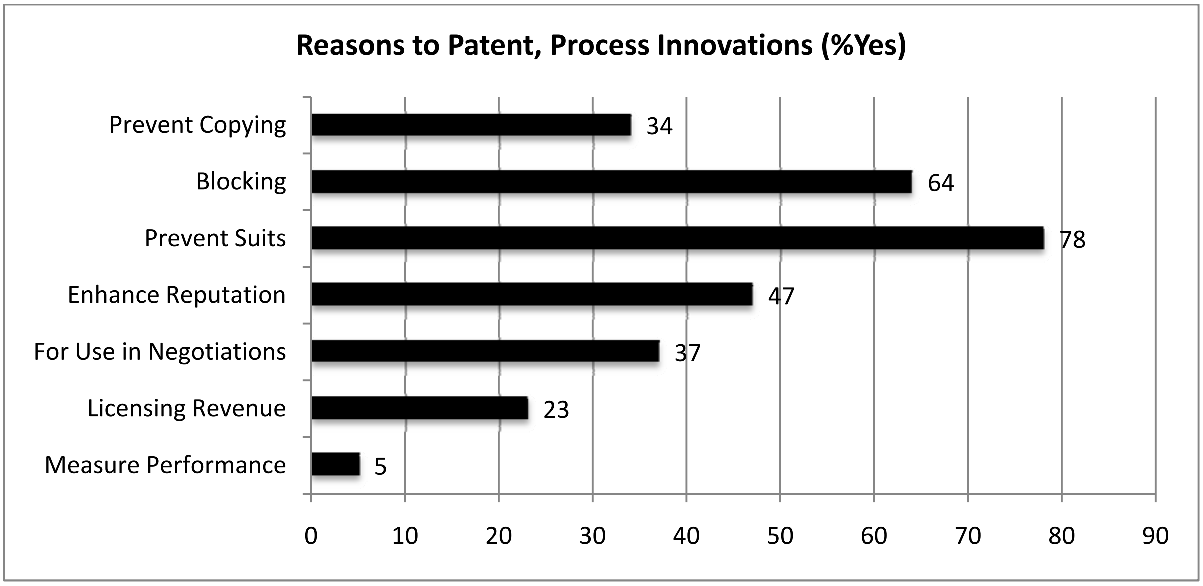
Over the last 10 years, we have begun to see a series of empirical studies asking the question "Why do firms patent?" A consistent finding from this research is that patents are important for preventing copying and for use in licensing agreements. However, these studies also find that "strategic" uses of patents are also important. For example, the Carnegie Mellon/NISTEP survey of R&D labs in the USA and Japan found that firms reported a variety of strategic uses for their patents (Cohen et al. 2000; Cohen et al. 2002b). Cohen et al. (2000) report only a modest correlation between the effectiveness of patents (interpreted as their use for commercialization or licensing) and R&D spending. They argue that one explanation for this low correlation is that patents may generate benefits (that would induce R&D) distinct from their traditional uses in commercialization and licensing. In their survey, they asked respondents to indicate which of a list of reasons motivated their most recent decisions to apply for a patent for a product and process innovation, respectively. The reasons for patenting considered include the prevention of copying, the prevention of another firm's attempts to patent a related invention ("patent blocking"), the earning of licensing revenue, use to strengthen the firm's position in negotiations with other firms (as in cross-licensing agreements), the prevention of infringement suits, use as a measure of internal performance of a firm's technologists, and the enhancement of the firm's reputation (the results are in the attached charts).

Figure 4-1: Reasons to Patent, Product Innovations, United States



Source: Cohen et al. (2000).

Figure 4-2: Reasons to Patent, Process Innovations, United States



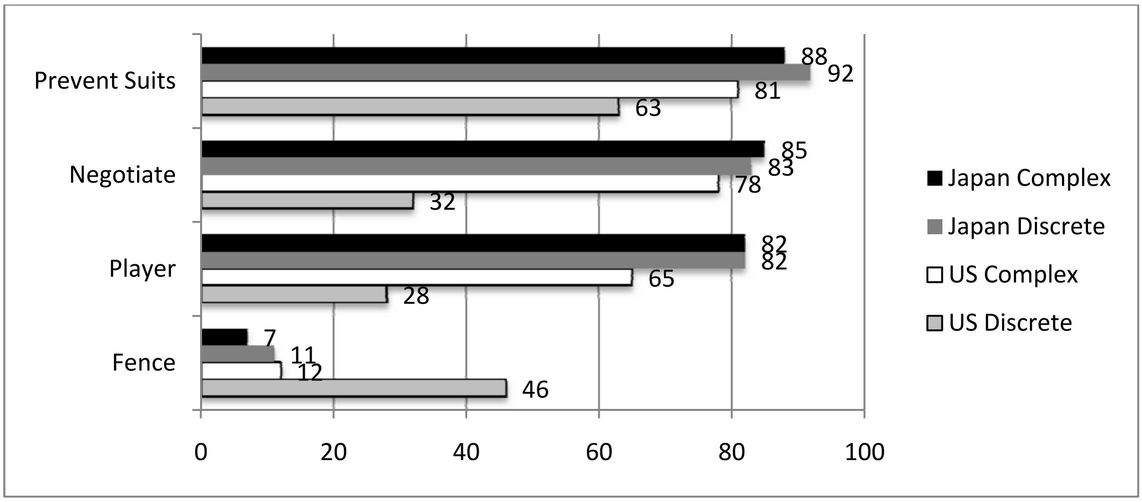
Source: Cohen et al. (2000).

Cohen et al. (2000) report that blocking rival patents on related innovations was almost as important as preventing copying as a reason to patent. Preventing suits was also reported as a key reason for patenting. This was especially true for process patents (where these reasons were more prominent than preventing copying). These reasons suggest that a key strategic use of patents is to ensure freedom to operate, allowing firms to develop their technologies without fear of holdup (cf. (Heller, Eisenberg 1998; Jaffe, Lerner 2004; Shapiro 2000). Cohen et al. (2002b) show that the ranking of reasons to patent are similar in the USA and Japan, with blocking and prevention of suits coming right after preventing copying as reasons to patent. Survey-based studies of motives for patenting in Europe also generally find that, after protecting their inventions, firms rate blocking (offensive and/or defensive) and use in negotiations as important motives for patenting, although in the most recent survey of German firms, use in negotiations seems have become relatively less important (see Blind et al. 2006 for review). Patenting to enhance the firm's image was also found to be an important reason in the latest German survey (Blind et al. 2006), although this reason was not seen as so important in prior surveys (e.g. Cohen et al. 2002b)). This motive is most important for small firms. Being able to use patents as an internal performance measurement was also an important reason to patent in Germany (Blind et al. 2006) and Japan (Cohen et al. 2002b).

Blind et al. use a factor analysis to partition these motives into five main components: protecting, blocking (offensive or defensive), reputation, exchange, and (internal) incentives (Blind et al. 2006). De Rassenfosse and Guellec (n.d.) conduct a similar analysis, and come up with three main components: exclusion, money (either from licensing or from investors) and defensive (freedom to operate). These results suggest that patents have distinct (non-exclusive) uses. The first is the traditional use of protecting a commercialized invention. Closely related is the use of patents for licensing, which still involves protecting a commercialized intellectual asset. The second is some combination of blocking/defensive patenting, which includes both offensive and defensive blocking (see below). The third is as a vehicle for signaling firm performance in capital or R&D alliance markets. Additional motives of internal performance evaluation are also important in some cases.

Cohen et al. (2002b) also refine the definitions of blocking patents into two categories, which they label as "fence" and "player". The fence strategy involves filing a variety of non-use patents related to a commercialized invention to prevent firms from introducing rival technologies into the market (Blind et al. (2009) refer to these as "offensive" blocking). The classic case is a chemicals company patenting several variants of its major product to prevent rival firms from inventing around the technology. For example, in the 1940s du Pont patented over 200 substitutes for nylon to protect its core invention (Hounshell, Smith 1988). Turner (1998) documents the case of the "Fan" patent where Du Pont patented an improvement on its already commercialized color proofing process for photographic film in order to prevent its preemption in the market place. To the extent that a single patent effectively covers the product (as in pharmaceuticals), fence building may not be necessary. However, if rivals can introduce competing drugs in the same class, then even pharmaceuticals firms might have an incentive to build fences around their blockbuster drugs. The fence strategy is designed to keep rivals out and to ensure the effectiveness of the surrounded patent, in effect to broaden that patent. In contrast, the player strategy involves generating a large enough portfolio of patents related to a product market that any rival would have to respect the threat of a countersuit and therefore abstain from filing suit to keep the focal firm out of the market. In this case, the patents are used not necessarily to keep rivals out, but to ensure that the focal firm can play in the market (what Blind et al. (2009) refer to as "defensive" blocking). Often, the player strategy is cemented by a cross-licensing agreement, a kind of peace treaty ensuring each access to the market. The classic case is large electronics firms cross-licensing their patent portfolios related to computers, cell phones or semiconductors, and then each competing on lead time, manufacturing capabilities, or other means of capturing the rents from innovation. Such uses can also create oligopolistic markets, with each of the players licensing to each other, but not to new entrants that lack the patent portfolio needed as an admission ticket to play in the market.

Figure 4-3: Reasons to Patent Product Innovations (%Yes), United States and Japan, by discrete and complete product industries



Source: Cohen et al. (2002b).

Cohen et al. (2002b) argue that the fence strategy should be more prevalent in discrete product markets (such as drugs and chemicals), while the player strategy should be more common in complex product markets (such as machinery and electronics). They report that in the USA, there are the expected differences, with the fence strategy more common in discrete product industries and the player strategy more common in complex product industries. Industry-based studies confirm these results (

Figure 4-3). For example, Thumm (2004) finds little evidence of "strategic patenting" in Swiss biotechnology, a discrete products field where patents are generally considered strong, while (Hall, Ziedonis 2001) find such strategic patenting is widespread in semiconductors, a complex product field. However, in Japan, Cohen et al. find that the player strategy is relatively more common and the fence strategy relatively less common than in the USA and that there is much less difference between complex and discrete product industries in their uses of fence and player strategies. They argue that these relative differences in the propensity to engage in different types of strategic patents are explained by different institutional environments, especially the breadth of patents and the penalties for patent infringement (Cohen et al. 2002b). Recent data from Germany also finds fewer differences between discrete and complex products, perhaps because the underlying technologies are less distinct than before (Blind et al. 2006).

Subsequent studies have replicated these findings on blocking and cross-licensing. For example, several studies show that, in addition to using patents to protect their commercialized innovations, or for licensing, firms also use patents to ensure freedom of operations (Blind et al. 2006; Giuri et al. 2007; Hall, Ziedonis 2001; Ziedonis 2004). Reitzig replicates the Cohen et al. findings of high rates of blocking patents, based on European data (Reitzig 2004). He also shows that, like in the USA, "strategic patenting" is common in both complex and discrete technology sectors, but that it takes different forms, with the player strategy more common in complex products and fence strategy more common in discrete products.

There are also several studies showing the importance of cross-licensing (player strategy) and how it varies by sector. Based on an analysis of security commission filings of licensing contracts, Nagaoka and Kwon find that the rate of cross-licensing is highest (almost 20% of licenses) in electrical machinery and lowest (2%) in pharmaceuticals (Nagaoka, Kwon 2006). Motohashi (2008) also finds that in Japan, cross licensing is relatively high in the electronics and electrical sectors, as well as in precision machinery, both of which are "complex product" industries with many patentable components in a commercial product. He also finds that blocking patents is common in chemicals, and argues that these are likely to be for fence building (consistent with Reitzig (2004), and Cohen et al. (2002b)).

Table 4-1: Percent of Patents Used for Blocking and for Cross-licensing

Study	Region	Blocking (% of patents)	Blocking (% of unused)	Cross-licensing (% of patents	Cross licensing (% of licenses)
Nagaoka and Walsh[a] (2009)	US	14	36	3	23
Nagaoka and Walsh[a] (2009)	Japan	15	40	5	26
Motohashi (2008)	Japan	33	68	9	15
Giuri et al. (2007)	Europe	19	52	3	
Nagaoka and Kwon (2006)	Japan	--	--	--	8

[a]Triadic (US, Japanese and European) patents

4.3 Prevalence of Strategic Patenting

How common are these strategic uses of patents? Kortum and Lerner (1999) argue that the growth in patenting is in part driven by the proliferation of strategic patenting. Most prior work estimates the uses of patents at the firm level (estimating the percent of firms that engage in strategic patenting, or the relative importance of patent strategies in their portfolio, see above). For example, Blind et al. (2009), based on a survey measure of motives for patenting, also find that blocking patents are most common in chemicals. They also find, somewhat surprisingly, that the exchange motive (i.e., use in negotiations, cross-licensing) is strongest in the chemicals industries (not electrical). They explain this (somewhat anomalous) finding by arguing that the measure reflects the underlying importance of patents, as well as the specific motives, so that chemicals, where patents are important, tends to rank all motives highly on their measures. Blind et al., categorize 40% of firms as having a patent portfolio focused on defensive blocking, 18% focused on offensive blocking, and 3% focused on exchange.

However, recently, inventor surveys in Europe, Japan and the USA have collected patent-level indicators of the uses, and particularly, the "strategic" non-use, of patents for large samples of inventions spanning a broad set of technology classes (Table 4-1). Based on inventor surveys in Europe, Giuri et al. report that 19% of European patents were not used (accounting for about half of all unused patents) and were patented for strategic blocking and 3% are used for cross-licensing, suggesting that "strategic" patenting is fairly common (Giuri et al. 2007). They also find that blocking patents (measured as unused patents that were applied for with the intent of blocking others) are most common in the chemicals and drugs sector, suggesting these are being used for fence building (Cohen et al. 2002b; Reitzig 2004). Similarly, based on inventor surveys in Japan and the USA, Nagaoka and Walsh (2009) report that about 15% of triadic (US, Japanese, Europeean) patents are not commercialized (about 40% of unused patents), but are used for blocking or preventing inventing around the patent and 3-5% are used for cross-licensing (accounting for over 20% of licensed patents). Because the US-Japan survey was limited to triadic (US, Japanese and European) patents, it is not surprising that the rates of strategic patents are somewhat lower. But even these global patents include a significant number of blocking patents. About 1 in 7 triadic patents are used for blocking. Motohashi (Motohashi 2008) reports that, based on a survey of Japanese firms with patent applications, about half of issued patents are not used, and of those unused patents, about 2/3 are held for defensive "blocking" purposes. Thus, based on these data, 33% of all Japanese patents are reported to be for blocking. In addition, cross-licensing (as in a player strategy) is also an important use, accounting for about 9% of all patents (Motohashi 2008). However, based on data from licensing contracts, Nagaoka and Kwon find a somewhat lower rate of cross-licensing (about 8% of licensed patents) (Nagaoka, Kwon 2006).

Thus, not only is strategic use an important reason to patent (alongside preventing copying), but also that a significant fraction of patents are used exclusively for strategic purposes, either fence building or to ensure freedom of operations (player strategy).

4.4 Correlates of Uses of Patents

If firms use patents in different ways within industries, are there systematic features to these intra-industry differences? We will consider firm size, familiarity of the technology, and other aspects of the firm or technology that might explain uses of patents (in addition to the industry differences described above). Cohen et al. (2000) report that significant positive correlations between the number of respondents' patent applications and using patents strengthen your bargaining position in negotiations as well as prevent infringement suits. Blind et al. (2006) also find a correlation between firm size and the importance of strategic patenting, with small firms more likely to use patents to enhance reputation (similar to Cohen et al.) and large firms more likely to use patents for negotiations. Similarly, Hall and Ziedonis (2001) argue that large firms develop strategic patent portfolios to protect their investment in complementary assets. Jung (2009) also finds blocking is associated with firm assets (capital intensivity), net of firm size, suggesting that it is protection of complementary assets that drives defensive patenting. Motohashi (2008) finds in Japan a curvilinear relationship between firm size and blocking (with medium-sized firms having the highest rates of blocking patents). Based on patent-level data from Europe, Giuri et al. (2007) find that large firms are more likely to engage in blocking patents (declining monotonically with size).

Nagaoka and Kwon (2006) examine the relations between firm size and cross-licensing. They find cross-licensing is most common for the largest firms, and when only patent (not know-how) is involved, suggesting many of these cross licenses are for a player strategy (freedom to operate). Motohashi (2008) (based on the JPO survey of patenting and licensing) also finds that it is the largest firms that are most likely to engage in cross-licensing. Motohashi (2008) also finds that start-up firms are much less likely to have blocking patents or engage in cross-licensing. Giuri et al. (2007) find that cross-licensing is common both for large and small firms (compared to medium-sized firms). Blind et al. (2009) find that (for German firms) using patents for exchange (e.g., cross-licensing) is most important for very large firms (more than 5,000 employees).

Blind et al. (2006) also find that greater firm competition is associated with more emphasis on blocking, while firm cooperation is associated with greater emphasis on negotiations. Similarly, Jung (2009) analyzes how strategic interaction might affect the use of patents and finds that greater component familiarity (the extent to which a firm is familiar with a particular technology trajectory) is associated with less likelihood of blocking patents, suggesting that blocking patents are most critical when the future of technology is uncertain, and hence may be important for staking a claim in a field when the exact direction of development is not foreseeable.

These results on strategic patenting suggest that patents play a key role in protecting firm assets and in negotiating in mature technology spaces (with high technology interdependence), even if many of the particular patents are not linked to commercialized products (i.e., are "unused" patents). These results also suggest that large firms generate more unused patents, which can then be applied for strategic purposes. This is likely, due to both fixed cost spreading, and to the importance of protecting expensive complementary assets. While the results consistently show that the largest firms are most likely to engage in blocking or cross-licensing, there is some evidence that the smallest firms might also actively use these strategies as well. This latter result is somewhat inconsistent with our expectations about what drives strategic patenting and needs further analysis.

4.5 Strategic Patenting and Patent Value

One important question is the relation between these strategic uses of patents and the value of these patents. How important are strategic patents individually and as part of a patent portfolio? This is a very complicated and difficult question, because the value of a given patent may depend heavily on the context in which it is embedded (i.e., what other patents exist, who owns them, how is that technology progressing, and what are the competitive conditions?). Blind et al. (2009) find that companies that concentrate on using patents to protect their commercialized inventions (the traditional "exclusion" use of patents) tend to receive higher citations (i.e., have higher average patent value) (Blind et al. 2009). In contrast, they find firms that use their patents for a player strategy have fewer citations and less oppositions to their patents, suggesting many low value patents, using traditional measures of value. Finally, using patents for offensive blocking (fence building to keep others out) is related to a higher incidence of oppositions. These results suggest that strategic patents are, in general, of low value using traditional bibliometric measures of value. Similarly, Jung (2009) finds that inventors rate strategic patents (those used for blocking) lower in both technical significance and economic value compared to patents used in-house or for licensing, which is not surprising, since these strategic uses are defined as patents that are not commercialized. Finally, de Rassenfosse and Guellec (n.d.) find, based on an international survey of firms which had applied for European patents, that firms that emphasize defensive patenting have lower patent quality (measured as the average number of countries the patents are filed in).

However, Ceccagnoli (2009) finds that blocking patents (either fence or player) significantly increases the ability of firms to capture the returns from their own R&D (if they also have market power, when facing threat of entry and when competition is largely incremental), suggesting that such strategic patenting may be a critical component of an effective R&D strategy. At the same time, using the case of computer software, Noel and Schankerman (2006) find that greater concentration of patent rights among rivals (less patent complexity to use the terminology of Cohen et al.) reduces both R&D and patenting by reducing the need to have many defense blocking patents (less emphasis on the player strategy). On the other hand, fewer strategic patents (and less patent complexity) are associated with greater market value, because of lower transactions costs, suggesting a social welfare cost to strategic patenting. Thus, these strategic patents may have important individual benefits and at the same time reduce social welfare.

4.6 Conclusions

A growing body of research has shown that patent uses and non-uses are being expanded beyond the traditional uses of protecting products and for licensing. These uses include blocking others from patenting and preventing inventing around (either to build a fence or to ensure access), use in negotiations, and to enhance the reputation of the firm (for example, to raise capital). Overall, these uses suggest that firm strategy now includes patents in a broader strategic interaction game across rivals (and across generations of technologies). Our best estimate is that 15-20% of all patents are primarily utilized for blocking purposes. This research also suggests these uses vary by firm size, with large firms more likely to accumulate large patent portfolios used either for fence building or a player strategy and small firms more likely to use patents to enhance reputation. We also see country differences in the use of patents for internal performance measures, with this use relatively high in Germany and Japan, and much lower in the USA.

There is growing concern that this growth of strategic patenting is also associated with adverse welfare effects resulting from hold-up and excessive transaction costs (Heller, Eisenberg 1998; Jaffe, Lerner 2004; Saunders 2002; Shapiro 2000). Until now, there is limited empirical evidence to support these concerns (Walsh et al. 2003). However, further work is needed to understand the dynamics of strategic competition based on the use and non-use of patents. Initial work suggests that these patents play an important role in firms' R&D strategy and in protecting their rents from R&D (Ceccagnoli 2009). However, there are still concerns about patent races producing undesirable effects from increasing transaction costs (Noel, Schankerman 2006). However, such transaction costs may be an unavoidable component of a system that encourages investment in innovation in the face of limited appropriability through a single patent. And, prior work suggests that firms have found ways to reduce the transaction costs such patent complexity might otherwise create (Walsh et al. 2003), with the player strategy being one example (Cohen et al. 2002b; Hall, Ziedonis 2001).

These uses of patents are key to understanding the private value of patents. Even though a large percentage of patents are "unused", in the sense of not covering any commercialized product and not licensed for revenue, they may still play an important role in protecting firm's markets and firm's complementary assets. Fence-building may be necessary to expand the scope of patent protection and keep rival technologies out (as in chemicals industries) in order to ensure sufficient market power to recover R&D investments. Building large patent portfolios for defensive blocking or for cross-licensing (as in semiconductors) may be necessary in order to ensure the ability to use one's other competitive advantages (such as complementary manufacturing or sales capabilities, or lead time advantages in product introduction) in market competition. Thus, a significant share of a firm's patent portfolio may be indirectly engaged in creating strategic advantage for the firm. In addition, because the key alternative to patenting is secrecy (Cohen et al. 2000), these same patent strategies may have the added social welfare advantage of increasing R&D information flows (Cohen et al. 2002b; Noel, Schankerman 2006). Thus, the net effect of these strategies is not clear.

This does not, however, imply that all patents have high value. Firms may generate many speculative patents that produce dead ends, or generate minor patents as part of their routine inventive activity. Thus, in valuing patents, we need to account for the important "supporting patents" in the non-use portfolio, while still acknowledging the high probability of minor patents that have no direct or indirect commercial value. And, we are still left with the debate about the net effect of these strategic patents on social welfare. This is an important area for future research.

5. Descriptive Statistics

Ulrich Schmoch, Peter Neuhäusler

For an appropriate interpretation of indicators referring to the value of patents, it is necessary to look at some basic structures of the relevant patent systems. In this chapter, the basic structures at the European Patent Office are described in detail. In particular, the development of patent applications, grants and refusals, withdrawals, citations, maintenance and family size are considered.

5.1 Legal Status of Patent Applications

The structures at the European Patent Office (EPO) have changed considerably since the beginning of the 1990s to arrive at the present situation, as in this period the number of applications more than doubled (Figure 5-1). This enormous growth, which took place in particular between 1995 and 2000, implied an enormously increased workload at the EPO and as a result the examination behavior changed. The reasons for the patent surge in the second half of the 1990s have been intensively discussed in the literature (Arundel, Patel 2003; Blind et al. 2006; Hall, Ham 1999; Hall, Ziedonis 2001; Jaffe 2000; Janz et al. 2001; Kortum, Lerner 1997; Kortum, Lerner 1999). In particular, it is obvious that patent growth is much stronger than the growth of industrial research and development (R&D), so that new attitudes of the applicants have to be stated. One general aspect is that technology became more important in the international economic competition and linked to this, patent protection too. Other arguments, like the strong growth of specific fields such as biotechnology or software, as well as the higher efficiency of R&D processes were put forward.[6] In any case, it is obvious that many different factors play a role, but there is broad agreement that the relevance of strategic patent applications has substantially grown. So in addition to the protection of inventions, blocking competitors, preventing knowledge drain in cooperations, incentives for creative employees, or the increase in the market value of companies have become relevant additional motives to apply for patents. It seems obvious that this changing pattern of applications will have an impact on the value of patents.

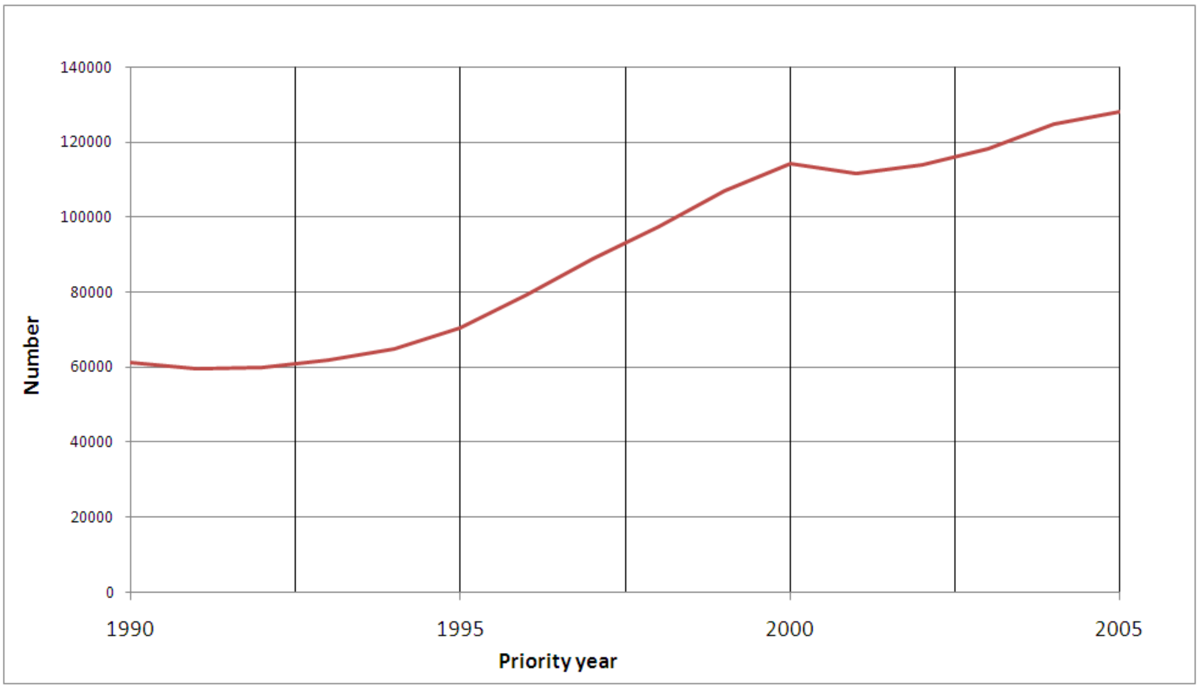
As a first intermediate result, the direct correlation between industrial R&D and the absolute number of patent applications was lost in the second half of the 1990s. However, since the year 2000 this general growth stopped with the end of the new economy boom, but since then a slight increase can once again be observed. In any case, the application numbers did not decrease to the level of 1994; rather, the higher level of patent applications was maintained. With regard to the examination process, different types of legal status can be distinguished:

- granted patents
- refused applications
- withdrawn applications or
- pending applications where no decision, grant or refusal was taken yet.

6 A relevant literature survey is given in Blind et al. (2006).

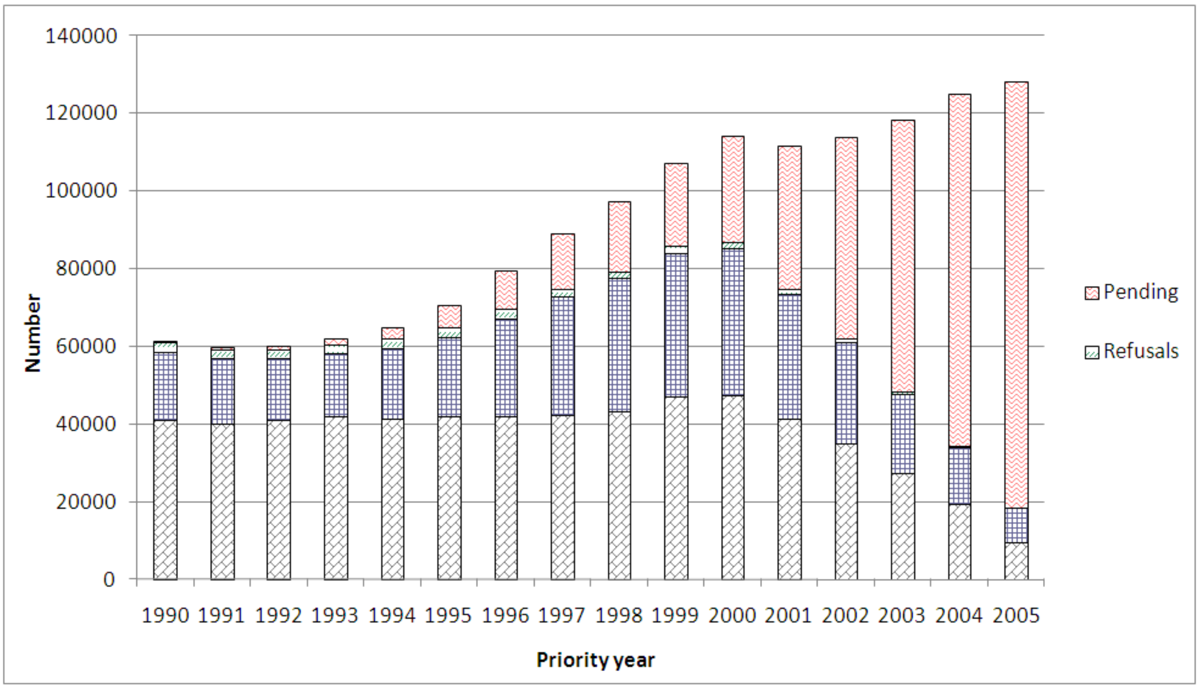
Withdrawal refers to the retraction of an application by the applicant before a decision about grant or refusal is made.

Figure 5-1: Number of applications at the European Patent Office



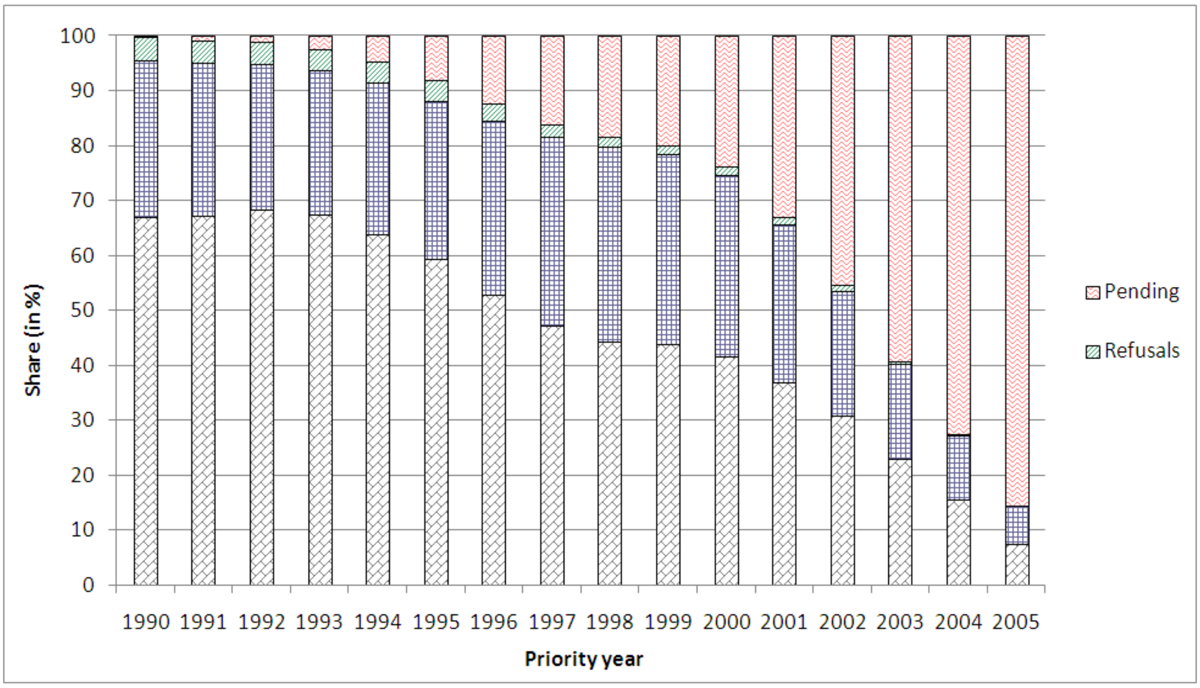
Sources: PATSTAT (EPO), searches and computation by Fraunhofer ISI.

Figure 5-2: Number of applications at the EPO by legal status



Sources: PATSTAT (EPO), searches and computation by Fraunhofer ISI.

Figure 5-3: Shares of applications at the EPO by legal status



Sources: PATSTAT (EPO), searches and computation by Fraunhofer ISI.

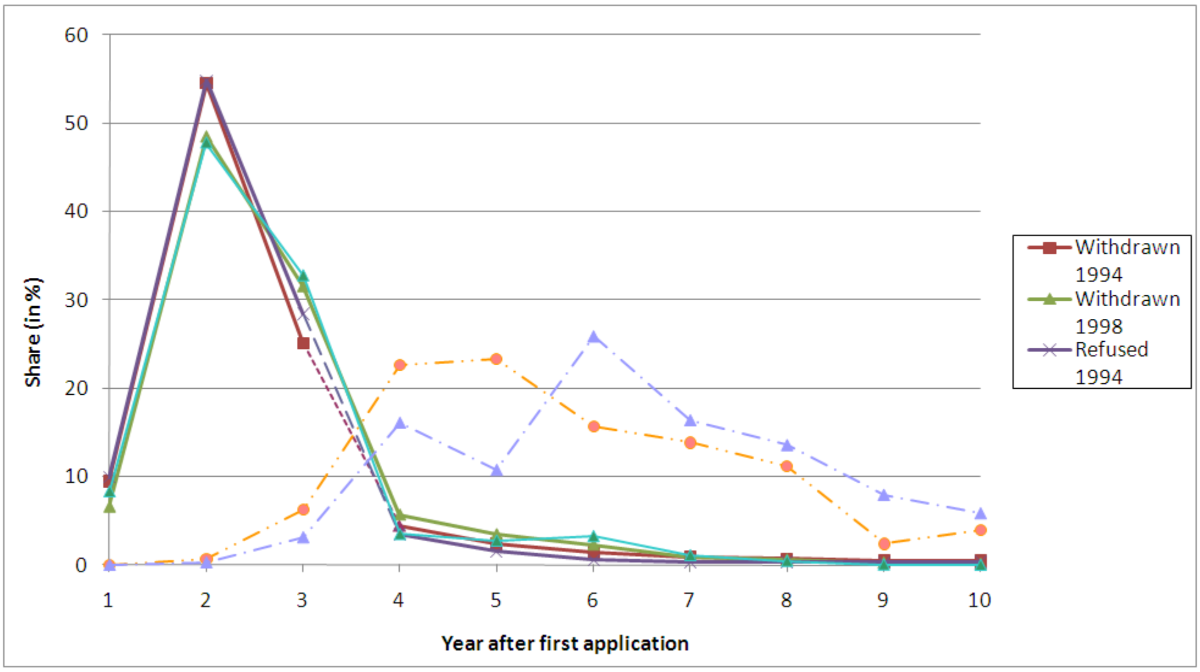
Looking at the legal status of the applications, it is obvious that, for recent years, the majority is still pending, for instance, for many applications within the period 2003 to 2005 with an update of the legal status in March 2009, a decision on grant or refusal was not yet made (Figure 5-2 and Figure 5-3). However, it is surprising that quite a large share of applications even from the year 2000 is still pending – no final decision has been made yet for about one quarter of the applications.

Looking at the share of grants between 1990 and 1994 reveals a slight decrease of the grant rate from 67 to 64% of all applications (Figure 5-3). The withdrawal rate remains quite stable in this period at a level of about 28%. The number of refusals is quite low, at 4% of all applications. The share of applications pending from 1994 is still at a level of 5%. That means that for 5% of all applications of the priority year 1994, no decision has been taken within 14 years. After 1994 – thus at the beginning of the patent surge – the grant rate steadily decreases from 64% to 44% in 1999, and in parallel the withdrawal rate increases from 28% to 35% in 1999. In the same period, the refusal rate decreases from 4% to 2%. This development may be interpreted in terms of a decreasing patent value linked to a higher share of strategic patent applications. However, the share of pending applications increases from 5% to 20% between 1994 and 1999; thus for a quite high share of applications, the final decisions about grant, withdrawal or refusal are still open.

Looking at the time of action as to withdrawals, refusals and grants, an interesting pattern appears with reference to the priority years 1994 and 1998. First of all, the decisions about withdrawal and refusal are taken quite early, in general three years after the time of first application (Figure 5-4). The percentage of decisions about withdrawal and refusal are nearly equal for the year 1994 as well as for 1998, suggesting that both actions are closely linked.

Obviously, the majority of applicants decides to withdraw when a negative decision of the examiner is probable, based on the results of the search reports. The applicants intend to avoid the negative signal of a refusal and prefer the less visible withdrawal variant (Harhoff 2009). Furthermore, they can economize on the grant and eventually also the examination fees. Against this background, withdrawals and refusals have to be treated as equivalent actions and can be taken together. The majority of withdrawals and refusals in 1998 still occurs quite early, but all in all, a little bit later than in 1994. Therefore withdrawals and refusals in the first three years seem to be an early indicator for grants. However, the overall analysis for the period between 1999 and 2005 also shows that the withdrawal and refusal rate steadily decreases after 1999. Here too a considerable time lag becomes visible (Figure 5-5).

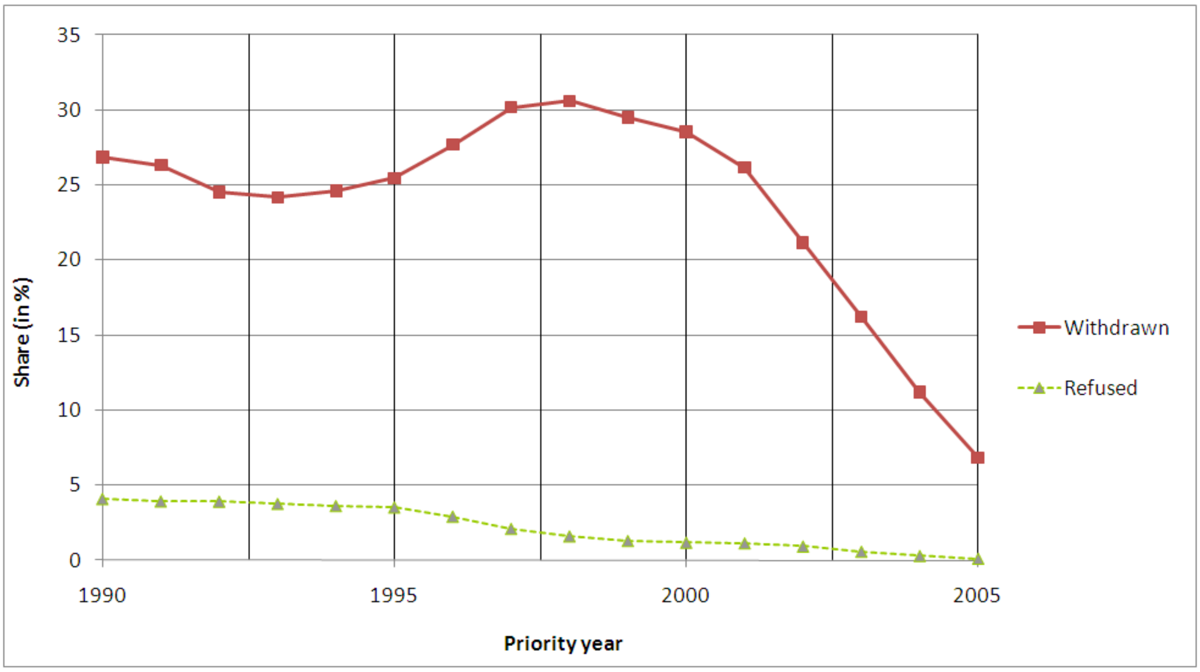
Figure 5-4: Time of decision about withdrawals, grants, and refusals with reference to all decisions on the respective legal status of the applications of the year considered



Sources: PATSTAT (EPO), searches and computation by Fraunhofer ISI.

The time lag of grants already visible for the years 1994 and 1998 is distinctly higher than that of withdrawals and refusals; thus the decrease of the grant share from 64% in 1994 to 23% in 2003 is primarily caused by administrative problems linked to the work overload at the European Patent Office and less to a decrease of value. Only the growing share of withdrawals between 1994 and 2000 may be interpreted in terms of a decreasing value of the applications in this period. Besides, the time lag of grants at the USPTO is also quite high, in particular with regard to applications of non-US origin (Schmoch 2009).

Figure 5-5: Withdrawal and refusals within the first three years after the priority date



Sources: PATSTAT (EPO), searches and computation by Fraunhofer ISI.

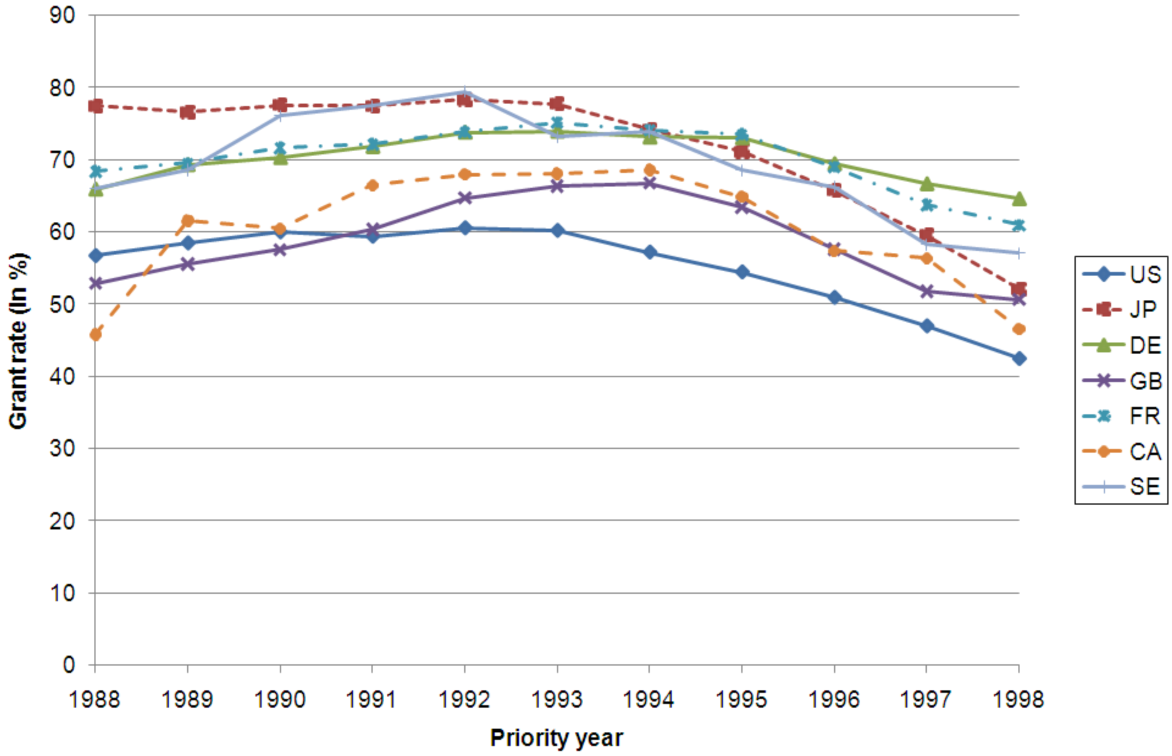
Even if the decreasing share of grants between the mid and the end of the 1990s is interpreted as an indicator of a decreasing value of patent applications, it is still difficult to use for topical country comparisons. A comparison of the grant shares by country for the period of 1988 to 1998 with a fixed ten-year window shows a generally slight increase of the grant shares between 1988 and 1993 and a decrease in the following period until 1998 (Figure 5-3). Again, this decrease may be linked to the growing backlog at the European Patent Office.

Looking at specific countries, the German grant rates are distinctly higher than the US ones for the whole observation period. At first sight, this finding is unexpected, as the US applications primarily refer to research-intensive technologies, whereas in the German portfolio the share of less research-intensive technologies is relatively high. This difference is attributed to the different specialization profiles of the USA and Germany, but also to the geostrategic position of both countries. From the perspective of German enterprises, interest in neighbouring European markets is obvious, also in consumer goods, whereas US enterprises, first of all, aim at US consumers in this low-tech area. The US portfolio at the European Patent Office represents a selection of technologies with a clear focus on high level technologies.

If the lower grant share of US applications at the EPO cannot be convincingly explained by their technological portfolio, it is more probable that differences in the legal system in the USA and Europe play a major role. The mode of drafting a patent application in the USA and in Europe is quite different (Avery, Mayer 2003). In particular, the claims are drafted in a different way. This means that a simple translation of an application at the United States Patent and Trademark Office (USPTO) is not sufficient for a successful application at the EPO. In particular, the claims have to be completely reformulated. If this is not done in all cases, a lower grant rate of applications of US origin is the logical consequence. This assumption is confirmed by the lower grant rate of applications of Canadian origin, as Canada has a similar patent system to the US one. Furthermore, the grant rate of US applications is lower than the German one in all fields of technology, even in biotechnology, where the high standard of US technology is generally acknowledged.

In this context it is quite difficult to interpret that the grant share of applications of Japanese origin in 1988 was distinctly higher than the German one, but distinctly lower in 1998 (Figure 5-6). An explanation may be that Japanese applicants also increasingly use the PCT system instead of direct applications at the EPO and the USPTO, and in PCT applications they may prefer the US style of applications, as for them the United States are still the preferred market. Then they run into the same problems of incompatibility as the US and Canadian applicants. All in all, a sound interpretation of grant rates by countries seems to be quite difficult.

Figure 5-6: Grant rates within ten years after the date of first application by country

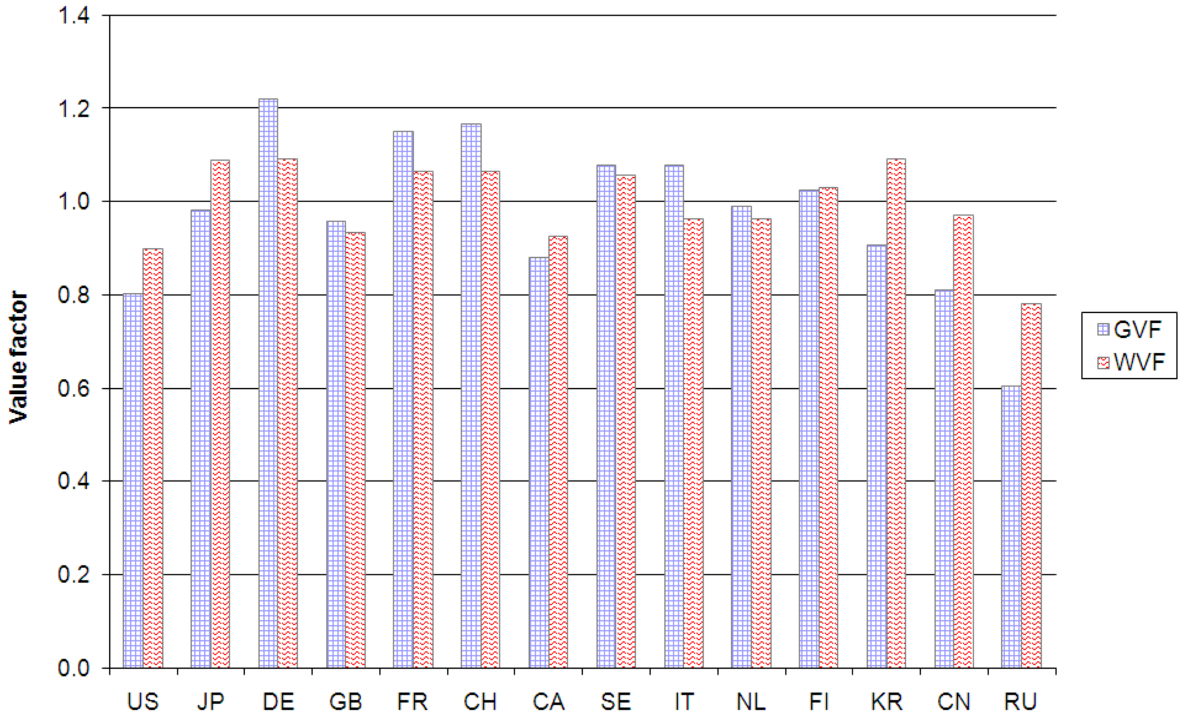


Sources: PATSTAT (EPO), searches and computation by Fraunhofer ISI.

In this context, a plausible approach of value assessment is to look at withdrawals, as the value of the referring applications seems to be quite low, indicated by a low citation rate – described in the section further below. Thus the withdrawn applications could be subtracted from the total applications of a country and the focus placed on applications with a reasonable value. The remaining share of non-withdrawn applications with reference to all applications can be compared to the average share for all applications, and a withdrawal-based value factor WVF can be calculated. In Figure 5-7 it is compared to a grant-based value factor GVF which is conceived in a similar way. With reference to the withdrawal-based value factor, the US applications are less devalued than assessed by the grant-based value factor compared to Germany. The factor for the USA is higher, but still below average; the value for Germany lower, but still above average. In particular, Korea, China and Russia profit from the WVF compared to the GVF.

To summarize, the different legal systems of the United States and Canada still have an impact on an assessment, based on withdrawals, but less pronounced than that based on grants. However, the differentiation between countries by the WVF is moderate.

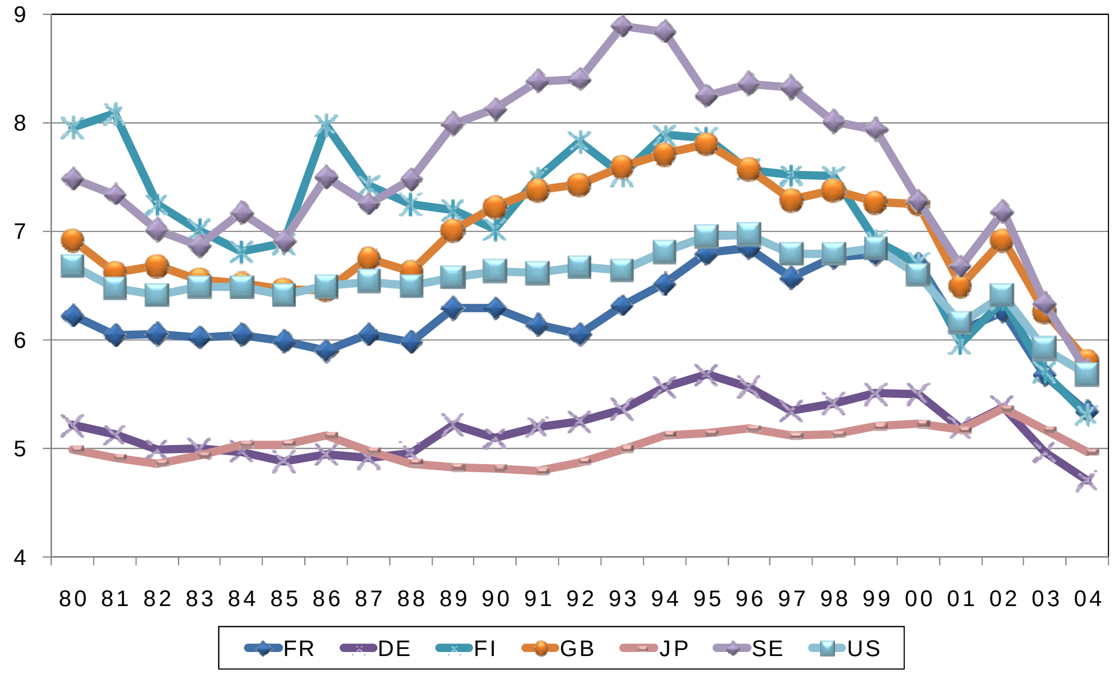
Figure 5-7: Withdrawal-based and Grant-based Value Factors by country for 1998



Sources: PATSTAT (EPO), searches and computation by Fraunhofer ISI.

The size of patent families is interpreted as reflecting market potentials and, in consequence, the larger a family is the larger is the potential market value of the patented technology. The average size of patent families – these are INPADOC families excluding singletons and counting each application authority only once to balance for effects of national patent systems – reaches rather stable trends for the large countries, except for the United Kingdom and it develops very dynamically for smaller countries like Sweden or Finland (see Figure 5-8). The growth of the patent families that occurred until the mid 1990s ended when the absolute number of filings was increasing considerably and now reaches a similar level like in the late 1980s. It is interesting to note that the levels are considerably different with Germany and Japan at the lower end and Finland, Sweden, but also the United Kingdom at the upper end of this distribution. The United States are in the middle of the countries. The decreasing trend in the new century can hardly be interpreted as it takes about 7-10 years after first filing until a family is almost settled. This is due to the processing at the USPTO but especially at the EPO. While the USPTO did not publish applications, but only granted patents until the priority year 2001, and the average time to grant a patent is about 5-7 years, these numbers were missing or entered the system with a considerable delay. The EPO also takes 5-7 years to grant a patent. Though, they publish applications the effect of the EPO procedure on the families has a different reason. The EPO is application and granting office, but a granted patent at the EPO might diverge into several national patents within Europe. The applicant will decide on the day of granting, in which countries to protect the technology. This could be up to 35 European countries, which signed the European Patent Convention. And this could have a high impact on the average family size. So patent families are not a suitable and handy indicator of patent value to topically balance national patent portfolios.

Figure 5-8: Average size of patent families by countries, 1980-2004



* Average number of distinct application authorities, excluding singletons; INPADOC-family definition

Source: EPO – PATSTAT; Fraunhofer ISI calculations.

5.2 Citations

Citations are considered an important indicator of the value of patents, as described in the above chapters in further detail. In this section, the structures at the European Patent Office are examined in order to show the impact of the geostrategic position and of the administrative procedures at a specific office on citation analysis.

A first specific feature of the European Patent Office (EPO) compared with the United States Patent and Trademark Office (USPTO) is that at the EPO the citations are primarily examiner-given, whereas at the USPTO the patent law requires that the applicants/inventors have to indicate their knowledge about the state-of-the-art as completely as possible, and many of the applicant-given citations appear in the official search reports. Also, in applications at the EPO the applicant often cites prior art in the description of the invention in the full text of the application, but these references are only sometimes adopted by the examiner and appear in the official search report. As a first consequence, the number of citations per examination report at the USPTO is distinctly higher than at the EPO. A further consequence is the potential difference of the content of the citations at the EPO and the USPTO.

A first assumption is that the citations at the EPO are more objective than those at the USPTO, as the EPO examiners exclusively look at relevant documents for the examination process, whereas in the applicant-given citations at the USPTO other motives may play a role, such as insufficient knowledge on the part of the applicant, or the attempt to distract the examiner.

A counter-assumption may be that the USPTO citations reflect the real knowledge flows in a better way, as only the applicant knows his or her sources of inspiration. However, Breschi and Lissoni (2004) convincingly show that an analysis of knowledge flows with EPO data leads to comparable and even better results than with USPTO data.

A further specific feature of the EPO is that the citations in the research and examination reports are categorized by different types (Table 5-1). First of all, there are citations/references which are particularly relevant regarding the assessment of the novelty or the inventiveness of the application (invention) examined; these are the "relevant" citations with the codes X or Y. A further important category is A citations, defining the general state-of-the-art or the technological background. All other types of citations are less important in terms of quantity. An interesting category is D documents, which refer to documents cited in the application, so these are inventor-given citations. The share of D citations is quite modest, at 8% until the mid 1990s and 7% in the following years. If the D citations appear in the search report, they are associated with the general categories X, Y or A, as multiple associations of categories to a citation are possible.

In the analysis of citations, citations of PCT search or examination reports are included as well, in order to be as topical as possible. The PCT reports are only included if they were made by the EPO to avoid mixing different patent systems. For instance, when the USPTO is the examining authority in the PCT context, it tends to include all inventor-given citations and focuses on patents at the USPTO. Here the EPO has a quite different practice. Since 1990, the share of documents which are exclusively cited as X or Y references steadily increases (Table 5-1); for this analysis a 4-year citation window is used in order to achieve comparable data over time. With the growing workload since 1994, the examiners obviously tried to shorten the examination process as much as possible and to concentrate on documents relevant for the examination decision.

Table 5-1: EPO search codes and their meaning

X Particularly relevant documents when taken alone (a claimed invention cannot be considered novel or cannot be considered to involve an inventive step).
Y Particularly relevant documents if combined with one or more other documents of the same category - such a combination being obvious to a person skilled in the art.
A Documents defining the general state-of-the-art (but not belonging to X or Y).
O Documents which refer to non-written disclosure.
P Intermediate documents - documents published between the date of filing of the application being examined and the date of priority claimed.
T Documents relating to the theory or principle underlying the invention (documents which were published after the filing date and are not in conflict with the application, but were cited for a better understanding of the invention).
E Potentially conflicting documents – any patent document bearing a filing or priority date earlier than the filing date of the application searched, but published later than that date, and the content of which would constitute prior art.
D Documents cited in the application *i.e.* already mentioned in the description of the patent application.
L Documents cited for other reasons (*e.g.* a document that may throw doubt on a priority claim).

Source: EPO; own compilation.

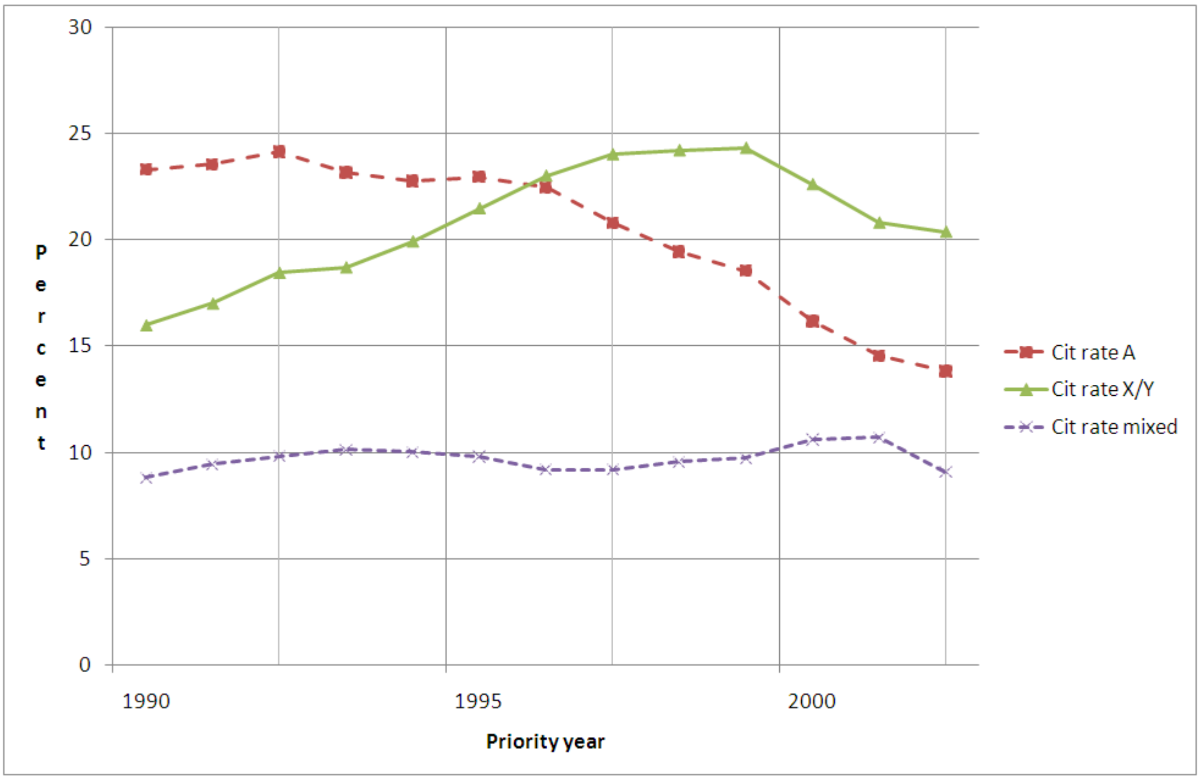
In particular, the refusal option is an event which shortens the process. In this context, the X and Y citations are sometimes called "killing" citations. In parallel to the increase of relevant citations, the share of citations referring to the background decreases. The A citations are – to a certain extent – a service for the applicant, and for this, the capacity of the EPO examiners is reduced. A third type of documents is cited as A, X or Y and may be called "mixed". The share of these applications is at about 10% with reference to all applications. The share of documents never cited within 4 years is at a level of 45 to 50 and steadily increases after 2000 due to the delay of the publication of search reports.

These findings may be described in a different way. Some applications are cited once only, and thus are exclusively cited as A or X or Y. Thus the citation rate (citations per application) of this category is rather low. A small share of the applications – the mixed category - is cited more often.

An alternative interpretation of the increasing share of X or Y citations may be the growing number of applications for strategic purposes, but of a low technological standard, so that the examiners try to finish the patent process as soon as possible with the argument of lack of novelty.

The majority of citations is covered by exclusive A, X, or Y or mixed references. The other categories, in particular the P, T, E, and D types are co-classified with A, X, or Y. Therefore the share of citations without A, X, or Y is quite low, at about 2 to 3%.

Figure 5-9: Share of applications with different categories of forward citations (4-year citation window) with reference to all applications at the EPO



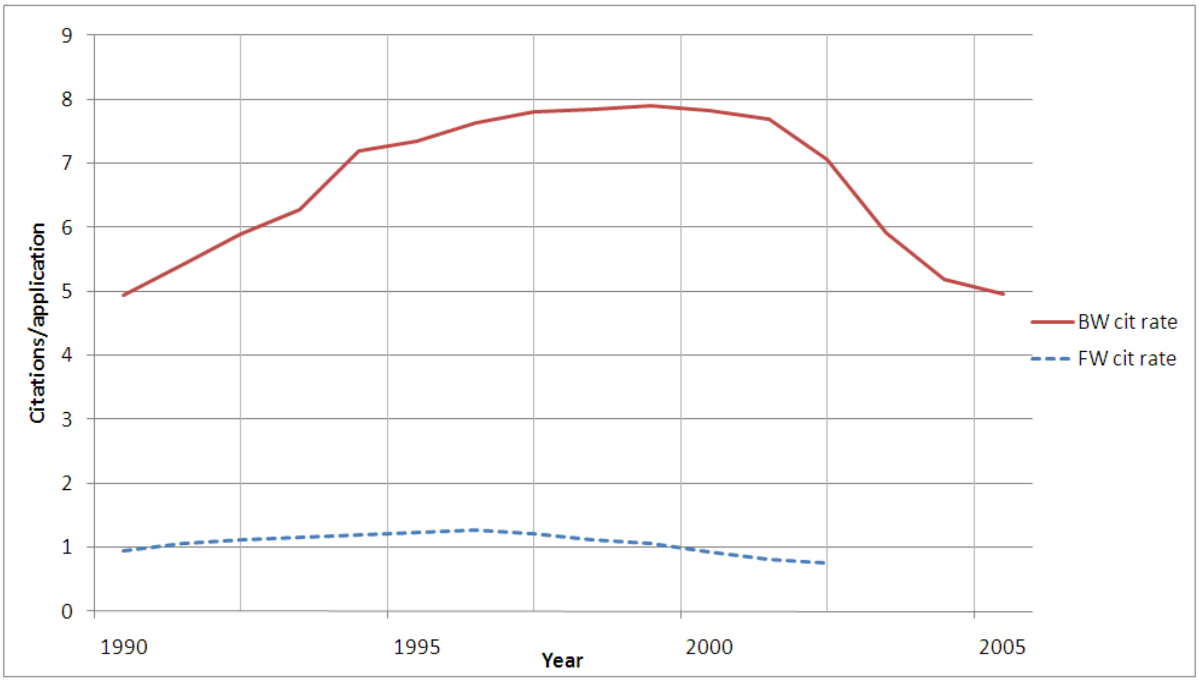
Source: PATSTAT (EPO), search and calculations of Fraunhofer ISI.

Looking at the development of citations over time, the number of citations per citation report, the so-called backward citations, increases between the beginning and the middle of the 1990s from an average level of 5% to a level of 8% percent and decreases after 2002 back to 5 again (Figure 5-10). Obviously, the EPO tries to make the research process more efficient. By the way, about 4% of the applications are withdrawn before the search report is published, so that the number of average citations for applications with search report is a little bit higher than that displayed in Figure 5-10.

As to the average number of forward citations, measured in a 4-year citation window and with reference to cited applications, the average level is quite stable at about 4, but sharply decreases with the year 2003. The forward citations refer to the number of citations that a specific application receives by search reports of applications of the subsequent years.

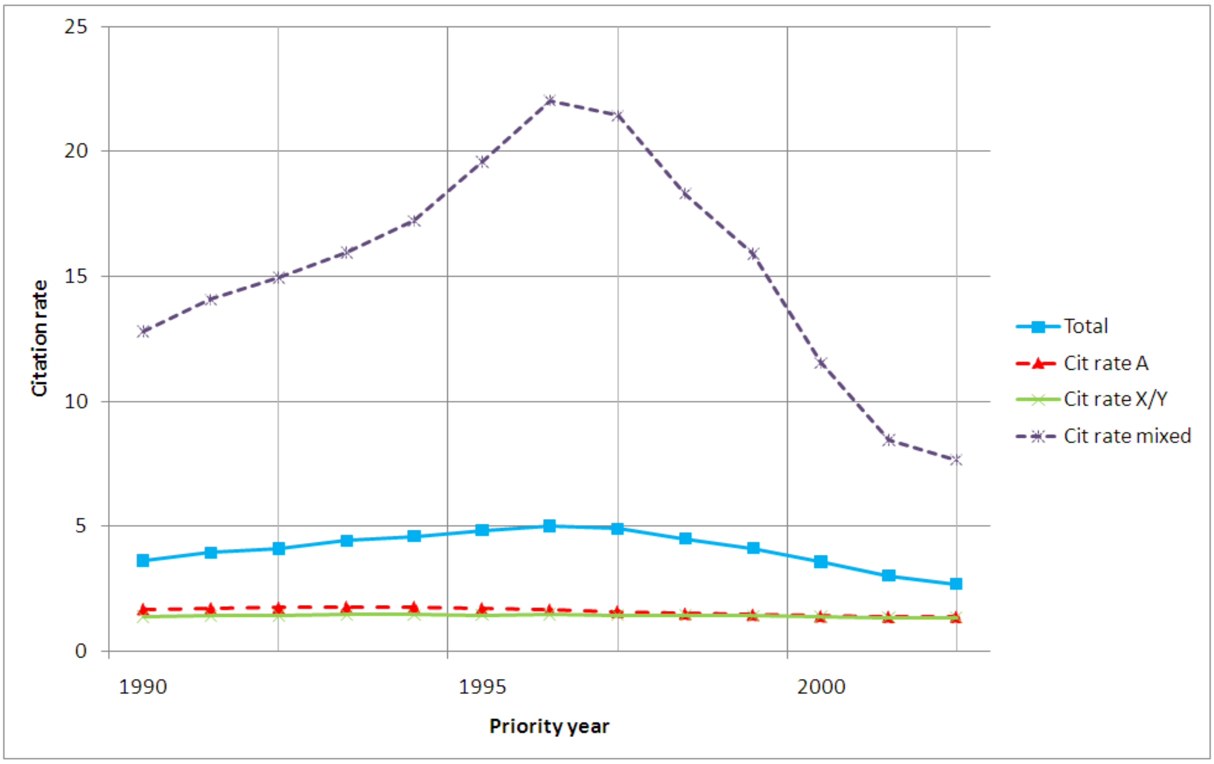
That means that not all search reports are available yet for applications of 2003 with 2006 as the last year of the 4-year citation window. This statement refers to a version of the PATSTAT database of 2009 with publications until March 2009. In principle, all search reports should be available at the time of the first publication of the application, i.e. 18 months after the priority date, so that the search reports for all applications of the year 2007 should be available. In reality, the search reports are often delayed and even the year 2006 is incomplete. There are even indications that the year 2005 is not fully-fledged yet.

Figure 5-10: Number of backward and forward (4-year citation window) citations per application at the EPO



Source: PATSTAT (EPO), search and calculations of Fraunhofer ISI.

Figure 5-11: Forward citation rate (4-year citation window) by different types of cited applications at the EPO



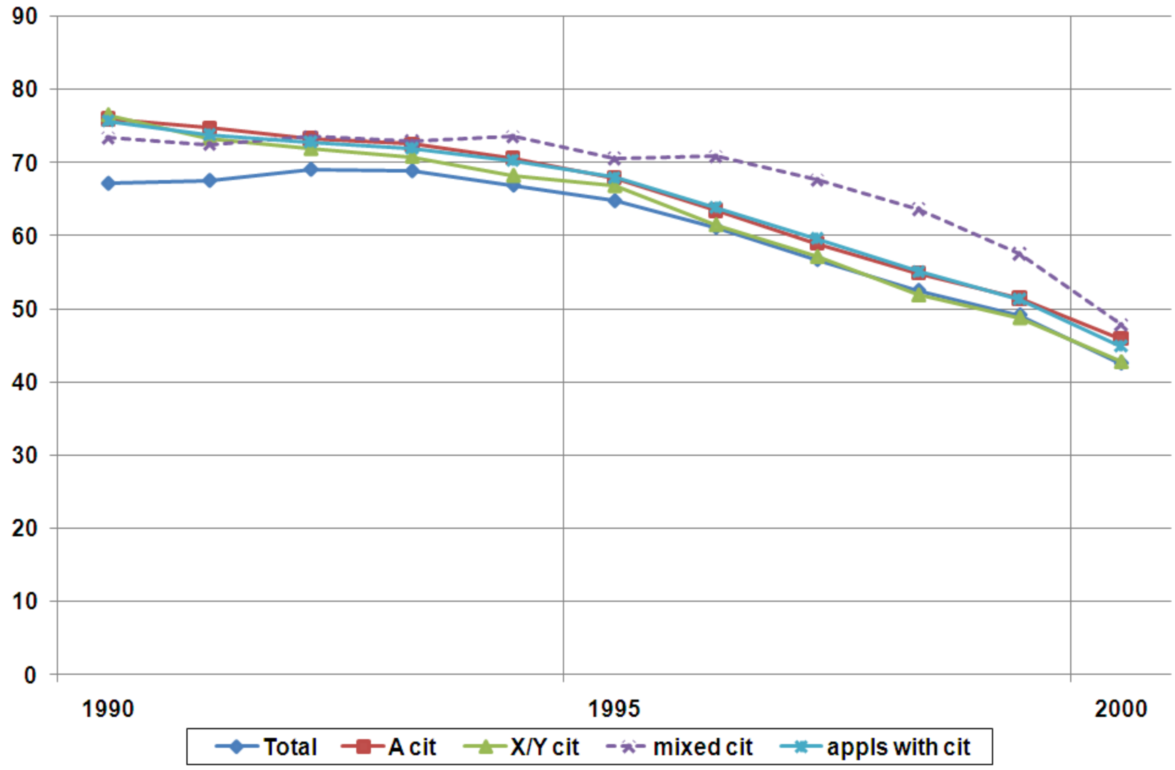
Source: PATSTAT (EPO), search and calculations of Fraunhofer ISI.

When the citations are differentiated by category of citation, the forward citation level of the applications that are exclusively cited in the category A or exclusively in X or exclusively in

Y is quite modest at about 1.5 (Figure 5-11). The difference between the citation rates of the A, X, or Y categories is negligible. However, the citation rate of the mixed documents – about 18% in 1998 - is substantially higher than that of the documents exclusively cited in one category. Here the citation rate decreases in recent years, but it is still much higher than that of the exclusively cited ones. This structure reflects a very skewed distribution of citation rates.

If the grant rate is taken as an indicator of quality, the rates of exclusively cited documents and that of the mixed category are almost identical (Figure 5-12), so that it is not possible to claim that the quality of applications with A citations is different from those with X or Y citations. Since 1996, only the grant rate of the mixed documents appears to be distinctly higher than for the other categories. The convergence of the levels of the different categories in 2000 may be due to the high level of pending cases in 2000 (see chapter above). Thus there is strong evidence that the category of documents with mixed citations has a higher quality. In any case, there is no compelling evidence that a differentiation by categories of citations should be made in a citation analysis at the EPO.

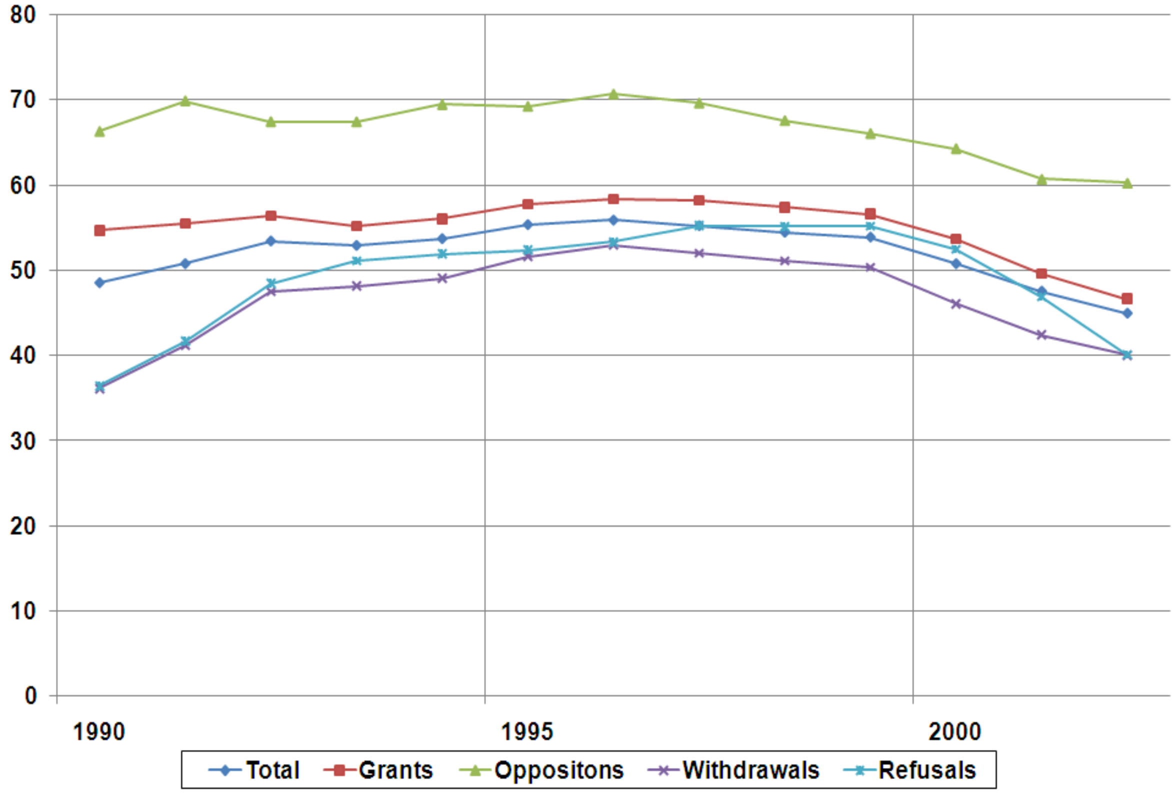
Figure 5-12: Grant rate by different types of cited applications at the EPO



Source: PATSTAT (EPO), search and calculations of Fraunhofer ISI.

An investigation of the share of applications with citations by legal status shows that the citation share of granted applications is only slightly higher than that of the refused ones (Figure 5-13). For instance, in 1998 57% of the granted documents were cited within a 4-year citation window and also 55% of the refused applications. The differences are a little bit more pronounced, if the citation rates are computed instead of the citation shares, but the differences are still not substantial. However, the citation share of granted patents which were opposed is clearly considerably higher than that of all other types and represents patents with a value above average, a finding which is confirmed by the literature (cf. for instance, Harhoff et al. 2003). The withdrawn applications are cited less frequently than grants and also refusals, but they nearly reach the level of the other types of applications.

Figure 5-13: Share of cited documents (4-year citation window) by legal status of the applications at the EPO

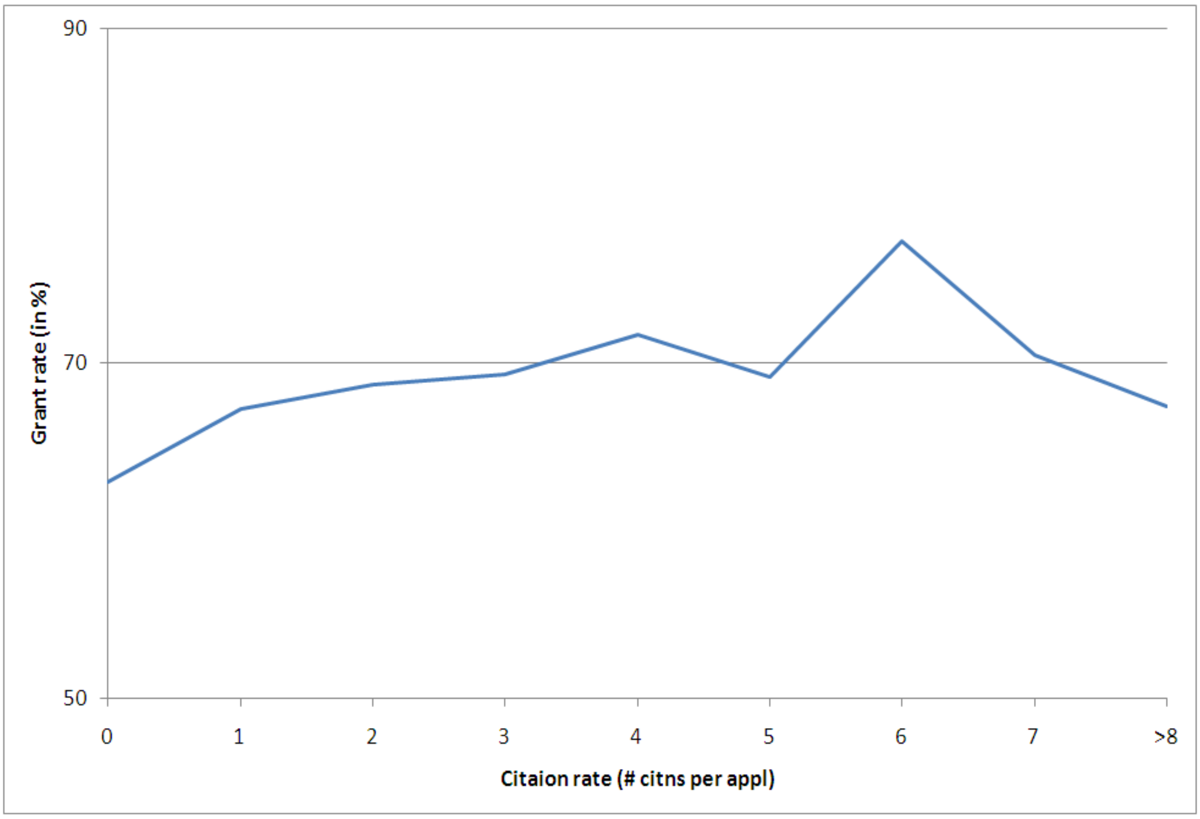


Source: PATSTAT (EPO), search and calculations of Fraunhofer ISI.

If the citations are taken as an indicator of value, it is still not necessary that clear differences can be found at the country level. Considering the average citation rate for all citations, a value of 2.06 is found for all applications of 1998 within a 4-year citation window. The citation rates of Germany appear to be distinctly lower, at a level of 1.7, those of the United States or Finland clearly higher at 2.3 or 2.71 respectively (Figure 5-16). All in all, Germany is at a medium level compared to other countries. The citation rates prove to be discriminating between countries and the results appear to be plausible. For the United States, Finland, Sweden or the United Kingdom, the technology portfolio is oriented towards research-intensive technologies, whereas the relative devaluation of Italy with a stronger focus on less research-intensive technologies and for China as a technology follower is quite similar.

A further potential approach is to exclusively consider applications with very high citation rates. A first argument against this method is that it is not representative of the innovation-oriented activities of a country, which cover much more than only innovations of very high value (cf. chapter 2). A further problem is the weak statistical basis, as for sufficiently topical analysis a window for analyzing forward citations should comprise about 4 years. But then the numbers for applications with more than two citations become very small, so that a differentiation by countries cannot lead to reliable results. Finally, the grant rates by number of forward citations lead to the expected result that grant rates increase with the number of citations. However, for applications with more than 7 citations, the grant rates decrease again (Figure 5-14). This may be due to the effect of very low numbers, but in any case, the exclusive analysis of applications with very high citation rates has no sound basis.

Figure 5-14: Grant rate of EPO applications by citation rate (priority year 2005, 4-year citation window)



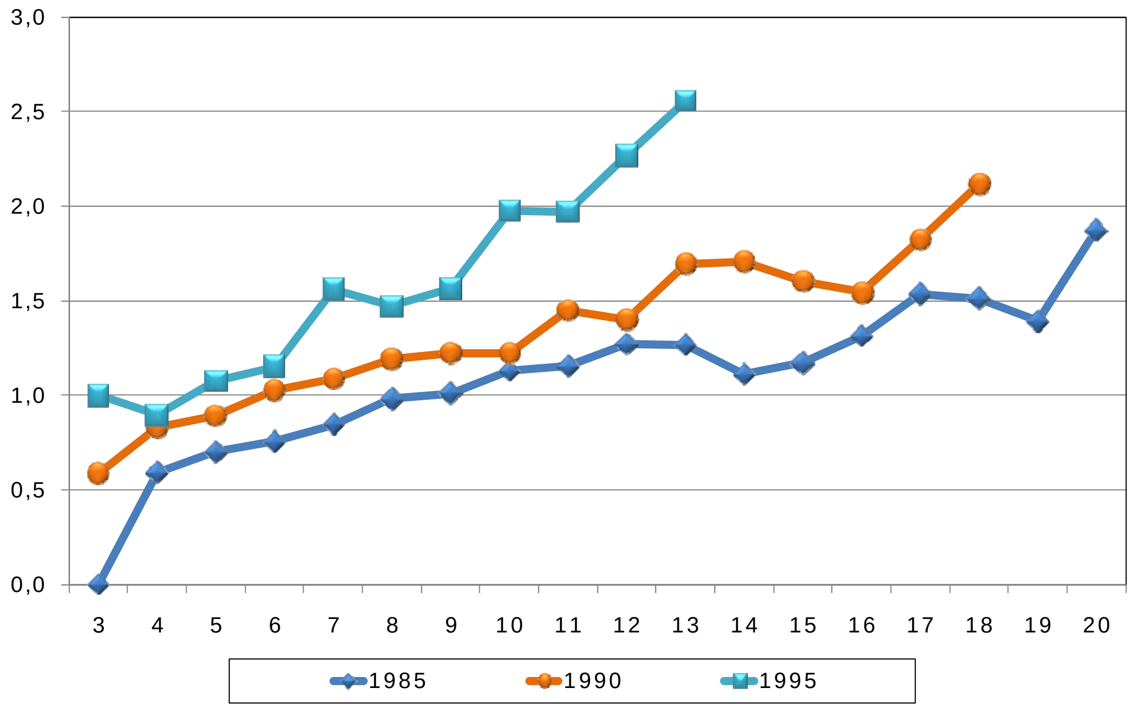
Source: PATSTAT (EPO), search and calculations of Fraunhofer ISI.

An alternative approach is to look at applications with mixed citations. Here the average rate for all applications of this category is 6.3. In the case of the United States, it is 10.8, for Germany 2.73. At first sight, the differentiation by the citation rate of applications of the mixed type seems to be much stronger than that of the average citation rates. However, the shares of mixed-type applications are also quite different by country. In the case of the United States, this share is 11%, for Germany it is 34%. Obviously, this type of document refers to a very small share of leading-edge technologies in the case of the United States and to a broader set of medium-level technologies for Germany.

As a solution, the shares and citation rates of the mixed documents can be multiplied, leading to a similar ranking as for the average citation rates (Figure 5-16). This effect becomes clearer when the average citation rates and the index for the mixed citations are normalized by the world averages, thus when mixed citation-based value factors MCVF are calculated. Then the relatively higher value of Finnish applications based on the mixed index becomes more pronounced, and also the existence of a small number of high-level applications from Russia gets more visible than on the basis of the average citation rates (Figure 5-17), thus on the basis of average citation-based value factors ACVF.

Figure 5-15 displays the average duration of maintenance of granted patents by forward average citation rate in a four-years-window after filing the priority document. The maximum maintenance is 20 years – due to the legal regulation – and the average is about 12-14 years. The latter is the reason why younger cohorts than priority year 1995 can hardly be analysed as a large number of these patents are still maintained. Two considerable effects can be seen. First, more highly cited patents are maintained longer. Second, this is even more the case for younger, even against the background of higher average citations in the more recent cohorts.

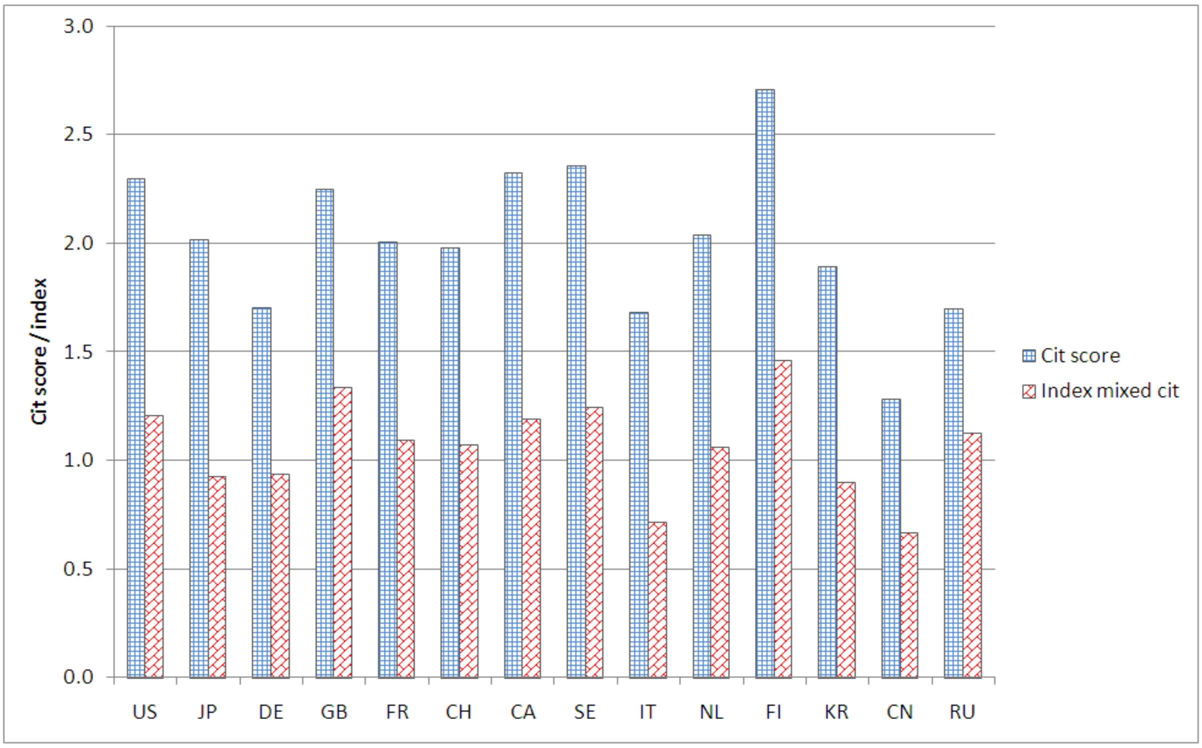
Figure 5-15: Average duration of patent maintenance by average citation rate



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

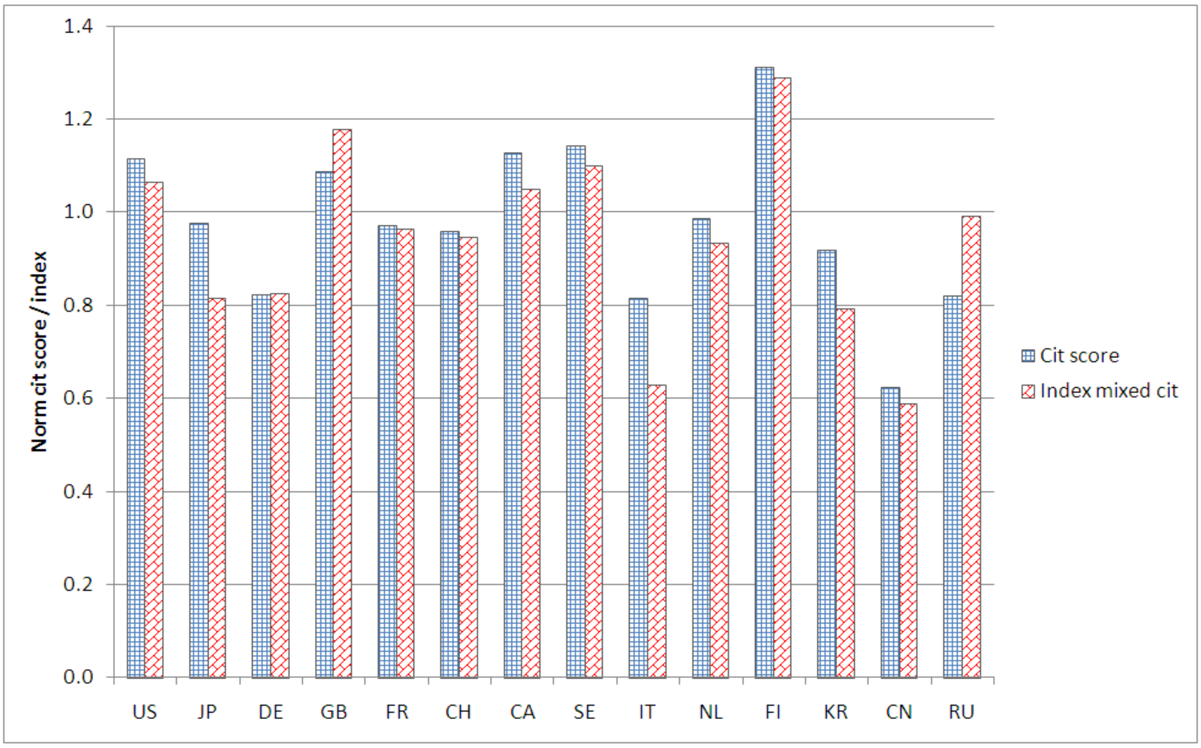
To summarize, the introduction of citation-based value factors implies a differentiation between countries at the aggregate level, and the revalidation appears to be much more plausible than that based on grant rates.

Figure 5-16: Forward citation rate (4-year citation window) and index of applications with mixed citations (citation rate multiplied by share) at the EPO by countries of origin



Source: PATSTAT (EPO), search and calculations of Fraunhofer ISI.

Figure 5-17: Normalized forward citation rate (4-year citation window) and normalized index of applications with mixed citations (citation rate multiplied by share) at the EPO by countries of origin



Source: PATSTAT (EPO), search and calculations of Fraunhofer ISI.

5.3 Citations and grants by technology

The distinct differences in citation scores between countries might be due to different technology profiles of each country. So it seems to be plausible that countries with a specialization in more basic technologies have higher citation scores than those with a focus on more specific technologies. For instance, the specialization profile of Germany at the beginning of the 1990s was nearly opposite that of the United States (Abramson et al. 1997: 250ff.). The German patents focused on fields of mechanical engineering, whereas the US ones specialized in information technology, pharmaceuticals, and biotechnology. Against this background, the higher citation rate of the United States compared to Germany seems obvious. However, the hypothesis that the overall citation scores are closely related to technology profiles cannot be verified statistically.

The results of four different tobit-models using different value indicators as dependent variables are displayed in Table 5-2. It can be seen that German patents are cited at a lower level than all other countries except Austria, even when controlling for country and technology effects. Denmark, the United Kingdom and Japan are at the top and the USA reaches a good position in the upper part of this list. In the case of grant rates almost the opposite is true. The USA, the United Kingdom and Canada perform rather badly, while Germany and Austria are at the top together with other countries, among them Japan.

Table 5-2: Coefficients of tobit-models for different value indicators as dependent variables, country coefficients

	Forward citations	Grant rate	Backward citations	Family size
DK	1.07***	0.00	0.75***	1.12***
GB	0.96***	-0.09***	0.95***	1.60***
JP	0.83***	0.03*	0.31	-0.52***
NO	0.79***	0.03*	2.05***	1.08***
CA	0.63***	-0.08***	0.33	1.30***
NL	0.60***	-0.02	0.05	0.85***
US	0.58***	-0.12***	-0.49**	1.11***
BE	0.55***	-0.03*	-0.10	0.97***
SE	0.52***	0.00	0.88***	2.36***
FI	0.48***	0.00	0.61***	0.90***
CH	0.46***	-0.01	-0.02	1.36***
FR	0.29**	0.03*	-0.27	1.04***
IT	0.19*	-0.05***	-0.86***	0.45**
ES	0.15	-0.15***	-0.72***	-0.54***
AT	-0.13	0.02	0.27	0.03

Reference categories: Germany, Low-Tech; coefficients not mentioned in the table: constant, priority year, number of applications, and dummies for the 35 technological fields; * for p<.05, ** for p<.01, and *** for p<.001.

Source: EPO – PATSTAT; Fraunhofer ISI calculations.

In addition, it is revealing to examine the structures of citations more closely – and also grants – by technologies. First of all, we have to take into account that the citation scores of large fields, in terms of application numbers, have a higher impact on the overall scores than smaller fields. Using the classification of research-intensive fields as generally used in the reports on the international competitiveness of advanced countries (e.g. Frietsch, Schmoch 2010), the largest field are "other technologies", i.e. less research-intensive fields (Figure 5-18). They represent about 35% of all applications, and thus the citations referring to less research-intensive fields strongly affect the overall citation score. Other large fields are bio-technology, communications and pharmaceuticals, suggesting the hypothesis that the high overall citation score of the USA compared to Germany is largely based on the US strengths in these latter fields.

A further question is whether the citation rates really differ by field. In Figure 5-19, the fields are sorted by the citation rate level. The citation rates by field differ substantially in the range from 0.39 to 2.17 with reference to the overall citation rate. The fields organic basic materials, pharmaceuticals, biotechnology, and other special chemicals appear as fields with the highest citation scores. Obviously, fields with a more basic character or with stronger reference to science have the highest citation rates. The grant rates also substantially differ by fields. However, the grant rates generally are high in fields with low citation rates and vice versa. Although this observation does not apply to all fields in a strict way, the correlation between grants and citation rates is strong and negative at a level of R=0.61.

Looking at the specific case of Germany, the share of less research-intensive fields is above average, with a share of 38% (Figure 5-20). The largest research-intensive fields are automo-biles, communications, special purpose machinery, power machines, pharmaceuticals, and biotechnology. But the low overall citation rates are obviously not due to a relative strength in less research-intensive fields and within the research-intensive ones on high-value technology (and less cutting-edge technology). Rather, the citation rates are below average in almost all fields. Conversely, the grant rates in almost all fields are above average.

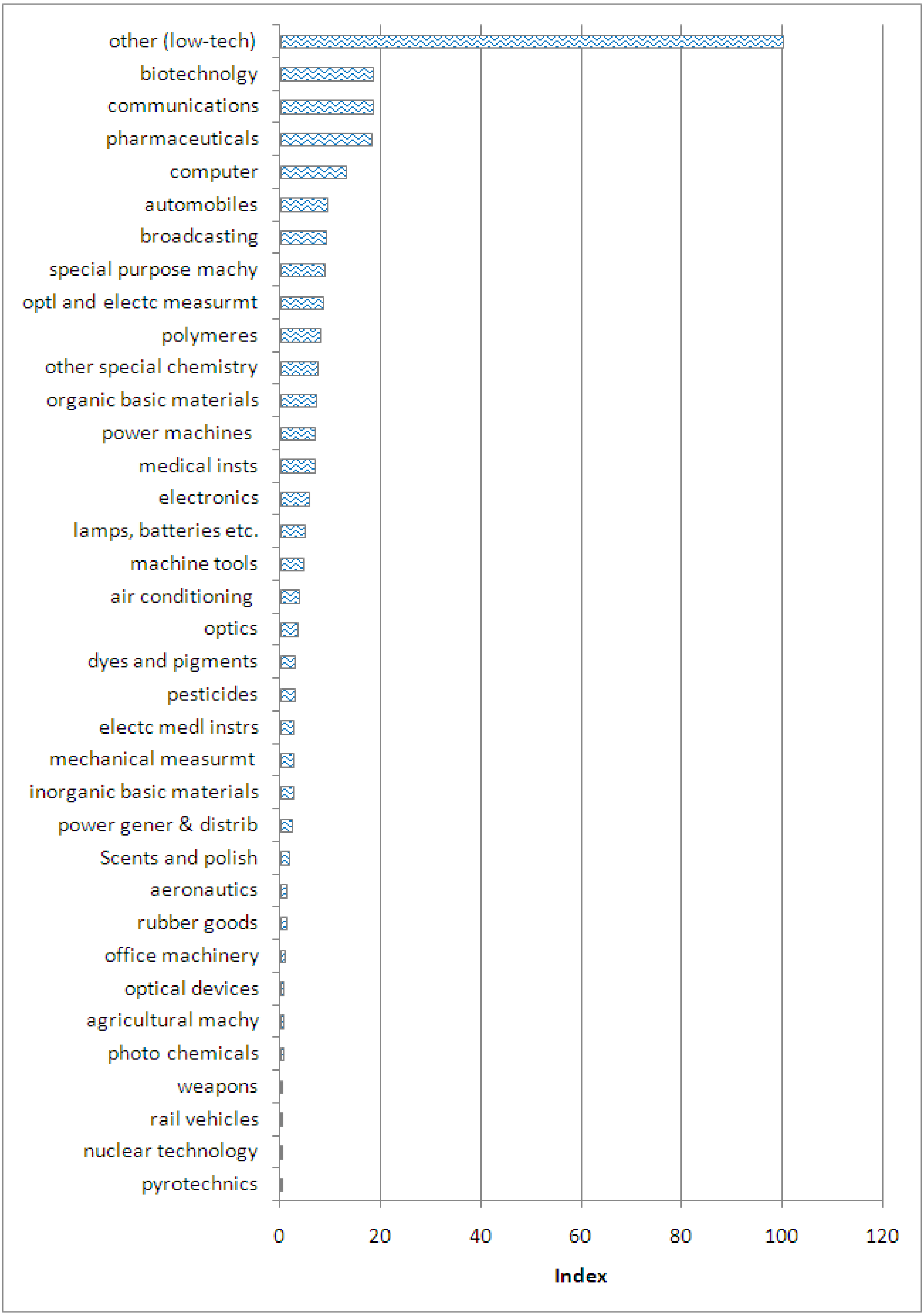
In the case of the United States, the less research-intensive technologies are the largest field as well, but with a share distinctly below average of 30% (Figure 5-21). The following fields are – as for Germany – automobiles, communications, special purpose machinery, power ma-chines, pharmaceuticals, and biotechnology. Thus the size of the fields largely depends on field characteristics and less on country specializations. In the case of the United States, the citation scores for almost all fields are above average and the grant rates below average. Thus the picture for citations and grants is just the opposite of the German one.

The general difference between Germany and the United States in terms of grants was already discussed in section 4.1. in more detail. Here the legal differences between the European and the US American systems appear to be the most convincing explanation. As to the citations, a first hypothesis may be that more basic or general applications attract more citations, whereas more specific and incremental applications are less often cited. This assumption is supported by the ranking of citations by fields as depicted in Figure 5-19. In Germany's perspective, the applications at the EPO refer to neighbouring countries, in the perspective of the United States, the applications refer to overseas countries and are far away in geographical terms. The geostrategic position is clearly unequal. Thus the applications of the United States may represent a selection of more basic inventions even in less research-intensive fields, and those of Germany may include a higher share of specific applications. However, this assumption does not explain the above average citation scores of the United Kingdom, Sweden and Finland and the below average score of Japan.

A further explanation may be that the legal regulations in the United States require more illustrative patent abstracts than the European ones, so that the examiners have a preference for applications with abstracts in the US style which the US applicants transfer to their European filings. Again, this thesis does not explain the above average citation rates of the United Kingdom, Sweden and Finland. It will be necessary to check a larger set of applications individually to verify whether one of the hypotheses suggested applies or other aspects are relevant.

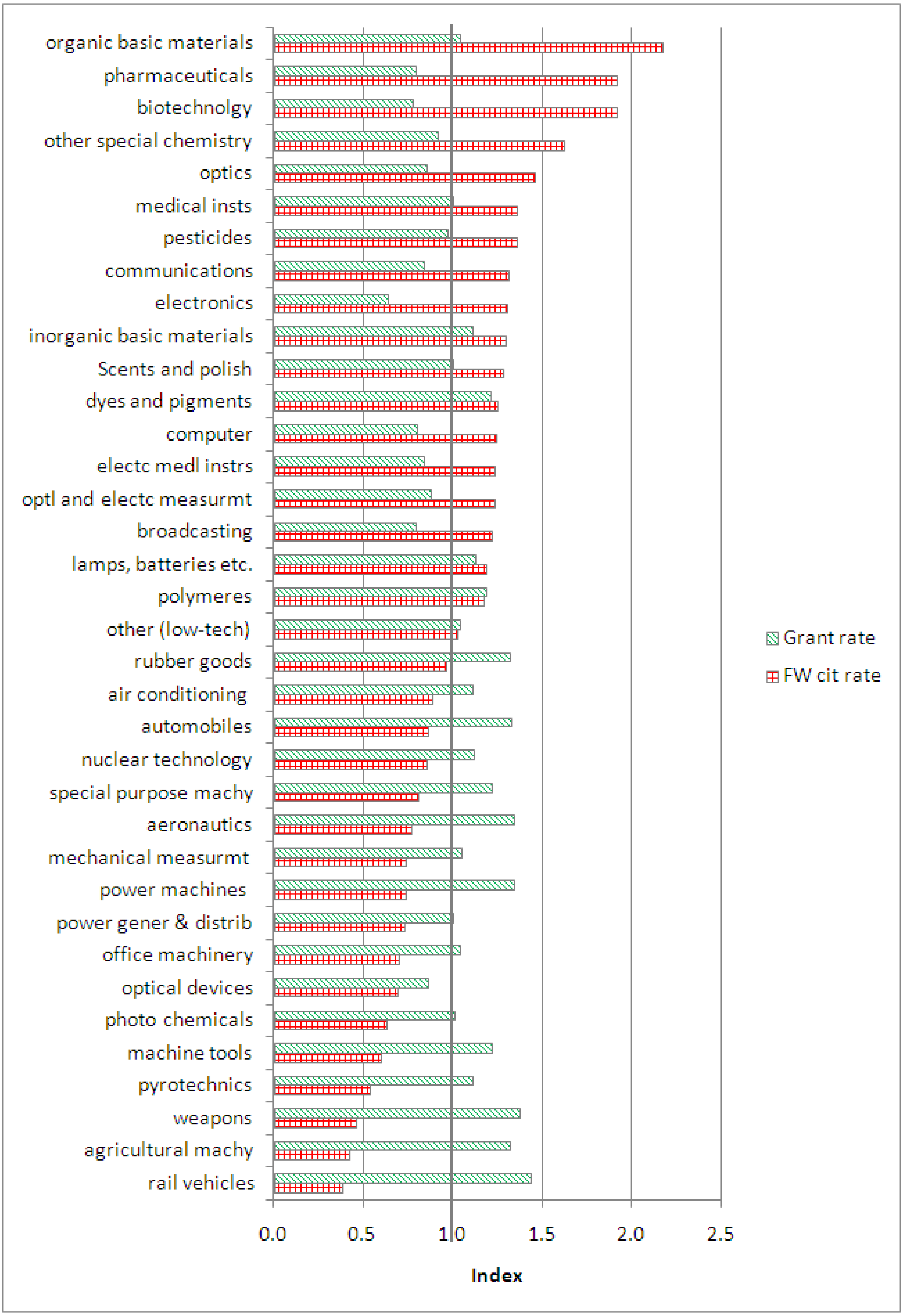
To summarize, the consideration of citation and grant rates by field suggest that the differences referred to do not reflect differences in terms of value, but rather differences in legal regimes, geostrategic differences, and differences in the citation behaviors of examiners.

Figure 5-18: Number of EPO applications by field, 1998
(index # other fields = 100)



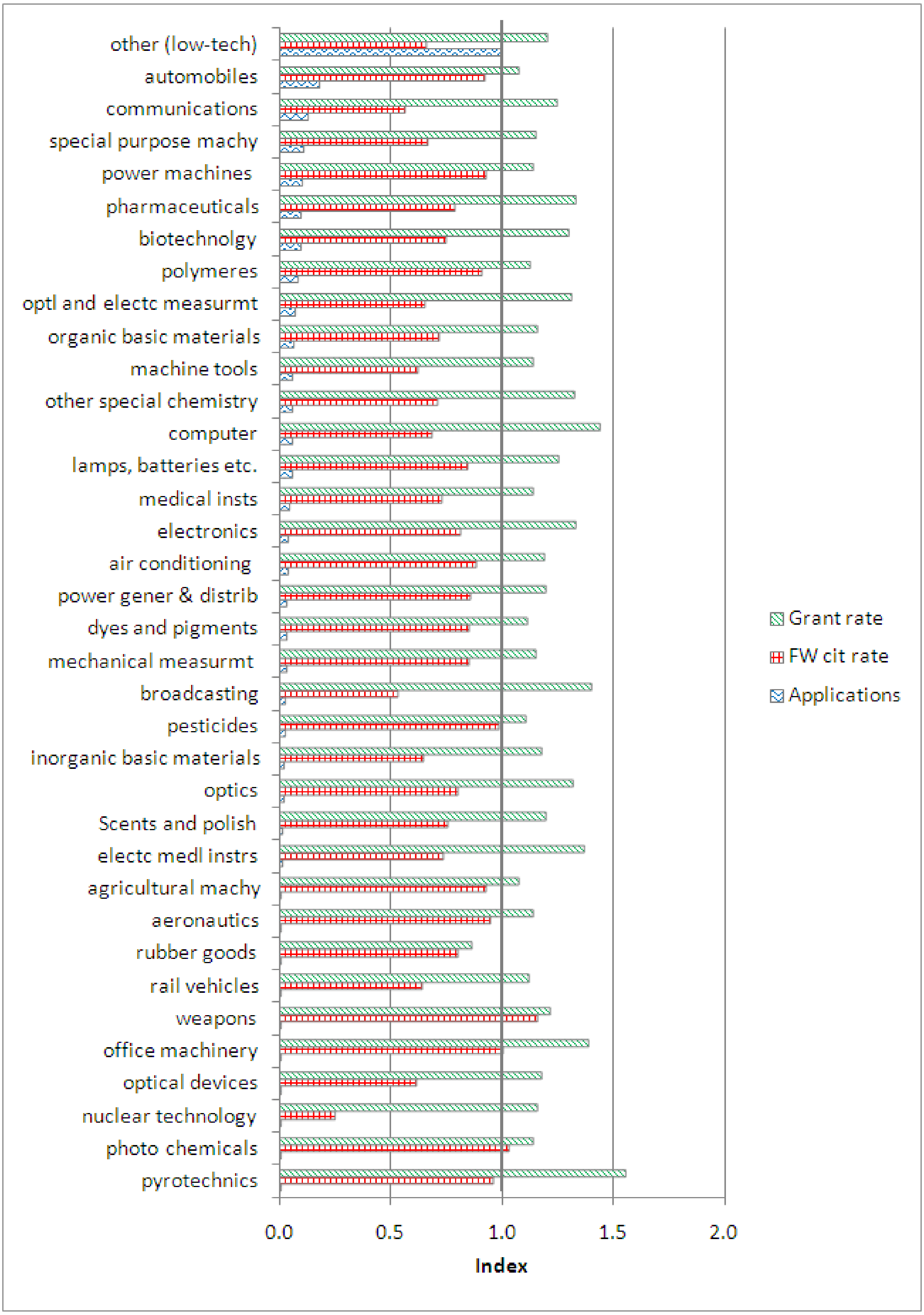
Source: PATSTAT (EPO), search and calculations of Fraunhofer ISI.

Figure 5-19: Normalized grant and forward citation rates, 1998
(index overall grant and citation rates = 1)



Source: PATSTAT (EPO), search and calculations of Fraunhofer ISI.

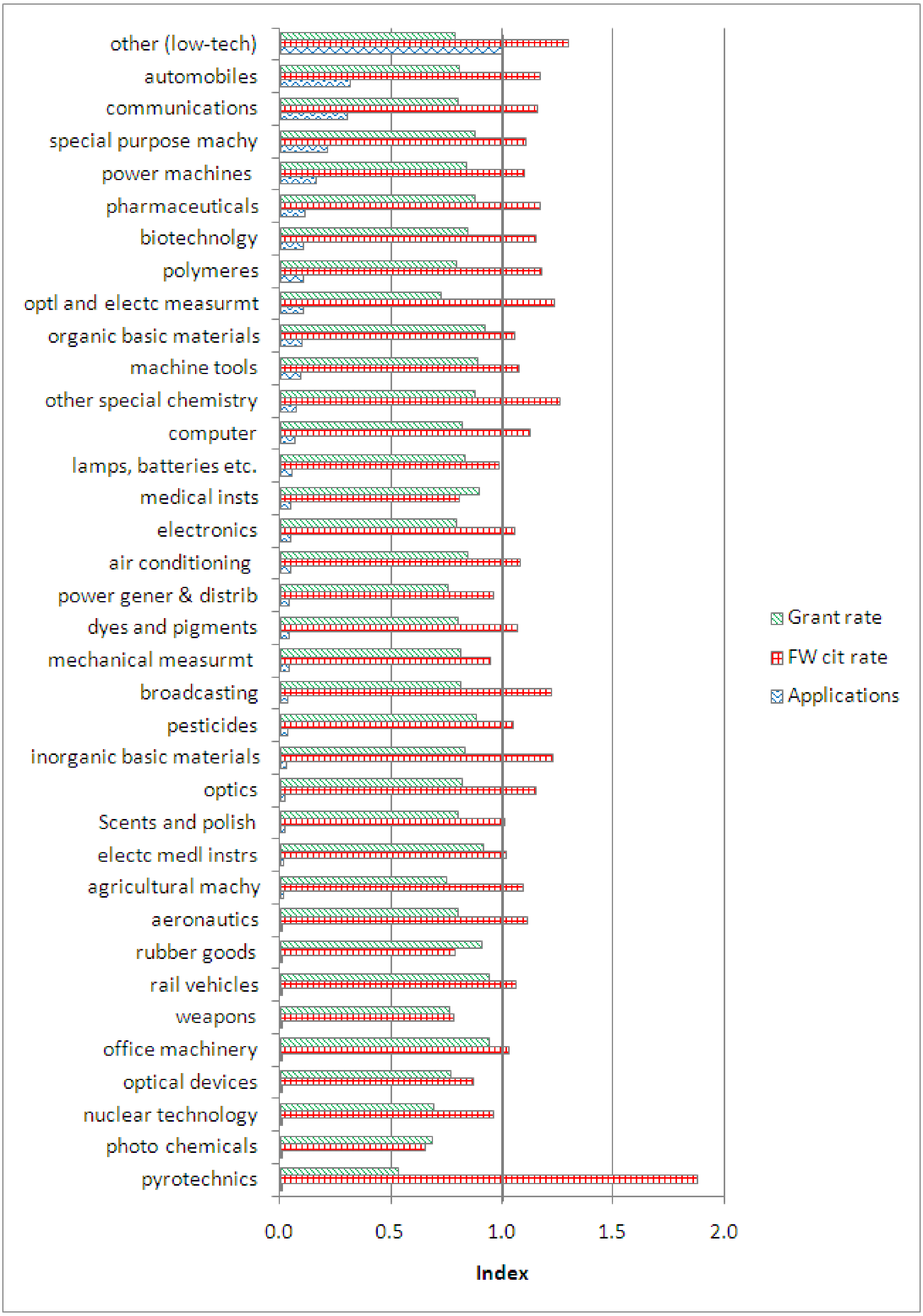
Figure 5-20: Normalized field size, grant and forward citation rates for Germany, 1998
(index # applications in German other fields, overall world grant and citation rates by field = 1)



Source: PATSTAT (EPO), search and calculations of Fraunhofer ISI.

Figure 5-21: Normalized field size, grant and forward citation rates for the United States, 1998

(index # applications in US other fields, overall world grant and citation rates by field = 1)



Source: PATSTAT (EPO), search and calculations of Fraunhofer ISI.

6. Towards a Value-adjusted Patent Count

Torben Schubert

6.1 Introduction

Measuring the innovative capacity of countries is often (though not necessarily exclusively) based on patent-related indicators. However, the use of unweighted patent counts has raised considerable criticism, the most prominent being that patents are standardised measures only in a juridical, but not in an economic sense. This means that, although from a legal point of view one patent is in principle like another, the economic value or impact may be quite different between any two of them.

Therefore, the literature has proposed several approaches to reweighting patent counts with complementing data which is said to express quality or value aspects of the patent. Following this idea, a variety of alternative indicators, such as using citation-weighted patent counts, triadic patents or grants was developed. In most cases, however, these concepts are built on theoretical reasoning; and less on empirical evidence with respect to the hypothesised (positive) relationship to value. Since studies already show that these indicators tend to explain little of the economic value of the underlying patent (Gambardella et al. 2008), any of these concepts is, at best, partial.

In this paper we propose an approach to derive a country-specific value adjustment factor which is based on the incorporation of renewal data. To be clear from the beginning, the aim of the paper is not to assess the value of an individual patent in advance. Instead, we intend to develop a method that allows the value of a patent portfolio to be assessed.

Calling this patent portfolio value PPV, we will show how renewal data can be used to determine this value by country up-to-scale. Specifically, we present a method to determine a value adjustment factor VAF, if there exists a valued-adjusted patent count $VAPC$ that is proportional[7] to the value of the patent portfolio. Thus, for each country k:[8]

$$PPV_k \propto VAPC = P_k \cdot VAF_k , \qquad (1)$$

The seeming triviality of this formula should however not disguise that it is quite difficult to argue for a sensible value adjustment factor.

One way of doing this is to use renewal data, which allows the valuation of individual patents (among others, Schankerman, Pakes 1986). However the novelty of our analysis lies in the argument that the raw values resulting from the usual application of these formulae are cen-

7 Even with renewal data, however, we are not able to measure the absolute value of the patent portfolio. The reason for this will become obvious in section 3, but in a nutshell, the reason is that renewal fees only reflect a part of patent costs.

8 From a conceptual point of view, it is interesting to note that the citation-weighted patent count falls in this class. VAF would here simply be taken to be e.g. the forward citations by country (i.e. the number of all citations received by the patents in one country) or some normalised variant of this.

sored. Since it is well known that the value distribution of patents is highly skewed, censoring might result in severe biases: only a few high-value patents – whose measured value is cut off – might make up a large share of the total portfolio value (Harhoff et al. 1999; Harhoff et al. 2003). We therefore propose a way to recover the uncensored value distribution. This is basically a step-wise procedure, where we first use the unconditional but censored value distribution to derive an uncensored value distribution which is conditional on explanatory variables. This can in turn be used to recover the distribution of interest: the unconditional and uncensored distribution of the patent value. We use this to determine value adjustment factors to reweight country patent portfolios.

The remainder of this chapter is organised as follows: section 2 describes several indicators of patent value proposed in the literature. Section 3 describes the model used to determine the patent value based on renewal fees. Section 4.1 presents the step-procedure to recover the uncensored value distribution. Section 4.2 presents the estimation results. Section 5 concludes.

6.2 The Patent Value and Suitable Indicators

6.2.1 Defining Patent Value

Let us first briefly define what we mean by patent value. This is not as trivial as it may sound because of the numerous ways in which a patent may be used, i.e. in which it may possess value. In the literature, we find words like private or social values, we also find authors distinguishing between traditional and strategic values, where the term traditional refers to the traditional motive of reaping a monopoly rent for a product that results from the patented invention. Concerning the strategic value, authors further distinguish between the types of strategic action, e.g. active blockade or passive blockade (see e.g. Blind et al. 2006). Sometimes we also find authors who attribute a technological value to patents (Grimpe, Hussinger 2008).

It is not surprising that the definition of reasonable indicators requires us to fix our notion of patent value. In our case, the use of renewal data to determine patent value already imposes its definition. Since the basic idea of using renewal data is based on the notion that the owner of the patent will renew only if the expected returns exceed the renewal fees, we inevitably talk about private value. Therefore, what we are able to measure using renewal fees is only the value that accrues to the owner. The renewal history cannot be used to recover value that is socialised in terms of external effects, e.g. via knowledge spillovers (compare Grönqvist 2009). Furthermore, considering the private value, no distinction can be made between the sources of this private value. It can be true that an owner intends to retain monopoly rents from selling a product exclusively. But it could also be true that he simply wants to use it strategically. Thus what renewal fees measure is closely related to what Harhoff et al. (2003) call the asset-value of a patent.

In essence, there are two ways of determining patent value. The first class of procedures derives it in monetary terms, where the procedures all have in common that their value measure refers to the private value.

However, basically since all these methods are either methodologically complicated or are not widely (i.e. routinely) applicable, simpler value indicators are also widely found in the literature. These, in any case, do not come up with a value expressed in monetary units rather they provide numbers which are given in real terms. Some of the latter indicators are said to grasp also some features of the socialised value, e.g. when backward citations are used to measure knowledge spill-flows (which are in essence positive external effects). In the following, we will give a short review of both groups of approaches to measure patent value.

6.2.2 Methods Calculating Patent Value

To our knowledge, there are three ways to determine patent value directly: the first is based on *survey data*. That is, applicants, inventors, or owners of patents are directly asked for the patent value (Harhoff et al. 1999; Harhoff et al. 2003). Even though this entails a subjective component or measurement error, this probably applies to all methods predicting patent value. The major disadvantage is not the measurement error induced by the subjective component, but rather that this approach gives information only for the survey itself. This probably means that surveys are good for conceptual scientific work, but are of limited (direct) use for the somewhat routine work of measuring the innovative performance of countries.

The second approach makes use of data when patents are sold, for example, in *auctions or by licensing* (Sampat, Ziedonis 2004). Here the patent value is taken as the price that some bidder or licensee was willing to pay. Again, this approach is limited to very small subsets of patents because of data availability. So the same drawbacks that apply to survey data are relevant here.

The third approach, probably the one receiving the most attention in the past years, is to use data on *renewal fees* (Bessen 2008; Grönqvist 2009; Lanjouw et al. 1998; Schankerman, Pakes 1986). The idea is quite simple, in principle: because patents only stay alive, if regular payments (so called renewal fees) are made, the private returns accruing for a particular period must be at least as large as the renewal fee paid for that period of time. Under further assumptions (some of them heavy), theoretical models can be developed which allow formulae for the patent value to be derived (see section 3). The merit of these formulae is that they depend only on data that is usually available in the patent databases. This makes the method widely applicable. However, some caveats remain. Renewal data is retrospective, because only the lapse of patent (naturally occurring with a lag) contains precise information on the value. Furthermore, the formulae are based on model assumptions. If these do not hold, then any calculation based thereon is necessarily more or less biased.

6.2.3 Some Value Indicators

In the past, several indicators of patent value were proposed. Basically, they can be divided into two groups, the first consisting of indicators that are available from patent databases (mainly information about features of the document itself), while the second contains indicators which are not available from patent databases (mainly referring to applicant or inventor information beyond bibliometric data).

In this chapter, we only deal with the first group, i.e. we neglect the institutional background and only deal with widely accessible information from databases. Among the indicators proposed, *citation-related measures* especially have become important, although they are used for different (though interlinked) phenomena. (Narin, Noma 1987) use them as an indicator to evaluate the technological component incorporated in the patent. Hall et al. (2005) use patent citations to predict market capitalisation of firms. Other authors like Bessen (2008) use citations in the context of the economic value of a patent.

A different indicator is whether there are *references to non-patent often scientific literature* (Meyer 1999) where it is claimed that references to this kind of information indicate greater vicinity to science and therefore both higher technological and economic value.

Putnam (1996) analyses the role of *patent families*. In short, a family in a narrow understanding is a group of patent documents that refers to the same invention, i.e. patents at different national offices that protect the same invention. In a broader sense, a family will also include patents that do not refer to the same invention, but are significantly closely related, as may occur during the strategic use of patent thickets. The reason for assuming a positive relationship between value and family size has several reasons. Firstly, an invention that is filed at several national offices is probably more valuable, as the owner deems it to be relevant for more markets. In line with this reasoning is the use of triadic patents, which in fact are just a special patent family. Secondly, since a family might protect a series of related inventions, a strategic portfolio effect might also emerge. For example, one patent in a given family might simply exist to protect another patent in the same family, which increases the value of the latter. Another indicator related to patent families is the *number of designated countries*. In fact, this is can be viewed as a special family, which is not yet realised.

The role of *oppositions and litigations* is also broadly discussed (Allison et al. 2004; Lanjouw, Schankerman 1997; Merges 1999; van der Drift 1989), where the usual reasoning is related to the costs of using the legal system. A patent will usually be opposed only, so the reasoning, if the assumed value in litigation is high enough.

Further indicators that might predict the patent value concern the *characteristics of the inventor team*, for example, how large or how international it is, where either larger or more international teams might be able to exploit a broader knowledge basis.

6.3 Calculating Patent Value Using Renewal Data

We already mentioned that it is possible to calculate the value of a patent based on its renewal history. In fact, letting $\bar{r}_j$ be a fixed return rate, r^m the capital costs of a firm, and $\left(c_i, t_i\right)$ a set of pairs of renewal fees and renewal times, plugging (A3) into (A1) in the appendix and setting $t_1 = 0$, the value of a patent that lapsed after period i^* can be calculated by

$$PV_j = \left(c_{i^*} \frac{\mathrm{e}^{-r^m t_{i^*}} - \mathrm{e}^{-r^m \left(t_{i^*} + t_{i^*+1}\right)}}{\mathrm{e}^{-r^m t_{i^*}} - \mathrm{e}^{-r^m t_{i^*+1}}} \right), \qquad (2)$$

which only depends on components principally observable. This formula is a slight variation of Bessen's approach (2008).[9] In any case, we should note two important facts.

Firstly, renewal fees are only a partial measure of the total patent value, because they do not take into account all costs induced by a patent (e.g. attorney or litigation costs). In a certain sense they just measure the tip of the iceberg.

It may come as a surprise that although we are not able to determine the complete gross patent value due to this partial view, we are still able to correctly determine the relative value between any two patents from the renewal data alone, at least if we are willing to assume that the unobserved costs are sunk at the moment of the renewal decision. This is, in any case, a reasonable assumption because much of the additional patent costs occur at the beginning of the application process. These cannot be recovered by the decision not to renew the patent. Because of that, even though the patent value derived from the renewal history is (much) too low in absolute terms, it will still correctly depict differences between any two patents. For the sake of simplicity, we stick with the term 'patent value' even though it is only a fraction of the real value.

Secondly, if the patent is maintained for the maximum legal period (in Europe 20 years), the patent value has to be considered as censored. This is made more obvious by the derivation of equation (A2). More intuitively, if a patent is prolonged to the legal maximum duration, we can only determine a lower boundary for the patent value. That is, for a patent living for 20 years we know that its value is at least as large as the incurred costs, but we do not know how much larger it is. To determine this, we need to have an upper boundary. But this can be observed only when a patent is deliberately allowed to lapse. However, this censoring might be particularly important for our purpose of measuring the value of a country patent portfolio, because a large part of its economic value is determined by a few high-value patents. Thus a lot of work in this article is devoted to recovering the uncensored value distribution, rather than the observed, but censored distribution based on the application of Eq. (2).

6.4 Three Steps Towards a Value-adjusted Patent Count

6.4.1 General Remarks on the Construction of the Data Set

The following analyses are based on patent applications at the European Patent Office (EPO), where we use two cohorts of patent applications from 1986 and 1996.[10] We do not come closer to the present time, because we are only able to derive an uncensored value for lapsed

9 The most important difference is that his formulae depend on a hard to measure rate of depreciation rate. This actually occurs also in formulae (A1) and (A3), but it drops out, when we focus on the patent value instead of the return rate.

10 There is probably no sense in employing more recent data, because the majority of patents expire after 13 to 14 years (see Table 6-2). Moving closer to the present will therefore result in a severe increase of the share of censored patent values.

patents. The more recent the data set we use, the more patents are still alive, whose value cannot be assessed properly.

A very important feature of the data set comes from the fact that an EPO application might split up into several national patent documents after the patent is granted. In essence, we decided to treat each document as a separate observation. That is, an EPO patent that goes to, say, France, Germany, and Italy after the grant, will appear three times in our data set. (We explain below how we deal with this clustered data econometrically.) Thus, we only consider patents for which renewal fees were paid at least once at the respective national patent office.

We further considered the inventor countries from Europe: Germany, France, Great Britain, Italy, the Netherlands, Switzerland, Sweden, Greece, Portugal, Finland, Belgium, Luxemburg, Denmark, Ireland, Spain, Austria, Norway, and Iceland. Additionally we took into account the following countries from outside Europe: Korea, Japan, Canada, and USA.

6.4.2 Step 1: Recovering the Unconditional Censored Value Distribution

The first step consists in determining the patent value according to Eq. (2). As already argued, we know that this distribution is censored. Thus it cannot be the final result. A further problem is that Eq. (2) still contains the capital costs. We should note here that the choice of the capital costs is not too important, because it affects all patents in the same way. That is, while the absolute level of the patent value is changed, the relative position of any two patents remains virtually unchanged. Since we are not able to measure the absolute value anyhow, this appears to be rather unimportant.

Without further ado, it seems sensible to set the capital costs at some reasonable average debt financing costs, say 6%.

Thus, with this value at hand, we can complete the first step by plugging it into Eq. (2) and then determine the value of each patent individually. Since this value is censored, we proceed by recovering an uncensored value distribution which is conditional on explanatory variables in Step 2. We can use this in Step 3 to calculate what we are really interested in: the unconditional uncensored value distribution, which we can of course split by country.

6.4.3 Step 2: Recovering the Conditional Uncensored Value Distribution

Using the censored distribution from Step 1 for country comparisons can seriously bias the results, if one country has considerably more high-value patents than another. Thus, we need a way to recover the uncensored value distribution.

A step that brings us closer to this is determining the uncensored conditional distribution. One way is to make use of a censored regression model, where we let the previously calculated censored patent value be explained by a set of explanatory value indicators (see section 2.2). From this we can calculate a conditional uncensored value distribution, which can then be used to determine an uncensored unconditional distribution by country (see section 4.1.4). As a by-product of this regression, we can also check the predictive power of the patent value indicators, which is interesting in its own right.

The objective is to derive an estimation strategy determining relevant influencing factors on the patent value PV_j of patent j.[11]

If PV_j^* is the latent uncensored patent value, x_j is a vector of observable explaining variables, β a coefficient vector, and ε_j a random error. We should think of the following data generating process:

$$\log PV_j^* = x_j\beta + \varepsilon_j$$

$$\log PV_j = \begin{cases} PV_j^* & t_{j,i*} < K \\ \bar{r}_j\left(\left(1-\mathrm{e}^{-r^m K}\right)\Big/\left(r^m + d\right)\right) & t_{j,i*} = K \end{cases} \tag{3}$$

If we are willing to assume that $\varepsilon_j \mid x_j \sim N\left(0,\sigma\right)$, Eq. (4) has the structure of a Tobit model, which basically can be estimated in a straightforward way.[12]

If we are additionally interested in the implications of the coefficients (e.g. they can tell whether more forward citations imply greater economic value?), however, we have to adjust the estimated standard errors from this regression, because of the intra-cluster dependence of the data (see section 4.1.1). This can be dealt with by bootstrapping, where random sampling is across independent clusters instead of individual observations (see Davison, Hinkley 1997, p. 71). In any case, because asymptotic normality still holds, we can rely on a normal approximation adjusted with a bootstrapped variance.

6.4.4 Step 3: Recovering the Unconditional Uncensored Value Distribution

If we want to calculate the unconditional distribution from the one conditional on x, we formally need to integrate out the explanatory variables. Depending on the distribution of x this can be complicated. An easy workaround however is if we assume that the vector $\left(x,\varepsilon\right)$ is multivariately normal.[13]

Then, because of Eq. 5, multivariate normality implies that the logarithmic patent value is also normal, i.e. $\log PV^* \sim N\left(\mu,\sigma\right)$, for which we just need to calculate mean and variance.

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11 Note that Bessen (2008) focuses on the initial return rate. But since this is a somewhat fuzzy concept, we prefer to make assumptions about the patent value.

12 Note, however one subtlety. We do not impose a fixed censoring limit (for example, the observed initial return rate is censored, if it takes a value y), but we allow patents to have different censoring values. This more general statement is necessary, because the total renewal costs and thus the according patent values differ by patent office.

13 Note that this is consistent with the assumptions made in the previous section, because this implies that $\varepsilon \mid x$ is also normal.

Using Eq. (4) we can calculate the population mean by taking iterated expectation:

$$\mu \equiv \mathrm{E}\left(\log PV^*\right) = \mathrm{E}\left(\mathrm{E}\left(\log PV^* \mid x\right)\right) = \mathrm{E}\left(x\beta\right) = \mu_{x\beta} \tag{4}$$

Similarly, using the properties of conditional variances, we have:

$$\begin{aligned}\sigma^2 \equiv \mathrm{Var}\left(\log PV^*\right) &= \mathrm{E}\left(\mathrm{Var}\left(\log PV^* \mid x\right)\right) + \mathrm{Var}\left(\mathrm{E}\left(\log PV^* \mid x\right)\right)\\ &= \mathrm{E}\left(\sigma_\varepsilon^2\right) + \mathrm{Var}\left(x\beta\right)\\ &= \sigma_\varepsilon^2 + \sigma_{x\beta}^2 \end{aligned} \tag{5}$$

where the first term simply is square of the Tobit scale parameter and the second is the variance of the (linear) single indexes. Both come for free as by-products of the regression described in section 4.2.2.

It follows from normality of the logarithm of the patent value that the patent value itself is log-normal. More precisely:

$$\log PV^* \sim LN\left(\exp\left(\mu_{x\beta} + \frac{\sigma_\varepsilon^2 + \sigma_{x\beta}^2}{2}\right), \exp\left(2\mu_{x\beta} + \sigma_\varepsilon^2 + \sigma_{x\beta}^2\right)\cdot\left(\exp\left(\sigma_\varepsilon^2 + \sigma_{x\beta}^2\right) - 1\right)\right) \tag{6}$$

Under the assumptions made, this is the unconditional uncensored value distribution that we were looking for. The first term in brackets gives the expectation and the second the variance. All terms can be estimated from the regression results stemming from Eq. (4).[14] The country distributions can be derived by conditioning the estimator on the inventor country.

Thus to summarise the procedure, we have to do the following:

1) Calculate the patent value based on the renewal formula Eq. (2).
2) Use a Tobit model to regress this value on explanatory variables.
3) Use Eq. 7 to estimate mean and variance of uncensored distribution. The terms $\mu_{x\beta}$, $\sigma_{x\beta}^2$, and σ_τ^2 can be calculated in a straightforward manner from the regression results in Step 2. (Alternatively, if complicated features of this distribution are required, use a random number generator.)

6.5 Results

6.5.1 Description of the Data

The first cohort of patent applications is based on EPO applications in 1986. We restrict our sample to patents which were renewed at the national offices at least once. Given the men-

14 For example by replacing the true moments by sample moments. Then because of their convergence in probability, this implies convergence in distribution of the necessary convergence in distribution: $\log \hat{PV}^* \xrightarrow{d} \log PV^*$.

tioned restrictions, in the first cohort we end up with a total of 22,391 applications at the EPO[15], which split up into 120,067 different patent documents at the national offices. Likewise, the second cohort consists of 1996 applications. Here we have 150,333 individual patent documents, which correspond to 33,171 applications at the EPO.

The data set contains document information for each patent on the value indicators derived from the discussion in section 2 (see Table 6-2), the technology incorporated, where fractionalised dummies based on the ISI High-tech list (Grupp et al. 2000; Legler, Frietsch 2007) were calculated, and on the patent value based on the renewal data. The latter is calculated as the gross renewal value, i.e. it is not net renewal costs.

Concerning the features of the indicators for patent value, some general descriptive statistics are given in Table 6-1 Starting with the first cohort, the number of forward citations ranges from zero up to 83. Almost all of the patents are domestic (average value of 1.03), but they may have inventors from as many as 7 different nations. Roughly 36% of the patent documents also cite non-patent literature, while only 8% of the patents are opposed. The mean number of international patent offices a patent is filed is 7.69 and reaches a maximum of 49[16]. The average number of designated countries is 8.91.

Although some indicators such as the number of different inventor nations and the number of designated countries do not change much, some changes are conspicuous. The number of inventors has gone up, reaching a value of 2.67 in 1996. Even more interesting, the share of patents including references to non-patent literature has increased by almost 40%. This might suggest that the scientific linkages have become more important. The share of oppositions has probably increased since 1986, because (even though 8% are opposed in both cohorts), in the 1996 cohort many patents have not yet lapsed and may be opposed in the future.

Another interesting descriptive statistic is given when comparing the mean patent durations by country. If there were great differences, this would already give an indication as to whose patents are likely to be more valuable.

Looking at Table 6-2, it is interesting to note that there are some differences in the 1986 cohort (e.g. Danish patents lapse after about 14.5 years, while Finnish patents lapse 2 years sooner), almost all country differences disappear in the second cohort. However, this does not mean that differences will remain absent also in the future. Since renewal fees usually increase disproportionately over time, high drop-out rates for countries with a high share of low value are likely to appear later in time. It should be noted that the drop in mean patent lifetime

15 This number should roughly correspond to the number of patents that were finally granted, because the number of patents that were granted by the EPO but never appeared at the European Patent Office should be low.

16 This number is quite large, because the Inpadoc family contains not only patent documents at different national offices referring to the same invention, but also different patents that somehow belong together, e.g. when patents are split up later on in the patenting process.

from 1986 to 1996 is a trivial effect, because some of them are still alive and will lapse in the future.

Table 6-1: Descriptive Statistics for the Value Indicators

	Cohort: 1986			Cohort: 1996		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
Count: forward citations	3.09	0	83	3.12	0	126
Count: inventor nationalities	1.03	1	7	1.03	1	8
Count: inventors	2.29	1	19	2.67	1	26
Ref. Non-patent literature	0.36	0	1	0.49	0	1
International family size	7.69	1	49	9.64	1	43
Opposition	0.08	0	1	0.08	0	1
Count: designated countries	8.91	0	14	9.50	0	18

Table 6-2: Mean Length of Patent Lives by Inventor Nations[17]

Country	1986	1996
Germany	12.66	11.04
France	12.52	11.06
UK	13.27	11.24
Japan	14.45	11.95
US	13.71	11.63
Italy	12.34	11.31
Netherlands	12.94	11.39
Canada	12.8	11.5
Switzerland	13.02	11.53
Sweden	13.96	11.81
Finland	12.41	11.98
Korea	---	11.94
Belgium	13.01	11.51
Luxemburg	---	---
Denmark	14.45	11.61
Ireland	---	---
Greece	---	---
Portugal	---	---
Spain	13.00	11.29
Austria	12.69	11.36
Norway	13.74	11.77
Iceland	13.48	11.87

6.5.2 Quality of the Patent Value Indicators

Section 6.1.3 presented the regression approach to determine the quality of the data. The estimation results of this general, clustered Tobit model are presented in the following Table:

17 We follow the strategy of not reporting numbers for countries that have less than 50 EPO grants in the respective cohort. Thus we do not report numbers for Korea, Luxemburg, Greece, or Portugal. Since the Korean numbers are substantially higher in 1996, we report them here. The same statement applies to Table 6-4 and Table 6-5.

Table 6-3: Regression Results (Dependent Variable: log Value)

	Cohort: 1986			Cohort: 1996		
	coeff.		p-val.	coeff.		p-val.
Technol. dummies (only sign.) Reference: low-tech						
Biotechnology	-0.0069		0.6915	-0.0657	*	0.0940
Computer	0.0447	***	0.0003	0.0214		0.1214
Electronics	0.0597	***	0.0000	0.0127		0.4249
Communication engin.	0.1217	***	0.0000	0.1425	***	0.0000
Optical measurement	0.0378	***	0.0013	0.0022		0.8896
Optics	0.0263	*	0.0937	0.0243		0.3484
Dyes and pigments	0.0053		0.8170	-0.0569	**	0.0310
Inorganic materials	0.0101		0.5566	-0.0690	**	0.0141
Organic materials	-0.0120		0.4140	-0.1115	***	0.0000
Polymers	0.0118		0.2626	-0.0357	***	0.0075
Pyrotechnics	-0.1742	*	0.0895	0.0000		1.0000
Photo chemicals	0.0385		0.1225	-0.2197	***	0.0000
Office machinery	0.0258		0.3140	0.0721	**	0.0366
Power generation	0.0737	***	0.0000	-0.0103		0.7110
Broadcasting engin.	0.0179		0.1665	0.0428	**	0.0344
Medical instruments	0.0435	**	0.0206	0.0448	*	0.0998
Value indicators						
Count: forward citations	0.0000		0.9828	0.0036	***	0.0001
Count: inventor nationalities	0.0101		0.4212	-0.0166		0.2693
Count: inventors	0.0025	*	0.0649	0.0062	***	0.0012
Ref. non-patent literature	0.0008		0.8847	0.0131	*	0.0810
Value indicators						
International family Size	0.0016	***	0.0032	-0.0006		0.4384
Opposition	0.0320	***	0.0014	0.1187	***	0.0000
Count: designated countries	-0.0021	***	0.0019	0.0036	***	0.0000
Constant	YES			YES		
Controls	YES			YES		
Patent Office Dummies	YES			YES		
N	120,067			150,333		
M	22,391			33,171		
Pseudo-R^2	0.7123			0.7367		
Pseudo-R^2 (indic. only)	0.0120			0.0180		

*: significant at 10% level, **: significant at 5% level, ***: significant at 1% level

Although our primary goal is to develop a method to recover the uncensored value distribution, it is worthwhile sticking with the regression results for some time. Of special interest are the value indicators, where for most of them we find that they are indeed positively related to the patent value. The number of inventors and the oppositions positively affect patent value in both cohorts. For both we can furthermore determine an intensifying relationship in terms of statistical significance over time. The family size, on the contrary, loses its significant (partial) correlation over time and no longer displays an influence in 1996. The reference to non-patent literature, however, has gained importance until 1996. This seems to corroborate the indications we already had when looking at the descriptive statistics (as a reminder, the share of patents with references to non-patent literature was 40% larger by 1996). Somewhat surprisingly, in 1986 the number of designated countries was negatively correlated with patent value. In 1996 however, it becomes positive and thus now has the predicted sign, because more designated countries should correspond to larger markets.

So ultimately, is this good news for the current practice of using value indicators? The answer is: it depends on what we want to do with it. At first sight, everything seems to be in order, because the pseudo-R^2 at over 0.7 is very high in both cases. Unfortunately, this is almost completely attributable to the dummies for offices where a patent was filed plus the control variables, most prominently the year in which the patent lapsed. The latter of course does not come as a surprise, because the longer a patent lives, the higher the cumulated fees and the higher the value returned by Eq. (2). Thus, this explanation is trivial and simply states: the longer a patent is maintained, the higher its value.

Thus, in order to judge the merit of the value indicators, it is important to determine the effect of the non-trivial explanatory variables (i.e. technology dummies plus value indicators). The disillusioning result of running the regression including only non-trivial variables is a negligible goodness-of-fit of 0.012 in 1986 and 0.018 in 1996. Thus the predictive power of all these variables is only marginal, despite their statistical significance. This conforms completely with Gambardella et al. (2008), who find that their value indicators explain only about 2.7% of the variance in the patent value.

Contrary to that, if we are interested in assessing the monetary value of complete patent portfolios (e.g. countries), we do not have to be as strict with the predicting power for basically two reasons: firstly, the procedure described here does not aim to predict the value of an individual patent but the value distribution. Because random deviations are likely to level out with larger numbers, we might still be able to recover the distribution correctly, even if we cannot predict the value of a single patent accurately. Secondly, much of what we called "trivial" predicting power, such as the dummies indicating where a patent is filed, can be used to predict value, because the become known early. Furthermore, even though a lapse of patent, the indicator with extra-ordinarily high predicting power might occur late, a large part of patents drops out quite early after the grant. In both cohorts far less than 10% actually live for the complete 20 year period. In a nutshell, even if this explanation is somewhat trivial and may not help to understand the patenting process, it still is very useful to recover the uncensored distribution. In any case, what this analysis shows is that value indicators are so noisy that using them alone (e.g. citation-weighted patent counts) conveys almost nothing about the economic value of an individual patent, and probably not even about a country's patent portfolio value.

6.5.3 Distribution of the Patent Value at the EPO

To recover the uncensored distribution based on the regression results, we used Eq. (7) to simulate the value distribution of an individual patent document.[18] From the resulting distributions we can calculate the parameters of interest, e.g. the mean.

Now, if we are interested in the mean value of an EPO application, we still need to multiply this value by the EPO family size (i.e. the number of national EPO offices where the patent is finally filed). The results for 1986 and 1996 are shown in the following two tables, where the first column gives the average value of an EPO application, the second the application count, the third is a normalised adjustment factor (in this case a country's average application value divided by a weighted mean of average application values). Thus, *VAF* is greater than one if the average value of an EPO application in one country is higher than the average value taken over all patents. Finally, the fourth is the value adjusted patent count (see Eq. (1)).

Table 6-4: Patent Value by Countries in 1986

Country	Av. Applic. Val.	No. Appl.	VAF	VAPC
Germany	32227	4939	0.95	4694
France	39836	2071	1.17	2433
UK	38727	1435	1.14	1639
Japan	23923	5059	0.71	3569
US	38845	5111	1.15	5854
Italy	33004	769	0.97	748
Netherlands	33717	757	0.99	753
Canada	39723	202	1.17	237
Switzerland	39840	810	1.17	952
Sweden	41577	340	1.23	417
Finland	33222	65	0.98	64
Korea	---	5	---	---
Belgium	48635	277	1.43	397
Luxemburg	---	15	---	---
Denmark	66419	85	1.96	166
Ireland	---	30	---	---
Greece	---	7	---	---
Portugal	---	1	---	---
Spain	55366	52	1.63	85
Austria	34560	240	1.02	245
Norway	33901	51	1.00	51
Iceland	43131	70	1.27	89

18 If we do that by country, then for example for France, $\mu_{x\beta}$ and $\sigma^2_{x\beta}$ are replaced with the corresponding mean and variance in the subsample of French patents.

As an interesting fact, Denmark's patents are the most valuable ones with almost twice the average value in 1986. Germany is slightly below average with about 95% of the average value. The US patents are about 15% above. Furthermore, Japan's patents reach the lowest value, which can partly be explained by the fact that Japanese inventors only go for big European markets when they apply at the EPO. This would reduce family size and thus the average value of an application, which is proportional to the EPO family size.

If we look at the 1996 results we can see some movement in the relative patent values, but no overwhelming changes. Germany, a bit better than 10 years before, is still not more than average. The US loses ground, but is still better than Germany. Japanese patents fall even further behind, and now reach a value of 64% of the average only. Finland is now above average with a value of 1.07 (3% below average value in 1986). Finally, Denmark is still above average, but only with about 39%. The new leader is Belgium with 1.51, which was already quite good in 1986 with 1.43.

Of course, all these differences in value are dominated by size effects. Germany, even though its patent values are rather average, still commands the second most valuable patent portfolio right behind the USA both in 1986 and 1996. This is simply because it files a large number of patents. Thus, the value adjustment is comparatively unimportant relative to differences in size. However, if we compare size-adjusted indicators such as patent intensities, a value adjustment is likely to have great influence on the design of a league table.

Thus, we think that a value adjustment is especially important if we compare size-adjusted indicators between countries. We should note, however, that using the value adjustment factors to reweight simple patent counts according to Eq. (1) is retrospective, in that they extrapolate structures from the past: they critically depend on both the explanatory variables x as well as the estimated coefficients β.

Therefore, whenever either the distribution of the explanatory variables in one country changes (e.g. French patents may be cited more frequently) or the structure of the regression model expressed by the coefficients changes, then the value adjustment factor needs to be re-estimated. In any case, Table 6-3 tells us that coefficients appear not to change excessively. Thus, it seems not too critical to extrapolate them to the present. It is more likely that changes in the distributions of the explanatory variables account for differences in the value adjustment factor. If, for example, we would like to deduce the VAF for patents with priority year 2005, we could take the coefficients from the regression model corresponding to the data from 1996. We would then use them to derive predicted values for 2005. With these at hand, we again use Eq. (7) to derive the value adjustment factor. This procedure clearly implies the constancy of coefficients, but it allows for changes in the distributions of the explaining factors. In any case, we cannot exclude the existence of a structural change after 1996. It is well known that this is the time of the patent surge, which may have induced more severe changes in the regression model. However, this remains to be seen when more recent data becomes available.

Table 6-5: Patent Value by Countries in 1996

Country	Av. Applic. Val.	No. Appl.	VAF	VAPC
Germany	34751	7101	1.00	7131
France	40147	2642	1.16	3065
UK	36385	2086	1.05	2193
Japan	22293	6403	0.64	4125
US	36584	7985	1.06	8442
Italy	38560	1252	1.11	1395
Netherlands	41268	973	1.19	1160
Canada	35756	390	1.03	403
Switzerland	46945	1082	1.36	1468
Sweden	37345	912	1.08	984
Finland	36967	405	1.07	433
Korea	30417	157	0.88	138
Belgium	52398	462	1.51	700
Luxemburg	---	28	---	---
Denmark	48134	326	1.39	453
Ireland	32428	63	0.94	59
Greece	---	11	---	---
Portugal	---	10	---	---
Spain	35248	177	1.02	180
Austria	44044	405	1.27	515
Norway	33153	141	0.96	135
Iceland	41385	160	1.20	191

6.6 Conclusion

The primary objective of this paper was to recover distributions of patent values by countries. To do this, we proposed a statistical 3-step procedure based on renewal data. We argued that this method is much more reliable than using crude values based on renewal data, because these are censored for high-value patents. Our results show that there are considerable differences in average patent values by countries, where Denmark and Switzerland are among the leading inventor countries at the EPO, while Japan performs significantly worse. Germany, alongside the USA, is about average. We also argued that if we assume that the model linking the explanatory value indicators to the patent value calculated from renewal data remains structurally unchanged in the medium time horizon, this method can also be used to enrich patent analyses that need to be much more up-to-date. In any case, although we observe some changes in the model structure, this approach is certainly more reliable than the common approaches, i.e. not correcting patent counts at all or using an adjustment based on a single value indicator (such as citation-weighted patent counts).

The latter conclusion is true because, as a by-product of this analysis, although we were able to show that most commonly used value indicators have the presumed positive relation to patent value, they have virtually no predictive power.

6.7 Annex

Define $\bar{r}_j$ to be the initial return rate associated with a specific patent. The return rate can basically measure any return, no matter if they accrue from selling a protected product or blocking a competitor. Assume that the (non-discounted) return rate at a future point in time $\tau > 0$ can be calculated by $\bar{r}_j \cdot \mathrm{e}^{-d\tau}$, where $d \geq 0$ is a depreciation rate. That is, we assume that returns resulting from a patent are exponentially damped. Suppose that there are discrete points in time t_i, $i = 1, 2, \ldots K$, where the owner of a patent has to decide whether he wants to renew it. Denote by PV_j the total value of patent j and by $PV_{i,j}$ the return that is attributable to the period $[t_i, t_{i+1}[$, that is between any two dates, where renewal decisions are necessary. Letting r^m be the internal rate of return (possibly, but not necessarily equal to observable interest rates), then we can calculate the net present value of a patent accruing to the period $[t_i, t_{i+1}[$ as follows:

$$PV_{j,i} = \int_{\tau=t_i}^{t_{i+1}} \bar{r}_j \, \mathrm{e}^{-(r^m+d)\tau} \, d\tau$$

$$= \bar{r}_j \left(\int_{\tau=0}^{\infty} \mathrm{e}^{-(r^m+d)\tau} d\tau - \int_{\tau=t_{i+1}}^{\infty} \mathrm{e}^{-(r^m+d)\tau} d\tau - \int_{\tau=0}^{t_i} \mathrm{e}^{-(r^m+d)\tau} d\tau \right)$$

$$= \bar{r}_j \left(\int_{\tau=0}^{\infty} \mathrm{e}^{-(r^m+d)\tau} d\tau - \int_{\tau=t_{i+1}}^{\infty} \mathrm{e}^{-(r^m+d)\tau} d\tau - \int_{\tau=0}^{\infty} \mathrm{e}^{-(r^m+d)\tau} d\tau + \int_{\tau=t_i}^{\infty} \mathrm{e}^{-(r^m+d)\tau} d\tau \right)$$

$$= \bar{r}_j \left(\int_{\tau=t_i}^{\infty} \mathrm{e}^{-(r^m+d)\tau} d\tau - \int_{\tau=t_{i+1}}^{\infty} \mathrm{e}^{-(r^m+d)\tau} d\tau \right)$$

$$= \bar{r}_j \left(\frac{\mathrm{e}^{-r^m t_i} - \mathrm{e}^{-r^m t_{i+1}}}{r^m + d} \right) \quad \text{(A1)}$$

Because the returns are steadily decreasing in time (by assumption) and the renewal fees are steadily increasing (as a matter of fact), a patent is renewed, if and only if $PV_{j,i} \geq c_i \, \mathrm{e}^{-r^m t_i}$, where c_i is the renewal fees to be paid in period i.

Now, suppose a patent is renewed in time t^* but not in the next period, we trivially have $PV_{j,i*} \geq c_{i*} \, \mathrm{e}^{-r^m t_{j,i*}}$ and $PV_{j,i*+1} \leq c_{i*+1} \, \mathrm{e}^{-r^m t_{j,i*+1}}$. Therefore, if the periods t_i and t_{i+1} are close together, then both $PV_{j,i*}$ and $PV_{j,i*+1}$ do not differ by much, and we do not lose much in replacing both conditions by the following relationship:

$$PV_{j,i*} \approx c_{i*} \, \mathrm{e}^{-r^m t_{j,i*}} \quad \text{(A2)}$$

Using (2), setting $t_1 = 0$ and solving for the initial return rate yields

$$\bar{r}_j = \begin{cases} \left(c_1 \dfrac{r^m + d}{1 - e^{-r^m t_2}} \right) & \textit{lapsed after } t_1 \\ \left(c_2 \, e^{-r^m t_2} \dfrac{r^m + d}{e^{-r^m t_2} - e^{-r^m t_3}} \right) & \textit{lapsed after } t_2 \\ \ldots & \ldots \quad \ldots \quad \ldots \\ \left(c_K \, e^{-r^m t_K} \dfrac{r^m + d}{e^{-r^m t_K} - e^{-r^m t_{K+1}}} \right) & \textit{lapsed after } t_K \end{cases} \tag{A3}$$

It is worthwhile noting that it is conceptually justified to treat the initial return rate as observed when all variables in Eq. (3) are known and the model assumptions hold. The most important implication is that the initial return rate is a *non-random* transformation of observed data rather than a statistical estimator. The same holds of course for the patent value in Eq. 2.

7. The Value of Patents Estimated by Export Volume

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7.1 Introduction

This chapter examines the linkage between patenting and export performance for selected countries at the level of technology fields. In several empirical studies it was shown that there is a close connection and considerable correlation between patents and the economic success in international markets (Dosi et al. 1990; Gehrke et al. 2007; Grupp et al. 1996; Münt 1996; Porter 1998; Wakelin 1997; Wakelin 1998a; Wakelin 1998b). For example, Blind and Frietsch (2006) showed, based on a time series analysis of a set of industrialised countries, that patents explained export streams, especially in high-tech sectors, but also in low-tech areas. This result corresponds to the discussion in the empirical and theoretical literature which assumes that the long-term development of market shares is not driven by price competition, but by technology and quality competition (Kleinknecht, Oostendorp 2002; Legler, Krawczyk 2006; Maskus, Penubarti 1995). This suggests that patents – as they are an output indicator of R&D processes – influence the export performance.

The overall aim of this analysis is to assess whether the patent value indicators have any explanatory power to estimate the export value of countries by technology fields. In chapter 1, it was discussed that the economic valuation of patents is one of the biggest challenges in empirical patent value analysis. Renewal fees are one way to assess the value of patents and measuring licensing income is another one, even though such data is hard to obtain, as neither the licensor nor the licensee have an interest in disclosing this information. The most direct way is to survey inventors and ask them for the value of the patent, for example, on the day of granting. Finally, and this path is pursued here, export data can be used on a macro or meso level of technologies to serve as a measurable value of patents.

Many existing studies examine the connection and correlation between patents and export performance. However, to the best of our knowledge, no study has yet made use of exports to assess the predicting power of patent value indicators on the average export value of patents. This idea is the basis of this chapter, using an integrated dataset of patents and exports by countries and technology fields. The merger of patents and exports was achieved by applying the definitions of a set of 35 high-tech fields and the residual low-tech area, both in terms of SITC (exports) and IPC (patents). This definition relies on Grupp et al. (2000), as well as Legler and Frietsch (2007).

For this study, a novel panel dataset consisting of annual data of international trade, patenting, and country characteristics for recent years (1988-2007) was constructed. The panel comprises 18 OECD countries (Austria, Belgium, Canada, Switzerland, Germany, Denmark, Spain, Finland, France, Great Britain, Ireland, Italy, Japan, Korea, the Netherlands, Norway, Sweden, and the United States) and China. All patent and trade data are aggregated to 35 technology groups for each country for each year.

For patent data the "EPO Worldwide Patent Statistical Database" in its September 2009 version (henceforth, PATSTAT) is used. The PATSTAT database provides rich information about published patents collected from 81 patent authorities worldwide. For each of 35 technology fields (Legler, Frietsch 2007), the annual sum of patent applications filed by each country at the European Patent Office (EPO) were counted. We restrict the analyses to EPO data in order to focus on a consistent and homogeneous patent system, including patent citations. Though we included PCT citations, if the EPO search report makes reference to the PCT document. All patent data reported are dated by their priorities, i.e. the year of worldwide first filing. Export and import figures were extracted from the United Nation's Commodity Trade Database (henceforth COMTRADE). Because trade data in COMTRADE is aggregated by commodity groups, a concordance table between the technology classification for patents (IPC) and the commodity classification (Standard International Trade Classification Revision 3 or SITC3 for short) was applied, according to the definitions in Legler and Frietsch (2007). Additional information was collected from OECD databases (OECD Stats) for example on GDP, inhabitants, exchange rates or purchasing power parities (PPP).

The COMTRADE database on foreign trade as well as patent applications in selected countries and technology fields are used to analyze correlations, their change over time and their difference over countries. Furthermore, the export intensity – which is defined as the value of exports per patent – is calculated, that can be interpreted as the export value of patents. Econometric analyses are engaged whereby the additional effect of patent predictors on export performance is disentangled – beside R&D expenditures, capital investments etc. Finally, comparisons of the patent and the export profiles of countries are conducted, applying the Revealed Patent Advantage (RPA) and the Revealed Trade Advantage (RTA) index.

7.2 Literature Review

In the traditional international trade theories, international trade of goods occurs because of differences in comparative advantage in manufacturing goods between two countries. Based on the idea of comparative advantage, the most widely accepted and tested factor that affects the comparative advantage is factor endowment. Heckscher-Ohlin (HO) theory predicts that a country abundant of a particular factor relative to other factors would export more of a good integrating more of that particular factor. For example, according to the Heckscher-Ohlin theory, the United States must export capital-intensive goods and import labor-intensive goods because it has strength in capital relative to labor. However, paradoxically, empirical data showed an opposite result as first presented by Leontief (1953). As a natural response to this paradox, many alternative explanations and empirical examinations followed[19]. As one of those alternative (or complementary) explanations, some scholars paid attention to the equal technology assumption in the HO model. The assumption made by the HO theory that production technology is the same across countries is not only unrealistic, but also does not explain the impacts of technological change on international trade.

19 See Deardorff (1985) for a review of the alternative theories and empirical evidence.

The theoretical stream called "product cycle model" or "technology gap model" of international trade addresses this gap in the HO trade theory. The product cycle model was first proposed by Michael Posner (1961) and Raymond Vernon (1966; 1979) and further elaborated by Paul Krugman (1979), Giovanni Dosi and Luc Soete (1983; 1991). In essence, the product cycle model assumes a dynamic change of production technology and different ability to exploit new technologies between countries. Also, it assumes the presence of imitation lag, i.e. it will take time and costs for a following country to absorb a superior technology developed in advanced countries and apply it for manufacturing process. Under these conditions, new or advanced products integrating superior technologies will form oligopolistic markets, at least temporarily, before the followers catch up. Therefore, firms located in technologically advanced countries will develop new products integrating the superior technology and dominate the export markets for these products.

The empirical evidence is largely consistent with the product cycle model. Most empirical studies had tested whether export performance of a country in a particular sector was positively associated with technological capability (for example, as measured by stock of patents in that sector). Soete (1981; 1987) showed for 40 industrial sectors that there was an positive association between the export performance of OECD countries in 1977 and the country share of US patents for the past 15 years, after controlling for capital-labor ratio, population, and geographic distance from some assumed 'world center'. He obtained similar results for 4 different measures of export performance. They are export market share, revealed comparative advantage (or Balassa index), export-import ratio, and the export-GDP ratio. He also found strong positive associations for most sectors between export performance, as measured by exports per capita, and technology level, as measured by granted US patents, after controlling for investment per employee and wages on value added (Dosi, Soete 1983). These results, however, also revealed a sectoral heterogeneity of the relationship between technology and exports. This is quite natural, given that some products integrate more technology elements while others do not.

From bilateral trades among 9 OECD countries in 1988, Wakelin (1998b) found that relative specialization of patents was positively associated with relative export values between two countries for some sectors after controlling for relative investment intensity and relative wage rate. Similar findings are reported for temporal variation of export performance for the UK (Greenhalgh 1990; Greenhalgh et al. 1994).

Fagerberg (1996) reports interesting sectoral patterns of exports and R&D linkage. For 10 OECD countries in 22 industries, he regressed exports in 1985 on three R&D measures: 1) direct R&D investment, 2) indirect R&D investment as defined by purchases of capital goods and intermediate goods, and 3) foreign share of indirect R&D. He controlled for investment in physical capital, wage, size of domestic market, and dummies for country and product groups. He found that indirect R&D is twice as large as direct R&D overall. More interestingly, while the impact on exports of indirect R&D is high in low R&D-intensive sectors, what is more influential in high-tech sectors is direct R&D.

Besides sectoral heterogeneity, there is also country heterogeneity. Van Hulst et al. (1991) studied the association between the export performance of five industrialized countries and their technology specialization, as measured by the sectoral share of US patents of a country divided by the sectoral share of US patents of all countries. They found some distinct patterns among the five countries: 1) the Netherlands, Germany, and Sweden show congruence between patenting and export; 2) no relationship between technology and trade for France; and 3) strong sectoral deviance (high dependence of "factor-proportions" products for some industries and technology-driven export for some high-tech industry) for Japan.

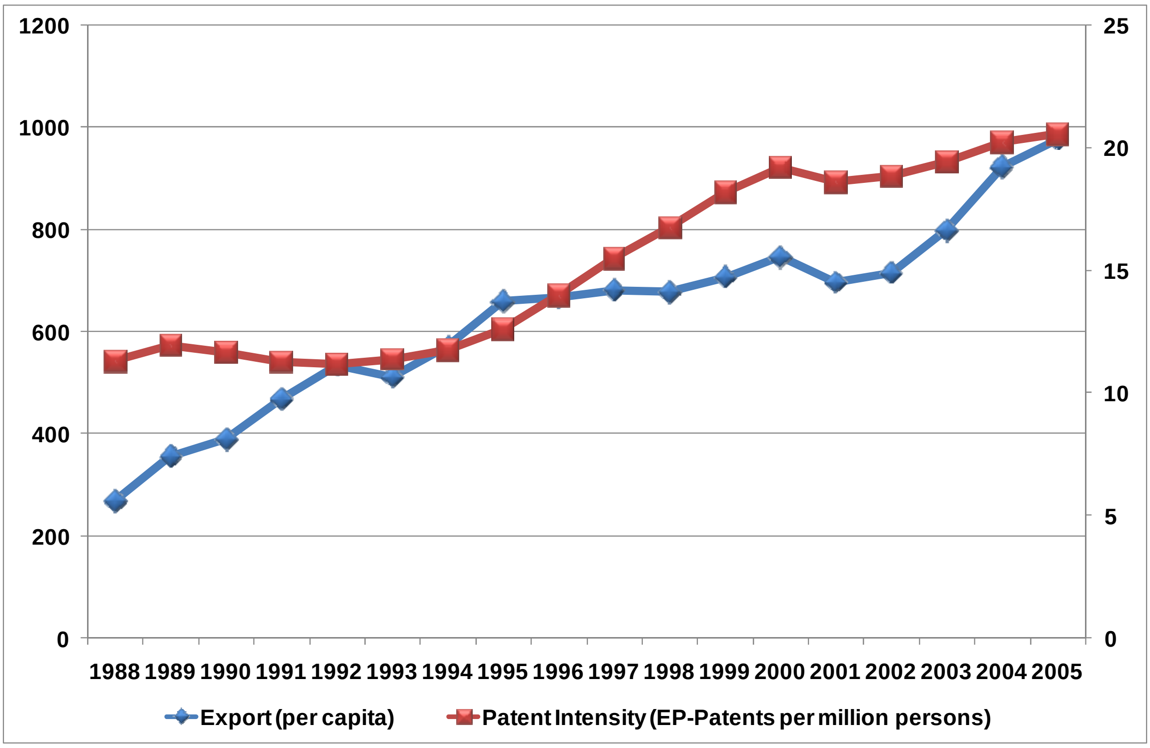
In sum, the above cross-sectional studies support the hypothesis that innovation is positively associated with export performance. However, this does not necessarily establish the fact that innovation should cause export. At the firm level, a study by German researchers addresses the endogeneity of innovation in export regression (Lachenmaier, Wößmann 2006). Using exogenous impulses and barriers to innovation as instrument variables, it shows that innovation drives the increase in export shares of German manufacturing firms. Madsen (2007) recently reported results from an analysis of panel data of 18 OECD countries in the period 1966-2000. His findings are consistent with previous studies in that innovative activities explain a large proportion of cross-country variations in export performance. He further finds that patents filed in exporting markets are particularly important in terms of the impacts on export.

7.3 Sample Characteristics

Before digging into the multivariate analyses, a brief overview of the sample characteristics and some descriptive statistics are appropriate. Since 1988, the number of EPO patent applications and the export amount show growing trends, although not monotonically (Figure 7-1). The patent upsurge that was encountered in the second half of the 1990s was not accompanied by a similarly steep increase of worldwide export volumes. However, as can be seen from the two lines, a more parallel development occurred after the year 2000, with a slightly more extreme impact of the economic situation on the export trends. Though we did not use worldwide filings here but EPO patents, which mostly follow the international trends at a lower level.

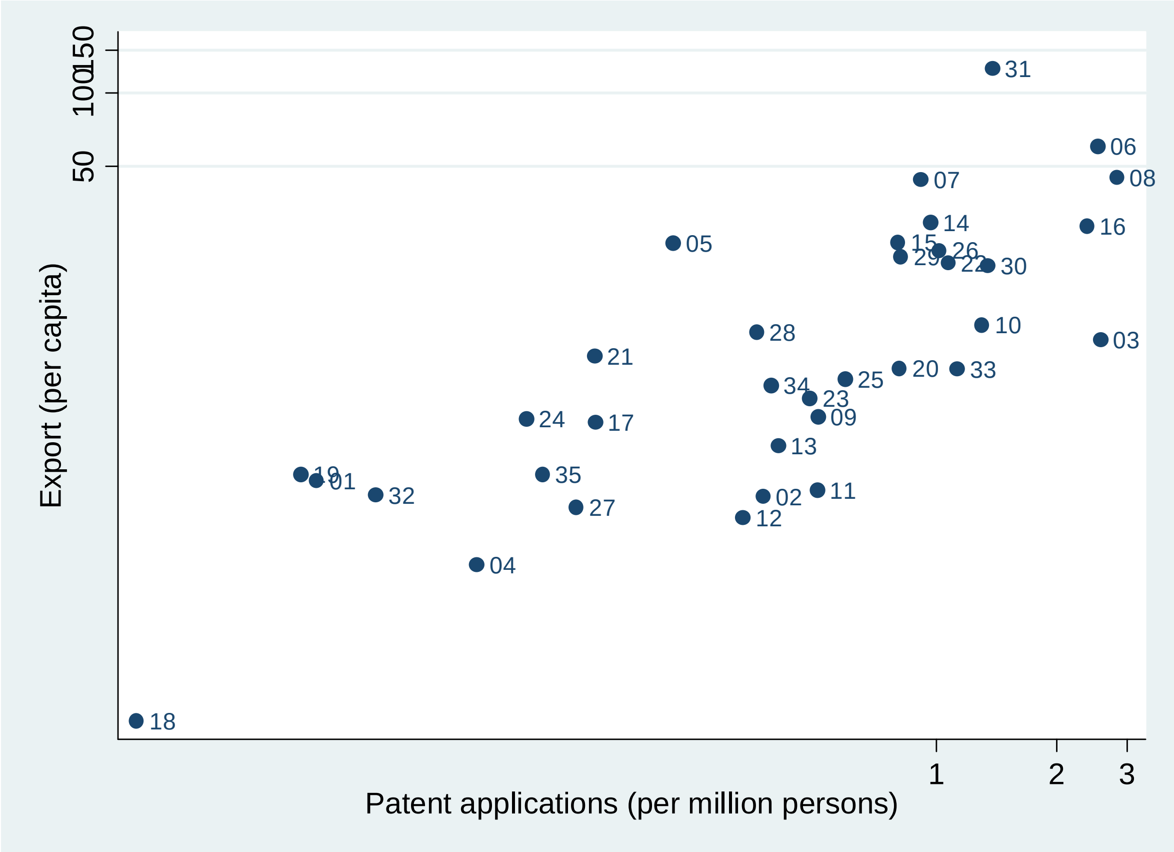
Figure 7-2 plots the export amount by the number of patent applications by technology fields in the year 2005. This graph shows that technological fields populated with more patent applications are associated with larger export amounts – or, to put it in other words, there is a strong correlation between patenting and exporting activities. Computers, communications engineering, and pharmaceuticals are located in the upper right corner of the graph indicating that they are both patented and exported most actively. Biotechnology is actively patented but exported only in mediocre amounts. On the other hand, automobiles and engines are placed top in terms of export amounts but ranked fifth in the number of patent applications. Pyrotechnics, photo chemicals, nuclear reactors and radioactive elements, weapons, and rail vehicles are neither much exported nor patented.

Figure 7-1: World export volume and total patent applications at the EPO per million inhabitants, 1988-2005



Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

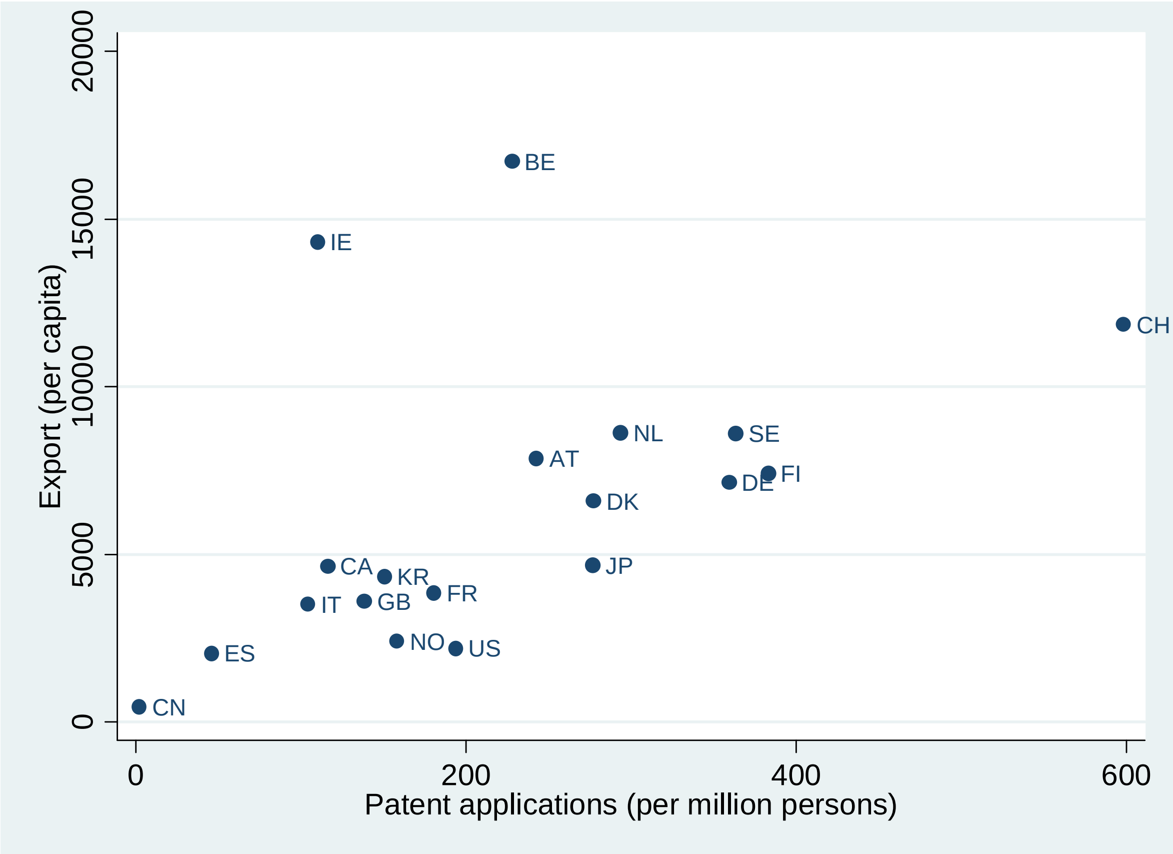
Figure 7-2: Export amount and patent applications by technology, 2005



Note: 1=nuclear reactors and radioactive elements; 2=pesticides; 3=biotechnology and agents; 4=weapons; 5=aeronautics; 6=computer; 7=electronics; 8=communications engineering; 9=electronic medical instruments; 10=optical and electronic measurement technology; 11=optics; 12=dyes and pigments; 13=inorganic basic materials; 14=organic basic materials; 15=polymers; 16=pharmaceuticals; 17=scents and polish; 18=pyrotechnics; 19=photo chemicals; 20=other special chemistry; 21=rubber goods; 22=power machines and engines; 23=air conditioning and filter technology; 24=agricultural machinery; 25=machine tools; 26=special purpose machinery; 27=office machinery; 28=power generation and distribution; 29=lamps, batteries etc.; 30=broadcasting engineering; 31=automobiles and engines; 32=rail vehicles; 33=medical instruments; 34=mechanical measurement technology; 35=optical and photo-optical devices.
Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

Next, the export amount versus the number of patent applications – both in per capita – in the year 2005 is plotted for each country under examination here (Figure 7-3). Again, this graph shows a positive association between exports and the number of patent applications, indicating that the more active a country in patenting the more exports, where however Belgium and Ireland seem to deviate from this relationship. Both countries have considerable import amounts that relate to the exports. In other words, these countries have a low value added and act in some areas as a market hub or a trans-shipment center. In the case of Belgium, this is especially obvious in the automobile sector, where it performs even better than Germany in terms of exports per patent.

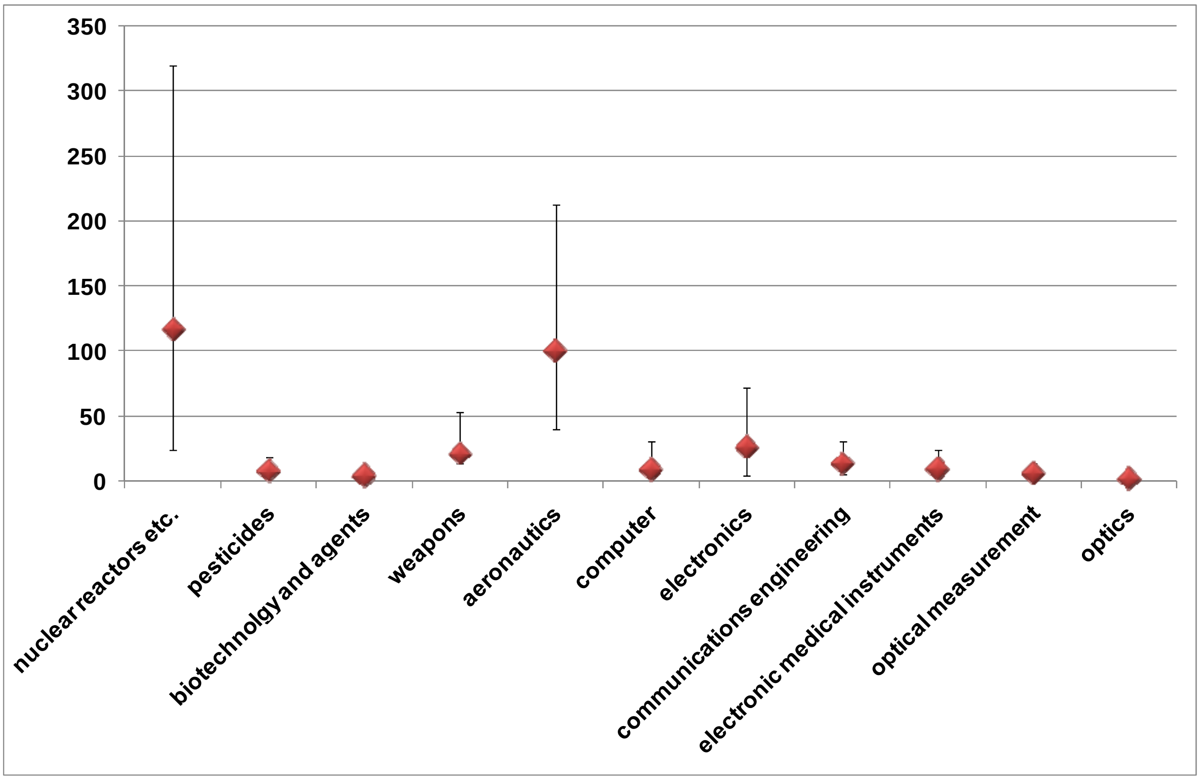
Figure 7-3: All technologies: Export amount and patent applications by country, 2005



Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

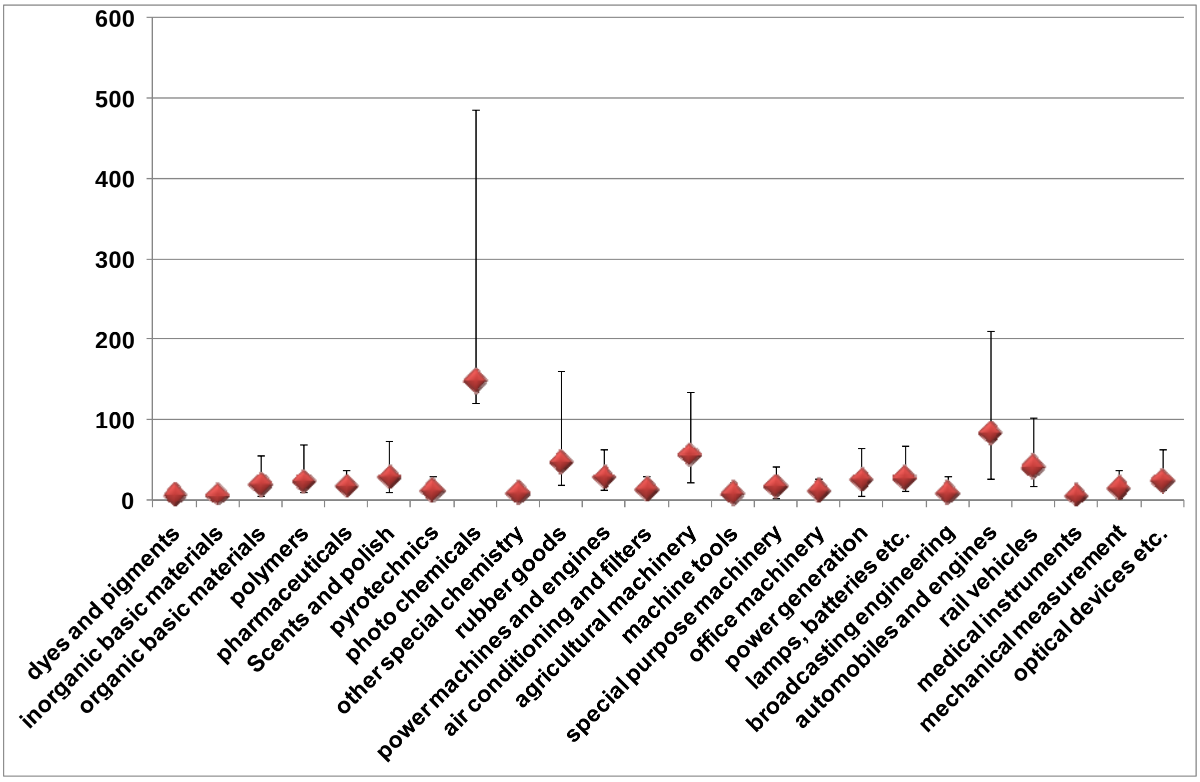
Figure 7-4 and Figure 7-5 depict the median of export intensities – export volume in million PPP$ per patent application at the EPO – and the 25% und 75% quartiles for each of the 35 technology fields. The median is calculated for each field individually across all countries for the year 2005. In the area of leading-edge technologies it is especially nuclear reactors, but also weapons and aeronautics, which show an extreme range of values. These fields are rather small in terms of exports and especially in terms of patents, but all three of them are subject to massive governmental regulation and governance. It is interesting to note that electronics also has a rather high variation. Looking at Figure 7-5 that covers the high-level technologies, it is especially photo chemicals, rubber goods, and agricultural machinery that considerably deviate from the overall pattern, both in terms of the median values and their variations. All of them are rather small technological fields and some of them – especially photo chemicals – have been subject to a considerable decline of relevance. Among the high-level technologies it is interesting to note that automobiles and engines have a high median value and also great variation. A tentative explanation is more complex in this case. On the one hand, some countries are very patent-active in relation to the export activities – among them Germany and Japan. On the other hand, as already mentioned above, countries like Belgium have a high export volume of automobiles and engines, but a low patenting activity. The reason is that they import a large number of cars before they export them again – they act as trans-shipment centers.

Figure 7-4: Median and quartiles (25%, 75%) of export intensities (exports per patent) in leading-edge technologies, 2005



Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

Figure 7-5: Median and quartiles (25%, 75%) of export intensities (exports per patent) in high-level technologies, 2005



Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

Table 7-1 and Table 7-2 display the mean and the standard deviations for different kinds of export intensities. On the one hand, applications as well as granted patents are used as a denominator. On the other hand, not only exports but also the trade balance – defined as exports minus imports – are used as a nominator. The latter is to balance the trans-shipment effects, though more than just this aspect is covered by the trade balance.

The case of automobiles (Table 7-1) shows that the exports per application, but especially the exports per granted patent reach a huge standard deviation, while in the case of trade-balance-related indicators, the standard deviation (in relation to the mean) is below the average of the other fields. This is another proof of what was said above on trans-shipment effects. Similar effects are visible for pharmaceuticals and computers. Both are also areas of trans-shipment and in the case of computers, for example, also subject of imported input to assembling processes before exports with a restricted added value occur.

What can also be derived from Table 7-1 is the fact that the export intensities vary greatly between the fields. Some of them are more patent-intensive while others are less intensive. One must not forget that we are especially focusing on high-tech fields here, which have – as a matter of fact – a higher international orientation and which are more subject to international trade than low-tech goods. However, also a great variation in the value of the technologies/goods has an impact on the intensity indicators, as well as the number of units that are traded. To put it more simply, and in line with the findings of the analyses in previous chapters, structure matters and differences between technological fields have to be taken into account.

Table 7-2 contains the average export intensities and standard deviations by each country for the 18 years that we have reliable data on. Some of the countries have considerably developed within this period – among them Canada and Ireland – so that their high standard deviations can be largely explained by this fact. The fact that the grant rates considerably differ between countries also explains another part of the differences between application- and grant-based indicators here.

The correlations between the four intensity indicators and the patent value indicator reveal a rather low bivariate association between the factors (Table 7-3). The reasons are that the countries as well as the fields are heterogeneous and show different patterns. The conclusion here is that only a multivariate analysis, controlling for country and field idiosyncrasies, might be capable of detecting patterns of co-variation.

To sum up, depending on the perspective, each of these four indicators might provide interesting and relevant information for our discussion of patent values. This is the reason why all four export intensity factors are taken into account in the examination of patent indicators to predict/indicate patent value. At the same time, Belgium and Ireland are outliers in relation to the patterns that we found for the other countries, so that it is justified to exclude them from the estimation of the regressions to evaluate the predictive power of the patent indicators, or at least to treat them with caution when the RTA and RPA models are estimated, excluding the early years of these countries from the analysis.

Table 7-1: Mean and standard deviations for a selected set of export intensities (per patent) by technologies, 1988-2005

	Exports per application		Exports per grant		Trade balance per application		Trade balance per grant	
	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.
nuclear reactors etc.	96.4	9.0	216.7	26.2	-5.9	6.0	-37.9	18.2
pesticides	7.7	0.4	32.7	4.4	-3.0	0.6	-2.2	3.0
biotechnolgy and agents	8.2	0.8	54.2	10.4	2.7	0.7	18.1	7.6
weapons	46.6	4.4	81.0	7.4	3.4	3.7	9.0	6.5
aeronautics	232.9	16.1	492.2	49.0	-51.9	13.2	-47.9	26.0
computer	83.5	11.3	276.7	40.5	-33.0	8.2	-127.1	30.1
electronics	68.9	8.6	303.7	43.1	-28.9	4.3	-62.7	17.0
communications engi-neer.	24.1	1.5	87.9	14.7	-3.7	1.4	-11.3	11.2
electronic medical instr.	17.9	1.6	59.4	7.2	1.0	1.5	1.1	4.7
optical measurement	10.3	0.6	48.8	6.7	-3.0	1.0	-5.2	4.7
optics	3.4	0.3	11.2	1.3	-2.1	0.4	-4.5	1.4
dyes and pigments	12.4	1.1	28.9	3.0	-7.4	1.2	-10.6	2.4
inorganic basic materials	12.7	0.9	40.7	5.0	-4.2	0.9	-9.9	2.9
organic basic materials	104.5	24.4	346.7	92.0	56.8	21.8	168.1	80.7
polymers	32.3	2.1	106.5	15.1	-16.0	2.4	-33.4	9.5
pharmaceuticals	22.7	3.5	220.7	78.9	8.3	3.1	83.9	65.6
scents and polish	50.9	11.5	129.2	30.3	13.2	9.8	32.4	26.8
pyrotechnics	14.4	1.6	33.1	6.0	-2.4	1.6	-1.7	3.8
photo chemicals	102.1	12.9	232.1	32.4	-10.4	8.9	24.9	18.0
other special chemistry	14.2	1.9	74.5	13.5	1.5	1.6	13.4	10.2
rubber goods	105.7	12.3	209.0	24.0	-14.5	5.1	-32.3	9.7
power machines	36.9	1.7	95.9	13.3	-9.5	2.2	-28.8	10.6
air conditioning and filters	16.0	0.6	60.5	8.2	1.1	0.7	8.6	3.5
agricultural machinery	67.5	3.4	140.1	11.6	-5.5	4.1	-8.2	10.6
machine tools	15.4	0.8	37.2	3.5	-2.9	0.9	-7.9	3.3
special purpose machinery	24.9	0.6	82.9	10.5	0.8	1.4	7.9	6.0
office machinery	31.6	2.2	80.0	8.2	-15.6	2.2	-32.2	5.8
power generation	42.3	2.6	136.3	13.2	5.0	2.1	13.7	8.7
lamps, batteries etc.	65.6	6.6	166.3	15.8	-26.4	3.8	-65.2	10.3
broadcasting engineering	30.0	3.6	99.5	13.9	-20.1	2.6	-98.5	15.8
automobiles and engines	193.9	17.5	674.7	238.2	-64.4	11.4	-125.4	46.5
rail vehicles	57.8	6.6	114.3	14.2	9.9	5.1	17.5	10.0
medical instruments	14.0	1.9	66.8	21.3	0.0	1.5	16.3	17.6
mechanical measurement	23.7	1.1	76.8	7.0	-5.5	1.3	-17.9	5.9
optical devices etc.	35.5	2.8	93.3	11.1	-13.8	3.6	-27.5	11.2
low-tech	41.1	1.6	133.8	14.2	-2.8	1.1	-19.6	10.1

Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

Table 7-2: Mean and standard deviations for a selected set of export intensities (per patent) by countries, 1988-2005

	Exports per application		Exports per grant		Trade balance per application		Trade balance per grant	
	Mean	Std.dev	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.
Austria	34.0	2.5	78.2	8.5	-12.6	1.9	-20.7	3.5
Belgium	69.8	7.8	326.3	50.7	4.1	2.4	8.3	9.4
Canada	101.8	10.6	407.1	124.1	-16.0	3.5	-53.1	20.6
Switzerland	25.4	1.0	67.7	6.1	-6.2	1.4	-8.3	4.5
Germany	23.2	1.2	56.6	4.8	5.0	0.4	12.0	1.3
Denmark	44.7	2.8	117.2	9.8	-20.3	3.4	-42.1	11.2
Spain	97.7	8.8	226.0	17.0	-42.5	5.5	-119.4	12.6
Finland	28.1	1.6	84.1	11.4	-20.3	3.2	-31.1	10.0
France	27.8	1.5	67.8	5.3	1.4	0.7	-1.0	1.9
Great Britain	40.6	2.4	123.7	8.8	2.0	1.2	-1.1	4.4
Ireland	191.0	23.6	610.4	105.0	47.9	22.1	248.1	94.2
Italy	41.4	2.8	93.7	6.5	-0.8	1.2	-8.1	3.9
Japan	24.7	1.3	76.5	7.1	8.7	1.7	29.0	6.1
Netherlands	58.1	5.5	155.6	15.0	0.2	2.1	6.7	4.8
Norway	40.1	2.6	78.3	6.2	-54.2	4.6	-111.0	12.7
Sweden	31.2	1.6	91.9	9.2	-7.5	1.3	-12.5	6.2
United States	20.4	1.3	106.5	11.2	-0.2	1.1	-20.4	8.6

Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

Table 7-3: Correlations for a selected set of export intensities (per patent) and different patent indicators, 1988-2005

	Exports per application	Exports per grant	Trade balance per appl.	Trade balance per grant
exports per application	1			
exports per grant	0.450	1		
trade balance per application	0.485	0.271	1	
trade balance per grant	0.433	0.562	0.684	1
share of grants	0.073	-0.143	-0.065	-0.007
N of applications with forward citations	-0.062	-0.028	0.025	0.008
N of forward citations	-0.060	-0.030	0.022	0.008
N of applications with backward citations	-0.059	-0.020	0.025	0.005
N of backward citations	-0.057	-0.023	0.024	0.007
N of grants with forward citations	-0.058	-0.034	0.028	0.011
average family size	-0.057	-0.019	0.024	0.005
average N of inventors	-0.029	-0.061	0.013	0.027
average N of IPC classes	-0.023	0.027	0.092	0.056
average N of backward citations	-0.030	-0.050	0.056	0.031
average N of forward citations	0.002	-0.042	-0.017	-0.008

Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

7.4 Dynamic Panel Data Analysis

In order to estimate the effects of patent applications on export volume, we use two econometric techniques: 1) fixed effects panel regression with the first order autocorrelation and 2) generalized method-of-moments (GMM) dynamic panel estimators. First, we should also care for autoregressive disturbances, because shocks to exports (e.g. economic down or upturns) might have quite persistent effects on export activities. Misspecification might lead to severely biased variance estimators in finite samples. This calls for the incorporation of AR-terms. Furthermore, simple Pooled OLS estimators are asymptotically biased, if models are subject to unobserved heterogeneity which is correlated with the explanatory variables or if the model contains lagged dependent variables. To account for the first we can use fixed effects regressions, which eliminate time constant unobserved heterogeneity. To account for the latter we use dynamic panel regressions, because it is quite likely that lagged exports affect the present period not only because of long-term persistence of random shocks but also structurally (Hughes 1986). These attributes justify using dynamic panel estimators over simple Pooled OLS or Random Effects Estimations. We additionally estimate the effects of patents on export using the Difference GMM estimators having the lagged observations of explanatory variables as instruments. This specification takes the first differences to eliminate the omitted variable bias created by unobserved country-specific or technology-specific effects and, moreover, uses the lagged values of the original regressors to eliminate simultaneity bias. A summary of variables is presented in Table 7-4. In the estimation we removed observations from two outlier countries: Ireland and Belgium. Therefore, estimation was done with observations from 17 countries and 35 technology fields from 1988 to 2007.

Table 7-4: Summary statistics

Variable	Symbol	Obs	Mean	Std. Dev.	Min	Max
($Exp/1000*Pop)$_{it}$	ExpCap	11723	65.50	149.62	0	2095.14
($Exp/1000*Pop)$_{i(t-1)}$	L.ExpCap	11128	63.87	145.75	0	2095.14
($Exp/1000*Pop)$_{it}$ - ($Exp/1000*Pop)$_{i(t-1)}$	D.ExpCap	10532	3.05	23.75	-671.36	645.02
(Pat/Pop)$_{it}$	PatCapF	11855	4.28	8.11	0	169.80
$\sum_{j=1}^{10}(1-\delta)^j Pat_{i(t-j)}/(1000*Pop_{it})$	PatCapS	10352	0.02	0.04	0	0.74
(GDP/Pop)$_{it}$	GDPCap	11855	22899.65	9152.38	369.01	42290.70
Pop $_{it}$	Pop	11855	117.20	279.07	4.21	1321.05

i is an index for technology-country and t for time (year). δ denotes depreciation parameter set to 0.15.

Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

Table 7-5: Correlation matrix

	ExpCap	L.ExpCap	L.PatCapF	L.PatCapS	L. GDPCap
L.ExpCap	0.9865*	1			
L.PatCapF	0.5937*	0.5921*	1		
L.PatCapS	0.5655*	0.5720*	0.9480*	1	
L. GDPCap	0.1332*	0.1349*	0.2646*	0.2591*	1
Pop	-0.1062*	-0.1062*	-0.1249*	-0.1069*	-0.5155*

Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

The estimation results are presented in Table 7-6. The first two columns estimate coefficients using all observations. The middle columns under the heading "Leading-edge" are theresults of estimations from leading-edge technologies[20], and the right two columns from the rest of the technologies. All models have acceptable fit statistics. The Difference GMM specifications are all correctly instrumented, as indicated by non-rejection of Sargan tests. We used the fourth order lagged ExpCap and year dummies as instruments.

The regression coefficients on patent applications in t-1 (L.PatCapF) are all significant and positive, indicating that additional patent applications per capita increase the export value on average. Interestingly, the impacts of patent flows on export value are greater for leading-edge technologies (regression coefficients in Fixed AR(1) model=3.89) than for non-leading-edge technologies (0.78). Similar patterns are observed for Diff GMM specifications, which indicate that additional patent applications increase export value of next year relative to the current year's export value even greater for leading-edge technologies than for non-leading-edge technologies.

On the other hand, patent stocks have diverging effects on the export value, depending on technologies. While the coefficient on patent stocks for non-leading-edge technologies is positive, the coefficient on patent stocks for leading-edge technologies is negative in Fixed AR(1) specifications. This implies that, for R&D-intensive technologies (i.e. leading-edge), technologies become obsolete at a faster rate and, therefore, stacking old technologies may work as a "competence trap" to deteriorate competence in the export market. The coefficients on GDP per capita and population are negative when they are significant. This also makes sense because larger levels of GDP per capita and population indicates larger domestic markets, which may dis-incentivize export.

Table 7-6: Dynamic panel data estimators: DV=Export per capita in constant 2000 USD*1000 (ExpCap); additional

	Full		Leading-edge		High-tech	
	Fixed AR(1)	Diff GMM	Fixed AR(1)	Diff GMM	Fixed AR(1)	Diff GMM
Observations	9124	9123	2835	2835	6289	6288
Number of id	595	595	187	187	408	408
Largest group size	18	18	18	18	18	18
Smallest group size	3	3	3	3	3	3
Chi-squared	.	1321.11	.	145.786	.	1029.38
R-Squared_between	0.985		0.933		0.99	
R-Squared_within	0.799		0.734		0.87	
R-Squared	0.962		0.897		0.979	
Sargan p-value		0.112		0.657		0.946
Arellano-Bond test for AR_1		0		0		0.001
Arellano-Bond test for AR_2		0		0		0

Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

20 1=nuclear reactors and radioactive elements; 2=pesticides; 3=biotechnology and agents; 4=weapons; 5=aeronautics; 6=computer; 7=electronics; 8=communications engineering; 9=electronic medical instruments; 10=optical and electronic measurement technology; 11=optics.

Table 7-7: Dynamic panel data estimators: DV=Export per capita in constant 2000 USD*1000 (ExpCap)

	Full		Leading-edge		High-tech	
	Fixed AR(1)	**Diff GMM**	**Fixed AR(1)**	**Diff GMM**	**Fixed AR(1)**	**Diff GMM**
L.ExpCap	0.865***	-0.552**	0.686***	-0.552	0.935***	-0.179
	(0.007)	(0.218)	(0.015)	(0.346)	(0.007)	(0.271)
L.PatCapF	2.270***	18.817***	3.894***	20.825***	0.780***	12.248**
	(0.138)	(3.588)	(0.242)	(4.537)	(0.181)	(6.068)
L.PatCapS	-297.407***	-4,276.220***	-355.030***	-3,311.409***	346.159***	-8,895.761***
	(31.208)	(851.172)	(50.613)	(990.575)	(48.961)	(2,949.564)
L. GDPCap	-0.001***	-0.014	-0.002**	-0.362*	-0.001***	0.033
	(0.000)	(0.035)	(0.001)	(0.215)	(0.000)	(0.048)
pop	-0.078	-71.643***	0.047	-117.536***	-0.056	-75.633***
	(0.062)	(10.829)	(0.150)	(26.930)	(0.055)	(20.303)
dyr_89	0.000	-941.387***	0.000	-4,057.269**	0.000	-678.852***
	(0.000)	(201.495)	(0.000)	(1,793.023)	(0.000)	(204.748)
dyr_90	-14.427***	-904.710***	-10.716	-3,789.324**	-9.092***	-662.575***
	(2.791)	(183.656)	(6.732)	(1,652.832)	(2.464)	(186.230)
dyr_91	-16.954***	-854.009***	-10.078	-3,557.730**	-12.897***	-627.615***
	(2.975)	(172.129)	(7.390)	(1,549.628)	(2.590)	(174.743)
dyr_92	-13.902***	-812.762***	-8.989	-3,492.138**	-9.408***	-582.017***
	(3.022)	(173.361)	(7.595)	(1,540.838)	(2.618)	(177.136)
dyr_93	-14.339***	-777.994***	-7.432	-3,403.226**	-11.273***	-549.482***
	(2.997)	(171.619)	(7.546)	(1,512.909)	(2.594)	(176.166)
dyr_94	-8.441***	-741.171***	-4.189	-3,350.886**	-4.156	-508.922***
	(2.996)	(174.034)	(7.573)	(1,511.795)	(2.588)	(180.236)
dyr_95	-8.235***	-695.223***	0.549	-3,076.848**	-6.139**	-491.657***
	(2.813)	(157.812)	(7.112)	(1,383.099)	(2.430)	(161.912)
dyr_96	-8.378***	-650.506***	0.069	-2,843.305**	-6.046***	-466.584***
	(2.660)	(144.655)	(6.731)	(1,274.348)	(2.299)	(147.781)
dyr_97	-3.191	-602.277***	6.266	-2,610.875**	-1.342	-434.946***
	(2.511)	(132.174)	(6.339)	(1,169.127)	(2.171)	(134.755)
dyr_98	-6.613***	-545.966***	3.324	-2,315.847**	-5.157**	-401.440***
	(2.322)	(115.120)	(5.820)	(1,029.014)	(2.015)	(116.829)
dyr_99	-7.880***	-494.898***	3.054	-2,062.920**	-7.310***	-365.371***
	(2.183)	(101.693)	(5.452)	(911.281)	(1.896)	(103.469)
dyr_00	0.772	-437.557***	13.095***	-1,767.846**	-0.055	-326.593***
	(2.023)	(84.680)	(5.038)	(770.264)	(1.757)	(86.186)
dyr_01	-10.553***	-383.591***	-10.965**	-1,412.342**	-5.685***	-300.133***
	(1.824)	(62.374)	(4.508)	(587.947)	(1.592)	(63.871)
dyr_02	-8.340***	-330.809***	-5.686	-1,251.305**	-7.101***	-249.767***
	(1.771)	(56.437)	(4.362)	(523.957)	(1.541)	(57.639)
dyr_03	-7.700***	-273.535***	-3.579	-1,086.625**	-7.870***	-199.505***
	(1.725)	(51.997)	(4.238)	(469.834)	(1.502)	(53.504)
dyr_04	0.824	-209.141***	8.175**	-909.786**	-1.393	-143.982***
	(1.686)	(47.901)	(4.125)	(414.926)	(1.469)	(50.476)
dyr_05	1.001	-134.209***	10.488***	-590.984**	-2.758**	-93.332***
	(1.586)	(31.804)	(3.854)	(272.733)	(1.385)	(33.653)
dyr_06	3.928***	-71.922***	10.902***	-330.384**	1.241	-46.616**
	(1.456)	(18.995)	(3.474)	(156.572)	(1.282)	(20.949)
Constant	50.944***		61.677**		33.357***	
	(10.234)		(25.288)		(8.912)	

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

7.5 Export Intensities and Absolute Exports to Estimate the Predicting Power of Patent Value Indicators

In this section panel regression estimations are applied to export intensity as well as absolute export volumes or trade balances on patent value indicators and control variables – GDP per capita, field, and country. Several models with different independent variables were fitted. Hausman tests were applied to test for unobserved heterogeneity and in all models it was possible to accept the null hypothesis of no difference between the coefficients in the fixed and the random effects model. Therefore, we only report the results of the random effects models.

The average number of IPC classes in the patents is not a relevant factor in any of the regression models. In none of the models – except if the citation variables are omitted – does the number of IPC classes significantly add to the explanatory power of the model. The same holds for the average number of inventors per patent. This is the reason why both variables are omitted in the further course of the analyses.

From a theoretical point of view, the family size could be a good predictor for export activities. However, neither in the models where the export intensities are analyzed nor in the models where the absolute export performance is examined does the average family size show a significant impact. The reasons for this are at least twofold. On the one hand, technologies have a different propensity to internationalization, which means that for example ICT and pharmaceuticals are more internationally oriented – and therefore have a higher average number of family members – than for example machinery or automobiles. Countries with a higher orientation to ICT or pharmaceuticals therefore reach higher average family sizes than engineering-oriented countries. Though it has to be admitted that we controlled for the country and for the technology differences and so this argument does not hold as a single and exclusive explanation in this case. On the other hand, the individual family members will not all have the same export value. This means that a family consisting of the three most important markets in the world – namely the USA, Japan and Germany – might have a higher export value than a patent that is filed in five European countries like Belgium, Switzerland, Finland, Sweden and Greece, for example. And even if the patent is filed in the USA and Germany as well as in the five additional European countries, these additional countries might not outweigh, for example, Japan. To put it in other words: not all countries have the same market size and therefore calculating the average family size might not be appropriate for export value analyses. However, we keep the insignificant family variable in the model due to the theoretical arguments, but keep in mind the restrictions in the construction of this variable. It would be good to balance the family size, for example, by the size of the market in terms of export volume. This would be tautological for our analyses and as a better indication of family sizes is missing, we do not pursue any additional activities to introduce a weighting factor for this indicator.

It is interesting to note that the citation indicators are significant in models using exports or trade balance per applications as a dependent variable, while they are not significant when the exports (or trade balance) per grants are analyzed. Furthermore, in the case of exports the sign is negative and in the case of the trade balance the sign is positive. As the trade balance might be a better indication of patent value than absolute exports are, it seems justifiable from this perspective to use forward citations as value indicator, but having a negative impact on the balance. It is also interesting to note that backward citations have no predicting power, while the grant rate does. Especially in models where the granted patents are used instead of the total number of applications, the grant rate has a strong and significant impact. This is an indication that it carries relevant information, namely the information that otherwise would be included in the application information. From our perspective, this is a strong statement to use applications instead of granted patents only.

Table 7-8: Panel regression coefficients for different models based on intensities, 1988-1999

	Exports per application	Exports per grant	Trade balance per appl.	Trade balance per grant
Average N of forward citations	-1.7*	---	1.9**	---
Average N of backward citations	-0.2	---	0.2	---
N of grants with forward citations	---	-0.0	---	-0.0
Share of grants	18.5*	-135.8***	8.4	51.7***
Average family size	0.7	1.5	-1.0	-1.7*
R-square:				
within	0.2913	0.2231	0.1527	0.1696
between	0.1533	0.0082	0.1892	0.0400
overall	0.2909	0.2209	0.1527	0.1677
Number of observations	6090	5951	6090	5951

Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Coefficients for country dummies, field dummies, and GDP per capita are omitted for simplicity.

Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

Table 7-9: Panel regression coefficients for different models based on intensities, 1988-1999

	1988-2000 (including citation indicators)		1988-2005 (excluding citation indicators)	
	Exports absolute	**Trade balance absolute**	**Exports absolute**	**Trade balance absolute**
N of applications	10.6***	-2.2***	10.7***	-3.2***
Average N of forward citations	-8.1	82.4	---	---
Average N of backward citations	-41.3	-16	---	---
Share of grants	1699.2**	919.5	933	536.5
Average family size	-10.7	-16	-41	-4.1
R-square:				
within	0.7462	0.1375	0.7292	0.1300
between	0.8957	0.6438	0.809	0.5129
overall	0.7467	0.1379	0.7298	0.1302
Number of observations	6090	6090	9671	9671

Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Coefficients for country dummies, field dummies, and GDP per capita are omitted for simplicity.

Source: UN-COMTRADE, EPO–PATSTAT; Fraunhofer ISI calculations.

When absolute volumes are taken into account instead of intensities (see Table 7-9), it is first of all the absolute number of applications that has a significant and strong impact, which effectively is simply a size effect. However, after controlling for this, the citation and family variable do not add any additional predictive power to the models. What can also be seen is that the trade balance models in general have a lower overall fit, which means that – based on the variables in our dataset – the share of explained variance is much lower than in the models where only exports were used. On the one hand, the trade balance is guided by different factors that we are not able to control. This was already discussed in the descriptive section above. On the other hand, patents reach a much better correlation and therefore have a higher predicting power for absolute exports than for the trade balance, which confirm their role as an instrument to develop and structure markets. And even if producing or assembling is the main reason to enter a national market, a patent is still helpful or even necessary to secure the intellectual property.

In general, the findings of the panel regression stress the differing prediction power of citations and thereby an ambivalent use as a value indicator. This also confirms the findings from the descriptive analyses in chapter 4, which showed almost no difference in citation rates between granted patents and non-granted applications. However, if a value indicator has to be selected from the set of indicators at hand, then the forward citations, especially of applications rather than grants, seem to be most promising.

7.6 Technology Specialization Patterns and Economic Performance

The primary aim of this section is to evaluate to what extent different technological indicators differ with respect to 'predicting' economical performance at the level of national innovation systems (countries). Currently, the technological performance of countries is assessed by counting the number of patent applications and/or grants as observed within different patent systems (EPO, USPTO, JPO,…) At the same time, several studies suggest the relevance of more refined indicators such as the number of patent applications with forward/backward citations, the absolute number of forward/backward citations, the family size of the patents, the number of inventors and the number of IPC classes. All these indicators claim to provide an indication of the 'quality' of the technological activity of a country (Hall et al. 2005; Harhoff et al. 1999; Trajtenberg 1990). Within this analysis we examine this claim by comparing different measures of technological activity in terms of how well they coincide ('predict') with economical performance. This will be done for 35 different fields.

When analyzing the influence of technological performance (measured by patent data) on the economical performance (measured by export data) of national innovation systems (countries), we use relative technological and economical indicators. In a first section the calculation method of the different indicators will be explained. The statistical analyses will be resumed in the second section, followed by conclusions.

7.6.1 Calculation of RCA-RTA

The respective relative indicators for technological and economical performance are calculated with the subsequent formulas:

RTAij= Relative Technological Advantage in technology class i for country j =

$$(P_{ij}/\Sigma_i P_{ij}) / (\Sigma_j P_{ij}/\Sigma_{ij} P_{ij})$$

with Pij: the number of patents in a certain technology field I for a given country j.
with i = 1 ... N (N = the number of technology fields in the study);
with j = 1 ... M (M = the number of countries in the study = 17).

This index gives the share of country j in technology field i, compared to the share of all countries in technology field i, taking into account all patents of country j and all patents of all countries and fields. This index thus compares the share of patents of a certain country in a certain technology field with the share of this technology field in other countries.

RCAij= Relative Comparative Advantage in technology field i for country j =

$$(P_{ij}/\Sigma_i P_{ij}) / (\Sigma_j P_{ij}/\Sigma_{ij} P_{ij})$$

with Pij: the export in a certain technology field I for a given country j.
with i = 1 ... N (N = the number of technology fields in the study);
with j = 1 ... M (M = the number of countries in the study = 17).

This index gives the share of country j in technology field i, compared to the share of all countries in technology field i, taking into account the total export of country j and total export of all countries and fields. This index thus compares the share of export of a certain country in a certain technology field with the share of this technology field in other countries.

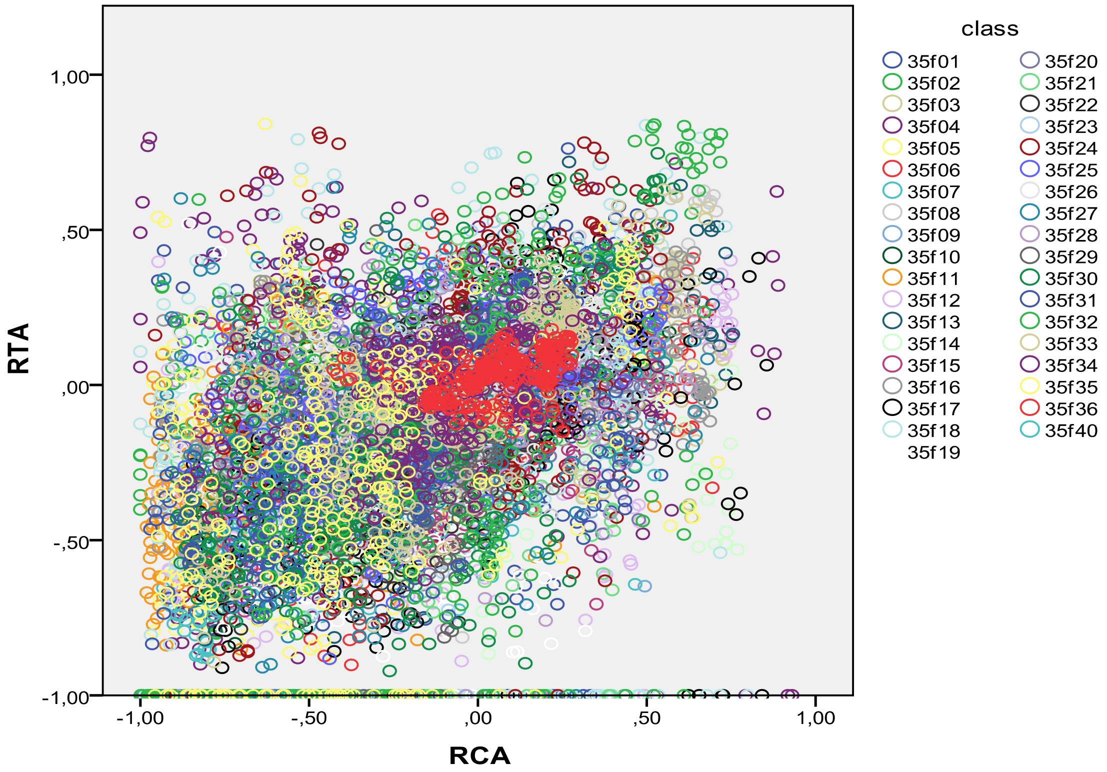
The value of these relative specialization indices varies from [0;+∞]. A value smaller than 1 indicates that a country has a relative disadvantage in the field in consideration, values equal to 1 indicate a neutral position of the index and values larger than 1 indicate a relative advantage. The index corrects for the 'size' of the technology field. Therefore this indicator is suited to make comparisons, to map changes over time and to identify changes in the level of specialization of a country or a group of countries as it is 'size' independent. One drawback of the use of traditional RTAs/RCAs is that 'extreme values' can occur. Therefore we opt to transform the relative indices using the following formula:

RTA = (RTA-1)/(RTA+1) and

RCA = (RCA-1)/(RCA+1)

After the transformation the value of the RTAs and RCAs varies from [-1;1] instead of from [0;+∞] (Figure 7-6).

Figure 7-6: RTAs and RCAs after transformation respectively based on EPO applications and exports in constant 2000 PPP-$ by Isi35 technology fields.



Source: UN-COMTRADE, EPO–PATSTAT; INCENTIM calculations.

Table 7-10: List of countries and availability of export data

Country	Availability of export data		Included in reference group
	From	until	
Austria	1988	2006	yes
Canada	1988	2006	yes
Switzerland	1988	2006	yes
Germany	1988	2006	yes
Denmark	1988	2006	yes
Spain	1988	2006	yes
Finland	1988	2006	yes
France	1988	2006	yes
Great Britain	1988	2006	yes
Ireland	1988	2006	yes
Italy	1988	2006	yes
Japan	1988	2006	yes
Korea	1988	2006	yes
Netherlands	1988	2006	yes
Norway	1988	2006	yes
Sweden	1988	2006	yes
United States	1988	2006	yes

Source: UN-COMTRADE, EPO–PATSTAT; INCENTIM calculations.

Table 7-11: Name of relative indicators for technological performance and underlying unit of measurement

Name of relative indicator	Measurement unit
RTA_ap_n	Number of patent applications EPO
RTA_gr_n	Number of grants at the EPO
RTA_ap_fcit	Number of EPO patent applications with forward citations (4 year time window)
RTA_ap_fcitn	Number of forward EPO citations (4 year time window)
RTA_ap_bcit	Number of EPO patent applications with backward citations
RTA_ap_bcitn	Number of backward citations
RTA_apnplcit	Number of European patent applications with non-patent literature (NPL) citations
RTA_nplcit_n	Number of NPL citations
RTA_gr_fcit	Number of grants with forward citations at the EPO (4 year time window)
RTA_fam_n	Number of patent families at the EPO*
RTA_invt_n	Number of different inventors
RTA_ipc_n	Number of different IPC classes

* excluding Singletons (counted when an application is at least filed at one other patent office different than EPO)

Source: UN-COMTRADE, EPO–PATSTAT; INCENTIM calculations.

17 countries are taken into account for this analysis. This lists all countries presented in Table I except China and Belgium (due to limited availability of export data over time). The relative specialization indices were calculated year by year over the time period 1988-2006.

In the introduction it was already mentioned that several indicators can be used to measure technological performance. In Table 7-11 the different indicators used to assess technological performance within this study are listed.

Export data expressed in constant 2000 PPP in dollars are used to measure economical performance. Purchasing Power Parity (PPP) was chosen to measure export to avoid potential influences of exchange rate fluctuations in the subsequent analyses.

7.6.2 Statistical analyses

7.6.2.1 Building the model

In order to evaluate the explanatory power of technological performance in terms of economic performance, several regression analyses were performed with RCA as dependent variable and the different RTAs as independent variables. In addition, the models include several control variables: size of a country (population), the richness of a country (GDP per capita) and finally year (to account for a time trend).

In total, the following 12 models were applied (for an explanation of the meaning of the different relative technology indicators (RTAs), see Table 7-11).

Model 1: RCA = RTA_ap_n + pop + GDP_pop + time + ε
Model 2: RCA = RTA_gr_n+ pop + GDP_pop + time + ε
Model 3: RCA = RTA_ap_fcit+ pop + GDP_pop + time + ε
Model 4: RCA = RTA_ap_fcitn+ pop + GDP_pop + time + ε
Model 5: RCA = RTA_ap_bcitn+ pop + GDP_pop + time + ε
Model 6: RCA = RTA_ap_bcit+ pop + GDP_pop + time + ε
Model 7: RCA = RTA_apnplcit+ pop + GDP_pop + time + ε
Model 8: RCA = RTA_nplcit_n+ pop + GDP_pop + time + ε
Model 9: RCA = RTA_gr_fcit+ pop + GDP_pop + time + ε
Model 10: RCA = RTA_fam_n+ pop + GDP_pop + time+ ε
Model 11: RCA = RTA_invt_n+ pop + GDP_pop + time + ε
Model 12: RCA = RTA_ipc_n+ pop + GDP_pop + time + ε

with pop = population (control variable for 'size' of a country).
with GDP_pop = Gross Domestic Product / population (control variable for 'wealth' of a country).
with time = pry (priority year) - 1988 (control variable to capture time trends).

The analyses were performed for all patent documents with a priority year before 2002 in order to exclude the impact of lags (grants) and to allow for citations to occur (four year time window for forward citations).

7.6.2.2 Results

The results of the regression models are analyzed by comparing the explanatory power of the different models expressed by means of the R^2 (amount of variance explained by the model). The analysis will be conducted for each of the technology sectors.

Table 3 shows the predictive power (R^2) of the models. A clear distinction can be observed between Model 1 where the average R^2 is highest (average R^2 = 0,372) and for example Model 8, where the average R^2 is lowest (average R^2 = 0,292). More generally, we observe that the models including the basic indicators for technological performance, such as patent applications and granted patents, have a higher explanatory power for economical performance than the other models, including the more refined indicators for technological performance such as forward citations, the family size of the patents, the number of inventors and the number of IPC classes[21]. Only exception is for Model 6 including the number of European patent applications with backward citations as independent variable (average R^2 equals to 0,369).

21 Robustness checks were performed by including fixed effect for countries, by removing all the RTAs with 'extreme values' (outliers) and by lagging the technological indicators with 1-2 years. The findings of these analyses coincide with the reported results.

Table 7-12: R^2 of regression models 1-12 by ISI35 technology fields

	Mod.1: Applications	Mod.2: Grants	Mod. 3: Patents with forward	Mod. 4: # forward citations	Mod. 5: # backward citations	Mod. 6: Patents with backward	Mod. 7: Patents with NPL cita-	Model 8: # NPL citations	Mod. 9: Grants with forward	Mod. 10: Family number	Mod. 11: Inventor number	Mod. 12: IPC number
nuclear reactors etc.	.297	.279	.274	.254	.299	.295	.273	.209	.253	.232	.276	.277
pesticides	.320	.277	.324	.361	.294	.316	.235	.177	.285	.176	.298	.312
biotechnology and agents	.241	.257	.250	.271	.192	.244	.255	.203	.242	.166	.237	.267
weapons	.118	.109	.094	.091	.118	.117	.094	.090	.092	.096	.111	.100
aeronautics	.496	.503	.406	.357	.457	.497	.390	.329	.412	.447	.480	.425
computer	.476	.398	.446	.330	.380	.456	.474	.321	.336	.318	.474	.381
electronics	.640	.619	.612	.558	.626	.647	.575	.546	.594	.597	.615	.605
communications engineer.	.460	.419	.494	.506	.459	.476	.315	.160	.444	.294	.384	.426
electronic medical instr.	.500	.502	.469	.403	.469	.495	.469	.447	.465	.478	.470	.477
optical measurement	.565	.530	.566	.519	.532	.563	.516	.450	.520	.503	.534	.514
optics	.498	.473	.507	.529	.460	.491	.481	.486	.484	.487	.470	.493
dyes and pigments	.334	.316	.352	.333	.324	.324	.309	.273	.328	.268	.294	.328
inorganic basic materials	.281	.191	.241	.188	.225	.264	.133	.084	.201	.188	.293	.211
organic basic materials	.038	.052	.028	.016	.025	.037	.016	.032	.042	.022	.020	.017
polymers	.243	.235	.254	.247	.236	.241	.271	.228	.245	.193	.283	.260
pharmaceuticals	.287	.297	.305	.358	.279	.285	.305	.271	.298	.236	.253	.324
scents and polish	.356	.328	.370	.374	.316	.353	.281	.196	.341	.247	.316	.359
pyrotechnics	.131	.101	.093	.076	.108	.124	.084	.069	.078	.098	.131	.117
photo chemicals	.478	.439	.442	.446	.431	.476	.414	.415	.424	.447	.461	.456
other special chemistry	.202	.207	.200	.203	.200	.201	.200	.199	.205	.199	.200	.202
rubber goods	.463	.465	.458	.457	.454	.458	.475	.485	.464	.464	.457	.457
power machines	.485	.463	.466	.422	.445	.478	.433	.404	.461	.452	.440	.431
air conditioning and filters	.377	.344	.385	.335	.373	.379	.329	.325	.394	.351	.361	.380
agricultural machinery	.293	.262	.206	.167	.238	.277	.122	.093	.184	.222	.247	.213
machine tools	.504	.425	.444	.404	.431	.505	.505	.457	.382	.419	.438	.465
special purpose machinery	.623	.573	.600	.576	.587	.612	.549	.549	.561	.450	.638	.634
office machinery	.237	.226	.229	.200	.198	.238	.216	.233	.231	.240	.239	.206
power generation	.423	.459	.415	.387	.411	.415	.399	.391	.429	.390	.403	.399
lamps, batteries etc.	.240	.231	.265	.246	.224	.238	.231	.260	.251	.243	.225	.224
broadcasting engineering	.407	.415	.414	.405	.374	.404	.360	.328	.414	.304	.373	.389
automobiles and engines	.440	.451	.393	.380	.432	.435	.274	.244	.403	.318	.416	.386
rail vehicles	.389	.352	.382	.316	.342	.372	.210	.179	.333	.364	.343	.364
medical instruments	.452	.456	.427	.394	.421	.457	.341	.283	.428	.344	.450	.386
mechanical measurement	.514	.502	.520	.509	.501	.515	.503	.500	.506	.507	.510	.499
optical devices etc.	.284	.271	.264	.284	.259	.280	.301	.311	.257	.222	.283	.316
low-tech	.338	.327	.337	.306	.311	.333	.295	.276	.326	.282	.290	.324
Average	0.373	0.364	0.359	0.339	0.345	0.369	0.323	0.292	0.342	0.313	0.353	0.351

Source: UN - COMTRADE, EPO – PATSTAT; INCENTIM calculations.

In order to analyze whether the explanatory power of the different models is significantly different from each other, a paired T-test was performed. Results are presented in Table 7-13 and show that all other models have a significantly lower predictive power than Model 1 which includes the number of European patent applications as an independent variable.

Table 7-13: Result matrix of paired T-test on R^2 of Models 1-12

	Mod.1: Applica-tions	Mod.2: Grants	Mod. 3: Patents with forward citations	Mod. 4: # for-ward citations	Mod. 5: # backward citations	Mod. 6: Patents with backward citations	Mod. 7: Patents with NPL cita-tions	Model 8: # NPL citations	Mod. 9: Grants with forward citations	Mod. 10: Fami-ly number	Mod. 11: Inven-tor number	Mod. 12: IPC number
M 1	1	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
M 2		1	0,41	0,08	0,03	0,00	0,00	0,00	0,01	0,00	0,84	0,02
M 3			1	0,00	0,00	0,03	0,00	0,00	0,00	0,00	0,33	0,00
M 4				1	0,40	0,00	0,13	0,00	0,60	0,03	0,15	0,52
M 5					1	0,00	0,03	0,00	0,47	0,00	0,13	0,89
M 6						1	0,00	0,00	0,00	0,00	0,00	0,00
M 7							1	0,00	0,05	0,30	0,00	0,00
M 8								1	0,00	0,04	0,00	0,00
M 9									1	0,00	0,13	0,00
M 10										1	0,00	0,00
M 11											1	0,35
M 12												1

Source: UN-COMTRADE, EPO–PATSTAT; INCENTIM calculations.

Organizing the results of the paired T-test in groups results in 8 subsets (Table 7-14). As previously mentioned, all models are significantly different from Model 1 ($p > 0.05$). The second subset contains Model 6 which is again significantly different from the other models. The third subset contains Models 2, 3, 11 and 12 with average R^2 ranging from 0.364 to 0.351. The fourth subset contains Models 2, 11, 12 and 4 with average R^2 ranging from 0.364 to 0.339. The fifth subset contains Models 11, 12, 4, 5, 9 and 7 with average R^2 ranging from 0.353 to 0.323. The sixth subset contains Models 7 and 10 with average R^2 ranging from 0.323 to 0.313. Finally, the seventh subset includes Model 8 with average R^2 of 0.292.

Table 7-14: Results of post-hoc test for homogeneous subsets after paired T-test on Models 1-12.

	Subsets						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Model 1: Applications	x						
Model 6: Patents with backward citations		x					
Model 3: Patents with forward citations			x				
Model 2: Grants			x	x			
Model 11: Inventor number			x	x	X		
Model 12: IPC classes number			x	x	X		
Model 4: # Forward citations				x	X		
Model 5: # Backward citations					X		
Model 9: Grants with forward citations					X		
Model 7: Patents with NPL citations					X	x	
Model 10: Family number						x	
Model 8: # NPL citations							x

Source: UN-COMTRADE, EPO–PATSTAT; INCENTIM calculations.

Finally, we examined the explanatory power of technological performance on economical performance for different technology domains (ISI35). The average R^2 for the different domains equals 0.373 with minima and maxima amounting to respectively 0.038 and 0.640 (see Table 7-15). We would expect a higher influence of technological performance on economical performance for the leading-edge technology fields compared to the high-level and low-technology fields. This is confirmed by the RTAs that are all significant with an average R^2 of 0.419 for the 11 leading-edge technological fields. For the 24 high-level technological fields the average R^2 equals 0.353, with significant influence of RTAs for all technological fields except for 'Organic basic materials' and for 'Other special chemistry'. For 'low-tech' the R^2 equals 0.338, with RTA as a significant variable. While these figures suggest the expected pattern, the difference between the R^2 of the leading-edge technological fields and the high-level technology fields is however not significant ($p = 0.24$).

Table 7-15: R^2 and significance of RTA for Model 1 by ISI35 technology fields.

	Field	Field name	R^2	RTA
Leading-edge technologies	35f01	Nuclear reactors and radioactive elements	0.297	yes
	35f02	Pesticides	0.320	yes
	35f03	Biotechnology and agents	0.241	yes
	35f04	Weapons	0.118	yes
	35f05	Aeronautics	0.496	yes
	35f06	Computer	0.476	yes
	35f07	Electronics	0.640	yes
	35f08	Communications engineering	0.460	yes
	35f09	Electronic medical instruments	0.500	yes
	35f10	Optical and electronic measurement technology	0.565	yes
	35f11	Optics	0.498	yes
High level technologies	35f12	Dyes and pigments	0.334	yes
	35f13	Inorganic basic materials	0.281	yes
	35f14	Organic basic materials	0.038	no
	35f15	Polymers	0.243	yes
	35f16	Pharmaceuticals	0.287	yes
	35f17	Scents and polish	0.356	yes
	35f18	Pyrotechnics	0.131	yes
	35f19	Photo chemicals	0.478	yes
	35f20	Other special chemistry	0.202	no
	35f21	Rubber goods	0.463	yes
	35f22	Power machines and engines	0.485	yes
	35f23	Air conditioning and filter technology	0.377	yes
	35f24	Agricultural machinery	0.293	yes
	35f25	Machine tools	0.504	yes
	35f26	Special purpose machinery	0.623	yes
	35f27	Office machinery	0.237	yes
	35f28	Power generation and distribution	0.423	yes
	35f29	Lamps, batteries etc.	0.240	yes
	35f30	Broadcasting engineering	0.407	yes
	35f31	Medical instruments	0.440	yes
	35f32	Mechanical measurement technology	0.389	yes
	35f33	Optical and photo optical devices	0.452	yes
	35f34	Automobiles and engines	0.514	yes
	35f35	Rail vehicles	0.284	yes
Low tech	35f36	Low tech	0.338	yes

Source: UN-COMTRADE, EPO–PATSTAT; INCENTIM calculations.

7.7 Concluding Remarks

Exports prove to be of good use to act as a valuation of patents, allowing for a meaningful interpretation of the data. The number of EPO patent applications and the export amounts are strongly correlated, though some disturbances to this parallelism are visible, especially as the exports react much more extremely in the overall economic situation. However, results are still ambiguous to some extent concerning the meaning and interpretation of the patent value indicators – namely citations, grant rate, family size, the number of IPC classes, or the number of inventors. While IPC classes and inventor counts do not prove to be of any relevance to predict the export value of patents, forward citations especially are promising when patent applications instead of granted patents are analyzed. The family size also has a very restricted predicting power, which was explained by the fact that the individual family members cover very differently value markets and therefore each member reaches a very differing export value. A simple summing up of family members does not seem appropriate in the value discussion.

The impact of patent applications on the export value is greater for leading-edge technologies than for non-leading-edge technologies. Furthermore, patent stocks have diverging effects on the export value, depending on technologies. While the impact of patent stocks for non-leading-edge technologies is positive, the coefficient of patent stocks for leading-edge technologies is negative, which implies that very R&D-intensive areas (i.e. leading-edge) have a higher deteriotion rate and shorter technology cycles. In line with the findings of the analyses in previous chapters, it again turned out that structure matters and differences between technological fields have to be taken into account. Furthermore, trans-shipment effects as well as the effects of intermediate inputs to production processes by imports could be taken into account, using the trade balance instead of exports only. However, the analyses show that patents are much more closely related to exports than to the trade balance – defined as exports minus imports. It was explained that also in the case of trans-shipment and assembling, protection of the intellectual property involved is advisable.

A remarkable conclusion also of the examination of patent and export profiles is that overall more basic indicators of technological activity in a country – such as the number of patent applications and the number of patents granted - display a higher explanatory power towards economical performance than more refined indicators such as the number of forward/backward citations, absolute number of forward/backward citations, the family size of the patents, the number of inventors and the number of IPC classes that give an indication of the 'quality' of the innovative activity in a country. As such, these findings suggest that the more firms are active in certain fields, the more they secure these activities by applying for patents. Again, technological activity per se, rather than success in these activities (e.g. grants), seems to be the better 'predictor' for the presence of economic activity.

Finally, it is striking that indicators with backward citations perform relatively well to predict profiles – while one would expect forward citations to be more relevant, especially against the background of the findings on the examination of intensities. At the same time, it can be noted that the occurrence of backward citations coincides with the maturity of a field. While at an early stage, less citations are to be expected (due to a lack of prior art), this changes during phases of growth and maturity. Within these latter phases, more economic activity is present as well, which could explain the relatively strong performance of indicators taking into account backward citations.

To sum up, patent applications as such – without any additional indications of values – are a reliable and handy predictor of export activities, especially in high-tech areas and even more in very R&D-intensive technological fields. Besides, in the case of export volumes or export intensities, forward citations are the most promising indicator to predict patent values in terms of exports. In the case of export and patent profiles, backward citations have a higher predicting power. This contradiction at first sight could be explained by the fact that profiles change rather slowly and reflect technological competences and technological paths. Backward citations are exactly this, namely references to existing knowledge and competences. Forward citations, on the other hand, are a measure of quality and market relevance, which is more suitable to reflect market activities and market development.

8. Summary: Comparative Ranking of Countries

Rainer Frietsch and Ulrich Schmoch

8.1 Introduction

The task of the project reported here was to check, whether a weighting factor needs to be introduced for comparative patent profile analysis, due to the increasing number of trivial patents and the findings from the literature that the economic value of patents follows an extremely skewed distribution, with only a few patents having a high economic value and the majority of patents having a low or almost no economic value. The literature review and the theoretical discussion revealed that there are at least two dimensions of the value of patents, whereof the first covers the items: economic, technological, and strategic value. Another dimension differentiates between private and public/social value. This latter dimension has not been analysed in this report beyond the literature review.

The starting point of the discussion was not to analyse patents in general, but to look at transnational patent applications of the selected set of industrialised countries with a special focus on high-tech areas, as this special kind of patents, on the one hand, is regularly used in comparative analyses of the technological competitiveness of nations. On the other hand, it is this kind of patents that are an appropriate indicator for evidence-based policy-making, because they offer a balanced analytical background beyond national idiosyncrasies, they are among the most topical patent indicators at hand, and they are capable of reflecting both, the output of R&D systems and input into the further economic system. The focus on transnational high-tech patents already implies a kind of weighting factor, or better to say a filter that already separates the wheat from the chaff – at least to some extent.

8.2 The different approaches to weight the patent profiles

For identifying potential weighting factors, first of all, a bundle of possible indicators from within the patent system – these were citations, grant rates (legal status), family size as well as number of IPC classes and number of inventors – have been presented and analysed for their applicability and usefulness as a weighting factor for patent profiles. The application of legal status as a weighting factor introduces clear differences between the countries. However, lower grant rates of the USA and recently also of Japan raise some doubts about the adequateness and the reliability of this indicator. It was discussed that the lower grant rates have their origin in the difference of application procedures at the USPTO and at international offices. Different regulations and examination habits in conjunction with obviously hardly adapted application files, result in a higher drop-out rate of highly USPTO-oriented countries. In consequence, Germany performs relatively better when only granted patents are analysed (see Figure 8-1 and Figure 8-2), which is not in line with the expectancy based on the technological competitiveness as well as on the value distribution found in the literature. In addition, the application of legal status information is additionally disturbed by a missing topicality. Granting procedures of five years and more as well as an increasing processing time only allows a lagged calculation of this correction weight. Therefore it is not recommended to use it.

The analysis of the data of the 1990s revealed that the majority of withdrawals and refusals take place in the first three years. Therefore it is obvious to make use of this for balancing the patent portfolios. However, empirical evidence was found that this indicator has changed since about the year 2000. It seems that the withdrawal and refusal rates of the early years have been decreasing so that also this indicator is not the best choice for a standard application as a balancing factor.

Citations, on the other hand, offer meaningful corrections of the absolute numbers and intensities. It was shown that it is not only one type of citations -X, Y or A-citations- can be used here, but all citations combined, as the characteristics of the different citation types in terms of grant rates are similar. To provide data that is as up-to-date as possible and at the same time reliable and independent of annual idiosyncrasies, a four years citation window was suggested. The loss of information compared to, for example, a 10 years window is acceptable at the expense of having only a four years time lag between the citation year and the priority year to be valuated.

The number of patent family members was also discussed as another alternative, especially as countries seem to be different also in this respect. However, also in this case some doubts were raised about the reliability and validity of this indicator. Neither in the analyses based on renewal fees nor the estimations applying export data as a valuation of patents revealed a considerable impact of the family size on the patent value. Furthermore, companies from different countries have different filing habits, resulting in different sizes of patent families. This is first of all the direct consequence of the market orientation of certain countries. For example such countries which are only targeting a few, but large markets are valued lower than such countries which have a large number of filing countries with a low market volume on their agenda. To put it in other words, weighting a family member at the USPTO or the EPO like a member in, for example, Belgium, Mexico or Russia does not seem to be appropriate. Furthermore, also this indicator introduces additional imbalances which are not plausible – at least compared to other innovation indicators like R&D expenditure or high-tech exports.

The use of renewal fees to estimate the average individual value of patents and to apply it as another weighting factor does not seem to be a good choice. First of all, the differences between the average patent value in different countries are hardly visible. Furthermore, an extreme time lag is necessary because for the estimation to full scale of patent maintenance should be used or at least a considerable time span of a least 10 to 15 years. Thirdly, as a direct consequence of this considerable time lag, structural changes within the period of observation can hardly be taken into account. This is especially true for the patent upsurge that occurred during the 1990s in all relevant offices around the world. The priority of a filing of the late 1980s can hardly be compared to the present applications of the second half of this new decade. Fourthly, the regression approach proved to be rather complicated to be permanently replicated on a year by year basis.

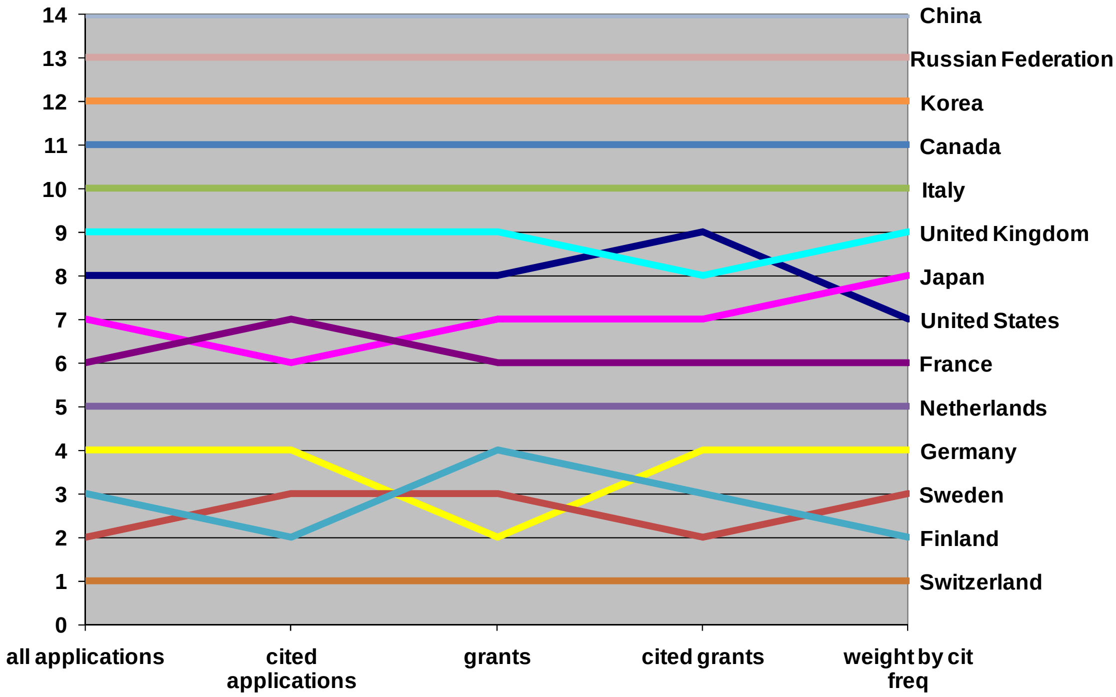
From the literature review it became evident that the values of patents are extremely skewed. In addition, it was discussed that especially large multinational companies, which account for a large number of patent applications, have better means to secure their values. The extreme valuable patents are by far more often owned by these multinational companies, whereas small and medium-sized firms are less often able to enforce their values. The concentration on a few patents with an extreme value to weight the whole patent portfolio of an innovation system does not seem to be meaningful for international comparisons of the economic and technological competitiveness of nations, especially as the activities of the small and medium-sized enterprises, which account for a considerable number of patents (Frietsch 2006; Frietsch, Jung 2009; Hingley, Bas 2009), target smaller markets and therefore may have a medium value. This is even more the case as innovation policy usually addresses this group of small and medium-sized companies.

The use of export data to estimate the average value of patens reveals a very close correlation between European patent applications and exports, although this observation varies by technological field. This close correlation can be observed using all applications without any filtering or weighting process. This observation supports the above statement that the use of the international perspective already implies an effective selection process and that the inclusion of applications referring to incremental innovation is helpful to reflect the whole spectrum of economic activities with regard to research-intensive goods. If the absolute number of applications is used in this context, the forward citations prove to be a significant factor for predicting export performance. They are obviously an appropriate indicator for the patent value in terms of export success. If the specialisation profiles of patents and exports are linked, the backward citations prove to be a significant factor. This finding may be interpreted as indication that profiles reflect accumulated knowledge. In any case the analysis is a strong evidence that international patents are a useful indicator for reflecting the innovation performance of countries with the specific advantage of the possibility of the precise definition of technology fields, of the free selection of aggregation levels, of the drawing of long time series without classification inconsistencies, the geographical strategies of countries with reference to specific areas etc.

8.3 Comparatively applying some weights

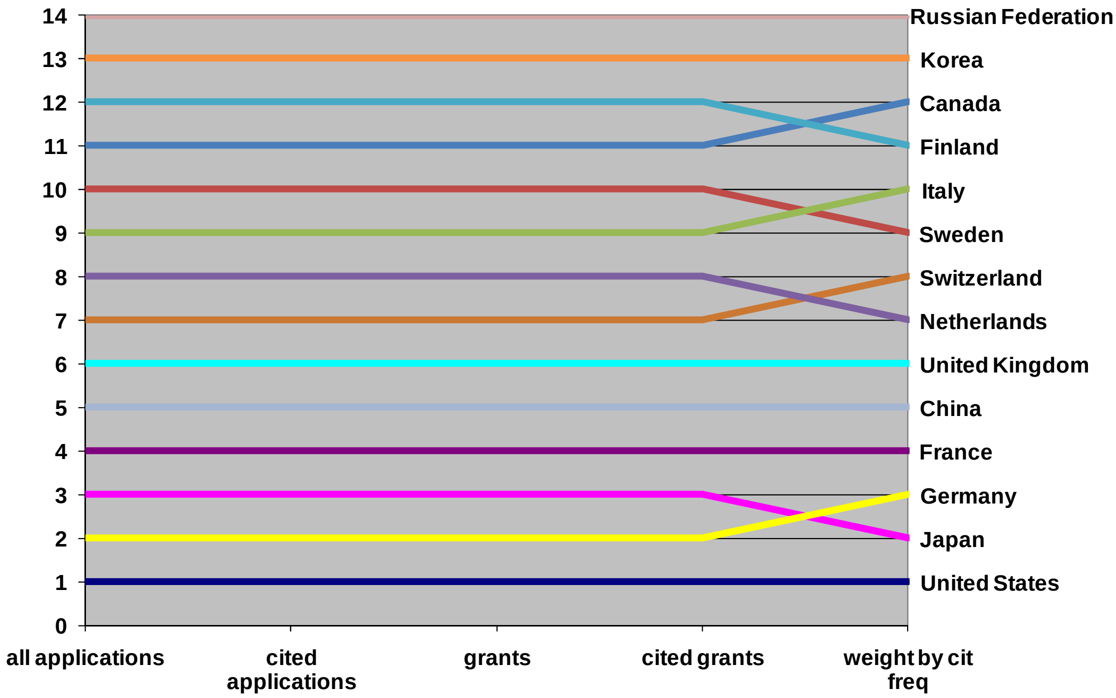
The different impacts of some weighting procedures are depicted in Figure 8-1 (patent intensities) and Figure 8-2 (absolute number of patent applications). As can be seen, the changes of ranks are restricted to changes within a certain range and within certain groups. For example, Figure 8-1 shows that in terms of patent intensities – defined as patents per one million employment – it is always Switzerland that is on the top while the three countries Germany, Sweden and Finland are swopping the ranks 2-4. It was mentioned above that the promotion of Germany based on grants only is not plausible so that effectively Sweden and Finland compete for rank 2. The USA, the United Kingdom and the United States swop ranks 7-9, depending on the weighting procedure. When all citations are taken into account, the USA prevails in this group while it looses ground when only the citations of granted patents are taken into account. All the other countries' patent intensities under observation here are not affected by the weighting procedure. The rankings based on the absolute numbers of patents are even less affected by the different weighting procedures. Only the frequency of citations results in changes of position for four groups of countries. However, their absolute numbers of patents has been very similar anyway.

Figure 8-1: Impact of different weighting procedures on the ranking of selected countries based on patent intensities (patents per 1 Mio. employment), 1998



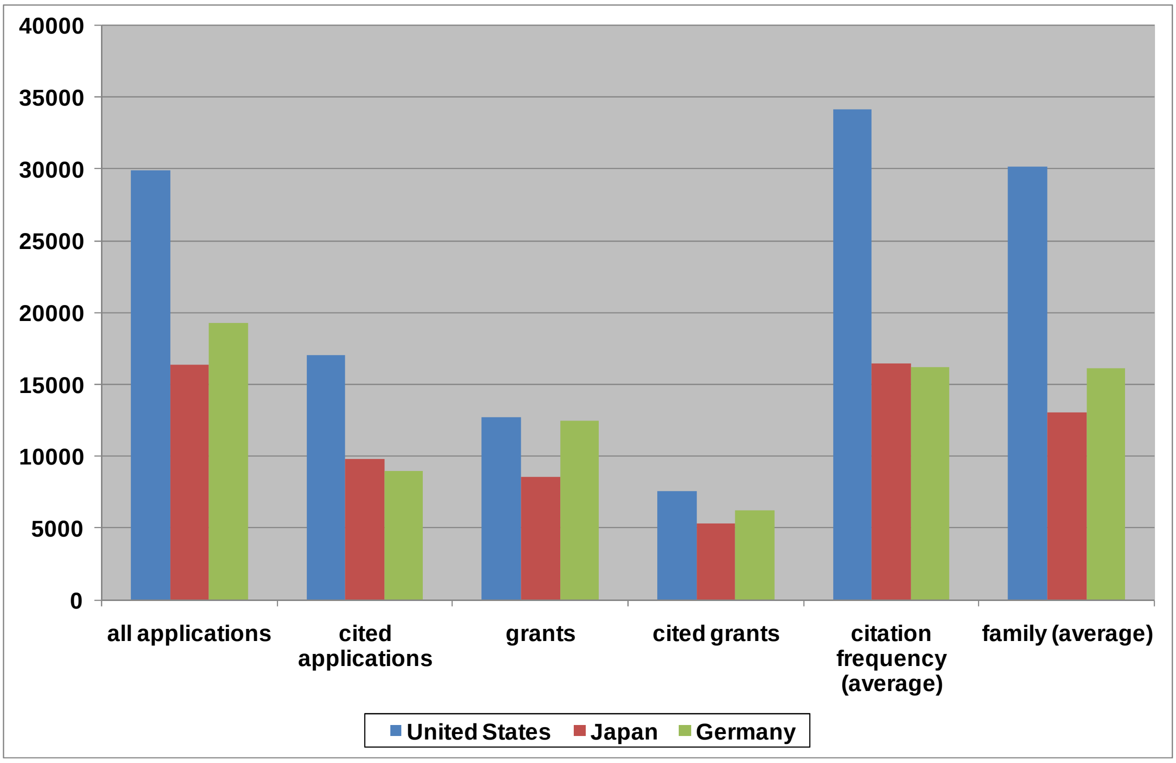
Source: PATSTAT; ILO –Labour Force Statistics; Fraunhofer ISI calculations.

Figure 8-2: Impact of different weighting procedures on the ranking of selected countries based on absolute patent counts, 1998



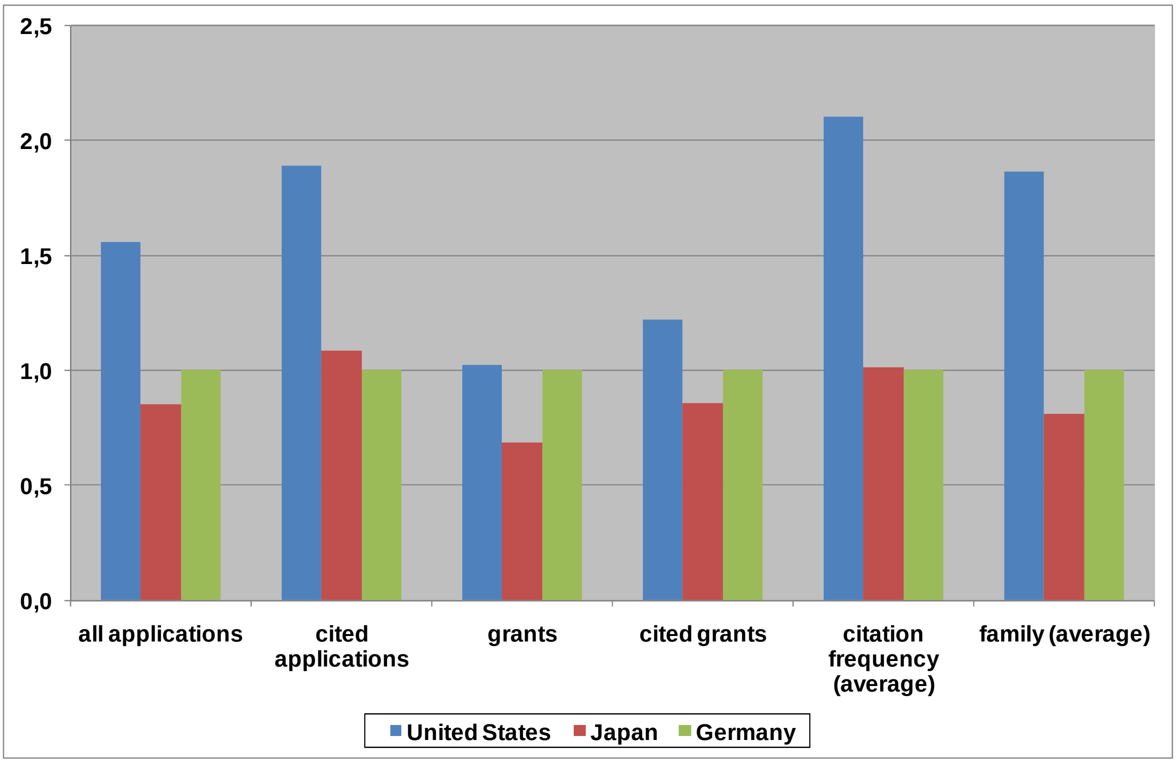
Source: PATSTAT; Fraunhofer ISI calculations.

Figure 8-3: Applying different weights: "distance" of 3 countries in terms of EPO patents, 1998



Source: PATSTAT; Fraunhofer ISI calculations.

Figure 8-4: Applying different weights: index* of 3 countries in terms of EPO patents, 1998



* index means German value = 1

Source: PATSTAT; Fraunhofer ISI calculations.

While the Figure 8-1 and Figure 8-2 were using ranks to show the effects of different weighting procedures on the patent activities of countries, Figure 8-3 and Figure 8-4 display absolute and relative patent counts for the three largest innovation-oriented countries, Germany, the USA, and Japan. The effects of the weights on the ranks were rather low, but the relations between the countries are much more affected. The number of EPO filings in 1998 of the USA was almost 30,000, Germany filed about 20,000 patents and Japan – still affected by the Asian crisis – about 17,000 applications. Using Germany as the benchmark and setting the German applications to 1, the USA files 1.56 times that number of patents and Japan filed 0.85 times the German numbers. If citations are used a weight to balance an unequal value distribution of patent portfolios, the USA and Japan gain weight, filing twice the German patents or 1.1 times, respectively. The relation between the USA and Japan is hardly affected by this, and using citations frequencies instead of the share of cited patents, it is almost the same picture. When grants are used instead, the picture is the opposite. The same is true when cited grants are applied as a weighting factor. The USA is downsized to the level of Germany and Japan also looses some ground. This is not a plausible relation of these countries, when other indicators like R&D spending or high-tech exports are taken into account. Finally, the family size has almost no effect at all and keeps the former relative positions of these three countries, with some disadvantage for Japan and a small advantage for the USA.

To sum up, also the size in terms of patent applications or weighted patent applications is either hardly affected by the weights or has a counter-intuitive effect. Again, only citations prove to be of some relevance, though they are also not fully satisfying as the position of Japan seems not appropriate.

8.4 Recommendations

The literature review offered a set of potential value indicators to weight or balance national technology portfolios, but it did not really favour one of them. Our empirical analyses also do not suggest one single best indicator. The analyses even suggest not applying any weight at all, as the direction or the size of the effects is not satisfying and their impact, both on rankings as well as on relative positions of the countries is very restricted. However, if weights are to be used, forward citations are the most promising one – suggested both, by the literature as well as by our own empirical analyses. Another interesting balancing factor could be the introduction of the withdrawal quota of the first 3 years after filing as an early approximation to the number of granted patents.

To sum up: If at all, citations would be the best choice as a weighting factor, but in general a weighting procedure for national patent portfolios to adjust for patent value distribution is not recommended.

9. References

Abramson, H.N.; Encarnação, J.; Reid, P.P.; Schmoch, U. (1997): Technology Transfer Systems in the United States and Germany - Lessons and Perspectives, Washington, D.C.: National Academy Press.

Achilladelis, B.; Schwarzkopf, A. (1990): The dynamics of technological innovation: The case of the chemical industry. In: Research Policy, 19(1), pp. 1-34.

Acs, Z.J.; Audretsch, D.B.; Feldman, M.P. (1994): R&D Spillovers and Recipient Firm Size. In: Review of Economics and Statistics, 76 (2), pp. 336-340.

Afuah, A.N.; Bahram, N. (1995): The hypercube of innovation. In: Research Policy, 24(1), pp. 51-76.

Agrawal, A.; Henderson, R. (2002): Putting Patents in Context: Exploring Knowledge Transfer from MIT. In: Management Science, 48(1), pp. 44-46.

Albert, M.B.; Avery, D.; Narin, F.; McAllister, P. (1991): Direct validation of citation counts as indicators of industrially important patents. In: Research Policy, 20 (3), pp. 251-259.

Alcacer, J.; Gittelmann, M. (2004): How do I Know what you Know?, Patent Examiners and the Generation of Patent Citations.

Allison, J.R.; Lemley, M.A.; Moore, K.A.; Trunkey, R.D. (2004): Valuable Patents. In: The Georgetown Law Journal, 92, pp. 435-479.

Almeida, P. (1996): Knowledge Sourcing by Foreign Multinationals: Patent Citation Analysis in the U.S. Semiconductor Industry. In: Strategic Management Journal, 17 (Winter Special Issue), pp. 155-165.

Arundel, A.; Patel, P. (2003): Strategic patenting, Background report for the Trend Chart Policy Benchmarking Workshop "New Trends in IPR Policy".

Atuahene-Gima, K. (2005): Resolving the capability-rigidity paradox in new product innovation. In: Journal of Marketing, 69(4), pp. 61-63.

Audretsch, D.B.; Feldman, M. (1996): R&D Spillovers and the Geography of Innovation and Production. In: American Economic Review, 86 (3), pp. 630-640.

Avery, D.; Mayer, R.L. (2003): Das US-Patent: Erwirkung und Durchsetzung unter besonderer Berücksichtigung der Rechtsprechung, Köln: Heymann.

Baumol, W.J. (2002): The Free-Market Innovation Machine, Princeton, NJ: Princeton University Press.

Belitz, H.; Edler, J.; Grenzmann, C. (2006): Internationalisation of Industrial R&D. In: Schmoch, U.; Rammer, C.; Legler, H. (eds.): National Systems of Innovation in Comparison. Structure and Performance Indicators for Knowledge Societies. Dordrecht: Springer.

Bessen, J. (2008): The value of U.S. patents by owner and patent characteristics. In: Research Policy, 37, pp. 932-945.

Blind, K.; Cremers, K.; Mueller, E. (2009): The influence of strategic patenting on company patent portfolios. In: Research Policy, 38, pp. 428-436.

Blind, K.; Edler, J.; Frietsch, R.; Schmoch, U. (2006): Motives to Patent: Evidence from Germany. In: Research Policy, 35 (5), pp. 655-672.

Blind, K.; Frietsch, R. (2006): Integration verschiedener Technologieindikatoren, Bundesministerium fuer Bildung und Forschung (BMBF) (ed.), Studien zum deutschen Innovationssystem Nr. 16-2006, Berlin: BMBF.

Breschi, S.; Lissoni, F. (2004): Knowledge networks from patent data. In: Glänzel, W.; Moed, H.; Schmoch, U. (eds.): Handbook of Quantitative Science and Technology Research. The Use of Publication and Patent Statistics in Studies on R&D Systems. Dordrecht/Norwell/New York/London: Kluwer Academic Publishers, pp. 613-643.

Carpenter, M.P.; Narin, F.; Woolf, P. (1981): Citation rates to technologically important patents. In: World Patent Information, 3 (4), pp. 160-163.

Ceccagnoli, M. (2009): Appropriability, pre-emption, and firm performance. In: Strategic Management Journal, 30, pp. 81-98.

Chandy, R.K.; Tellis, G.J. (2000): The incumbent's curse? Incumbency, size, and radical product innovation. In: Journal of Marketing, 64(3), pp. 1-17.

Christensen, C.M.; Rosenbloom, R.S. (1995): Explaining the attacker's advantage: Technological paradigms, organizational dynamics, and the value network. In: Research Policy, 24(2), pp. 233-257.

Cockburn, I.M.; MacGarvie, M.J. (2009): Patents, thickets and the financing of early-stage firms: Evidence from the software industry. In: Journal of Economics and Management Strategy, 18 (3), pp. 729-773.

Cohen, W.M.; Levinthal, D. (1990): Absorptive Capacity: A new perspective on learning and innovation. In: Administration Science Quarterly, 35, pp. 128-152.

Cohen, W.; Nelson, R.R.; Walsh, J.P. (2002a): Links and Impacts: The influence of Public Research on Industrial R&D. In: Management Science, 48, pp. 1-23.

Cohen, W.M.; Goto, A.; Nagata, A.; Nelson, R.R.; Walsh, J.P. (2002b): R&D spillovers, patents and the incentives to innovate in Japan and the United States. In: Research Policy, 31, pp. 1349-1367.

Cohen, W.M.; Nelson, R.; Walsh, J. (2000): Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or not), NBER No. 7552.

Colyvas, J.; Crow, M.; Gelijns, A.; Mazzoleni, R.; Nelson, R.R.; Rosenberg, N.; Sampat, B.N. (2002): How Do University Inventions Get into Practice? In: Management Science, 48(1), pp. 61-72.

Davison, A.C.; Hinkley, D.V. (1997): Bootstrap Methods and their Application, Cambridge: Cambridge University Press.

de Rassenfosse, G.; Guellec, D. Quality versus quantity: strategic interaction and the patent inflation Brussels: Universite Libre de Bruxelles.

Deardorff, A.V. (1985): Testing Trade Theories and Predicting Trade Flows. In: Jones, R.W.; Kenen, P.B. (eds.): Handbook of International Economics. Elsevier Science Publishers, pp. 467-517.

Dernis, H.; Kahn, M. (2004): Triadic Patent Families Methodology, STI Working Paper 2004/2, Paris: OECD.

Döhrn, R.; Edler, J. (2002): Internationales Wissensmanagement multinationaler Unternehmen, RWI; Fraunhofer-ISI (eds.), Essen/Karlsruhe.

Dosi, G. (1988): The nature of the innovation process. In: Dosi, G. et al. (ed.): Technical change and economic theory. London: Pinter, pp. 221-238.

Dosi, G.; Soete, L. (1983): Technology Gaps and Cost-Based Adjustment: Some Explorations on the Determinants of International Competitiveness. In: Metroeconomica, 35 (3), pp. 197-222.

Dosi, G.; Pavitt, K.; Soete, L. (1990): The Economics of Technical Change and International Trade, New York: Harvester Wheatsheaf.

Dosi, G.; Soete, L. (1991): Technical Change and International Trade. In: Dosi, G.; Freeman, C.; Nelson, R.; Silverberg, G.; Soete, L. (eds.): Technical Change and Economic Theory. London: Pinter Publishers, pp. 401-431.

Durand, T. (1992): Dual technological trees: Assessing the intensity and strategic significance of technological change. In: Research Policy, 21 (4), pp. 361-380.

Edler, J.; Döhrn, R.; Rothgang, M. (2003): Internationalisierung industrieller Forschung und grenzüberschreitendes Wissensmanagement – Eine empirische Analyse aus der Perspektive des Standortes Deutschland, Heidelberg: Physica.

Edquist, C.; McKelvey, M. (2000): Systems of Innovation. Growth, Competitiveness and Employment, Northampton, MA: Edward Elgar.

EPO; JPO; USPTO (2006): Trilateral Statistical Report - Edition 2005, Munich; Tokyo; Alexandria, VA: EPO; JPO; USPTO.

Etzkowitz, H.; Leydesdorff, L. (2000): The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. In: Research Policy, 29 (2), pp. 109-123.

Fagerberg, J. (1996): Competitiveness, scale and R&D, NUPI working paper No. 545.

Feldman, M.P.; Kelley, M.R. (2006): The ex ante Assessment of Knowledge Spill-overs: Government R&D Policy, Economic Incentives and Private Firm Behavior. In: Research Policy, 35, pp. 1509-1521.

Foster, R. (1986): Innovation: The Attacker's Advantage, New York: Summit Books.

Freeman, C. (1982): The Economics of Industrial Innovation, London: Pinter Publishers.

Frietsch, R. (2006): Micro data for macro effects. In: Hingley, P.; Nicolas, M. (eds.): Forecasting Innovations. Methods for Predicting Numbers of Patent Filings. Berlin: Springer.

Frietsch, R.; Jung, T. (2009): Transnational Patents - Structures, Trends and Recent Developments, Expertenkommission Forschung und Innovation (EFI) (ed.), Studien zum deutschen Innovationssystem Nr. 7-2009, Berlin.

Frietsch, R.; Köhler, F.; Blind, K. (2008): Weltmarktpatente - Strukturen und deren Veränderung, Expertenkommission Forschung und Innovation (EFI) (ed.), Studien zum deutschen Innovationssystem Nr. 7-2008, Berlin.

Frietsch, R.; Schmoch, U. (2006): Technological Structures and Performance Reflected by Patent Indicators. In: Schmoch, U.; Rammer, C.; Legler, H. (eds.): National Systems of Innovation in Comparison. Structure and Performance Indicators for Knowledge Societies. Dordrecht: Springer.

Frietsch, R.; Schmoch, U. (2009): Transnational Patents and International Markets. In: Scientometrics (forthcoming).

Frietsch, R.; Schmoch, U. (2010): Transnational Patents and International Markets. In: Scientometrics, 82, pp. 185-200.

Gambardella, A.; Giuri, P.; Luzzi, A. (2007): The market for patents in Europe. In: Research Policy, 36 (8), pp. 1163-1183.

Gambardella, A.; Harhoff, D.; Verspagen, B. (2008): The Value of European Patents. In: European Management Review, 5 (2), pp. 69-84.

Gehrke, B.; Krawczyk, O.; Legler, H. (2007): Forschungs- und wissensintensive Wirtschaftszweige in Deutschland: Außenhandel, Spezialisierung, Beschäftigung und Qualifikationserfordernisse, Bundesministerium fuer Bildung und Forschung (BMBF) (ed.), Studien zum deutschen Innovationssystem Nr. 17-2007, Berlin.

Gibbons, M.; Limoges, C.; Nowotny, H.; Schwartzman, S.; Scott, P.; Trow, M. (1994): The New Production of Knowledge. The Dynamics of Science and Research in Contemporary Societies, London: Sage.

Gibbons, M.; Littler, D. (1979): The development of an innovation: the case of porvair. In: Research Policy, 8(1), pp. 2-25.

Giuri, P.; Mariani, M.; Brusoni, S.; Crespi, G.; Francoz, D.; Gambardella, A.; Garcia-Fontes, W.; Geuna, A.; Gonzales, R.; Harhoff, D.; Hoisl, K.; Le Bas, C.; Luzzi, A.; Magazzini, L.; Nesta, L.; Nomaler, O.; Palomeras, N.; Patel, P.; Romanelli, M.; Verspagen, B. (2007): Inventors and invention processes in Europe: Results from the PatVal-EU survey. In: Research Policy, 36 (8), pp. 1107-1127.

Greenhalgh, C. (1990): Innovation and Trade Performance in the UK. In: Economic Journal, 100, pp. 105-118.

Greenhalgh, C.; Taylor, P.; Wilson, R. (1994): Innovation and Export Volumes and Prices - A Disaggregated Study. In: Oxford Economic Papers, 46, pp. 102-134.

Griliches, Z. (1992): The Search for R&D Spillovers. In: Scandinavian Journal of Economics, 94 (S29), p. 19.

Grimpe, C.; Hussinger, K. (2008): Building and Blocking: The Two Faces of Technology Acquisition, Discussion Papaer No. 08-042.

Grindley, P.; Teece, D.J. (1997): Managing intellectual capital: licensing and cross-licensing in semiconductors and electronic. In: California Management Review, 39, pp. 1-34.

Grönqvist, C. (2009): The private value of patents by patent characteristics: Evidence from Finland. In: Journal of Technology Transfer, 34 (2), pp. 159-168.

Grupp, H. (1996): Spillover Effects and the Science Base of Innovations Reconsidered: an Empirical Approach. In: Journal of Evolutionary Economics, 6, pp. 175-197.

Grupp, H. (1997): Messung und Erklärung des technischen Wandels: Grundzüge einer empirischen Innovationsökonomik, Berlin, Heidelberg: Springer-Verlag GmbH.

Grupp, H. (1998): Foundations of the Economics of Innovation - Theory, Measurement and Practice, Cheltenham: Edward Elgar.

Grupp, H.; Legler, H.; Jungmittag, A.; Schmoch, U. (2000): Hochtechnologie 2000. Neudefinition der Hochtechnologie für die Berichterstattung zur technologischen Leistungsfähigkeit Deutschlands, Karlsruhe/Hannover: Fraunhofer ISI.

Grupp, H.; Münt, G.; Schmoch, U. (1996): Assessing Different Types of Patent Data for Describing High-Technology Export Performance. In: OECD (ed.): Innovation, Patents and Technological Strategies: Proceedings of a Workshop held at OECD Headquarters in Paris, 8-9 December 1994. Paris: OECD, pp. 271-287.

Guellec, D.; van Pottelsberghe de la Potterie, B. (2000): Applications, grants and the value of patents. In: Economic Letters, 69(1), pp. 109-114.

Guellec, D.; van Pottelsberghe de la Potterie, B. (2001): The internationalisation of technology analysed with patent data. In: Research Policy, 30, pp. 1253-1266.

Hagedoorn, J.; Cloodt, M. (2003): Measuring innovative performance: is there an advantage in using multiple indicators? In: Research Policy, 32 (8), pp. 1365-1379.

Hagedoorn, J.; van Kranenburg, H.; Osborn, R.N. (2003): Joint Patenting Amongst Companies - Exploring the Effects of Inter-Firm R&D Partnering and Experience. In: Managerial and Decision Economics, 24, pp. 71-84.

Hall, B.H.; Jaffe, A.; Trajtenberg, M. (2005): Market value and patent citations. In: The Rand Journal of Economics, 36 (1), pp. 16-38.

Hall, B.H.; Thoma, G.; Torrisi, S. (2006): The market value of patents and R&D: Evidence from European firms, Cespri Working Papers No. 186.

Hall, B.H.; Ham, R.M. (1999): The patent paradox revisited: determinants of patenting in the U.S. semiconductor industry, 1980 - 1994. In: NBER Working Paper, 7062.

Hall, B.H.; Ziedonis, R.M. (2001): The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry, 1979 - 1995. In: The Rand Journal of Economics, 32 (1), pp. 101-128.

Harabi, N. (1995): Appropriability of technical innovations: An empirical analysis. In: Research Policy, 24, pp. 981-992.

Harhoff, D. (2009): Stock Market Reactions to Oppositions in Biotechnology and Pharmaceuticals, Patent Statistics for Decision-Makers, EPO conference, Vienna.

Harhoff, D.; Narin, F.; Scherer, F.M.; Vopel, K. (1999): Citation frequency and the value of patented inventions. In: Review of Economics and Statistics, 81 (3), pp. 511-515.

Harhoff, D.; Reitzig, M. (2004): Determinants of opposition against EPO patent grants - The case of biotechnology and pharmaceuticals. In: International Journal of Industrial Organization, 22 (4), pp. 443-480.

Harhoff, D.; Scherer, F.M.; Vopel, K. (2003): Citations, family size, opposition and the value of patent rights. In: Research Policy, 32 (8), pp. 1343-1363.

Heller, M.A.; Eisenberg, R.S. (1998): Can Patents Deter Innovation? The Anticommons in Biomedical Research. In: Science, 280 (5364), pp. 698-701.

Henderson, R.M.; Clark, K.B. (1990): Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. In: Administrative Science Quarterly, 35 (1), p. 9.

Hicks, D.; Narin, F. (2000): Strategic Research Alliances and 360 Degree Bibliometric Indicators. Strategic Research Partnerships, Strategic Research Partnerships: Proceedings from an NSF Workshop.

Hingley, P.; Bas, S. (2009): Numbers and sizes of applicants at the European Patent Office. In: World Patent Information, 31, pp. 285-298.

Hong, W.; Walsh, J.P. (2009): For Money or Glory? Commercialization, Competition, and Secrecy in Entrepreneurial University. In: The Sociological Quarterly, 50, pp. 145-171.

Hounshell, D.; Smith, J.K.Jr. (1988): Science and Corporate Strategy: Du Pont R&D, 1902-1980, New York, NY: Cambridge University Press.

Jaffe, A.; Fogarty, M.S.; Banks, B.A. (1998): Evidence from patents and patent citations on the Impact of Nasa and other Federal labs on commercial Innovation. In: The Journal of Industrial Economics, 46(2), p. 183^-205.

Jaffe, A.; Lerner, J. (2004): Innovation and Its Discontents, Princeton: Princeton University.

Jaffe, A.; Trajtenberg, M.; Henderson, R. (1993): Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. In: The Quarterly Journal of Economics, 108 (3), pp. 577-598.

Jaffe, A.B. (1986): Technological Opportunity and Spillovers of R&D: Evidence from Firm's Patents, Profits, and Market Value. In: American Economic Review, 76 (5), pp. 984-1001.

Jaffe, A.B.; Trajtenberg, M.; Fogarty, M.S. (2000): Knowledge Spillovers and Patent Citations: Evidence from a Survey of Inventors. In: American Economic Review, 2000(90), p. 2.

Jaffe, A.B. (2000): The U.S. patent system in transition: policy innovation and the innovation process. In: Research Policy, 29, pp. 531-557.

Janz, N.; Licht, G.; Doherr, T. (2001): Innovation Activities and European Patenting of German Firms: A Panel Data Analysis, Paper presented at the Annual Conference of the European Association of Research in Industrial Economics.

Jung, T. (2009): Use and Non-use of Patented Inventions, Atlanta: Georgia Institute of Technology.

Kleinknecht, A.; Oostendorp, R. (2002): R&D and Export Performance: Taking Account of Simultaneity. In: Kleinknecht, A.; Mohnen, P. (eds.): Innovation and Firm Performance. New York, pp. 310-320.

Koléda, G. (2005): The value of french patent protection assessed by renewals | [La valeur de la protection des brevets français appré ciée par leurs renouvellements]. In: Economie et Prevision, 168 (2), pp. 97-114.

Kortum, S.; Lerner, J. (1997): Stronger Protection or Technological Revolution: What is behind the Recent Surge in Patenting, National Bureau of Economic Research Working Paper 6204, Cambridge, MA.

Kortum, S.; Lerner, J. (1999): What is behind the recent surge in patenting? In: Research Policy, 28, pp. 1-22.

Krawczyk, O.; Legler, H.; Schadt, C.; Frietsch, R.; Schubert, T.; Schumacher, D. (2007): Die Bedeutung von Aufhol-Ländern im globalen Technologiewettbewerb, Studien zum deutschen Innovationssystem No. 21-2007, Berlin: Bundesministerium für Bildung und Forschung (BMBF).

Krugman, P. (1979): A Model of Innovation, Technology Transfer, and the World Distribution of Income. In: Journal of Political Economy, 87 (2), pp. 253-266.

Lachenmaier, S.; Wößmann, L. (2006): Does innovation cause exports? Evidence from exogenous innovation impulses and obstacles using German micro data. In: Oxford Economic Papers, 58, pp. 317-350.

Lanjouw, J.O.; Pakes, A.; Putnam, J. (1998): How to count patents and value intellectual property: the use of patent renewal and application data. In: Journal of Industrial Economics, 46, pp. 405-432.

Lanjouw, J.O.; Schankerman, M. (1997): Stylized facts of patent litigation: Value, scope, ownership, NBER Working Paper No. 6297, Cambridge, MA: National Bureau of Economic Research.

Lanjouw, J.O.; Schankerman, M. (2001): Charasteristics of patent litigation: A window on competition. In: Rand Journal of Economics, 25 (2), pp. 319-333.

Lanjouw, J.O.; Schankermann, M. (2004): Patent Quality and Research Productivity: Measuring Innovation with Multiple Indicators. In: The Economic Journal, 114, pp. 441-465.

Legler, H.; Grupp, H.; Gehrke, B.; Schasse, U. (1992): Innovationspotential und Hochtechnologie. Technologische Wettbewerbsposition Deutschlands im Internationen Wettbewerb, Heidelberg: Physica.

Legler, H.; Frietsch, R. (2007): Neuabgrenzung der Wissenswirtschaft - forschungsintensive Industrien und wissensintensive Dienstleistungen, Bundesministerium fuer Bildung und Forschung (BMBF) (ed.), Studien zum deutschen Innovationssystem No. 22-2007, Berlin.

Legler, H.; Krawczyk, O. (2006): The Global Distribution of R&D Activities. In: Schmoch, U.; Rammer, C.; Legler, H. (eds.): National Systems of Innovation in Comparison. Structure and Performance Indicators for Knowledge Societies. Dordrecht: Springer, pp. 31-45.

Lemley, M.A.; Tangri, R.K. (2003): Ending Patent Law's Willfulness Game. In: Berkeley Technology Law Journal, 18, p. 1085.

Leontief, W. (1953): Domestic Production and Foreign Trade; The American Capital Position Re-Examined. In: Proceedings of the American Philosophical Society, 97 (4), pp. 332-349.

Lerner, J. (1994): The importance of patent scope: An empirical analysis. In: Rand Journal of Economics, 25(2), pp. 319-333.

Levinthal, D.A.; March, J.G. (1993): The Myopia of Learning. In: Strategic Management Journal, 14(2), pp. 95-112.

Lundvall, B.-A.; Foray, D. (1996): The Knowledge-Based Economy. In: OECD (ed.): Employment and growth in the knowledge-based economy. Paris.

Madsen, J.B. (2007): Innovations and manufacturing export performance in the OECD countries, Oxford Economic Papers Oxford University Press.

Malecki, E. (1991): Technology and Economic Development. The Dynamics of Local, Regional and National Change, Harlow, Essex: Longman.

March, J.G. (1991): Exploration and Explitation in Organizational Learning. In: Organization Science, 2, pp. 71-87.

Maskus, K.E.; Penubarti, M. (1995): How trade-related are intellectual property rights? In: Journal of International Economics, 39 (3-4), pp. 227-248.

Mattsson, P.; Laget, P.; Nilsson, A.; Sundberg, C.-J. (2008): Intra-EU vs. Extra-EU scientific co-publication patterns in EU. In: Scientometrics, 75, pp. 555-574.

Maurseth, P.B.; Verspagen, B. (2002): Knowledge Spillovers in Europe: A Patent Citation Analysis. In: The Scandinavian Journal of Economics, 104(4), pp. 531-545.

Merges, R.P. (1994): Intellectual Property Rights and Bagaining Breakdown: The Case of Blocking Patents. In: Tennessee Law Review, 62, pp. 75-106.

Merges, R.P. (1999): Many as six impossible patents before breakfast: Property rights for business concepts and patent system reform. In: Berkeley Technology Law Journal, 14, pp. 577-616.

Meyer, M. (1999): Does science push technology? Patents citing scientific literature. In: Research Policy, 29, pp. 409-434.

Meyer, M. (2000): What is Special about Patent Citations? Differences between Scientific and Patent Citations. In: Scientometrics, 49(1), pp. 93-123.

Michel, J.; Bettels, B. (2001): Patent Citation analysis. A closer look at the basic input data from patent search reports. In: Scientometrics, 51(1), pp. 185-201.

Motohashi, K. (2008): Licensing or not licensing": An empirical analysis of the strategic use of patents by Japanese firms. In: Research Policy, 37, pp. 1548-1555.

Münt, G. (1996): Dynamik von Innovation und Außenhandel. Entwicklung technologischer und wirtschasftlicher Spezialisierungsmuster, Heidelberg: Physica-Verlag.

Nagaoka, S.; Walsh, J. (2009): Commercialization and Other Uses of Patents in Japan and the U.S.: Major findings from the RIETI-Georgia Tech inventor survey, Discussion papers 09011 Research Institute of Economy, Trade and Industry (RIETI).

Nagaoka, S.; Kwon, H.U. (2006): The incidence of cross-licensing: A theory and new evidence on the firm and contract level determinants. In: Research Policy, 35, pp. 1347-1361.

Narin, F.; Noma, E. (1987): Patents as indicators of corporate technological strength. In: Research Policy, 16 (2-4), pp. 143-155.

Nelson, A.J. (2009): Measuring Knowledge Spillovers: What Patents, Licenses and Publications Reveal about Innovation Diffusion. In: Research Policy, 38, pp. 994-1005.

Nelson, R.R.; Romer, P.M. (1996): Science, Economic Growth, and Public Policy. In: Smith, B.L.R.; Barfield, C.E. (eds.): Technology, R&D, and the Economy. Washington DC: The Brookings Institution.

Nelson, R.R.; Winter, S.G. (1982): An Evolutionary Theory of Economic Change, Cambridge: Harvard University Press.

Nerkar, A.; Roberts, P.W. (2004): Technological and product-market experience and teh success of new product introductions in the phamaceutical industry. In: Strategic Management Journal, 25 (8-9), pp. 779-799.

Nesta, L.; Patel, P. (2004): National Patterns of Technology Accumulation: Use of Patent Statistics. In: Moed, H.F.; Glänzel, W.; Schmoch, U. (eds.): Handbook of Quantitative Science and Technology Research. The Use of Publication and Patent Statistics in Studies of S&T Systems. Dordrecht: Kluwer Academic Publisher, pp. 531-551.

Neuhäusler, P. (2009): Formal vs. informal protection instruments and the strategic use of patents in an Expected-Utility framework, Innovation Systems and Policy Analysis No. 20, Karlsruhe: Fraunhofer ISI.

Noel, M.; Schankerman, M. (2006): Strategic Patenting and Software Innovation, 5701, Discussion Paper Series, London: Centre for Economic Policy Research.

OECD (ed.) (2004): Compendium of Patent Statistics 2004. Paris: OECD.

Patel, P.; Frietsch, R. (2007): Exploratory study to test the fesibility of using patent data for monitoring globalization of R&D- Report to IPTS by the ERAWATCH Networks ASBL, within Framework Service Contract No. 150176-2005-FISC-BE, Brighton and Karlsruhe: SPRU, University of Sussex, and Fraunhofer-ISI.

Pavitt, K.L.R. (1983): Sectional Patterns of Technical Change: Towards a Taxonomy and a Theory. In: Research Policy, 13, pp. 343-373.

Polanyi, M. (1967): The Tacit Dimension, New York: Anchor Books.

Porter, M.E. (1998): The Competitive Adavantage of Nations, 2. Auflage, New York.

Posner, M.V. (1961): International Trade and Technical Change. In: Oxford Economic Papers, 13 (3), pp. 323-341.

Powell, W.W.; Owen-Smith, J. (1998): Universities and the Market for Intellectual Property in the Life Sciences. In: Journal of Policy Analysis and Management, 17(2), pp. 253-77.

Putnam, J. (1996): The value of international patent rights, Yale: Yale University.

Reinganum, J.F. (1989): The Timing of Innovation: Research Development and Diffusion. In: Schmalensee, R.; Willig, R.D. (eds.): Handbook of Industrial Organization. North Holland, Amsterdam, pp. 849-908.

Reitzig, M. (2004): The Private Values of 'Thickets' and 'Fences': Towards an updated Picture of the use of Patents across Industries. In: Economics of Innovation and New Technology, 13 (5), pp. 457-476.

Reitzig, M.; Henkel, J.; Heath, C. (2007): On sharks, trolls, and their patent prey—Unrealistic damage awards and firms' strategies of "being infringed". In: Research Policy, 36, pp. 134-154.

Rivette, K.G.; Kline, D. (2000): Discovering New Value in Intellectual Porperty. In: Harvard Buisness Review, pp. 1-12.

Rothaermel, F.T.; Deeds, D.L. (2004): Exploration and Exploitation Alliances in Biotechnology: A System of New Product Development. In: Strategic Management Journal, 25, pp. 201-221.

Sahal, D. (1985): Technological Guideposts and Innovation Avenues. In: Research Policy, 14, pp. 61-82.

Sampat, B.N.; Ziedonis, A. (2004): Patent Citations and the Economic Value of Patents. In: Moed, H.F.; Glänzel, W.; Schmoch, U. (eds.): Handbook of Quantitative Sciense and Technology Research. pp. 277-300.

Saunders, K.M. (2002): Patent Nonuse and the Role of Public Interest as a Deterrent to Technology Suppression. In: Harvard Journal of Law & Technology, 15 (2), pp. 390-452.

Schankerman, M.; Pakes, A. (1986): Estimates of the value of patent rights in European countries during the post-1950 period. In: Economic Journal, 97, pp. 1-25.

Schankerman, M. (1998): How valuable is patent protection? Estimates by technology field. In: Journal of Economics, 29 (1), pp. 77-107.

Schmoch, U. (1999): Impact of International Patent Applications on Patent Indicators. In: Research Evaluation, 8 (2), pp. 119-131.

Schmoch, U. (2007): Leistungsfähigkeit und Strukturen der Wissenschaft im internationalen Vergleich, Bundesministerium fuer Bildung und Forschung (BMBF) (ed.), Studien zum deutschen Innovationssystem Nr. 11-2007, Berlin.

Schmoch, U. (2009): Patent analyses in the changed legal regime of the US Patent Law since 2001. In: World Patent Information, In Press, Available online 21 January 2009.

Schmoch, U.; Grupp, H.; Mannsbart, W.; Schwitalla, B. (1988): Technikprognosen mit Patentindikatoren, Köln.

Schmoch, U.; Schubert, T. (2008): Are international Co-Publications an Indicator for Quality of Scientific Research? In: Scientometrics, 74 (361), p. 377.

Schumpeter, J. (1908): On the Concept of Social Value. In: Quarterly Journal of Economics, 23, pp. 213-232.

Shapiro, C. (2000): Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard-Setting. In: Jaffe, A.; Lerner, J.; Stern, S. (eds.): Innovation Policy and the Economy. Cambridge: MIT Press, pp. 119-150.

Sheehan, J.; Martinez, C.; Guellec, D. (2003): Understanding business patenting and licensing: Results of a survey, I.a.E.P. (ed.), OECD Conference on Intellectual Rights, Paris: OECD.

Slaughter, S.; Leslie, L.L. (1997): Academic Capitalism, Baltimore, MD: Johns Hopkins University Press.

Slaughter, S.; Rhodes, G. (1996): The Emergence of a Competitiveness Research and Development Policy Coalition and the Commercialization of Academic Science and Technology Science. In: Technology and Human Values, 21, pp. 303-39.

Soete, L. (1981): A general test of technological gap trade theory. In: Weltwirtschaftliches Archiv, 117 (4), pp. 638-660.

Soete, L. (1987): The impact of technological innovation on international trade patterns: The evidence reconsidered. In: Research Policy, 16, pp. 101-130.

Soete, L.G.; Wyatt, S.M.E. (1983): The Use of foreign patenting as an internationally comparable science and technology output indicator. In: Scientometrics, 5, pp. 31-54.

Stevens, G.A.; Burley, J. (1997): 3000 Raw Ideas = 1 Commercial Success. In: Research Technology Management, 40 (3), pp. 16-27.

Stevnsborg, N.; van Pottelsberghe de la Potterie, B. (2007): Patenting procedures and filing strategies. In: Guellec, D.; van Pottelsberghe de la Potterie, B. (eds.): The Economics of the European Patent System. Oxford: Oxford University Press, pp. 155-183.

Stocks, D.E. (1997): Pasteur's Quadrant, Washington, DC: Brookings Institution Press.

Thompson, P.; Fox-Kean, M. (2005): Patent Citations and the Geography of Knowledge Spillovers: A Reassessment. In: American Economic Review, 95(1), pp. 450-460.

Thumm, N. (2004): Strategic patenting in biotechnology. In: Technology Analysis and Strategic Management, 16, pp. 529-538.

Thursby, J.G.; Jensen, R.; Thursby, M. (2001): Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major U.S. Universities. In: The Journal of Technology Transfer, 26, p. 59 (1)-72.

Thursby, J.G.; Thursby, M.C. (2002): Who Is Selling the Ivory Tower? Sources of Growth in University Licensing. In: Management Science, 48 (1), pp. 90-104.

Tong, X.; Frame, J.D. (1992): Measuring national technological performance with patent claims data. In: Research Policy, 23, pp. 133-141.

Trajtenberg, M. (1990): A penny for your quotes: patent citations and the value of innovation. In: Rand Journal of Economics, 21 (1), pp. 172-187.

Tsoukas, H. (2003): Do we really understand tacit knowledge? In: Easterby-Smith, M.; Lyles, M.A. (eds.): The Blackwell handbook of organizational learning and knowledge management. Cambridge, MA: Blackwell Publishing, pp. 411-427.

Turner, J.S. (1998): The Nonmanufacturing Patent Owner: Toward a Theory of Efficient Infringement. In: California Law Review, 86 (179), pp. 179-210.

Tushman, M.L.; Anderson, P. (1986): Technological Discontinuities and Organizational Viroments. In: Administrative Science Quaterly.

UNCTAD (ed.) (2005): World Investment Report 2005: Transnational Companies and the Internationalisation of R&D. Geneva: UNCTAD.

Utterback, J.M.; Abernathy, W.J. (1975): A dynamic model of process and product innovations. In: Omega, 3 (6), pp. 639-655.

van der Drift, J. (1989): Statistics of European patents on legal status and granting data. In: World Patent Information, 11, pp. 243-249.

Van Hulst, N.; Mulder, R.; Soete, L.L.G. (1991): Exports and Technology in Manufacturing Industry. In: Weltwirtschaftliches Archiv, 127 (2), pp. 246-264.

van Pottelsberghe de la Potterie, B.; van Zeebroeck, N. (2008): A brief history of space and time: The scope-year index as a patent value indicator based on families and renewals. In: Scientometrics, 75 (2), pp. 319-338.

Van Zeebroeck, N.; Stevnsborg, N.; Van Pottelsberghe De La Potterie, B.; Guellec, D.; Archontopoulos, E. (2008): Patent Inflation in Europe. In: World Patent Information, 30, pp. 43-52.

van Zeebroeck, N. (2008): The Puzzle of Patent Value Indicators, CEB Working Paper.

van Zeebroeck, N.; van Pottelsberghe de la Potterie, B. (2007): Claiming more: the increased voluminosity of patent applications and its determinants, Solvay Business School, Centre Emile Bernheim (CEB), Brussels: Université Libre de Bruxelles.

Vernon, R. (1966): International Investment and International Trade in the Product Cycle. In: Quarterly Journal of Economics, 80 (2), pp. 190-207.

Vernon, R. (1979): The Product Cycle Hypothesis in a New International Environment. In: Oxford Bulletin of Economics & Statistics, 41 (4), pp. 255-267.

Wakelin, K. (1997): Trade and Innovation. Theory and Evidence, Cheltenham.

Wakelin, K. (1998a): Innovation and export behaviour at the firm level. In: Research Policy, 26, pp. 829-841.

Wakelin, K. (1998b): The role of innovation in bilateral OECD trade performance. In: Applied Economics, 30, pp. 1335-1346.

Walsh, J.; Arora, A.; Cohen, W.M. (2003): Working through the patent problem. In: Science, 299, p. 1020.

Winter, S. (1987): Knowledge and Competence as Strategic Assets. In: Teece, D. (ed.): The Competitive Challenge: Strategies for Industrial Innovation and Renewal. Cambridge, MA: Ballinger.

WIPO (2009): WIPO Patent Report 2009 - Statistics on Worldwide Patent Activities, Geneva: WIPO.

Ziedonis, R.H. (2004): Don't Fence Me In: Fragmented Markets for Technology and the Patent Acquisition Strategies of Firms. In: Management Science, 50, pp. 804-820.