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Citations, family size, opposition and the value of patent rights

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**Abstract**

We combine estimates of the value of patent rights from a survey of patent-holders with a set of indicator variables in order to model the value of patents. Our results suggest that the number of references to the patent literature as well as the citations a patent receives are positively related to its value. References to the non-patent literature are informative about the value of pharmaceutical and chemical patents, but not in other technical fields. Patents which are upheld in opposition and annulment procedures and patents representing large international patent families are particularly valuable.

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*Keywords:* Patent rights; Patent-holders; Indicator variables

process[2](#_bookmark6) (such as output, information spillovers, the direction of research activities, etc.) have attracted the attention of researchers.[3](#_bookmark7) In the public policy de- bate, many government agencies regularly interpret the number of patents or patent applications held by domestic firms and individual inventors as a measure of their nation’s technological prowess. It is generally accepted by now that patent counts themselves do not constitute a good measure of inventive output. But the na¨ıve use of patent statistics is continuing due to a lack of practical alternatives. A theoretically ap- pealing solution would be to weight patents by their importance or value, thus generating value-weighted patent counts. Having a reliable construction of this type would be of considerable value for research in a

**1. Introduction**

For some decades, patents and patent statistics have been under intensive scrutiny by economists and policy-makers alike. In academic studies, both the prospect of studying incentive effects associated with the patent system[1](#_bookmark5) as well as the possibility of using patents to analyze particular aspects of the innovation

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1 It is more appropriate to speak of patent systems, since national differences do persist. Patent rights are always subject to national jurisdiction and legislation, and even a patent obtained through the European Patent Office for Germany is a patent according to German patent law. The relatively high degree of homogeneity of European patent rights is a consequence of reasonably harmonized national patent laws.

2 See, e.g. Trajtenberg et al. (1993) and [Jaffe and Trajtenberg](#_bookmark57) [(1996).](#_bookmark57)

3 See [Griliches (1990)](#_bookmark58) for a comprehensive survey about the use

of patents as economic indicators.

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1344

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

number of areas, among them productivity studies and the analysis of the industrial organization of techno- logically advanced sectors and firms. How one could generate an assessment of the value of patent rights from publicly available data is the central question of this paper.

The task of assessing the value of patent rights is a particularly difficult one, since the distribution of these values is highly skew. The skewness property has been discussed by numerous authors, e.g. [Scherer](#_bookmark61) [(1965),](#_bookmark61) [Pakes and Schankerman (1984),](#_bookmark77) [Pakes (1986),](#_bookmark76) and [Griliches, 1990.](#_bookmark58)[4](#_bookmark8) Summarizing the insights from several studies on this point, [Griliches (1990, p. 1702)](#_bookmark58) concludes: “These findings, especially the large amount of skewness in this distribution, lead to rather pessimistic implications for the use of patent counts as indicators of short-run changes in the output of R&D.” Any attempt to cast more light on the value of patent portfolios must therefore turn to additional in- formation which is correlated with the value of patent rights. Such correlates could conceivably be used to construct quality- or value-weighted patent counts which would measure inventive output with much greater accuracy than unweighted count statistics.

Using information contained in the renewal behav- ior of patent-holders has been one attempt to solve the problem described here. Studies in the patent renewal literature exploit the fact that it is expensive to holders of European patents to renew patent protection for an additional year.[5](#_bookmark9) The value measures obtained in this literature approximate the return to continued patent protection, given that the patent has already been published. [Pakes and Schankerman (1984)](#_bookmark77), [Pakes](#_bookmark76) [(1986),](#_bookmark76) and [Schankerman and Pakes (1986)](#_bookmark79) have been the first to develop and estimate models in which the observed renewal decisions are used to estimate the distribution of patent values. [Lanjouw (1998)](#_bookmark60) has refined this approach to the estimation of patent values. However, the results of these studies rest on assumptions regarding the unobserved value distribu- tion of the most valuable patents—those which are renewed to full statutory term.

Another strategy is to use a set of variables corre- lated with value and to estimate a regression function that can be used to approximate patent value and test hypotheses on its determinants. For example, [Lerner](#_bookmark62) [(1994)](#_bookmark62) uses the market value of biotechnology firms as a measure of the value of the respective patent port- folio. He relates the value measure to the number of international patent classifications (IPCs) referred to in the patent. He argues that this variable captures the scope of the patented invention and reports a posi- tive and sizable correlation between the firm’s market value and the average scope of its patents. [Trajtenberg](#_bookmark78) [(1990)](#_bookmark78) computes a measure of social returns to inno- vation in the computer-tomography scanner industry and relates that measure to citation indicators, finding a positive and significant correlation. [Putnam (1996)](#_bookmark80) points out that the number of jurisdictions in which patent protection is sought for a particular invention is likely to be correlated with the value of the invention and thus with the value of any single national patent right. A hope frequently expressed in the patent valu- ation literature is that the value of patent rights can be approximated with sufficient reliability by combining these and other indicators.

We follow this approach in the empirical part of our paper. We use a unique dataset with value assess- ments coming directly from a survey of patent-holders. These data allow us to circumvent the need for us- ing indirect measures of patent value. Moreover, since we observe the private value of patents in the hith- erto “unseen tail”[6 of](#_bookmark10) the value distribution, we also circumvent a major problem of the renewal literature. The value concept adopted in our study differs con- siderably from the one implied by previous patent re- newal studies. Failure to renew a patent means that the covered subject matter will move into the public domain, allowing it to be used by both the original patent-holder and others. In our survey, however, we measure the value of a patent right as the price for which the original inventor would be willing to sell the patent right. The sale of all rights in a patent to a third party implies that the buyer can prevent the original patent-holder from practicing the subject invention or demand license fees approaching the value of profits foregone. For broad patents that cover key features of products or processes—a case found in interviews to

6 [Griliches (1990, p. 1681).](#_bookmark58)

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detailed analysis of the data used in this paper strongly

supports the view that the patent value distribution is highly skew. See [Harhoff et al. (2003).](#_bookmark53)

5 Following the European examples, the US initiated a system

of renewal fees for patents that were applied for after 1980. See [Griliches (1990, p. 1681).](#_bookmark58)

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

1345

be common for the most valuable patents—the sale of rights puts at risk the whole stream of quasi-rents realizable from a product or process. Or at minimum, the sale of rights can impose upon the seller the profit sacrifice from foregoing key patented features or the cost of inventing around them. Therefore, higher val- uations are expected under our approach than under the renewal approach.

Using our survey estimates, we embark on a sys- tematic attempt to model patent right values in terms of observable correlates. We use a broad set of indi- cators to model the respective valuations, including

the number of citations a patent has received within

proach reflects this form of scaling. We use an ordered probit specification with known thresholds which al- lows us to obtain point estimates of the coefficients and of the variance of the error term of the condi- tional value distribution. Given the notorious problems in assessing the value of patent rights, our specifi- cations are surprisingly successful. Almost all of the above-mentioned correlates have explanatory power, and the size of the coefficients is well in line with a number of ex ante expectations. Our results sug- gest that both the number of backward citations (ei- ther to the patent or non-patent literature) as well as the citations a patent receives are positively re- lated to a patent’s value. The number of different four-digit IPC classifications is not informative about patent value. Patents which are upheld against opposi- tion and patents representing large international patent families are particularly valuable.

In the remainder of the paper, we first turn to the question of what we want to measure in our sur- vey of patent-holders. We consider various value con- structs and compare them. We then discuss in [Section 3](#_bookmark16) our survey of German patent-owners in which esti- mates for the monetary value of German patents were obtained.[7](#_bookmark12) These survey estimates will function as our dependent variables in the modeling exercise. In [Section 4,](#_bookmark22) we describe in more detail the right-hand side variables listed previously, and we discuss in de- tail the theoretical rationale for including them in our estimation equation, and in some cases our ex ante expectations as to the coefficient signs and sizes. In [Section 5,](#_bookmark28) we turn to our empirical results. We first discuss descriptive statistics of the value correlates and specify our regression function. A discussion of our multivariate results follows. Finally, in [Section 6,](#_bookmark43) we conclude with a summary of our results and a discus- sion of further research.

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the German patent system;

the analogous measure of citations received from subsequent applications in the European Patent Of- fice;

the number of references to prior patents, generated during the search and examination process;

and analogously, the number of references made to the non-patent literature, i.e. mostly to scientific journals.

These measures (also referred to as forward cita-

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tions for the first two and backward citations in the lat- ter cases) have been discussed intensively in the patent literature, but have not yet been included jointly in a study. We complement these indicators by using data on

the outcome of opposition proceedings, a kind of

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first-instance challenge suit attacking the patent’s validity;

patent “family size”, computed as the number of jurisdictions in which patent protection was sought for the same invention;

and the number of different four-digit IPC classifi- cations which has been taken to provide a measure of the scope of the patent.

The latter measure follows [Lerner’s (1994)](#_bookmark62) exam-

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**2. Theoretical issues in measuring the value of patent rights**

ple, while the “family size” variable has been proposed

by [Putnam (1996).](#_bookmark80) Our indicator generated from the outcome of opposition cases has not been used be- fore, and to the best of our knowledge, the opposition procedure has not been discussed in detail in the eco- nomics literature either.

Since our survey estimates of patent value were obtained using interval scales, our econometric ap-

Value constructs are not always precisely defined in the patent literature. In order to demonstrate the

7 Since our study focuses on data from the German patent system, a brief description of features unique to this German patent system is presented in [Appendix A.](#_bookmark47)

1346

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

Table 1

Value definitions

Cases

Definition A: “renewal value of the patent”

Definition B: “asset value of the patent” (*V*B)

(*V*A)

I. Standard case, no

*Π*1*(q* + *q*1*,q* + *(*1 − *λ)q*1*)* − *ΠN*+1*(q* + *q*1*)*

*Π*1*(q* + *q*1*,q* + *(*1 − *λ)q*1*)* − *ΠN (q* + *(*1 − *λ)q*1*,q* + *q*1*)*

cumulative invention, no blocking

1. Cumulative invention with blocking power
2. Substitute technology (sleeping patent)

*Π*1*(q* + *q*1 + *q*2*,q* + *(*1 − *λ)(q*1 + *q*2*))* −

*Π*1*(q* + *q*1 + *q*2*,q* + *(*1 − *λ)(q*1 + *q*2*))* −

*Π*1*(q* + *q*1 + *q*2*,q* + *q*1 + *(*1 − *λ)q*2*))*

*ΠN (q* + *(*1 − *λ)(q*1 + *q*2*), q* + *q*1 + *(*1 − *λ)q*2*)*

*Π*1*(q* + *q*1*,q* + *(*1 − *λ)q*1*)* − *ΠN*+1*(q* + *q*1*)*

*Π*1*(q* + *q*1*,q* + *(*1 − *λ)q*1*)* − *Π*2*(q* + *q*1*,q* + *(*1 − *λ)q*1*)*

importance of such a definition, it is helpful to con- sider various value constructs in the context of a sim- ple, yet fairly general theoretical model. We focus on the *private* value of patent rights and consider two concepts here: the value of renewed patent protection and the asset value of the patent right.[8](#_bookmark14) Since patents may serve different purposes, we compute these value measures for three scenarios of innovation which are likely to be relevant empirically. In the first scenario, the patent protects a quality improvement of a product, but there is no interaction between this particular and other patent rights. In the second scenario, we allow for such interactions as they occur in cumulative re- search processes. In such cases, control over one patent may affect the value of other patent rights as well, e.g. if the owner of one patent can block the use of an- other one. Finally, in the third scenario, we consider the case of multiple patents covering technologies that are perfect economic substitutes. We will comment on the empirical relevance of these cases later.

Ex ante, we consider a symmetric oligopoly with

For each of the three scenarios considered, we de- scribe the value definitions in terms of the profits that the patent-holder receives contingent on the quality of

its own and other firms’ products. Let *ΠN*+1*(a)* be the

profit (conceivably equal to zero) that each of the *N* +1

firms receive when their product quality is equal to *a*. If one firm has product quality *a* and all other firms have a lower product quality *b*, let the leading firm’s profit be given by *Π*1*(a, b)* and the profit of each of the *N* other firms by *ΠN (b, a)*. Note that by definition

*Π*1*(a, a)* = *ΠN (a, a)* = *ΠN*+1*(a)*. We assume further

that *Π*1*(a, b)* and *ΠN*+1*(a)* are monotonically increas-

ing in *a*; and that *Π*1*(a, b)* and *ΠN (b, a)* are monoton- ically decreasing in *b* and *a*, respectively. Finally, in one of our three scenarios, the case may arise that two firms own patents protecting different technologies, but yielding the same extent of product improvement. Let the profit of the two technology leaders then be

given by *Π*2*(a, b)*, and the profits of each of the *N* − 2

laggards be given by *ΠN*−1*(b, a)*, where *a > b* by as-

sumption. Based on these simple conventions, we can demonstrate important differences between the value concepts under consideration. We summarize the re- sults of our discussion in [Table 1.](#_bookmark13)

Consider the first innovation scenario (Case I) for which we assume that issues of cumulative research, patent blocking and “sleeping patents” are absent. Ex

*N* + 1 firms, all of which offer a product with qual-

ity *q*. Products may be differentiated horizontally. Ex post, one firm holds a patent on a technology which allows the firm to increase its product quality by *q*1. We allow patent protection to be less than perfect. Im- perfect patent protection implies that all other firms will be able to enjoy a costless improvement of their

ante, all firms have profits equal to *ΠN*+1*(q)*. Ex post,

own product quality by *(*1 − *λ)q*1 with *λ*

∈ [0*,* 1].

the patent-holding firm earns *Π*1*(q*+*q*1*,q*+*(*1−*λ)q*1*)*

Patent protection is perfect for *λ* = 1 and completely

while all other firms have profits equal to *ΠN (q* +*(*1 −

ineffective for *λ* = 0.

*λ)q*1*,q* + *q*1*)*. If the patent lapses into the public do-

main (i.e. if it is not renewed), then all firms will earn

8 A third value concept could be considered as well: the value of the patent right to a “stand-alone” inventor who compares her profit in the case of technical leadership to the profit gained in some ex ante state of the industry. Since this construct neglects strategic aspects completely, we do not include it here.

profits equal to *Π*

*(q* + *q )* ex post. If the patent

*N*+1

1

is sold by the original patent-holder to another firm

in the industry, then the inventor firm’s ex post profit is given by *ΠN (q* + *(*1 − *λ)q*1*,q* + *q*1*)*. From these

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

1347

terms, we can compute the respective values for the patented invention as summarized in [Table 1.](#_bookmark13) For the

not arise. Thus, in addition to the differences discussed in the first scenario, the renewal value concept will typically not capture the blocking value of patents as discussed here. Conversely, if the first patent is sold by the original patent-holder to another firm in the indus- try, then the second patent can no longer be used fully by the inventor. In this case, the inventor firm’s profit

case of a duopoly (*N* = 1), it is easy to verify from

these results that *V*B ≥ *V*A, i.e. that the asset value of

the patent dominates the renewal value. For increas- ing *N*, the same logic applies, although the difference between *V*B and *V*A is likely to decrease as *N* grows.

Note that as patent protection gets weaker (*λ* → 0),

is given by *ΠN (q*+*(*1−*λ)(q*1+*q*2*), q*+*q*1+*(*1−*λ)q*2*)*.

*V*B also converges to *V*A. The logic of this comparison is obvious: in the case of the renewal value, the coun- terfactual is a situation in which all firms have access to the patented technology. In the case of the asset value construct, technological leadership is transferred to another firm, imposing a much greater opportunity cost from the loss of the patent on the patent-holder than he perceives when all firms (including himself) get access to the technology.

Case II allows for cumulative invention processes and patent blocking in the following sense: we as- sume that the patent-holder has first obtained a patent protecting quality improvement *q*1, and then a sec- ond patent covering a further quality improvement *q*2. The second patent builds cumulatively on the first, and the second patented quality improvement can only be used fully by the firm also holding the first patent. In this stylized example, the holder of the first patent has blocking power over the second patent. Many ob- servers have argued that cumulative invention is an im- portant feature of advances in science and technology.[9](#_bookmark15) Again, both improvements are subject to spillovers due to imperfect patent protection. Ex ante, all firms

Again, it is easy to verify that *V*B ≥ *V*A. Moreover,

with weakening patent protection, we have again that

*V*B → *V*A.

In order to demonstrate that the ranking of val-

ues may be different under other circumstances, con-

sider Case III which allows for “sleeping patents,” i.e. patent rights that are never licensed or used in pro- duction by the patent-holder. Hence, there is no *di- rect* value that these patents have, say by generating above-average profits. Nonetheless, there may be a strategic advantage of owning the patent right, since such patents can possibly be used to exclude other firms from using technologies which are substitutes for the patent-holder’s own patented product or pro- cess. To clarify this point, suppose that one firm (the patent-holder) owns two patents protecting two differ- ent technologies leading to product improvements *q*1 and *q*2, respectively. Assume further that both patents are substitutes and that they cannot be used in conjunc- tion. Moreover, the patent rights can be exercised in- dependently, i.e. owning the first patent does not grant any blocking power over the second, and vice versa.

For simplicity, suppose that *q*1 = *q*2. In this case, the

have again profits equal to *ΠN*+1*(q)*. Ex post, the

patent-holder’s profit is given by *Π*1*(q* + *q*1*,q* + *(*1 −

patent-holding firm earns *Π*1*(q* + *q*1 + *q*2*,q* + *(*1 −

*λ)q*1*)*. If the first patent lapses into the public domain, the patent-holder and the other firms may be using different technologies, but the oligopolistic outcome

*λ)(q*1 + *q*2*))* while all other firms have profits equal

to *ΠN (q* + *(*1 − *λ)(q*1 + *q*2*), q* + *q*1 + *q*2*)*.

If the first patent lapses into the public domain,

is still symmetric. All firms will earn *ΠN*+1*(q* + *q*1*)*

but the second one does not, then the original patent-holder will still be able to make full use of the second invention. Hence, the patent-holder will earn

since control over the second patent does not allow the patent-owner to exclude other firms from using the substitute technology.

If the patent is sold to another firm, the situation is more complex: now we have two firms with access to different, but equally effective product improvements. The profit of each of the two leaders is now be given

profits equal to *Π*1*(q* + *q*1 + *q*2*,q* + *q*1 + *(*1 − *λ)q*2*))*

while all other firms will earn profits equal to

*ΠN (q* + *q*1 + *(*1 − *λ)q*2*,q* + *q*1 + *q*2*)*. Since the patent

lapses into the public domain, issues of blocking do

by *Π*2*(q* + *q*1*,q* + *(*1 − *λ)q*1*)*, while the other *N* − 2

firms earn *ΠN*−2*(q* + *(*1 − *λ)q*1*,q* + *q*1*)*. We would

9 For a discussion of blocking power in the semiconductor in- dustry see von Hippel (1982). The recent surge of patenting in that industry has been analyzed by [Hall and Ziedonis (2001)](#_bookmark60) who argue that the potential of blocking forces firms to patent excessively.

expect that without collusion among the two leading firms, a single patent-owner will earn higher profits than any of the two firms simultaneously producing the

1348

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

high-quality product. Thus, *Π*1*(q*+*q*1*, q*+*(*1−*λ)q*1*) >*

tures. It is therefore also a reasonable reflection of the incentives implicit in a competitive innovation process.

*Π*2*(q* + *q*1*,q* + *(*1 − *λ)q*1*)*. Moreover, it is plausible to

assume that *Π*2*(q* + *q*1*,q* + *(*1 − *λ)q*1*)* ≥ *ΠN*+1*(q* +

*q*1*)* with equality binding for the duopoly case where

*N* + 1 = 2. Thus, for this case we conclude that *V*B ≤

**3. Estimates of patent value**

*V*A. The logic here is again that the renewal concept captures the value of the patent being kept away from the public domain, while the asset value reflects the logic of transferring one of the two substitute patents to a competitor, thus generating two leading firms. However, in this case, the renewal value may be greater than the asset value, since it is better to have only one competitor matching one’s own technology than to have many equally skilled adversaries.

These simple calculations have several implica- tions. One can see easily that the renewal value of the patent is equivalent to the value of licensing the patent right to all other *N* firms in the market when the patent-holder maintains the right to use the patented technology. Thus, the former patent-holder may lose the leadership position previously enjoyed, but no other firm can dominate the industry ex post. In com- puting the asset value, we implicitly assume that lead- ership is transferred to the buyer of the patent right, including all rights to block other patent rights which are contingent on the acquired one. Obviously, there is no single concept of private value that is optimal for all purposes. But to the extent that blocking power is an important phenomenon (as the patent literature suggests), the asset value construct seems preferable over the renewal concept. Our own survey has pro- duced ample evidence that blocking power is indeed an important phenomenon. In 69 interviews with holders of particularly important patents (see [Harhoff](#_bookmark53) [et al., 2003),](#_bookmark53) we find evidence of some blocking phe- nomena in about one third of them. Conversely, the case of patenting several substitute technologies also occurs in our data, but only in two cases.

The consideration of the first scenario reveals another reason why the asset value construct is the- oretically more appealing than the renewal value: it approximates the prize that the winner of a patent race (with subsequent imperfect patent protection) will per- ceive. If several firms compete for the new patent right, their actions will be guided by the difference in profits from (i) having the patent and being the leader and (ii) not obtaining the patent and some other firm becoming the leader. This is exactly what the asset value cap-

In the survey upon which this paper is based, we obtained value estimates that were meant to capture the asset values of patent rights, i.e. measures that do explicitly include strategic aspects and the value of blocking power. The survey was directed at German patent-holders who were asked to assess the asset value of their patent rights. The survey was con- ducted in 1996, and the data were used to study the distribution of patent rights in detail in [Harhoff et al.](#_bookmark53) [(2003).](#_bookmark53) The survey considered all patent grants with a 1977 German priority date which were renewed to full term, i.e. expired during 1995. For 772 patents, value estimates were obtained in direct surveys of patent-holding firms.[10](#_bookmark17)

The German Patent Office supplied us with data on all 4349 patents that were entitled to a 1977 pri- ority and were renewed to full term and expired in 1995. Of these, 1431 patents were held by German patent-holders.[11](#_bookmark18) Of these 1431 full-term German patents, it was possible to trace 1325, or 92.3%, to surviving firms or individual inventors. Most of the untraced patent-owners were individual inventors or firms too small to be located through standard busi- ness directories. The 684 firms or individuals owning the 1352 traced patents were contacted by telephone to identify the most appropriate respondent, and a questionnaire was dispatched, usually by facsimile, on each relevant patent. Its essence was a single substantive counter-factual question, translated as follows:

If in 1980 you had known how its contribution to the future profitability of your enterprise would un- fold, what is the minimum price for which you would have sold the patent, assuming that you had a good-faith offer to purchase?

10 Details on the survey procedures used are presented in [Harhoff](#_bookmark53) [et al. (2003).](#_bookmark53) The subsequent discussion of the data builds on this paper. The data from this survey are also analyzed in [Scherer and](#_bookmark63) [Harhoff (2000)](#_bookmark63) and in [Scherer et al. (2000).](#_bookmark64)

11 We report further details on the 1977 application cohort in

[Section 4](#_bookmark22) of the paper.

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

1349

Respondents were asked to place their patent within one of five broad minimum selling price ranges: less than DM 100,000, 100–399,999, 400–999,999, 1–5

million, and more than DM 5 million. After extensive follow-up, positive responses were obtained on 772 patents (57.1% of the total on which contacts were made) held by 394 organizational entities and individ- ual inventors (including 10 unaffiliated inventors).

We then sought to conduct detailed interviews with the holders of the 99 patents that were associated with counterfactual sales prices in excess of DM 5 million. We conducted a total of 69 personal interviews, each of them taking between 1 and 2 h. In addition to ques- tions pertaining to the invention process, we asked our respondents to answer the previous question as pre- cisely as possible.[12](#_bookmark20) Thus, for a large number of par- ticularly valuable patents we obtained more precise information on the patent right’s value. We then pro- ceeded to obtain separate value estimates from profit flow data. The flow value estimates were computed from annual sales and profit ratio data multiplied by a correction factor accounting for the contribution of the patent,[13](#_bookmark21) with all values converted to 1995 price levels and then discounted back to the year 1980 at a 0.05 real discount rate. In these interviews, useable value responses were obtained on 69 patents originally val- ued at DM 5 million or more. For another 10 patents we were able to obtain rough estimates of bounds be- tween which the true value of the patent is expected to fall.

Among the 69 interview cases, profit flow esti- mates were available in 54 cases; counter-factual asset sale price estimates were available in 38 cases; and in 23 cases, both flow and asset sale estimates were obtained. In those 23 cases, the geometric mean value was DM 11.1 million per invention with flow estimation and DM 19.1 million in the asset sale counter-factual. The differences can presumably be explained by the strategic value of the patents which was not fully captured in our flow profit calculations. Although the differences appear sizeable, they are

Table 2

Respondents’ valuation of patents with full term—results after interviews

Valuation of patent

Cases

Percent

Less than DM 100,000 DM 100,000–399,999

DM 400,000–999,999

DM 1–5 million

DM 5–10 million

DM 10–20 million

DM 20–40 million

DM 40–80 million

More than DM 80 million

Total

203

200

154

129

28

16

15

5

2

752

27.0

26.6

20.5

17.2

3.7

2.1

2.0

0.7

0.3

100.0

Note: the survey also produced data for 20 other patents which were assessed by respondents of our written survey to be worth more than DM 5 million. In these cases, no additional information was available. See the text for explanations.

not significant at the 0.05 level (*t* = 1*.*21) in a test

of logarithmic means. In what follows, flow value estimates are used in all but the 15 cases in which they were unavailable and counter-factual estimates were substituted. In the interview cases, best estimate values were accompanied by an error range, whose average single-side magnitude was 25.05% of the best estimate, with a median value of 22.66%.[14](#_bookmark21)

The distribution of the value of patent rights is sum- marized in [Table 2.](#_bookmark19) In our estimation procedure, we will also assume that the 9346 German-owned patents which did not reach full-term status can be grouped together and that they are uniformly less valuable than the patents reaching full term. Thus, these patents form an additional value category. As one would expect from the discussion in [Section 2,](#_bookmark11) the value estimates obtained in our survey are considerably larger than value estimates from the renewal literature. For details, see [Harhoff et al. (2003).](#_bookmark53) But as we discussed in the [Section 2](#_bookmark11) of this paper, this result does not mean that the renewal-based value estimates are erroneous. Re- newal studies employ a different value construct, and our theoretical results let us expect that average val- ues from renewal studies are lower than asset values. This expectation is indeed borne out by the data.

12 As

in the telefax survey, respondents in the more detailed

interviews frequently asked us whether they should assume that the patent would be sold to a competitor. It was quite clear that this consideration mattered considerably for their value estimates.

13 To obtain this factor, we asked respondents to estimate the

share of total profits that could not have been earned without having ownership of the patent right.

14 The results reported below are robust in the sense that using either counterfactual asset values or value estimates from our flow profit calculation do not change the results in a major way.

1350

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

**4. Correlates of patent value**

is therefore to find an even stronger partial correlation between EPO citations and value than in the case of DPA citations.[15](#_bookmark23) Citations that occurred by July 1997 were included in our DPA citation count, while the EPO data include citations up to February of 1998.

*4.1. Patent scope*

The theoretical patent literature in economics has long since discovered that the scope of a patent may be an important determinant of the efficacy of patent protection (see, e.g. [Scotchmer, 1991, 1996](#_bookmark67)). How- ever, as [Merges and Nelson (1990)](#_bookmark70) point out, the eco- nomics of patent scope are rather complex. Moreover, the scope of a patent is difficult to operationalize and measure. We follow Lerner’s approach and generate a measure of scope computed as the number of different four-digit IPC classification codes in the application document.

*4.3. References to other patents (backward citations)*

Turning around the logic of citations received, it is plausible that a relatively small scope and—ceteris paribus—low monetary value should characterize a patent whose examination report contains a large num- ber of backward citations. After all, the logic of these references (*Entgegenhaltungen*) is to present subject matter that is held against the claims of the applica- tion. Several patent lawyers and examiners whom we confronted with this logic were not supportive of it. They pointed out that a patent application seeking to protect an invention with broad scope might induce the examiner to delineate the patent claims by insert- ing more references to the relevant patent literature. We may therefore expect backward citations to reflect broad scope as well as the existence of subject mat- ter that may restrict the scope of the patent. Absent a measure of the scope of patent claims (such as their number), it is therefore not clear whether the coeffi- cient should be positive or negative.[16](#_bookmark24)

*4.2. Citations received from subsequent patents*

It has long been argued that the value of patents can be assessed in a similar way as the impact of scien- tific publications, i.e. by looking at the frequency of citations that a particular contribution receives from subsequent works. This suggestion received consider- able support in Trajtenberg’s study of medical scan- ning devices (1990). Using data on a clearly defined set of products (computer tomography scanners), he showed that estimates of the social value of the in- vention were highly correlated with the incidence of subsequent citation. [Harhoff et al. (1999)](#_bookmark56) found that the number of citations received within the German patent system is highly correlated with the patent right’s value, but that the relationship is quite noisy.

Since we study German-owned patents, the most natural choice for the reference group of patents which can conceivably cite a given patent in our sample are other German patents. Thus, for each of the German patents held by German patent applicants, we com- pute the number of instances in which other patents and patent applications refer to the 1977 patents we are interested in. The European Patent Office ad- ministers a domain which is considerably larger (in terms of patents issued) than the German system. Hence, within this system one would expect to find higher instances of citation if the number of citations is computed in the same way as for the German Patent Office domain. Moreover, one would expect that these citations reflect the importance of the cited patent in international competition. Our expectation

*4.4. References to the non-patent literature*

Patents may be based in part or fully on new scien- tific knowledge.[17](#_bookmark25) Since published research results can be used to document the state of the art against which the application has to be evaluated, patent examiners

15 A

distinction between self-citations and citations by other

patent-holders would be helpful, but is not possible with the data at hand.

16 [Lanjouw and Schankerman (1997)](#_bookmark61) include the number of

claims and backward citations per claim in their probit analysis of litigation. The first variable turns out to have a positive and significant coefficient, the coefficient of the latter one is not sig- nificantly different from zero. The absence of a count of the num- ber of claims in our data is due to the fact that PATDPA did not include claims in their database in 1977.

17 The growing importance of the linkage between private patent-

ing activities and scientific knowledge has been documented by [Narin et al. (1997).](#_bookmark74) See also [Grupp and Schmoch (1992).](#_bookmark59)

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

1351

will then search for relevant references in the scien- tific literature. Again, the logic of these references is to document the material that is held against the ap- plication. As in the case of references to the patent lit- erature, a relatively high number of references to the scientific literature may therefore indicate patents of relatively high value.

The PATDPA database contains this information and allows us to compute the number of references to the non-patent literature included in the examiner’s report. Inspection of these references reveals an inter- esting picture. Based on an evaluation of 100 patent document records containing such references, about 60% of the references refer to scientific and technical journals. The remainder is made up largely by refer- ences to trade journals, to firm publications or to stan- dard texts in the respective technical field, e.g. for the classification of chemical substances or specific me- chanical designs.

The fact that not all non-patent references refer to scientific sources is well-known. Thus, the number of non-patent references is not a direct measure of the strength of a patent’s science linkage. This problem has been studied in detail by [Schmoch (1993).](#_bookmark68) A sur- vey of the literature on this topic is contained in [Meyer](#_bookmark71) [(1999).](#_bookmark71) However, the number of non-patent references is considerably easier to compute than the number of explicit links to the scientific literature. Moreover, we also expect that “science-based” patents contain a relatively high number of non-patent references. This is actually borne out by the data (see below). Thus, we maintain the easily available indicator which sim- ply counts the references to the non-patent literature and expect despite of the measurement problem that such references have greater explanatory power in science-based industries, such as pharmaceutical and chemical products than in less science-oriented areas. This expectation is also confirmed in our estimates.

survival span of patents, i.e. the time from applica- tion to non-renewal or to expiration, are highly corre- lated. To account for the potential explanatory power of “family size”, we obtained the number of nations in which protection for a particular invention was sought from Derwent’s World Patent Index (WPI) database for each of the patents in our database.

*4.6. Outcome of opposition cases*

While the opposition process has not been dis- cussed in the economics literature, its importance has been noted by legal scholars and practitioners. [Merges](#_bookmark69) [(1999)](#_bookmark69) argues that the opposition system of the Euro- pean Patent Office appears to be employed far more frequently than the USPTO’s reexamination proce- dure and may thus be far more effective in weeding out weak patents. [van der Drift (1989)](#_bookmark82) points out that opposition to patents granted by the European Patent Office (feasible within 9 months after the grant) can be helpful in assessing the value of patent rights. On average, 8% of all EPO patents are opposed, and 14% of the patents thus attacked are revoked. However, opposition rates and outcomes for EPO patents vary considerably. Leading companies have their patents opposed far more often than on average. For example, 23% of all Unilever patents in van der Drift’s data have been opposed, and 16% of the patents opposed have ultimately been revoked. Companies like Proc- ter and Gamble, ICI, Union Carbide and BASF face opposition rates far in excess of 10% of their EPO patent grants.[18](#_bookmark26) Personal interviews with patent ex- aminers suggest that similar differences characterize the opposition process at the German Patent Office.

[Table 3](#_bookmark27) shows the actual outcomes of opposition

and annulment procedures in the case of the 1977 ap- plication year cohort. In the sample used here, 8.4% of all patents encounter opposition. The annulment

18 van der Drift computes opposition indicators, which attempt to measure the extent and success of opposition activity, but he is not able to relate them to actual estimates of patent value. Nonetheless, the essence of his comments imply that opposed patents are likely to be valuable, and that a successful defense of the patent against opposition is an interesting (and early) indicator of patent value. Given that the opposition procedure at the EPO follows the corresponding German institution, these comments confirm our view that patents which survived opposition are likely to be particularly valuable. Opposition at the EPO is also studied in [Merges (1999).](#_bookmark69)

*4.5. Family size*

[Putnam (1996)](#_bookmark80) and subsequently a number of au- thors have argued out that information on family size may be particularly well suited as an indicator of the value of patent rights. The studies by [Putnam (1996)](#_bookmark80) and [Lanjouw et al. (1998)](#_bookmark65) have shown that the size of a patent family, measured as the number of jurisdic- tions in which a patent grant has been sought, and the

1352

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

Table 3

Outcome of opposition and annulment cases (1977 Priority Cohort)

the label of patents fully or partially upheld in the case of opposition or annulment. From interviews with patent attorneys, we know that the cost of an oppo- sition procedure can be substantial for the attacker. Cost estimates including attorney fees range between DM 20,000 and 50,000. However, these figures are dwarfed by the expenses incurred for an annulment process where the attacker may easily have to spend several DM 100,000. Accordingly, we anticipate that successfully withstood annulment should be a stronger indicator of the patent’s value than successfully de- feated opposition.

Cases

Percent

Opposition procedure (*Einspruchsverfahren*) Rejected (opposition not admitted)

Patent restricted Patent fully upheld Patent revoked

Patent withdrawn/lapsed

Total

26

328

482

638

526

2036

1.3

16.1

23.7

31.3

27.6

100.0

Annulment procedure (*Nichtigkeitsverfahren*) Patent upheld

Patent held invalid Other

Total

52

11

10

73

71.2

15.1

13.7

100.0

**5. Data, specification and estimation results**

Note: there were 11 cases with opposition and subsequent annul- ment procedure, i.e. 62 of the annulment cases had not been not subject to opposition.

*5.1. The 1977 sample of applications*

While our survey targeted the population of German-held full-term patents, we discuss in this sec- tion the full cohort of 1977 applications in order to gain further insight into the patent granting process in Germany.[20](#_bookmark30) [Table 4](#_bookmark31) summarizes the composition of the 1977 application year cohort. Of the total of 57,782 patent applications, only 24,116 (41.7%) were initially (prior to opposition) granted. The rate at which patents are initially granted by the German Patent Office differs considerably between German and foreign applicants (column 2). This effect is ex- pected, since obtaining patent protection in other than the own national jurisdiction is typically expensive. Applicants will therefore seek international patent protection only for their most valuable inventions (Putnam, 1991). Thus, foreign patents should also be more likely to pass the examination process. US patent applications are awarded patent grants in 38% of the cases, and French applicants have 40.9% of their applications approved. Although the pattern is confirmed for all non-German applications except the British applications, the performance of Japanese ap- plications is stunning: almost 64% of Japanese patent applications receive patent grants.

Once granted, 8.7% of the patent grants are chal-

lenged in the opposition process, and in 57.8% of these opposition cases, the challenger ultimately

20 To generate the statistics discussed here, we used the PATDPA data source. See [STN International (1990)](#_bookmark75) for details.

procedure (*Nichtigkeitsverfahren*) occurs at a much lower frequency in 0.3% of all cases in which a patent was granted initially. Opposition may be held inad- missible in which case it has no consequences for the patent-holder; it may lead to a restriction of the scope of the patent; or it may lead to the patent being upheld completely. These cases will be considered success- ful outcomes for the patent applicant in the analysis later, and they account for 41.1% of opposition cases. Alternatively, the patent may be revoked completely (31.3%). Moreover, the patent-holder may decide to let the patent lapse (by not paying renewal fees) or to withdraw the patent (27.6%). Attacks via the annul- ment procedure (*Nichtigkeitsverfahren*) are less fre- quent (73 cases) and the outcomes are more difficult to classify from the PATDPA data used in this study. However, it is clear from the data that requests for an- nulment are less successful than opposition cases: in 52 out of 73 cases the patent-holder prevails.

For the purpose of this study, we identify two groups of patents: those that withstood an attack in the reg- ular opposition procedure (*Einspruchsverfahren*), and those that survived the more complex and less frequent annulment procedure (*Nichtigkeitsverfahren*) which is often a consequence of patent litigation.[19](#_bookmark29) In some of the descriptive statistics, these are pooled under

19 In Germany, questions of patent validity (annulment challenges) and of infringement are dealt with separately. Validity cases are delegated by the civil courts to the central German Patent Court.

Table 4

Type and outcomes of DPA applications with priority year 1977 by applicant nation

Applicant nation

(1) Patent applications

(2) Patent applications withdrawn or patent not granted (% of (1))

(3) Patents initially granted (% of (1))

(4) Patents opposed (% of (3))

(5) Opposed patents fully or partially upheld (% of (4))

(6) Patents surviving oppostion or not opposed (% of (3))

(7) Patents renewed to full term (% of (6))

DE JP US FR CH GB

Other

Total

27,954

4,469

10,207

2,675

2,509

2,451

7,517

57,782

16,483 (59.0%)

1,582 (35.4%)

6,227 (61.0%)

1,496 (55.9%)

1,462 (58.3%)

1,813 (74.0%)

4,603 (61.2%)

33,666 (58.3%)

11,471 (41.0%)

2,887 (64.6%)

3,980 (39.0%)

1,179 (44.1%)

1,047 (41.7%)

638 (26.0%)

2,914 (38.8%)

24,116 (41.7%)

1,145 (10.0%)

207 (7.2%)

284 (7.1%)

87 (7.4%)

83 (7.9%)

55 (8.6%)

237 (8.1%)

2,098 (8.7%)

454 (39.7%)

98 (47.3%)

108 (38.0%)

44 (50.6%)

46 (55.4%)

26 (47.3%)

109 (46.0%)

885 (42.2%)

10,780 (94.0%)

2,778 (96.2%)

3,804 (95.6%)

1,136 (96.4%)

1,010 (96.5%)

609 (95.5%)

2,786 (95.6%)

22,903 (95.0%)

1,431 (13.3%)

936 (33.7%)

900 (23.7%)

221 (19.5%)

214 (21.2%)

166 (27.3%)

481 (17.3%)

4,349 (19.0%)

Notes: Patents with priority year 1977. Opposition (column 4) includes patents attacked in a *Patentnichtigkeitsverfahren* (annulment) as well as the more frequent

*Einspruchsverfahren* (opposition). See the text for explanations. Source: PATDPA (August 1997), authors’ computations.

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

1353

Table 5

Descriptive statistics for value indicators by outcome of application and opposition proceedings (patents of german applicants only) mean (S.E. of the mean)

Variable

(1) All patents initially issued

(2) Patents opposed

(3) Patents not renewed to full term

(4) Patents renewed to full term

Held invalid or withdrawn

Upheld

Never opposed

Opposed and upheld

Never opposed

Opposed and upheld

Number of Separate 4-digit IPC classes (“scope”)

Citations received in DPA patents by 7/1997

Citations received in EPO patents by 2/1998

Family size

References to the patent literature

References to the

non-patent literature Observations

SCOPE

1.36 (0.01)

1.41 (0.03)

1.33 (0.03)

1.35 (0.01)

1.31 (0.04)

1.37 (0.02)

1.36 (0.05)

CIT DPA

0.52 (0.01)

0.69 (0.05)

0.89 (0.08)

0.46 (0.01)

0.72 (0.08)

0.67 (0.04)

1.18 (0.16)

CIT EPO

0.57 (0.01)

0.76 (0.05)

0.83 (0.06)

0.52 (0.01)

0.77 (0.08)

0.79 (0.04)

0.92 (0.10)

FAMSIZE REFPAT

3.59 (0.03)

1.37 (0.02)

3.96 (0.15)

1.43 (0.08)

4.17 (0.18)

3.41 (0.16)

3.40 (0.04)

1.20 (0.02)

3.82 (0.20)

2.98 (0.18)

4.57 (0.11)

1.86 (0.08)

4.74 (0.32)

4.12 (0.31)

REFNPAT

0.30 (0.01)

0.27 (0.02)

0.68 (0.06)

0.27 (0.01)

0.52 (0.06)

0.42 (0.03)

0.96 (0.14)

11,471

691

454

9,066

283

1,260

171

Notes: see [Table 4.](#_bookmark31) Source: PATDPA (August 1997), authors’ computations.

1354

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

1355

prevails (columns 5 and 6). Again, patents owned by non-German applicants are attacked less frequently than German patents, and foreign patent-holders are more successful than their German counterparts in de- fending the patent grant. The only exception to this rule are US patents which survive opposition at about the same rate as German patents (38.0 and 39.6%, re- spectively). Of the remaining 22,898 patents, 19.0% reach full-term status. There are again major differ- ences between German-owned and other patents. Only 13.3% of the German-owned patents are renewed to full term, while the full-term renewal rate ranges be- tween 33.7% in the case of Japan and 17.3% for the residual group of applicant nations.

Table 6

Value ranges for scope and citation measures

Variable

Mean

Q25

Q50

Q75

Minimum

Maximum

SCOPE CIT DPA CIT EPO FAMSIZE REFPAT REFNPAT

1.354

0.504

0.563

3.564

1.367

0.302

1

0

0

1

0

0

1

0

0

2

0

0

2

1

1

5

2

0

1

0

0

1

0

0

9

15

20

24

27

18

Notes: *N* = 10,780. Q25, Q50, and Q75 refer to the lower quartile,

the median, and the upper quartile, respectively.

son of patents that were opposed and subsequently upheld.

[Table 6](#_bookmark33) contains information on the moments, range and distribution of the scope and citation measures. The sample used here consists of the 10,780 patents that either survived or never encountered opposition. Clearly, most of the indicator variables have skew dis- tributions, with the mean always considerably larger than the median. Some of the mean values should be surprising to readers familiar with citation indicators from the US patent system. As reported in a previ- ous paper ([Harhoff et al., 1999](#_bookmark56)), we find that the ci- tation counts, both in the German and the European system, are spectacularly low by USPTO standards.[21](#_bookmark34) There are two possible explanations. First, both the EPO and the DPA systems contain fewer applications and granted patents (per year) than the USPTO. Hence, if citations are affected by a “home bias” there are fewer candidates for a potential citation in our data. But more importantly, applicants at the EPO are not required to supply a full list of prior art—this require- ment presumably leads applicants at the USPTO to cite excessively. A detailed discussion of these differ- ences in citation behavior is presented in [Michel and](#_bookmark73) [Bettels (2001, 191f.).](#_bookmark73)

A separate analysis of these descriptive statistics

by technical field is not reported here, but demon- strates that these comments apply across the broadly defined technical areas chemicals and pharmaceuti- cals, electronics, mechanics and a residual group.[22](#_bookmark35)

21 The maximum number of USPTO citations for US patents in the study by [Harhoff et al. (1999)](#_bookmark56) was 169, the mean number of German Patent Office citations for German-owned patents issued in 1977 was 6. [Hall et al. (2000)](#_bookmark51) report that the maximum number of citations in their study of US patents is on the order of 200.

22 The definition of these groups is presented later.

*5.2. Descriptive statistics*

The sample studied here are the 11,471 patents that were initially granted. [Table 5](#_bookmark32) presents mean values and standard errors (S.E.s) for the indicator variables described before, and reports them separately for dif- ferent groups of patents. The main result of this table is that patents which defeated opposition turn out to differ with respect to most indicators from patents that were held invalid or were never opposed.

In column 2, we compare German patents that were held invalid, revoked or withdrawn to patents that were upheld (in either amended or unamended form) in opposition cases. The latter group has more DPA citations, EPA citations, larger patent families and more references to the patent and non-patent literature. With the exception of the family size vari- able, all of the differences turn out to be statistically significant. A second comparison focuses on patents that were never opposed versus patents that were opposed and subsequently upheld. We perform this comparison for patents that were not renewed to full term in column 3, and for full-term patents in col- umn 4. While the scope variable shows little variation across these groups, the other indicators turn out to be significantly higher for patents which were opposed. Moreover, a comparison of patents that were never opposed in column 3 to the same group in column

4 shows that unopposed full-term patents receive considerably more citations, contain more references and are part of larger patent families than unop- posed patents which were not renewed to full term. The same result holds for the analogous compari-

1356

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

Table 7

Pearson product–moment correlation matrix

Variable

SCOPE

CIT DPA

CIT EPO

FAMSIZE

REFPAT

REFNPAT

SCOPE CIT DPA CIT EPO FAMSIZE REFPAT REFNPAT

– 0.049

0.043

0.029

0.015

0.059

– 0.201

0.085

0.117

0.052

–

−0.017

– 0.054

0.061

0.052

0.045

– 0.247

–

Notes: *N* = 10,780.

However, some interesting particularities emerge, in particular for patents in the area of chemicals and pharmaceuticals. These patents are considerably more often cited in EPO patents than in German patents, and family sizes are on average much larger than for the other technical fields. Moreover, references to the non-patent literature, e.g. to scientific journals and publications, are more common for pharmaceutical and chemicals patents. These have on average 0.38 ref- erences to the non-patent literature. Again on average, electronics patents contain only 0.28, patents in me- chanical fields 0.19, and other patents only 0.14 such references, respectively. These differences between the group means are highly significant.

[Table 7](#_bookmark36) concludes the descriptive statistics with a summary of correlation coefficients for the scope and citation measures. The correlation coefficients be- tween our scope and citation variables are quite small, indicating that these variables carry largely orthogonal information. Notable exceptions are the correlation between references to the patent and references to

cators and is simply interested in approximating the value of a particular patent. Presumably, issues of en- dogeneity would matter greatly for a more structural exercise. For example, opposition is likely to lead to changes in the scope of the patent, its references to the patent and non-patent literature, and the citations that the opposed patents receive. At the same time, the likelihood of opposition is presumably a function of the patent right’s prospective value. At this point, little is known about these processes in the European context.

The structure of the data at hand is somewhat more complex than in a standard regression framework. For most of the patents surveyed, we do not know point estimates of the patent’s value, but only upper and lower bounds. In order to use all of the available in- formation, we apply an ordered probit framework in which some of the threshold values are known. In this framework (as in ordinary linear least squares), we can actually recover all coefficients. For 752 patents, we have information on the patent-holders’ valuations of the patent rights. For another 20 patents, we know that they were assessed to be worth more than DM 5 million in our first-stage survey.[23 In](#_bookmark37) 659 cases, we were unable to obtain patent valuations for patents renewed to full term. Moreover, in the vast majority of cases (9349 patents), we only observe that the patents were not renewed to full-term. We treat these cases in the following way. We assume that the value of full-term patents is delineated by a lower bound *α* which we treat as a parameter to be estimated. At the same time, this parameter *α* is considered the upper bound for the value of all patents which were not

the non-patent literature (*ρ* = 0*.*247), the correlation

between the two citation measures (CIT DPA and

CIT EPO, *ρ* = 0*.*201); and the correlation between

citations in the German patent system and the number of references to the patent literature (CIT DPA and REFPAT, *ρ* = 0*.*117).

*5.3. Multivariate specification*

We combine the previous indicators to model the mean value of patent rights as a function of observ- ables. We abstract from discussions of causality in this exercise, and we will also leave a number of en- dogeneity problems untouched. Our position is that of a researcher who has observed the respective indi-

23 See [Harhoff et al. (2003)](#_bookmark53) for details on the distributional properties of these data.

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

1357

renewed to full-term. To maintain a full-term patent, a patent-holder must spend about DM 20,000 on appli- cation and renewal fees plus an estimated amount of DM 10,000 for patent attorney services. Since a large number of our patents (even those that are not re- newed to full term) are actually part of an international patent family, the cost of obtaining and maintaining the patent family might even be higher. We therefore expect the estimated value of *α* to be in excess of DM 30,000.[24](#_bookmark38)

The econometric model starts by specifying the log- arithm of patent valuation ln(*Vi*) as the sum of a linear function *Xiβ* of observables and an error term *εi*. *Xi* is a vector of variables characterizing patent *i* and *β* is the vector of parameters to be estimated

(group B patents), the log-likelihood contribution is

ln*(δ) X β*

. .

ΣΣ

*i*

ln *L*B *(β, α, σ/X , δ)* = ln 1

−

−

*Φ*

*.*

*i*

*i*

*σ σ*

(3)

Those patents that were renewed to full-term with un- known valuation (group C) contribute

ln*(a)*

.

.

*X β*

ΣΣ

*i*

ln *L*C *(β, α, σ/X )* = ln 1 −

*Φ*

−

*.*

*i*

*i*

*σ*

*σ*

(4)

Finally, the log-likelihood contribution of those 9349 patents that were not renewed to full-term (group D) is given by[26](#_bookmark40)

ln*(Vi)* = *Xiβ* + *εi.*

(1)

ln*(a)*

*Xiβ*

*σ*

ln *L*D*i (β, α, σ/Xi)* = ln .*Φ* . −

ΣΣ *.*

(5)

*σ*

[25](#_bookmark39)

We assume that the error terms are distributed i.i.d.

Moreover, we assume normality of the error term such that the probability of observing a patent in the value interval of, say, between *γ*1 and *γ*2 (where *γ*2 *> γ*1) is

Estimates of the parameters can be obtained via maximum-likelihood, i.e. by maximizing the sum of the individual log-likelihoods with respect to the pa- rameter *β*, *α*, and *σ*. Note that all of these coeffients are identified, since most of the threshold values are known. Thus, our coefficients can also be compared directly across various sub-samples. Besides obtaining the usual maximum-likelihood test statistics, we also

given by *Φ(*ln*(γ*2*)/σ* −*Xiβ/σ)*−*Φ(*ln*(γ*1*)/σ* −*Xiβ/σ)*

where *σ* is the standard error of the disturbances *εi* and

*Φ*(·) is the cumulative standard normal distribution.

Thus the log-likelihood contribution for a patent for which we observe finite interval bounds (denoted as group A) is given by

compute a pseudo-*R*-squared measure as 1 − *(s*2*/τ*2*)*

where *s* is the estimate of *σ* from the unrestricted specification and *τ* is the estimate of *σ* from a re- stricted specification in which only a constant term is allowed for.

ln *L*A*i (β, α, σ/Xi)*

ln*(γ )*

ln*(γ )*

. .

*X β*

Σ

.

*X β*

ΣΣ

2

1

*i*

*i*

= ln *Φ*

−

−

*Φ*

−

*.*

*σ*

*σ*

*σ*

*σ*

(2)

*5.4. Empirical results*

For observations with value greater than some known amount *δ*, but no data on a potential upper bound

We summarize our estimation results in [Table 8.](#_bookmark41) Column (1) displays the coefficient estimates and stan- dard errors for the overall sample. In columns (2)–(5), we split the sample by technology field in order to test the robustness of the overall results and in order to study between technology differences.

The scope variable as used by [Lerner (1994)](#_bookmark62) is con- sistently insignificant in these specifications. The di- vergence between his and our result may be due to

26 Note that the likelihood contributions in (4) and (5) are those of the probit estimator for patents being renewed to full term among all patents that were not covered in the survey.

24 Note also that our counterfactual survey question asked respon- dents to take all information into account that they had learned during the life span of the patent. Given that the renewal decision had to be made on an annual basis without this knowledge, the total renewal fees may actually overestimate the ex post value of the patent.

25 This assumption may look innocent for a cross-section of

patents. However, some of the inventions in our cohort of patents may build on each other, and hence the economic value of some patents may be influenced by the value of others. We have to ignore this problem here, since we cannot test deviations from the assumption.

1358

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

Table 8

Ordered probit specifications-coefficient (standard error)

Independent variable

Full sample (1)

Drugs and chemicals (2)

Electronics (3)

Mechanical (4)

Other (5)

ln(SCOPE)

−0.150 (0.084)

−0.383 (0.497)

0.050 (0.109)

0.556 (0.230)

0.583 (0.217)

0.577 (0.129)

0.466 (0.164)

0.459 (0.257)

2.508 (0.502)

4.436 (1.810)

43.332 (5.118)

3.656 (0.266)

0.133

104.9

−1,456.8

3,153

−0.237 (0.260)

−0.537 (0.566)

ln(1 + CIT DPA)

0.505 (0.135)

0.893 (0.132)

0.811 (0.077)

0.751 (0.092)

0.448 (0.158)

2.415 (0.284)

3.753 (0.782)

45.144 (2.913)

4.174 (0.159)

0.139

512.3

−5,308.4

10,780

0.523 (0.502)

1.670 (0.398)

1.178 (0.244)

0.749 (0.307)

1.131 (0.447)

2.113 (0.946)

0.188 (3.410)

41.644 (7.721)

4.974 (0.466)

0.172

90.6

−782.1

1,301

0.461 (0.190)

0.793 (0.202)

0.780 (0.115)

0.804 (0.130)

0.319 (0.268)

2.263 (0.394)

3.296 (0.998)

46.647 (4.482)

4.114 (0.238)

0.118

236.7

−2450.4

5,026

0.812 (0.427)

0.903 (0.406)

0.673 (0.222)

1.216 (0.286)

ln(1 + CIT EPO)

ln(FAMSIZE)

ln(1 + REFPAT)

ln(1 + REFNPAT)

−1.001 (0.621)

OPPOSITION ANNULMENT

*α*/1000 *σ*

Pseudo-*R*-squared LR

log *L*

*N*

2.920 (0.828)

5.623 (1.913)

55.404 (8.563)

4.143 (0.441)

0.159

83.6

−597.1

1,300

Note: FIML estimates from an ordered probit specification with partially known thresholds. The technology classification is described in

the text. The pseudo-*R*-squared measure as 1 − *(s*2*/τ*2*)* where *s* is the estimate of *σ* from the unrestricted specification and *τ* is the estimate

of *σ* from a restricted specification in which only a constant term is allowed for. The likelihood ratio test statistic LR is based on the log-likelihoods of the two specifications used for computing the pseudo *R*-squared (d*.*f*.* = 8).

the use of patents which cover a broad set of tech- nical areas while his study focuses on biotechnology patents. There may also be important differences in the way the German and the US Patent Offices as- sign the IPC classification.[27](#_bookmark42) However, our results are clearly in line with [Lanjouw and Schankerman (1997)](#_bookmark61) who have also reported estimates according to which the scope measure calculated from IPC classifications does not positively affect the probability of infringe- ment litigation. They even detect a small and signifi- cant negative effect in their study while the respective coefficient is always insignificant in our results.

All other variables included in the specification turn out to have some explanatory power. We turn to the overall results in column (1) first before comment- ing on technology-specific differences. Both citation counts within the DPA patent database as well as the analogous measure from EPO patents are positive and

highly significant. However, the point estimate for the latter variable is significantly larger, consistent with our expectations. Family size, the number of jurisdic- tions for which patent protection was granted, also carries the expected positive sign and is again highly significant. [Lanjouw and Schankerman (1997)](#_bookmark61) report in their analysis of patent litigation that their measure of backward citations is not a significant determinant of the probability that a patent will be subject to liti- gation. We find that backward citations are positively correlated with the patent’s value in our study, and that the coefficient is again estimated with high precision. Moreover, references to the scientific literature are also informative about the patent’s value, though the average effect across all technology areas is smaller than for backward citations of patents, and the estimate is less precise. Finally, the indicators summarizing the outcome of the opposition and annulment process turn out to be quite large and highly significant. A patent which has defeated opposition in the more frequently encountered opposition procedure (*Einspruchsver- fahren*) is considerably more valuable (by a factor of 11.2) than a patent that was never attacked. If the patent has been under attack in the more expensive annulment procedure, its value is again much higher

27 [Schmoch (1990)](#_bookmark66) cites evidence that the primary IPC classifi- cations of about 50 percent of all US patents reaching the German Patent Office are being revised. He also argues that the IPC clas- sification in US patent documents is generated through a comput- erized reference list, and the US examiners primarily work with the USPTO classification. The latter are revised every 6 months, while IPC classifications are updated in 5-year intervals.

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

1359

than the value of unchallenged patent rights, in this case by a factor of 42.6, ceteris paribus. The upper bound for the value of patent rights not renewed to full term is estimated to be DM 45,144 (standard error of DM 2913). As anticipated, this value is higher than our benchmark of DM 30,000 which only encom- passes renewal fees and the cost of patent attorneys.

In columns (2)–(5), the same specification is ap- plied to patents within a particular field[28 of](#_bookmark44) technol- ogy. Qualitatively, very similar results emerge from these regressions. The scope variable is never signif- icant in these regressions, but some intriguing differ- ences are visible for the other variables. Consider first the results in column (2) which apply to patents in the area of pharmaceuticals and chemical substances. The information content in national citations appears to be low and also imprecisely estimated. However, cita- tions within the EPO system have a coefficient (stan- dard error) of 1.670 (0.398) which is the largest value among the technology-specific results. As already dis- cussed, given the global nature of competition in the respective industries, this result is not too surprising. Consistent with the view that the coefficient size is driven by the extent of global competition, the fam- ily size variable also carries the highest coefficient of all technology-specific sets of results. We also ar- gued in the previous sections that scientific content of the patent’s subject matter is likely to be high in the case of pharmaceuticals and chemicals. This is borne out in the relatively high coefficient for references to the non-patent literature. Opposition is again infor- mative, while results from annulment procedures are not. However, this may simply be due to the relatively small number of annulment cases—which again may reflect the relatively “water-tight” nature of patent pro- tection in these technical fields.

The results in columns (3)–(5) for patents in the

remaining three areas (electronics and electrical cir- cuitry, mechanical and other) come close to the ones for the overall sample. Forward citations are again

informative about patent value, but

family size ap-

pears to play a considerably less important role than

in the field of drugs and chemicals. The importance of backward citations varies across these fields, with the highest coefficient (standard error) of 1.216 (0.286) for the residual group, and the lowest coefficient of

0.466 (0.164) for electronics and electrical circuitry. Interestingly, references to the scientific literature do not have a statistically significant coefficient for any of the three groups. The coefficients for the opposi- tion and annulment indicators are again quite large and highly significant.

Considering these results together, there is clearly some variation across technology groups. But the re- sults are remarkably consistent with respect to their qualitative implications. Indeed most of the regressors in this study are of similar size in the various tech- nological fields and the effect sizes are typically es- timated with considerable precision. That should be taken as an encouraging sign for future studies.

**6. Conclusions and further research**

Determining the value of patent rights is a difficult task, but even slight improvements leading beyond the simple patent counts frequently used nowadays should be considered a success. This paper has at- tempted to use information from patent applications, examination reports and from the opposition process to model the value of patent rights. Since most of the patent literature has originated in the US, the partic- ularities of European systems have been somewhat neglected. Our analysis focuses on German patents, taking into account the specifics of the German patent system which is quite similar to the procedures ap- plied by the European Patent Office and other national patent offices in European countries. The value data used in this paper come from a detailed survey of west German patent-holders who assigned monetary values to particularly important patents. Thus, we are not compelled to use latent variable constructs or to rely strongly for the most valuable patents on iden- tifying assumptions as they are typically made in the patent renewal literature.

Our econometric analysis of these data has been quite promising: we have established clear evidence that a number of indicators are significantly correlated

28 The classification is the one used by [Lanjouw (1998).](#_bookmark60) Based on IPC classifications, she distinguishes between drugs and health patents (A61 and A01N), chemical patents (A62, B31, C01–C20), electronics patents (G01–G21, H), mechanical patents (B21–B68 excl. B31, C21–C30, E01–F40), and a residual group (A excl. A61 and A01N, B01–B20, F41–F42, G21), referred to here as “Other”. We aggregate the first two groups in order to have reasonably large subgroups for the analysis.

1360

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

with patent value. In a previous study using the data employed here, we found a significant correlation be- tween patent value and citations received from subse- quent patents ([Harhoff et al., 1999](#_bookmark56)). We confirm this result, but we can also show in this paper that other correlates of patent value have additional explanatory power. The measure for references to the patent liter- ature (backward citations) carries significant positive coefficients in all technical fields. Measures of family size and observed outcomes of opposition cases also contribute to an approximation of the patent right’s value. A successful defense against opposition and an- nulment claims is a particularly strong predictor of patent value. Presumably, valuable patents are more likely to be attacked in this process, and the stronger patent rights survive, amounting to a two-tiered se- lection process with a highly informative outcome. Contrary to previous results, we find that the num- ber of four-digit IPC classifications does not have any explanatory power. At least for the European con- text, it does not appear to be a good approximation of patent scope. As to the science linkage of patents: in science-oriented fields such as pharmaceuticals and chemicals, references to the non-patent literature carry explanatory power; in the other technical fields studied here there is no evidence of a statistically significant relationship.

Our results have a number of implications for the measurement of patent value. First, we show that re- lying on citations received from later patents alone is not likely to lead to the best possible approximation of patent value. Other measures, such as citations to previous patents and the scientific literature, the size of the international patent family or the success in the face of patent opposition, are also important in statisti- cal terms. But they are even more appealing on purely practical grounds, since they are available relatively soon after the patent has been granted. Backward ci- tations are part of the patent office’s research report. Information on family size is also available relatively early, since applications made in foreign jurisdictions are based on union priority claims, and these lapse 1 year after the national application has been filed.

A second implication from this paper concerns the relevance of the opposition procedure which does not exist in the US or UK, but is part of the patent grant- ing process at the EPO. The outcomes of opposition cases, which prove to be highly informative in our

data, are not available immediately. Moreover, in the German patent system applicants may delay examina- tion for strategic reasons for 7 years. Assuming that it may take another 5 years for examination and subse- quent opposition procedures, these indicators may not be observable for all patents of a given application co- hort before 12 years have passed since the application was submitted. However, in the ever more important EPO system, patents are examined *automatically* after the application has been submitted, and the delay in the EPO system will therefore be comparatively short. Hence, EPO opposition data may yield very attractive indicators for an approximation of patent value rights. Clearly, some of our results pose a number of questions for further studies. We cannot claim that the set of value correlates used here is complete, and additional variables or refinements of those we used already should be tested. For example, data on the timing of backward citations should be used in order to refine this particular regressor in our study.[29](#_bookmark45) More- over, some indicators, such as renewal of the patent to full-term, are easily observed ex post, but they only become available a long time after the application has been filed. Other indicators, such as the number of jurisdictions in which patent protection is sought for a particular invention, may be available around the time of application, but it is not known exactly how well they reflect the value of a patent. Citation measures could also be used to construct measures of how “general” or “basic” a patented invention is.[30](#_bookmark46)

We will consider those measures in future research.

Finally, it seems of some importance to study the determinants and effects of the opposition procedure in more detail. Opposition may replace some forms of patent litigation observed in the US, but it is not clear which legal system is more efficient in terms of maintaining incentives for R&D or suppressing incen- tives for strategic behavior, such as predatory litiga- tion. Since the link between legal and economic issues is far less understood in the European context than in the US, further research in this particular area may

29 See [Hall et al. (2000)](#_bookmark51) for a study in which extensive US data on citations is used. We note again that citations in the US patent system are often generated by the applicant and may therefore have different informational content than citations in European patents.

30 Cf. [Trajtenberg et al. (1997)](#_bookmark81) who operationalize the concept

of an invention’s “basicness”.

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

1361

also be helpful in analyzing the impact of opposition and litigation on R&D incentives.[31](#_bookmark48)

inventors whose applications have not been successful. The American Inventors Protection Act (1999) now requires publication of all applications after 18 months but excepts applicants opting to make a declaration that a patent will not be sought in a foreign jurisdic- tion requiring 18 months publication (35 USC §122). During the priority year (see [Fig. 1),](#_bookmark50) patent appli- cants can decide to submit their application to other national patent offices where the date of the German application will be taken as the priority date. Thus, only the state of the art developed up to the prior- ity date will be held against the patent application to determine the degree of novelty. Patent applicants in Germany may delay the actual examination of their application for up to seven years. However, payment of annual fees commences in any case at the beginning of the third year. Even prior to the official examina- tion, applicants may ask for a research report which offers them the patent office’s assessment of the state of the art (e.g. earlier patents). In the later examination process, these earlier patents are likely to be used to limit the scope of the patent, e.g. in form of backward citations to the patent literature. Such references are called *Entgegenhaltungen*, i.e. literally, material that

is held against the patent application.

Another source of differences between the US and the German system is the opposition process at the German Patent Office. Within 3 months after a German patent has been granted by the German Patent Office, any person or firm may register its opposition to the patent grant with DPA (*Einspruchsverfahren*). In the 1977 application cohort, 8.3% of all granted patents were subject to this form of opposition. A second, though less often used possibility to attack a patent al- lows interested parties to demand that the patent be de- clared void (*Nichtigkeitsverfahren*—annulment). This process may only be initiated once the time period for the regular opposition has passed. Only 0.3% of the patents granted were opposed using the annulment procedure.

On average, the patent examination process at the German Patent Office will take 3 years. If examina- tion is requested at the date of application (see [Fig. 1),](#_bookmark50) then the patent is typically granted after 3 years. Our patent data describing the application cohort of 1977 shows that the lag from application to patent grant is at the median 6 years. Decisions in opposition cases are typically rendered within 2 years. In some cases,

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**Appendix A. A brief overview of German patent law**

Since our data collection takes place in Germany, we summarize a number of particularities of the German patent system which set it apart from the better known US system.[32](#_bookmark49) [Fig. 1](#_bookmark50) presents a graphical depiction of the patent granting process at the German Patent Office. Contrary to the US system, all German patent applications are published 18 months after the applica- tion date. Thus even the subject matter of applications which are rejected reaches the public domain. Until re- cently, US patents were only published once the patent has been granted, thus maintaining secrecy for those

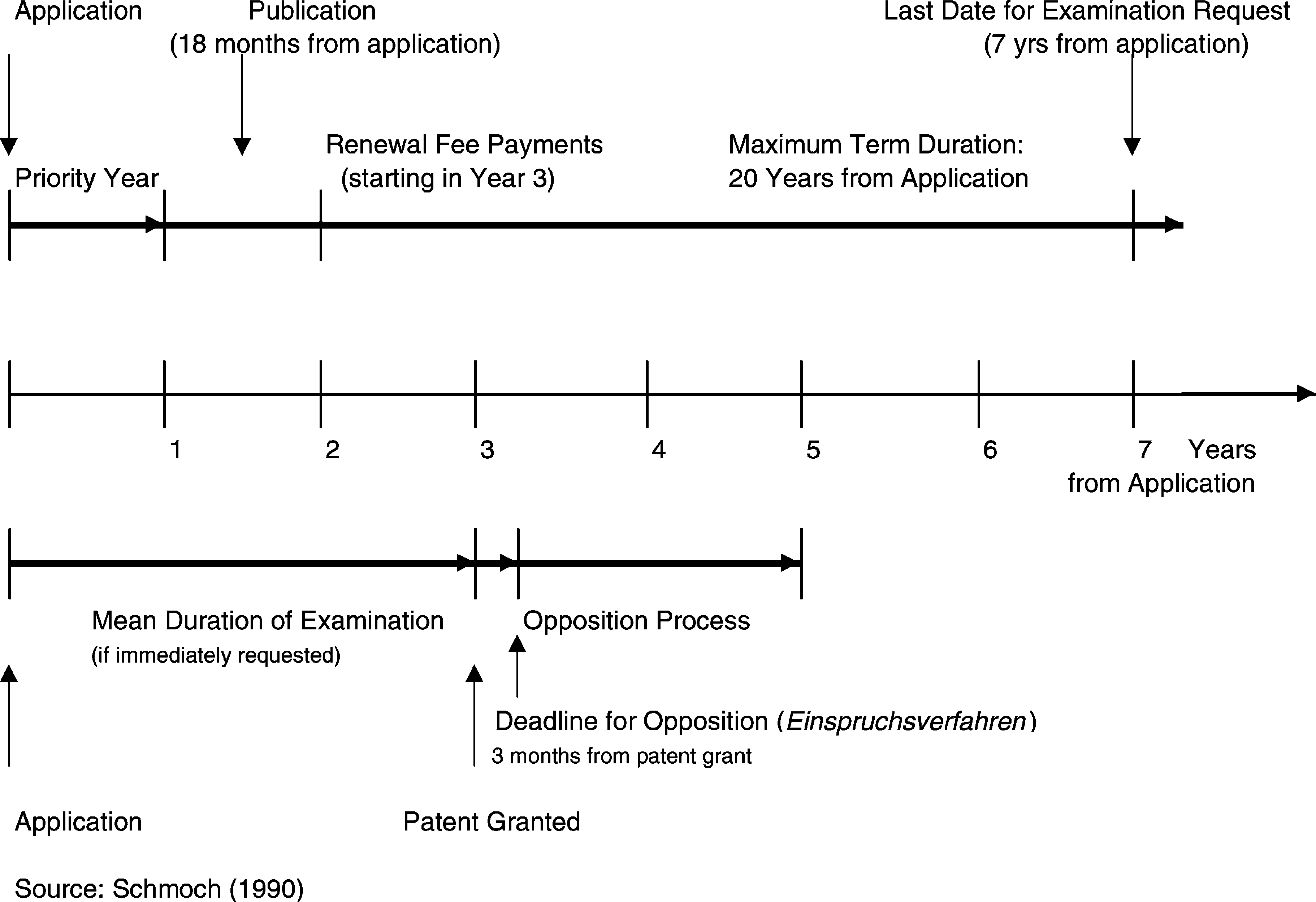
31 In

a few papers, researchers have embarked to study these

issues. [Harhoff and Reitzig (2002)](#_bookmark52) study the characteristics of EPO patent grants that have attracted opposition. [Graham et al. (2002)](#_bookmark54) compare the properties of patent re-examination at the USPTO and of EPO opposition proceedings.

32 Naturally, we can only cover selected features of the German

patent system and law. For details, see [Bernhardt and Krasser](#_bookmark55) [(1986).](#_bookmark55) Issues of opposition and patent litigation are covered in [Liedel (1979)](#_bookmark66) and [Straus (1996).](#_bookmark76) [Stauder (1989)](#_bookmark72) provides descrip- tive statistics on patent litigation cases in Germany.



1362

*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

Fig. 1. Patent examination and granting process at the German Patent Office.

however, they may take 6 years or more to be con- cluded.

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*D. Harhoff et al. / Research Policy 32 (2003) 1343–1363*

1363

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