

Return to Sender? Technological ‘Merit’ and the Reinvigoration of Novelty and Inventive Step

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Analyzing Inventor Incentives to File for ‘Quality Patents’ in a Structural Equation Model

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In the context of the ongoing reinvigoration debate for novelty and non-obviousness (inventive step) I empirically test the fundamental assumption that the private values of patents were correlated with objective technological quality in the past. To do so I suggest an original test to disentangle the impact of (objective) technological quality – as defined by patent offices and requested by non-obviousness requirements – on private patent value. The theoretical links between the private values of patents, technological invention quality, incentives to oppose patents before the European Patent Office (EPO), and observable patent characteristics are translated into a structural discrete choice equation model. Applying the model to polymer patent data between 1978 and 1990, the findings of this paper confirm the assumption that for the chosen sample, objective technological quality enhances a patent’s private value. At the same time, the results refine the understanding of how patent-based measures such as forward and backward citations are correlated with a patent’s commercial value.

Keywords: Patents, novelty, inventive step, opposition, patent indicators, discrete choice

JEL-Classifications: C25, C51, K41, L00, L20

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In the context of the ongoing reinvigoration debate for novelty and non-obviousness (inventive step) I empirically test the fundamental assumption that the private values of patents were correlated with objective technological quality in the past. To do so I suggest an original test to disentangle the impact of (objective) technological quality – as defined by patent offices and requested by non-obviousness requirements – on private patent value. The theoretical links between the private values of patents, technological invention quality, incentives to oppose patents before the European Patent Office (EPO), and observable patent characteristics are translated into a structural discrete choice equation model. Applying the model to polymer patent data between 1978 and 1990, the findings of this paper confirm the assumption that for the chosen sample, objective technological quality enhances a patent’s private value. At the same time, the results refine the understanding of how patent-based measures such as forward and backward citations are correlated with a patent’s commercial value.

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1 Introduction

Novelty and non-obviousness (known as inventive step in Europe) are two essential patentability requirements. Their purpose is to ensure that patents protect technology exceeding a threshold value of triviality. Theoretical scholars have written extensively about the optimal configuration (Scotchmer and Green, 1990; Green and Scotchmer, 1995; Burk and Lemley, 2005) of novelty and non-obviousness needed to increase welfare in different types of industries. While their contributions require different assumptions, they all share at least one fundamental supposition¹: for novelty and non-obviousness to function as policy levers (and not stall R&D), the “clients” of the patent system (i.e. inventors) must have incentives to develop technology exceeding the standard’s threshold in return for the exclusive use of the technology they invent. Such incentives exist if net profits from patenting (private patent value) are positive and higher than those of keeping the invention secret. It is usually assumed that these net profits are driven by (1) the technology’s potential to raise demand and/or reduce costs (and hence *vertically* differentiate products) and by (2) the patentee’s possibility of appropriating some of these rents (by excluding others from the use of the technology). If the technology was publicly available, its demand increase or cost cutting potential would usually be referred to as its objective technological quality or its “technological merit”². And – since technological merit would usually be proportional to the profits for a monopolist using the technology – the classical view is that a patent’s private value increases with both its underlying technological quality³ and its owner’s options to appropriate rents, albeit differently across industries.

As odd as it may be, however, the first part of this assumption, which is important, has never been empirically tested - until today. While there is abundant empirical evidence for the value of appropriability (Teece, 1986) that displays the benefits for the inventor to exclude competitors from using his/her proprietary technology, no studies exist that clearly confirms the link between a patent’s private value and its technology’s objective ‘technological merit’. This is particularly puzzling because it is a pivotal issue in the current debate on the reform of patentability requirements. Recently,

¹ Sometimes this assumption is implicit, often explicit; see e.g. Green and Scotchmer (1995), p. 22.

² The terms ‘objective technological quality’ and ‘technological merit’ are used interchangeably in this paper.

³ Quite clearly, in those cases where externalities break the proportionality between the social value of an invention and the potential monopoly profits of the holder of a respective patent, this assumption is not fulfilled (e.g. patents on HIV medication). These cases appear to be an exception, however.

researchers in the field became aware that some of the most precious IP assets from a corporate standpoint appear to be technologically marginal (Merges, 1999, for Priceline.com; see Reitzig, 2004a, for Nokia), which challenges conventional wisdom.⁴ In some of these cases, it seems as if the private value of the patent was not attributable to ‘technological merit’ but solely to the *exclusive* possibility of serving a niche of consumers with a *horizontally* modified, but legally inimitable product. Additional anecdotal examples from modern patenting in areas like business methods, such as Rockwell’s callback button patent or Amazon’s one-click-buy patent, shake the belief that patentability standards still ensure objective technological quality. One immediate and intuitive reaction by some scholars (e.g. Samuelson, 2004) is thus to postulate the reinvigoration of non-obviousness requirements. The question remains, however, whether a return to former standards – as the notion of a reinvigoration implies – is the way to go. Or in other words: did we ever even have it right in the past? Conclusive answers are lacking despite the richness of related prior work. Although earlier studies on patent value (Cockburn and Griliches, 1988; Megna and Klock, 1993; Conolly et al, 1986; Conolly and Hirschey, 1988; Bloom and van Reenen, 2000; Hall et al, 2000; Bosworth and Rogers, 2001; Harhoff et al., 2003; Hirschey and Richardson, 2004; Ramb and Reitzig, 2004) indicate that patents were clearly valuable for their holders, they stopped short of explaining *why* this was the case. They fail in particular to elucidate whether private patent values were attributable to objective technological merit or not. The striking similarities that Allison and Tiller (2003) find between modern business method patents and patents from classical industries as examined in the aforementioned studies stress at a minimum, however, the need for additional empirical evidence to judge whether a reinvigoration of patentability requirements can assure an increase in overall technological quality.

To shed light on current discussions, this paper analyzes whether in the past firms were likely to apply for and litigate about patents (partly) because the patents would protect objectively valuable technology. If this was the case, it would be a strong indication that the patentability requirements of novelty and inventive step (non-obviousness) were then functioning as predicted by theory (setting private incentives to produce overall valuable technology, at least up to a certain point). To examine the aforementioned question, this paper links the commercial private values of patents from the

⁴ These technologically marginal patents may appear even *ex-ante* trivial, however, if no substitutes for

polymer industry of the 1980s to their technological characteristics in a structural model using data on European patent oppositions and their outcomes. In my two-stage decision model, I condition the decision of a potential opponent to attack (invalidate) an existing patent at the European Patent Office (Stage 1) on his/her anticipated outcome of winning or losing the case (Stage 2). Whereas the objective probability of winning or losing the opposition case (Stage 2) is per definition *exclusively* determined by exceeding the required minimum of technical sophistication (the fulfillment of novelty and inventive step) as set by the patent office, the incentives for entering litigation (Stage 1), on the other hand, can be multifarious. These incentives *may* include those incentives set by the novelty and inventive step of the invention (i.e. technical sophistication as understood by the patent office) but they will likely comprise others, too. These other incentives are assumed to be of two distinctly different kinds. Namely, they may result from a different understanding of technological quality as perceived by the patent office and applicants/opponents. Or they may be posed by the patent's technology unrelated commercial value. Estimating the two equations for Stage 1 (opposition) and Stage 2 (opposition outcome) simultaneously allows me to disentangle the value-driving effects of objective technological quality from the other effects. Finally, a subordinate but important research question follows from the central issue that relates to the actual meaning of patent value indicators. In order to differentiate between technology related and technology unrelated effects, this paper makes extensive use of existing bibliometric patent indicators. Thus, the findings presented, though the result of a subordinate research question in this paper, simultaneously refine our understanding of patent indicators as value measures. A substantial part of the discussion is accordingly devoted to this issue.

This paper, which makes a variety of contributions, has three paramount results. The first is technical by nature. Based on the extant economic literature on litigation, I present the first estimator tailored to empirically disentangle the effects of the two main drivers for patent oppositions. Namely, these are the “value at stake” and the anticipated probability of winning or losing the trial. Applying this estimator to the test of the relation between a patent's technological merit and its private value yields the major empirical findings. For the complete sample of polymer patents in Europe filed between 1978 and 1990 I can confirm that a relation exists between the patents' private values and the

them can be invented (Gallini, 1992), then they can still assume tremendous value.

underlying technological quality of the invention behind the patent. With respect to the measures used in the analysis, I finally find that forward citations are an unambiguous measure of technological merit, whereas family size and backward references proxy both technological quality and the technology unrelated factors of a patent's private value.

The remainder of the paper is structured as follows. Section Two summarizes the most relevant prior theoretical and empirical research. It recalls why and how novelty and inventive step requirements are assumed to be effective by reserving patent protection for technologically qualitative inventions. It also presents related existing empirical evidence, pointing at the ambiguity of the existing results regarding disentangling the contributions of technological merit to private patent value. Section Three provides the theoretical framework that leads to the empirical test for this paper. Building on the theoretical literature on patent litigation, I show how technological quality, if of private value to the patentee and the opponent, should be reflected in their behavior. A two-stage simultaneous equation model is developed that unambiguously distinguishes between the effect of objective technological quality (as measured by the patent office) and other drivers of private patent value. Bringing prior knowledge on patent indicators (Section Two) and theory on oppositions (Section Three) together, Section Four presents different hypotheses. Section Five describes the data and empirical estimation results that are discussed in Section Six. Section Seven concludes.

2 Related prior research – a theoretical and empirical sketch

2.1 Novelty and inventive step – levers to ensure technological quality

The economic rationale for granting patent rights is to add value to society by stimulating research and development (R&D) and diffusing the technical knowledge underlying the inventions made. While inevitably inefficient from an *ex-post* perspective (i.e. after an invention has been made), patents can from an *ex-ante* perspective be an efficient mechanism for reaching the aforementioned goal (i.e. before the research effort has been undertaken). *Ex-ante* efficient patent systems minimize dead-weight losses by optimally balancing one fundamental trade-off, namely, that between welfare maximization through the creation and diffusion of technical knowledge on the one hand and social

profit reduction by excluding society from the use of an invention on the other. The legislative setscrews in the aforementioned optimization process are the same across jurisdictions where patents are subject to a granting procedure, including: the patent's lifetime (patent duration) as well as the substantial patentability requirements, such as disclosure, novelty, and non-obviousness (corresponding to 'inventive step' in the European system).⁵ While the patent's duration should give the patent holder just enough time to recuperate R&D expenses, disclosure ensures that the patentee's technical knowledge enters the public domain in return for the enjoyment of a temporary exclusion right. Novelty and non-obviousness (inventive step) requirements exist to ensure that patents protect technology exceeding a threshold value of triviality, preventing small derivative improvements to an existing technology from substituting a prior patent on the latter technology and depriving the current patent holder of his/her profits (see Green and Scotchmer, 1990). One (classic) assumption here is that the expected returns for the patent holder from his/her invention rise with the technological sophistication of the invention, albeit at a different pace than for society. In cumulative technologies where one invention builds upon another, the goal of protecting such non-trivial inventions with relatively strong novelty requirements can partly conflict with the goal of diffusing information using the patent system. In this case, weaker novelty requirements may therefore be *socially* desirable. This additional trade-off has deservedly received particular attention from Scotchmer and Green (1990). Irrespective of these overall welfare considerations, however, the *private* value of a particular patent is assumed to increase with technological sophistication regardless of the cumulative character of the industry. We therefore usually assume that potential patentees will react accordingly to a policy lever that is coupled with the technological invention quality.

While this fundamental premise appears intuitive at first sight, there are two problems with accepting it without testing. First, it requires that the technological quality set forth by the patent granting authority is similarly perceived by the clients of the patent system, namely applicants and opponents. Whether or not this is the case, however, has remained untested until today to the best of my

⁵ Next to the aforementioned legal constructs (patent duration, disclosure, novelty, non-obviousness/inventive step), patent 'breadth' or 'scope' has often been discussed (see Klemperer, 1990; Gilbert and Shapiro, 1990; Merges and Nelson, 1990) as a separate policy lever even though strictly speaking it is already captured by the disclosure requirements and is not established by statute itself (see also Scotchmer, 2004, p.97). Patent breadth determines 'how much' of a given invention can be claimed for exclusive use by the patentee. This is constrained by the amount of disclosed information.

knowledge. Second, *even if* there is a corresponding understanding of technological quality among patent offices and their clients, technological quality still might not be the driving factor for seeking patent protection for many types of inventions. Especially in the area of modern high-tech consumer goods, patented inventions may unfold enormous commercial private values for their owners when blocking so-called horizontal product modifications that are technically similar to existing products (see Reitzig, 2004a for the example of one of Nokia's most precious IP assets; see Merges, 1999, for the Priceline.com example).⁶ The following section will show that the empirical literature in the field - despite its outstanding contributions - has not yet sufficiently addressed the question of whether the technological merit irrelevance for private patent value in these recent examples is due to the ostensibly lower contemporary standards, or whether private patent values were driven by other factors than technological merit in the past, too. Quite obviously, if private patent values were always rather independent of technological merit, it would significantly affect the reinvigoration debate. It would also require a reassessment of how much firms can be demanded to produce technologically valuable knowledge (via novelty and inventive step requirements), if there are only few incentives for market participants to generate knowledge and diffuse it through the patent system.

In the following, I will briefly summarize the most important aspects of current empirical knowledge regarding the relation between objective technological quality and private patent values. Section 3 then grapples with the questions that remain open from Section 2.2 and demonstrates how respective empirical evidence can be gathered theoretically by describing the theoretical links between a patent's commercial private value, its underlying technological quality as perceived by the patent office and its clients, and the incentives to "litigate" about the validity of the patent (known as "to oppose it" in Europe). Section 3.3 translates these considerations into a testable model.

⁶ Note: the reader may wonder whether the worthiness of patent protection for these types of inventions was not effectively rejected in prior discussions. Note that for the purpose of this paper's central idea I subscribe to the "classical" view that patents should protect inventions that exceed a minimum of objective technological quality, in order to examine whether these prerequisites were fulfilled in the past. However, this premise may of course be challenged. Particularly, without empirical evidence that alternative protection mechanisms such as copyrights can adequately compensate inventors for these types of technologically marginal activities and that technologically marginal but costly-to-develop inventions do not increase overall welfare, it appears dangerous to exclude technologically marginal inventions from patent protection *ex-ante*. The latter discussion is an entirely different one, however, and is left to future studies.

2.2 Empirical evidence

The assertion that in certain industries patents are valuable assets both at the welfare and individual level seems to be an indisputable fact today. Scholars have provided a fair amount of evidence that patents are valuable assets for corporations operating in high-technology industries. Both direct (Levin et al., 1987; Cohen et al., 2000; Harabi, 1995; Harhoff et al., 2003; Reitzig, 2004b) and indirect empirical evidence (Cockburn and Griliches, 1988; and Megna and Klock, 1993; Conolly et al., 1986; Conolly and Hirschey, 1988; Bloom and van Reenen, 2000; Hall et al., 2000; Bosworth and Rogers, 2001; Hirschey and Richardson, 2004; Ramb and Reitzig, 2004) support the assumption that – at least in the past – patents were valuable to their owners in classical R&D-intensive manufacturing industries. However, to judge whether this value correlation means that policy levers such as novelty and non-obviousness (inventive step) were functioning, empirical evidence relating the objective technological quality to patent value is required. Here, the picture becomes much less clear, though.

2.2.1 *Direct evidence*

To the best of this author's knowledge, direct empirical evidence on the aforementioned question has been extremely rare until today. As a matter of fact, the only study relating primary survey data on private patent values for their owners to an expert's assessment of technological quality relates to an individual portfolio of 127 patents from one semiconductor firm (Reitzig, 2003). While the results point at a positive correlation between patent value and technological quality, they cannot be considered to provide a full answer to the question posed in this paper. First, the small number of observations prohibits generalizations. Second, the focus on one firm in one industry makes general inferences difficult. Finally, the technology assessment was not objective in the sense that it was carried out by technical experts within the firm and not by the patent office.

2.2.2 *Secondary evidence using patent indicators*

Far more studies using secondary rather than primary data exist that relegate their findings to a link between technological quality and patent value. In a nutshell, these studies differ with respect to the dependent variable used as a proxy for the patent's private value, the respective research design,

and with respect to the independent variables used to measure technological quality. What the studies do have in common, however, is that none of them provide a structural test that clearly allows for the assessment of the correlation between objective technological quality and private patent values. None of the dependent measures – be they expert assessments for the private values of patents (Albert et al., 1990; Harhoff et al., 2003), stock-market values of corporations (Cockburn and Griliches, 1988; and Megna and Klock, 1993; Conolly et al, 1986; Conolly and Hirschey, 1988; Bloom and van Reenen, 2000; Hall et al, 2000; Bosworth and Rogers, 2001; Hirschey and Richardson, 2004; Ramb and Reitzig, 2004), or the likelihood of litigation (Lanjouw and Schankerman 2001; Harhoff and Reitzig, 2004; Reitzig, 2004c) – are an unambiguous proxy for technological merit. Hence, reduced form estimations linking these measures to measures of patent quality cannot “prove” the importance of objective technological quality. This being said, however, many of the indicators used as independent measures in the aforementioned studies plausibly capture objective technological quality, at least to some extent, as the short synopsis in the following paragraphs will show. This summary is organized according to the respective indicators and reassumes the rationales of why or why not the independent proxies of patent value could be correlates of technological quality. By doing so, it lays the basis for the part of the hypotheses formulated in Section 4 that addresses the right-hand side measures. Regardless of all attempts to make these hypotheses as compelling as possible, however, I shall also make very clear that the description of the linkages between certain indicators, objective technological quality, and a patent’s private value cannot be conclusive given the current empirical evidence. For many of the value indicators both technology related and technology unrelated rationales may apply. In the empirical estimations (see 5.3), these ambiguities are taken into account by estimating non-disjunct parameterizations – allowing the estimator to pick those variables to capture technology related and technology unrelated effects that have the highest explanatory power for either type of effect. However, on the other hand the model is only barely identified without exclusion restrictions; hence, it seems advisable to start from as much theory as possible when running the estimations. Finally, the following summary explicitly does not attempt to give a full overview of all empirical studies being carried out up to the present; instead, it selectively refers to the major arguments brought forth in the discussion on the link between patent indicators, patent value, and technological quality

Backward citations (references), defined as quotations of prior art relevant to the patentability of an invention during the granting procedure, were originally introduced by Carpenter et al. (1980) and Narin et al. (1987), and are supposed to be positively correlated with value for different reasons. In the case of references to prior *patent* literature, one rationale is that they measure existing market potential (Harhoff and Reitzig, 2004) and need not be technology related. In the case of references to the *non-patent* literature – especially scientific publications (see Meyer, 2000; Narin et al., 1997) – economists often argue that a patent’s invention being linked to basic research indicates high technological quality and therefore economic value (Carpenter et al., 1980). Yet Lanjouw and Schankerman (2001) provide evidence that backward cites are negatively correlated with the likelihood of litigation, inferring that more backward cites indicate derivative research. In conclusion, backward citations to both patent and non-patent literature belong to the fairly well-validated indicators of patent value. It appears, however, as if they potentially measure various (potentially counteracting) effects.

Forward citations, defined (most simply) as the number of quotations a patent receives itself during the subsequent granting procedures of younger patents, turn out to be positively correlated with a patent’s value in all known studies (see Hall et al., 2000/2005, for a comprehensive overview). Various rationales are put forth. The dominant one (see the original contribution by Trajtenberg, 1990) is that forward citations are supposed to measure the technological sophistication or quality of the underlying invention. This rationale holds especially – but not exclusively – true for citations made by an examiner. At the same time, however, it cannot be precluded that forward citations may also capture technology unrelated effects (Harhoff and Reitzig, 2004). This appears particularly plausible if the quotations were inserted by the applicant himself/herself.

Family size is an indicator that measures the size of the territory in which the patent holder enjoys exclusivity (see Putnam, 1996, for the original idea). The potential arguments for family size being a value indicator are theoretically multifold. One of the first contributions by Lanjouw et al. (1998) contains no explicit statements about why exactly internationally protected inventions should be more valuable than others, nor do subsequent papers. Eventually, the argument that addresses the

cost commitment the applicant makes for protecting his/her invention, causes the question to remain open as to whether technology related or technology unrelated considerations drive the family size. At least for European patents, it makes sense to assume, however, that family size at least partially addresses technological quality. This is because the patent applicants' risk of losing their patent for all member states in just one opposition case increases the larger the European patent family size becomes. The alternative of filing separate national applications and reducing EP family size is more costly, but likely to be favored if the technological quality of the invention is limited (see Reitzig, 2004c, for the respective rationales).

A series of other indicators have been tested as value indicators in earlier studies, too. Among those are the *scope* variable (introduced by Lerner, 1994), the *ownership* variable (Lanjouw and Schankerman, 2001), indicators referring to the *filing route* ("*strategy*"), the *number of inventors*, *applicants*, and *cross-border research co-operations* (the latter introduced by Guellec and van Pottelsberghe, 2000), as well as the *accelerated examination request* (introduced by Reitzig, 2004c), and the *claims* (introduced by Tong and Frame, 1992). As of today, the empirical evidence of their validity varies; however, they all still belong to the extended set of weighting measures for patent counts currently applied in the field. More interesting for the purpose of this paper are the differences in their theoretical foundations. Whereas claims and scope are supposed to proxy a patent's breadth (and are therefore assumed to be technology related) the number of applicants and the amount of cross-border research co-operations should reflect a high degree of technological sophistication because resources from different corporations are pooled. The filing route variables and the accelerated examination request are deemed mainly to be signs of the market proximity of the invention and not (so much) technology related.

Thus, taken together, a complex picture emerges. For a start, however, it seems as if indicators such as backward references to the non-patent literature, the number of inventors, and the number of applicants should theoretically be correlates of patent value *primarily* because they measure objective technological quality. In the case of backward references to the patent literature, family size, indicators referring to the filing strategy, and the accelerated examination request, the link to patent value should be *primarily* technology unrelated. Forward citations should be measures of both technological and

non-technological quality. Eventually, however, these alleged relationships remain speculative based on the empirical evidence for the reasons mentioned above. Ultimately, only a structural model that unambiguously disentangles the effects captured by the aforementioned indicators can resolve the problem. The next section develops such a model.

3 Theoretical framework and model derivation

This section seeks to derive a theoretical model that enables the testing of the correlation between the private value of a patent and the objective technological quality of the underlying invention. Methodologically speaking, the formal logic extends the work of various predecessors. Like Lanjouw and Lerner (1998) and Harhoff and Reitzig (2004) the model seeks to exploit observable information regarding legal arguments about the validity of a patent right. Unlike the aforementioned works, however, it also uses the observable outcome of these arguments to draw inferences. In this respect the approach remotely resembles Somaya (2003), albeit only at very first sight. Similarly, Somaya's (2003) model is a two-stage equation model using patent litigation data. However, it differs fundamentally in various aspects – the most obvious being that the second stage is endogenous in Somaya and exogenous in this paper. In more detail, this means that in Somaya's model the agent makes decisions both in the first stage (whether to litigate) and in the second stage (whether to settle). In the model developed on the following pages, a different logic applies. Here, the agent can only decide in Stage 1 whether or not to oppose a patent, whereas the patent office (nature) decides the outcome of the opposition procedure. Hence, the decision-making logic of the agent in the first stage is conditional on an exogenous event in the second stage. The agent cannot – as in Somaya (2003) – decide whether to settle or not at any point in time. Once the opposition is filed (see Harhoff and Reitzig, 2004, for the details), the opposition division is bound to pursue the case. Consequently, once having filed the opposition, the opponent is formally deprived of his settlement bargaining options. Quite clearly, the two approaches pursue distinctly different purposes. In the following, the theoretical sections bring together the notions of patent value, incentives to oppose, and technological quality to derive the test design.

3.1 Patent value

Assessing the private commercial value of a patent for its owner is a difficult task. As Harhoff et al. (2003) show in a formalized fashion, for most of the empirically relevant scenarios, this private *asset* value is best defined as a profit difference; namely, as the difference between the profits in the case in which the patent holder enjoys exclusive protection and the case in which his/her severest competitor owns the patent. As the two scenarios mutually exclude one another, one of them will always be counterfactual, requiring a non-trivial profit estimation when assessing the patent's private value. While the results of these patent *asset* valuation attempts are not usually observable to the public and respective data is not easily accessible, the outcome of a similar yet nonidentical valuation problem is frequently disclosed; namely that is the decision made by a third party to invalidate a granted patent in court. In the following, I will show how the asset value of a patent (private value) and the observable opposition decision by a third party are correlated.

3.2 Patent value and incentives to oppose

In the European patent system, third parties can attack a patent within nine months after its granting by filing a so-called opposition. The opposition procedure differs slightly from the challenge suit procedure in the US (see Graham et al., 2002, for details), but the fundamental logic is comparable. There are three potential outcomes of an opposition procedure. Either (1) the patent is upheld and remains unchanged, or (2) the patent is amended, or (3) it is revoked.⁷ According to Article 100 of the European Patent Convention (EPC), the ruling on the outcome is made by the European Patent Office based on a (re)assessment of the patentability requirements, the main ones being: novelty, inventive step, and commercial applicability (susceptibility to industrial exploitation). Finally, insufficient disclosure of the invention can also lead to revocation or an amendment of the patent.

⁷ Graham et al. (2002) note that there is a 'fourth' outcome category, i.e. the opposition procedure is "closed". The way they define this category is that it "refers to cases in which the patent holders do not renew patent protection after the opposition has been filed, which causes the patent to lapse into the public domain". For want of better information they suggest considering these cases as successful challenges of the patent's validity. While there may be explanations for doing so, this paper takes a different approach based on intense discussions with a senior representative at the Technical Board of Appeals at the European Patent Office. The expert argues that the 'closure' of an opposition as reported in the data source www.epoline.org is a decision made by the opponent and most likely a 'retreat' from the legal attack. To test the robustness of the results in the empirical part, an alternative variable declaration is tested. The counterintuitive results of this alternative test (not shown in this paper) support the interpretation chosen in this paper.

Since an opposition procedure is costly and since the most obvious alternative option to an opposition is a settlement agreement, I assume - like Harhoff and Reitzig (2004) – that

A1: The incentives to file an opposition are determined by the value at stake, settlement costs, and the likelihood, as subjectively perceived by the parties, of the patent being upheld, amended, or revoked. Uncertainty regarding all of the aforementioned determinants affects the incentives to oppose.

This assumption is buttressed by the general theoretical economic literature on litigation (Priest and Klein, 1984; Cooter and Rubinfeld, 1989; Waldfogel, 1998) as well as by reduced-form empirical evidence (see 2.3). Lanjouw and Lerner (1998) custom tailored a simplified theoretical model (neglecting settlement costs) to the litigation for US patent *validity (challenge) suits*, the type of court procedure resembling a European opposition most closely. Harhoff and Reitzig (2004) elaborate on Lanjouw and Lerner (1998) and adjust their game theoretical surplus model to the specificities of a European *opposition* procedure. The authors introduce settlement costs into Lanjouw and Lerner's (1998) model and argue why these costs will be relatively high compared to court and attorney fees in European opposition proceedings. Essentially, the authors' formal rationale takes into account that the option to centrally oppose a European patent expires nine months after its grant, a period within which effective out-of-court settlement agreements can seldom be reached according to the various practitioners interviewed (Harhoff and Reitzig, 2001). Incentives for preventive opposition are therefore high in most empirically relevant scenarios.⁸ This means, however, that the opposition rationale will be dominated by the opponent's subjectively perceived likelihood of winning or losing the opposition and the value at stake. Figure 1 illustrates the decision making problem.

Insert Figure 1 about here

⁸ However, note again, as mentioned in the introduction to this section, that the according to Article 114 of the European Patent Convention the EPO may pursue the opposition on its own behalf even if the opponent withdraws his original invalidation request. This may counteract the competitors' opposition rationale if a licensing deal based on a valid patent is the ultimate goal. Their incentives to oppose are reduced as the EPO might invalidate the patent even though the opponent dropped his/her opposition and a return-sharing out-of-court settlement with the patent holder could become infeasible. According to interviewed practitioners it seems as if the likelihood of the patent being revoked decreases with the opponent dropping his/her opposition. This could be interpreted as an indication that the opponent keeps some de-facto bargaining power to settle the case even after the opposition has been filed. Quite clearly, however, this would still be a situation that substantially differs from the US litigation as modeled by

The (potential) opponent will attack the patent holder if his/her profits in the case of an opposition exceed his/her profits in the event of passive behavior. His/her decision-making problem and the resulting likelihood of an observable opposition can thus be expressed in formal terms.

$W = 1$ if

$$\pi_{rv} \cdot p_{opponent}(revoc|opp) > \pi_{no} - \pi_{rj} \cdot p_{opponent}(rejec|opp) - \pi_{am} \cdot p_{opponent}(amend|opp) \quad (1)$$

and

$W = 0$ otherwise

Equation (1) shows a probability-weighted profit difference for various scenarios. Namely, for the case in which the opponent successfully manages to invalidate the patent and the invention lapses into the public domain, and for the remaining potential cases in which the opponent either unsuccessfully or partially unsuccessfully opposes the patent, or in which he/she does not act at all. In all of the latter cases, the patentee will – at least to some extent – retain exclusive rights over his/her protected technology. While Equation (1) does not exactly reflect the asset value of the patent, it will, however, often be highly correlated with the prior one. The simplest of all imaginable scenarios shall serve as an illustration. In a one-product world with two competitors in which the patent holder enjoys monopoly profits and a successful opponent receives symmetric duopoly profits in a co-operative agreement with the former patent holder (i.e. the monopoly profits are split between the former patent holder and the successful opponent), the value at stake during an opposition is 0.75 times the asset value of the patent. As Harhoff and Reitzig (2004) discuss in more detail, the aforementioned relation between the value at stake during an opposition and the asset value of the patent changes with the competition characteristics. For the purpose of this paper, however, it seems sufficient to note that in industries where two or only a few players use patents fiercely to exclude each other from the use of

Somaya (2003). Moreover, large-scale empirical evidence for the allegations are missing. Consequently, this paper models the European opposition procedure in alignment with the existing regulations.

their proprietary inventions, theory predicts a highly positive correlation between the value at stake during the opposition and the asset value of the patent.

3.3 Incentives to oppose and technological quality (novelty and inventive step)

According to theory, technological quality should enter the decision to oppose a patent at two different stages and in two different ways. As mentioned before, the (subjective) technological quality of the invention as perceived by the opponent will constitute part of the value of stake. As also mentioned before, several other factors will additionally drive the value at stake, including, among others, market considerations in connection with the invention that are not technology related. Objective technological quality as assessed by the patent office will affect the outcome of the opposition; hence, to the extent that the opponent can estimate the decision of the patent office it will enter the opponent's rationale in the first stage, namely whether or not to attack the patent holder with an opposition. One lacuna for empirical researchers is to exploit this twofold impact of objective and subjective technological quality on the opposition decision. To turn the condition in Equation (1) into an estimation model that allows for the aforementioned test, some further assumptions and simplifications are necessary. The assumptions are mostly unproblematic. Thus, they are only briefly described and corroborated in the following.

A2 condenses some of the prior discussions in the text and is mentioned for the sake of completion.

A2: The value at stake can theoretically be driven by objective technological quality as set forth by patentability requirements (novelty, inventive step) as well as by subjectively perceived technological quality and other non-technological factors.

A3: The opponent can anticipate reasonably well the decision of the opposition procedure by the European Patent Office (EPO). The EPO bases its ruling on the opposition solely on two criteria, namely the fulfillment of novelty and inventive step (i.e. objective technological quality).

This assumption is necessary to infer from observable outcomes of opposition decisions (see below) on the opponent’s estimation of objective technological quality. The second part of the assumption is entirely unproblematic because it reflects the dogmatic guidelines of the EPO, but the first part is also very plausible, at least in those industries where considerable litigation experience among opponents exists (see also Harhoff and Reitzig, 2001, and below in Section 4, “Data selection”). In a formalized fashion, this assumption⁹ states that

$$\tilde{p} = p_{Opponent}(amendment/opp.) + p_{Opponent}(rejection/opp.) = f(novelty, inventive\ step) \quad (2).$$

Despite its plausibility in the European patent arena, however, Assumption 3 is theoretically strong. In more general areas of litigation (see Cooter and Rubinfeld, 1989; Waldfoegel, 1998), the uncertainty about the outcomes of court cases is considered a major determinant for the likelihood of litigation. “Suppressing” the effects of uncertainty in this design by assuming that opponents can anticipate reasonably well opposition outcomes can be a potential source of error.¹⁰ Consequently, the discussion of the empirical results relaxes Assumption 3 when necessary to explain potential inconsistencies in the findings.

Finally, the last two assumptions are the following:

A4: The opponent’s profits given the different possible rulings of the EPO are determined as follows:

$$\pi_{no} = 0; \pi_{rj} = \pi_{am} = -c; \pi_{rv} = g(novelty, inventive\ step, other\ factors) - c$$

(where c = costs for an opposition and “other factors” comprising subjectively perceived technological quality or technology-unrelated determinants of stake value)

and

⁹ Note that in Equation (2) I use the terms “novelty and inventive step” to denote objective technological quality. Strictly speaking and as discussed lengthily in the introduction, however, novelty and inventive step are threshold values of objective technological quality, of course. Nonetheless, from here until the end of the paper the terms are sometimes used instead of “technological quality” to assure that the reader does not lose the focus of the envisaged test.

¹⁰ This error may be firm specific. For example, the Henkel KGaA in Germany enjoys an overproportionally high opposition success rate which may be attributed to superior private information the corporation has. I thank Bronwyn Hall for sharing this thought with me.

A5: The opponent's decision to file an opposition is not significantly co-determined by the possibility to appeal against the EPO ruling on the opposition procedure.

Assumption 4 is the most simplifying of all. As discussed, its suitability is subject to the competitive scenario (Harhoff and Reitzig, 2004).¹¹ It also contains a simplification in that it sets the profits for two outcome scenarios equal, namely the amendment of the patent and the rejection of the opposition. From talks with patent attorneys (Reitzig, 2004c), however, it seems that this simplification also reflects reality sufficiently well in certain industries (see Section 5.1, "Sample selection"). Hence, for the empirical test to produce meaningful results, it comes down to picking an industry in which A4 is most likely to be fulfilled. Finally, Assumption 5 potentially simplifies the opponent's rationale in that it no longer considers subsequent appeal or litigation possibilities in detail.¹²

Implementing A1, A2 and A4 into (1) then yields the following condition for an opposition:

$$W = 1 \text{ if } \tilde{p} \cdot (\pi_{am,rj} - \pi_{rv}) > (\pi_{no} - \pi_{rv})$$

and (3).

$$W = 0 \text{ otherwise}$$

3.4 A theory-based two-stage simultaneous discrete choice model

Equation 3 is in fact a system of two equations (the probability of an opposition conditioned on the opposition outcome) that need to be estimated simultaneously. Despite the great variety of various two-stage simultaneous discrete choice models described in the econometric literature, no standard estimator suitable for this decision problem appears to exist. For this reason, a custom-tailored

¹¹ In a sector in which patents are mainly used as bargaining chips, this assumption could lead to a distraction from the 'real' results. In these industries, the value of a patent does not lie in the option to exclude others from the use of the technology (as assumed in this paper), but bargaining options play a major role in creating revenues. For the industry analyzed in this paper, the assumption should hold well, though (see also the following Section 5.1, "Sample selection").

¹² The simplification seems inevitable for both theoretical and practical econometric reasons. From a theoretical econometric perspective, estimating a three-stage model accounting for appeal or other subsequent litigation possibilities following opposition does not appear feasible and just increases the data truncation problem that comes with the observation of appeal cases (see Section Four). For practical reasons Assumption 5 also appears necessary (see footnote 19 for an elaboration of the practical problems).

estimator was derived for the present problem using maximum likelihood.¹³ Measuring novelty and inventive step (objective technological quality) by indicators X (and error term ε) and other value driving determinant factors (subjective technological quality and technology-unrelated factors) by indicators Z (and error term η) makes it possible to disentangle the effects of objective technological quality and other factors on private patent value and hence finally helps to explain *why* patent indicators measure patent value. For econometrically very well-trained readers I present the final likelihood function and a respective legend of the major parameters first. Those readers may want to skip the following pages and move on to Section 4 immediately. For interested readers, the derivation of the model is described in the following.

$$\log L = (1-W) \cdot \log \left(\Phi \left(-\frac{a}{\sigma_{\xi}} \right) \right) + W \cdot \left[V \cdot \log \left(\Phi^2 \left(\frac{a}{\sigma_{\xi}}, x\beta, \rho_{\xi, \varepsilon} \right) \right) + (1-V) \cdot \log \left(\Phi^2 \left(\frac{a}{\sigma_{\xi}}, -x\beta, -\rho_{\xi, \varepsilon} \right) \right) \right] \quad (4)$$

, where

$W = 1$ denotes the occurrence of an opposition ($W = 0$ otherwise),

$V = 0$ denotes the revocation of the patent ($V = 1$ otherwise),

$$a = (1 - \Phi(x\beta)) \cdot (x\beta + z\gamma) - c,$$

$$\xi = (1 - \Phi(x\beta)) \cdot (\varepsilon + \eta), \text{ and}$$

$$\rho_{\xi, \varepsilon} = \sqrt{\frac{(1 + \rho_{\eta, \varepsilon})}{2}}.$$

Condition (1) for an opposition being filed is as follows:

$$\pi_{rj} \cdot p_{\text{opponent}}(\text{rejection|opp}) + \pi_{am} \cdot p_{\text{opponent}}(\text{amendment|opp}) + \pi_{rv} \cdot p_{\text{opponent}}(\text{revocation|opp}) > \pi_{no} \quad (1)^{14}$$

¹³ Full identification was numerically established using simulated data.

¹⁴ Numbering is kept consistent with formula numbering in the preceding sections.

Using assumptions A1, A2 and A4 and abbreviating $p_{Opponent}$ (*patent upheld/opposition*) to \tilde{p} , this yields equation (3a)

$$\tilde{p} \cdot \{-c - g(\text{novelty, inventive activity, other factors})\} > (0 + c) \quad (3a)$$

which denotes the simplified condition for an opposition being filed.

Defining

$$\text{novelty, inventive step} = x\beta + \varepsilon \quad (3b)$$

and accordingly

$$\text{other factors} = z\gamma + \eta \quad (3c)$$

yields

$$g(\text{novelty, inventive step, other factors}) = x\beta + z\gamma + \varepsilon + \eta \quad (3d)$$

as the simplest form for g (linear combination).

If H1, H2, and H3 are true, condition (3) must then take the following form:

$$\begin{aligned} \tilde{p}[-c - (x\beta + \varepsilon + z\gamma + \eta - c)] &> (0 - (x\beta + \varepsilon + z\gamma + \eta - c)) \\ \Leftrightarrow (1 - \tilde{p})(x\beta + \varepsilon + z\gamma + \eta) - c &> 0 \\ \Leftrightarrow (1 - \tilde{p})(x\beta + z\gamma) - c &> (1 - \tilde{p})(\varepsilon + \eta) \end{aligned} \quad (5).$$

In the following, the observable term $(1 - \tilde{p})(x\beta + z\gamma) - c$ is referred to as a , and the unobservable term $(1 - \tilde{p})(\varepsilon + \eta)$ is referred to as ξ .

A likelihood function reflecting Equation (5) has three distinct probabilities, $prob(W=0)$, $prob(W=1, V=0)$, and $prob(W=1, V=1)$, where

$W=1$ denotes the occurrence of an opposition ($W=0$ otherwise), and $V=0$ denotes the revocation of the patent ($V=1$ otherwise).

According to (5), the likelihood of no opposition taking place is given by

$$prob(W = 0) = \Phi\left(-\frac{a}{\sigma_{\xi}}\right) \quad (6),$$

assuming that ε and η are normally distributed with covariance $\begin{bmatrix} 1 & \rho_{\varepsilon,\eta} \\ \rho_{\varepsilon,\eta} & 1 \end{bmatrix}$.

In the case of an opposition, there are two possible outcomes depending on the (opponent's anticipation of the) EPO's decision. Using assumption A3 yields the following additional condition for the opponent's anticipated probability of the patent being upheld after the opposition (2nd stage):

$$\tilde{p} = Prob(x\beta + \varepsilon) > 0 \quad (7).^{15}$$

The probability of an opposition taking place and the patent being upheld (or amended) is described by the binormal distribution

$$prob(W = 1, V = 1) = \Phi^2\left(\frac{a}{\sigma_{\xi}}, x\beta, \rho_{\xi,\varepsilon}\right) \quad (8),$$

where $\sigma_{\xi}^2 = 2(1 + \rho_{\eta,\varepsilon})$ if $\sigma_{\eta} = 1$, and $\rho_{\xi,\varepsilon}$ is the correlation coefficient between the disturbances of the 1st stage (opposition yes/no) and 2nd stage (patent revoked/upheld or amended), which can be calculated to

$$\rho_{\xi,\varepsilon} = \frac{(1 - \Phi(x\beta)) \cdot (1 + \rho_{\eta,\varepsilon})}{(1 - \Phi(x\beta)) \cdot \sqrt{(2 + 2 \cdot \rho_{\eta,\varepsilon})}} = \sqrt{\frac{1 + \rho_{\eta,\varepsilon}}{2}} \quad (9).$$

Analogously to (9), the probability of the patent being revoked can be calculated as

$$prob(W = 1, V = 0) = \Phi^2\left(\frac{a}{\sigma_{\xi}}, -\sum x\beta, -\rho_{\xi,\varepsilon}\right) \quad (10).$$

¹⁵

Note: this estimator does not treat the anticipated probability of an EPO ruling as a *conditional* probability given that opposition actually takes place. This simplification is, however, easily vindicated when it is taken into consideration that *potential* opponents would *always* have an anticipated probability of winning or losing their case – *no matter* whether they eventually file an opposition or not. In that respect it is consistent with one of the major underlying assumptions of the paper (A3). Statistically speaking, the simplification has advantages in that it keeps the complexity of the estimator manageable.

Equations (6), (8), and (10) finally constitute the ML estimator function (4) given above.

The estimator described in Equation (4) maximizes the likelihood of an opposition including the opponent's anticipated probability of winning or losing his/her case.¹⁶ The value of the patent is modeled by novelty, inventive step, and other value determining parameters; the opponent's anticipation of the patent being upheld (revoked) is modeled by novelty and inventive step only (consistent with Assumption 3). A potential point of criticism is that the estimation assumes that the marginal effect of objective technological quality (with threshold values determined by novelty and inventive step) on private patent values is identical to the marginal effect of technological quality on the likelihood of patent survival in an opposition procedure. At this point, attention should be paid to two considerations, though. First, it is an explicit aim of this paper to evaluate patentees' and opponents' *shared* perceptions of technological quality as a patent value driver. Second, and more importantly, however, an estimator that seeks to introduce a further parameter distinguishing between the two aforementioned marginal effects is simply not identified.

4 Hypotheses and data prerequisites

Based on the comprehensive description of the estimation model (Section 3) and the existing empirical evidence on patent value indicators (Section 2), the derivation of the hypotheses should follow naturally and is hence kept very brief. Below, four hypotheses are formulated. The propositions are drafted in such a way that the first sentence relates to the abstract question to be tested, while the second one translates the abstract question into the econometric test design. This intended redundancy is meant to facilitate the reader understanding.

The fundamental hypothesis to be tested in this paper is Hypothesis 1:

H1: The private values of patents increase with objective technological quality as set by novelty and inventive step requirements. Econometrically speaking, this means that a group of patent value indicators, X , exist that are individually and jointly positively correlated

¹⁶ This feature distinguishes the estimator from known discrete choice models that are available in statistical software packets, such as multinomial/nested logits or Heckman's probit (see e.g. Heckman, 1979). Neither do econometric textbooks (see e.g. Maddala, 1983) refer to an estimator of the above

(a) with the likelihood of an opposition, and simultaneously with
(b) the likelihood of the patent being upheld after this opposition
in an estimation model as described by Equation (4).

Whereas Hypothesis 1 is the central contextual proposition of this paper, the discussion of the prior research above also identified a series of related measurement issues that require clarification in order to get a better grip on the impact assessment of technological quality on patent value using secondary measures. In more detail, the existing empirical evidence suggests that different patent indicators should exhibit varying suitability to measure the different determinants of a patent's value:

H2: Indicators such as backward references to the non-patent literature, the number of inventors, and the number of applicants should be correlates of patent value primarily because they measure objective technological quality. This means that these indicators should belong to the group of X indicators in the estimation model described by Equation (4) rather than to the group of Z indicators.

Vice versa:

H3: Indicators such as backward references to the patent literature, family size, indicators referring to the filing route, and the accelerated examination request should be primarily technology unrelated proxies of patent value. This means that these indicators should belong to the group of Z indicators in the estimation model described by Equation (4) rather than to the group of X indicators.

Finally:

H4: Forward citations should be measures of both technological and non-technological quality. Hence, they should belong to the group of X indicators as well as to the group of Z indicators in the estimation model described by Equation (4).

Table 1 summarizes Hypotheses 2, 3, and 4.

kind that models a selection bias but focuses on the estimation of the unselected (Stage 1) rather than the selected sample (Stage 2).

Insert Table 1 about here

Testing the aforementioned hypotheses within the chosen research design implies various data prerequisites. The model underlying the estimator is based on the premise that the value of a patent revocation for the opponent is proportional to the value of the patent for its holder. This assumption is best fulfilled in markets where patent holders enjoy temporary monopoly profits and would have to share duopoly profits if they did not have legal protection. Therefore, running the empirical test on patent data from a discrete product industry (see Merges and Nelson, 1999) in which one product is protected by only few patents seems advisable.

Moreover, one main distinguishing feature from earlier empirical studies on patent litigation or opposition is the explicit modeling of the key assumption that anticipated success and failure rates enter the rationale of the opponent or the plaintiff.¹⁷ In the present paper, *observable outcomes* of opposition procedures are used to model the opponent's anticipation. Thus, the data must comprise the sets of value indicators as described in H1 through H4, the observable opposition, and the corresponding EPO ruling. This means, however, that the data for the analysis are in principal truncated and non-trivial sample selection problems arise. The next section shows how the sample selection seeks to address the data prerequisites.

5 Empirical results

5.1 Sample selection

For two reasons, the sample chosen for the analysis contains European polymer patents.¹⁸ First, it seems that in the case of polymers, individual patents could protect most of the technology inherent in the final product (see e.g. Cohen et al., 2000). Thus it is reasonable to assume that the value of a patent revocation to the opponent is highly correlated with the value of the valid patent for its

¹⁷ To the best of my knowledge the study by Graham et al. (2002) is the only one that presents litigation and opposition outcome data at all. That study, however, contains no structural validation of value indicators modeling subjective outcome anticipations in any way.

¹⁸ The patents were identified via the OST INPI ISI classification based on IPCs.

owner. This was an important prerequisite for the chosen model to yield plausible results. Second, to the best of my knowledge, there is no large-scale empirical study on the European polymer patents. Beyond its primary goal of structurally testing the relationship between objective technological quality and a patent's private value structurally, the sheer data presentation in this paper already extends our knowledge base of patents in this industry in a more general fashion.

The selection of the industrial field was based on an updated version of the widely accepted OST INPI ISI classification by Schmoch (1994, personal note on an update from 1998). Polymer patents were identified as showing one of the following IPC subclasses as their main classification: C08B, F, G, H, K, L; C09D, J. As of December 2003 (the date of the data extraction) the European patent register contained 31,181 granted patents in these areas. At this point, 3,126 (10.03%) patents in the sample had been opposed. For 2,608 of these opposed patents, a decision by the *first instance* at the EPO – the opposition division – was observable in December 2003. For the remaining part of the patents, no clear ruling by the opposition division could be identified at that date (pending case either in opposition or appeal). Figure 2 shows the share of unidentified oppositions among the total sample versus the year of patent priority.

Insert Figure 2 about here

Figure 2 shows a steep ascent of unidentified opposition outcomes after the year 1990. Pending a better explanation I take it that this increase can be attributed to the share of opposition cases still to be decided in December 2003 by the first instance at the EPO, namely the opposition division.¹⁹ As this paper (see Assumption 5) primarily focuses on the decision of the opposition division (no further appeals, no subsequent litigation), I cut off the tail of patents applied for from 1991 onwards and obtain a residual percentage of approx. 2.1% of unidentified first ruling opposition

¹⁹ Data on the average duration of opposition procedures have been published in the literature for the fields of pharmaceuticals and biotechnology only. As Graham, Hall et al. (2002) describe, opposition procedures may take about 2.7 (2.8) years (post/pre-1991 applications). Adding the average granting time of 4.3 years for patents in the same area (Reitzig, 2004c) to that value yields an average period of 7 years from grant to opposition ruling in these industries. Looking further at the variance of this period it is therefore entirely plausible to observe an increase in undecided opposition procedures of 11 to 12-year-old patent applications as is the case here.

cases between 1978 and 1990.²⁰ Thus, the final data for the analysis comprises 16,980 granted EP patents with priority dates between 1978 and 1990, of which 2,024 were opposed.

5.2 Descriptive statistics

Table 2 shows the descriptive statistics for the sample.

Insert Table 2 about here

The most interesting findings are briefly explicated (they will be discussed in the next section). At 11.91%, the rate of opposition in the polymer chemistry industry is significantly larger than in the total population of EP patents for this period. It is even higher than in the litigious pharmaceutical and biotechnological industry (10.79% and 10.24% opposition between 1978 and 1990). In about 39% of all oppositions, third parties attack holders successfully according to the notion of this paper; i.e. the patent is revoked by the opposition division. In about 28% of the cases the patent is amended, in another 26% of the observations, the opposition is rejected because it is not considered to be substantiated. Both cases are considered to be defeats for the opponent in the current paper.²¹ In the remaining roughly 6% of the oppositions the procedure was either closed (4.7%) or no outcome can yet be identified (see above, 2.1%). The latter two cases are also regarded as defeats for the opponent.²²

²⁰ The resulting “imperfection” of the data set appears acceptable considering that with 2.1% unidentified cases the “disturbance” of the opposition outcome variable is negligible.

²¹ The reason is that in a discrete product industry such as polymer chemistry amendments can theoretically be backed up fairly well by the integration of so-called fall-back options. Those are inserted in the form of dependent claims in the patent draft (Reitzig, 2004c). Thus, it is likely that amendments are less harmful for the patent owner than in other industries.

²² With respect to the closures, this appears plausible for two reasons: First, talks with an expert from the Board of Appeals reveal that this interpretation appears suitable (see above, footnote 7). Second, there is no indication that these patents – if lapsed – were lapsed *because* of the opposition procedure. Besides, the share is very small.

With respect to the unidentified cases, the following argument can be put forth to consider them defeats for the opponent. The only strategic value for an opponent to prolong the opposition by an appeal (all other variables being equal) is to create uncertainty on the side of the patentee. Since product cycles are relatively short in the polymer industry compared to pharmaceuticals, however, it is reasonable to assume that for an opponent a successful attack consists in achieving a fast ruling on the invalidity of the patent. Again, however, the share is so small that interpreting undecided cases either way does not change results substantially.

The age structure of the sample reflects the general application trend at the European Patent Office. About 15% of the patents have priority dates between 1977²³ and 1980. Roughly 35% of the patents in the sample refer to priorities between 1981 and 1985, and the rest of the patents to priority dates between 1986 and 1990.

The explanatory variables are not conspicuous in that their order of magnitude corresponds to various earlier studies in related industries. On average, three and a half references to patents of prior art were made by the EPO examiners during the European search procedure.²⁴ On average, five out of ten patents cite a non-patent literature reference as relevant state of the art. The patents were applied for in 7.5 states on average,²⁵ and almost three inventors (2.7) were involved in each application. The mean for accelerated examination requests is fairly low. Less than one percent of all patents are applied for following the *Programme for Accelerated Prosecution of European Patent Applications (PACE)*. Interestingly, however, the percentage of filings according to Chapter II of the Patent Corporation Treaty (PCT) is high compared to Reitzig (2004c). The latter findings indicate that applicants delay cost intensive decisions in more than 6% of the applications by choosing the PCT II route. Finally, the average number of forward citations (in a three-year time window after publication) in subsequent EPO search procedures is 0.66. This figure is fairly low compared to Lanjouw and Schankerman (2001) or Harhoff and Reitzig (2004), indicating that the average scientific impact of a polymer patent on subsequent applications may be lower than in pharmaceuticals or biotechnology. However, these considerations remain speculative to a certain extent. Thus, in the following the structural estimation seeks to contribute to a somewhat better understanding of what the indicators really measure. Before that, however, reduced form estimation results are presented to explore the data further.

²³ Note that while the European Patent Office was not inaugurated until 1978, priority applications may date back until 1977.

²⁴ Note: As Harhoff and Reitzig (2004) and Reitzig (2004c) this paper adds the patent references of the international search to the number of references made in the European search if the patent was a PCT patent and the EPO acted as the International Search Authority for the World Intellectual Property Organization.

²⁵ Note that the number of states eligible for designation increased over the years. To account for this phenomenon, one may either limit the analysis to the number of states eligible from the beginning or one can introduce time dummies. In this paper, I choose the latter approach.

5.3 Multivariate analysis

Estimating the likelihood of an opposition (Stage One) without correcting for the opponent's expected probability of winning or losing the case (Stage Two) yields ambiguous results. Estimating the outcome of the opposition (Stage Two) without correcting for the selection bias created in Stage One theoretically produces distorted results, too. As mentioned above, only the simultaneous structural regression of the two stages of the aforementioned decision-making problem enables a clear identification of the patent indicators' meaning. However, the model does make a set of assumptions. To get an optimal understanding of the data, I first show exploratory reduced form estimation results for each of the individual stages alone and then present theory-driven regression results from the simultaneous equation model in the structural form for comparison.

5.3.1 *Reduced Form Estimates*

Table 3 shows the results of six simple probit estimations. In Column A the probability of an opposition (Stage One) is modeled by the set of indicators based on the entire sample. In Columns B and C, the conditional probability of the patent being upheld after opposition (Stage Two) is modeled on the same set of indicators. However, whereas in Column B all observations are used for the estimations (no matter whether or not the patent was actually opposed at all), regression C is carried out on the restricted sample of opposed patents only. Columns 3A, 3B, and 3C show two different estimations each, a full specification using all exogenous variables and a downward-tested specification (from which individually and jointly insignificant variables were excluded).

Insert Table 3 about here

Overall, the models of the probability of an opposition presented in Column A are well-determined, as can be seen from Table 3. In specification 3.A.I, individually significant coefficients are found for the backward citations to the patent literature and to the non-patent literature, the number of inventors, the family size, the accelerated examination request, the forward citations, and the time dummies. The remaining variables are individually and jointly insignificant ($\chi^2(3)$ -test: 0.36; $P > 0.94$). Downward

testing of 3.A.I yields specification 3.A.II, in which all coefficients are individually and jointly significant.

A look at Column 3B shows that three variables, namely backward references to the non-patent literature, the family size, and the forward citations are highly significantly correlated with the maintenance of the patent after opposition if tested on the unrestricted sample (the other variables are individually and jointly insignificant ($\chi^2(6)$ -test: 6.03; $P>0.42$). It is noteworthy (and will be discussed in the following section) that the significant variables show the *opposite* signs in regression 3.B.I and 3.B.II compared to the regressions in 3A.

Finally, looking at the first specification in Column C, only the number of inventors, the PCT II indicator, and the time dummy referring to the priority period after 1985 are significantly correlated with the maintenance of the patent in an opposition procedure. All the remaining variables are individually and jointly insignificant ($\chi^2(8)$ -test: 6.24; $P>0.62$). However, the overall model is still well-determined. Again, model 3.C.II shows the downward-tested parameterization. The differences between 3.B and 3.C are obviously due to the selection bias that is not modeled in the reduced form regression 3.C and should not be surprising. Correlations among the independent variables are moderate overall (-0.10 to 0.23) and are therefore not reported separately here.

5.3.2 *Estimations in the structural form*

Table 4 shows the results of the novel simultaneous equation model that reflects the decision-making rationale of the opponent in Stage One (opposition), depending on his/her anticipated outcome in Stage Two (EPO ruling on the opposition outcome).

Insert Table 4 about here

According to the above notation, X denotes the set of indicators that are supposed to capture the effects of objective technological quality on patent value. Correspondingly, Z denotes the set of indicators that are supposed to be value correlates of the patent not related to objective technological quality.

To test H1 through H4, specification 4.I starts from a partly disjunct parameterization for the two equations that are estimated simultaneously, which assigns the various indicators to X and Z based on the discussion of the empirical evidence in Section 2.2.2. This model is overall only significant at the margin ($\chi^2(14)$ -test: 25.93; $P=0.02$). However, it seems to show that forward citations are correlated with the value of the patent and reflect the patent's technological quality, whereas backward references to the patent literature and family size are positively correlated value measures that point towards a market potential of the invention that is independent of objective technological quality. The remaining variables in X and Z are individually and jointly insignificant (XB: $\chi^2(5)$ -test: 7.02; $P>0.22$ / ZG: $\chi^2(6)$ -test: 9.11; $P>0.16$).

Given the statistically weak overall explanatory power of model 4.I, as well as the aforementioned shakiness of the theoretical foundations of the different value indicators, model 4.II finally presents a full parameterization using all exogenous variables contained in the data set. Overall, the model is well-defined ($\chi^2(22)$ -test: 106.67; $P<0.001$) and seems to show that none of the patent indicators are “pure” measures of technology-unrelated market potential or “subjectively perceived” technological quality by the applicants or opponents that would differ from the patent office's assessment. On the other hand, the findings suggest that backward references both to the patent and the non-patent literature, forward citations, family size, the number of inventors, and the accelerated examination request do reflect the technical value of the patent. Almost all of the coefficients of the significant variables show the expected positive sign.

6 Discussion

This section interprets the multivariate findings in light of the initial hypotheses. To do so, the discussion first (mainly) ponders statistical consistencies and inconsistencies between the different estimations. It departs from the strictest “theory-driven” estimation 4.I. The results are then put into perspective by contrasting them to the more exploratory yet structural estimation 4.II. In this discourse, the reduced form estimates 3A through 3C enter the discussion in order to buttress the

structural analysis. Finally, an economic discussion complements the statistical discussion in order to judge the overall suitability of the findings.

According to model 4.I, Hypothesis 1 can be confirmed. Looking at the goodness of fit for equation XB ($\chi^2(6)$ -test: 24.42; $P < 0.01$) and the positive effect size of the individually significant coefficient, the effect on the likelihood of an opposition exerted by XB should be positive. In other words, the objective technological quality of a patent's underlying invention as measured by forward citations impacts positively on the private value of the patent. This is the first central result of this study. Patents were valuable for individuals at least partly because of the objective technology of their underlying inventions.

Unexpectedly, however, a series of indicators suspected to measure objective technological quality turns out to have insignificant coefficients, and model 4.I suggests the rejection of Hypothesis 2. Hypothesis 3 is confirmed only in part as the family size variable *seems* to be positively correlated with the value of the patent without necessarily measuring objective technological quality. Finally, Hypothesis 4 is again only partially confirmed. The forward citations are important measures of the objective technological quality of the patent's underlying invention. However, they do not measure effects that are unrelated to objective technological quality in model 4.II.

As mentioned above, the results of 4.I should be considered with care. The parameterization chosen in 4.I was based on the theoretical discourse of patent-based measures in Section 2.2.2, which – as admitted – is partly speculative given the prior empirical evidence. Model 4.II pays tribute to the preliminary character of the theoretical knowledge on the suitability of patent-based measures to capture distinct value determinants of a patent. Its results are enlightening in various ways. At first, and consistent with model 4.I, model 4.II clearly supports Hypothesis 1. As a matter of fact, this specification supports the view even more strongly that the dominant value driving factor of patents – to the extent that it can be captured by indicators – was objective technological quality for the chosen period. In contrast to 4.I, however, the number of inventors also becomes a significant proxy for the patent's objective technological quality, as do the backward citations to the non-patent literature. The statistical significance of these two indicators supports Hypothesis 2; however, the negative sign for the backward references to the non-patent literature requires an explanation since it appears

economically counterintuitive at first glance. A brief look at regressions 3A and 3C helps to preclude identifying the finding in 4.II as a statistical artifact of the structural regression. Moreover, economically speaking, Meyer (2000) lends support to the results, as do Lanjouw and Schankerman (2001). Whereas Carpenter et al. (1980) and Narin et al. (1997) argued that quotations to the *non-patent* literature reflect the link of the patent's invention to basic research and indicate high technological quality, Meyer (2000) finds that many non-patent literature references are not necessarily restricted to scientific publications. For this paper, a proper distinction into scientific and non-scientific backward references was not carried out. Hence, pending further knowledge, I assume with Meyer (2000) that the backward reference measure is "distorted" in this sample in the sense that it captures both scientific and non-scientific references, supposedly exhibiting distinctly different impacts on a patent's value. Most interestingly, however, model 4.II appears to reject Hypothesis 3 and therefore questions the finding of specification 4.I. None of the patent-based indicators in 4.II would be correlated with the patent's value without measuring objective technological quality at the same time. Quite obviously, the multiple correlations among individual variables in the structural model can lead to various significant sub-specifications for XB and ZG. Extensive downward testing of 4.II could show how these multiple correlations affect the differences between 4.I and 4.II, but it appears more enlightening to refer back to the simpler reduced form estimates to understand the structure of the data. A glimpse at the simpler, reduced form estimates 3A and 3B gives a hint that three variables are measures of the patent's objective technological quality in this particular dataset, namely backward references to the non-patent literature, family size, and forward citations. Their opposite signs for the likelihood of opposition (Stage 1) and maintenance of patent after opposition (Stage 2) could be interpreted as follows: as the backward references to the non-patent literature, family size, and forward citations rise, the patent becomes more valuable²⁶, and hence is attacked more often. On the unrestricted sample, however, these indicators simultaneously seem to decrease the probability that the patent is maintained after opposition – in other words they increase the likelihood of patent revocation. This counterintuitive finding most likely reflects the selection bias that is not modeled in 3B, but also shows that the three indicators are probably all measures of technological

²⁶ Obviously, the indicators are not *causal* for the rise in value!

objective quality, which enters into both Stage 1 and Stage 2 of models 4.I and 4.II. Hence, it appears reasonable to include them in X in the structural equation model – and that is what 4.II (but not 4.I) does. Along the same line of thought, the backward references to the patent literature, the number of inventors, as well as the accelerated examination request at first sight (i.e. without correction for the selection bias in Stage 2) appear to be measures of patent value that are not technology related. These findings make the specification 4.II appear more suited than 4.I overall.

Finally, consistent with 4.I, 4.II partly rejects Hypothesis 4 in that it finds no evidence that forward citations would measure any of the patent's technologically unrelated value.

Through less statistical and more theoretical lenses, many of the unexpected results are plausible, at least *ex-post*. The most important one is that technological quality as proclaimed by 'novelty and inventive step' requirements expectedly increases the private value of patents. However, it seems that our knowledge of measurement regarding the precise determinants of patent value needs to be refined. Apparently, all of the patent-based measures with significant coefficients used *in this data set* address the technology related value of the patent's underlying invention. Some also capture technology unrelated effects, however, these effects appear minor compared to the measurement of technological quality; namely, the indicators are insignificant in Z if used in X simultaneously. Economically speaking, this finding leaves room for interpretation. One may, of course, take the radical stance that the structural estimation results contradict the initial theoretical considerations for some of the proxies. In more detail, one may reject Hypothesis 3 by saying that backward references to the patent literature, family size, and the accelerated examination request are simply measures of the objective technological quality of the patent – like forward citations and others. Whereas this interpretation cannot easily be falsified, it appears more convincing, however, to assume that the nature of the specific sample (polymer patents filed in the 1980s) displays characteristics that drive the results. In other words: it appears plausible to assume that the non-technological residual value of a patent is small compared to the technological value of a patent in this particular industry in which products are sold from business to business rather than from business to final consumers. Under this premise, the insignificance of the indicators in Z would not necessarily disqualify them as measures of non-technological value determinants (as was discussed in 2.2.2), but their simultaneous relevance as

measures of objective technological quality would simply outweigh other functions. This aspect appears very important in the overall discussion. Quite clearly, the legal patent-based measures are less ambiguous proxies than empirical economists may desire. Another indication supporting this idea is shown by the comparison of coefficient effect sizes in estimations 3A and 4.II. Going from 3A (recall: simple probit of the likelihood of an opposition) to 4.II (recall: structural estimation of the likelihood of an opposition contingent on the opponent's anticipated probability of winning his case) shows a drop in effect sizes for backward references to the non-patent literature and the family size. However, it also shows an increase in the effect size for backward references to the patent literature, the number of inventors, the forward citations, and the accelerated examination request. This comparison indicates either (a) that "subjectively" perceived technological quality as measured by the value indicators is relevant for the opponents and/or (b) that all of the "value indicators" also capture part of the opponent's uncertainty of winning or losing the case (and that Assumption 3 may have to be relaxed). The model does not allow for the separation of the effects of "subjective" technological quality and uncertainty on the side of the opponent from one another. However, model 4.II corrects the effect sizes for the value indicators by separating their "objective technological" value component from any other component (be it uncertainty or subjectively perceived technological quality), so to speak. From an economic standpoint, it is hence quite intuitive to observe that the corrected size for the effect for the rather unambiguous forward citation value measure increases, whereas less unambiguous indicators (e.g. backward references to the non-patent literature) become less effective.

7 Summary and future research

This paper started with the observation that the currently proposed reinvigoration of non-obviousness (inventive step) requirements implicitly assumes that inventive step (non-obviousness) requirements were more effective in the past than they are today in that they fostered technologically more valuable research than they do now. For this rationale to make sense at all, however, one needs to presume more generally that in the best case increasing the requirement of objective technological quality for patentability up to a certain threshold increases firms' incentives to perform R&D, however, at minimum does not dissipate these incentives. In other words: the assumption is needed

that “clients” of the patent system (i.e. inventors) feel that there are net profits to be gained in patent-protecting inventions that reach (or even exceed) a certain non-obviousness threshold of objective technological quality (as defined by the patent offices). As was shown in this article, however, this premise regarding the correlation between objective technological quality of an invention and a patent’s private value for his/her owner has not been explicitly tested in the empirical literature until today. Related existing empirical evidence is ambiguous.

In this paper I have therefore developed an original structural equation model in an attempt to shed light on the aforementioned fundamental question. The estimation model is the first of its kind to disentangle the effects of “value at stake” and the trial’s outcome probability on the likelihood of litigation. It makes use of two types of legal information as dependent variables. Specifically, these are the (likelihood of an) opposition against a patent in the European patent system (Stage 1) and the contingent outcome of the opposition case (Stage 2). Within the custom-tailored two-stage discrete choice model the likelihood of an opposition conditional on the opponent’s anticipated probability of winning or losing the case was modeled by a set of patent-based measures that are regarded as established value indicators in the respective literature.

Within the framework of different assumptions and for the chosen sample, the major empirical result is that the private values of patents *did* increase with objective technological quality (as defined by the patent offices) in the past. Moreover, at least in the European polymer industry during the 1980s, objective technological quality – as considered by the patent offices at the time – was the *major* value driver of a patent from an inventor’s perspective. With respect to the question introduced at the start of this paper, however, this also means that a “return” to novelty and inventive step (non-obviousness) standards of the 1980s – all else being equal – should create incentives to produce and protect technologically qualitative R&D.

This being said, the following caveats appear to be in order, however. This study is not suited to answer the question whether current patentability standards actually *require* a reinvigoration or not. It merely says that the goal of returning to prior standards is not entirely mistaken. Whether a discrepancy between current and prior standards actually necessitates a reinvigoration requires an empirical demonstration of a decrease in the technological quality of patents over time. As was

mentioned in the introduction, other contributions (like Allison and Tiller, 2003) cast doubt on this necessity. This study *only* focuses on one important aspect, namely whether the allegation of a relation between high technological quality and high patent value from the corporate perspective was true in the past.

Furthermore, it cannot be excluded that already during the 1980s the European Patent Office had novelty and inventive step (non-obviousness) standards in place that were too low to ensure objective technological quality as defined along some other (more demanding) yardstick. Finally, the conclusions gained in this paper could be erroneous due to the lack of suitability of patent indicators to capture technology unrelated effects at all. In which case, the results would be biased.

This last notion, though possible, seems unlikely, particularly when findings regarding the suitability of certain indicators to proxy technology and non-technology related determinants of the patents are looked at. Within the confines of the structural estimation model, it seems unambiguous now that forward citations and backward citations referring to the patent literature are primarily measures of a patent's underlying technological quality. This result was partly expected and partly unexpected. It is still less ambiguous why the widely used family size indicator proxies a patent's private value. However, there is clearly reason to believe that it does not exclusively address the patent's technological quality, but also the technology unrelated value driving effects. The fact that family size and backward citations referring to the patent literature are (also) significantly correlated with the technology unrelated value of the patent in Specification 4.I supports the notion that, in principle, some indicators capture technology unrelated effects, too.

This paper leaves ample space for future research in the area. One potentially important research trajectory was referred to previously. It relates to the question of whether patent offices assessed technological quality consistently over the years. An affirmative answer would weaken the reinvigoration postulations in light of this study's result, whereas evidence for inconsistent assessments would strengthen it. Moreover, no attempt was made in this study to discuss the "optimal adjustment" of novelty and inventive step as policy levers; i.e. just how much technological quality should optimally be demanded. While incentives to patent must exist (as argued in this paper), maximizing private patent value is not a goal in itself (see Merges, 1988, for a comprehensive

discussion). In addition, I do not claim that this paper provides generally inferable empirical evidence on the suitability of value indicators across industries. Different research designs are needed to estimate the optimal setting of novelty and inventive step requirements. Running the presented structural model in this paper on data from different industries may be enlightening with respect to the value composition of patents and the related suitability to proxy a patent's value with the use of indicators. Finally, it might be even more enlightening to carry out a somewhat modified analysis on US data since the reinvigoration debate is primarily conducted in the context of US patent law.

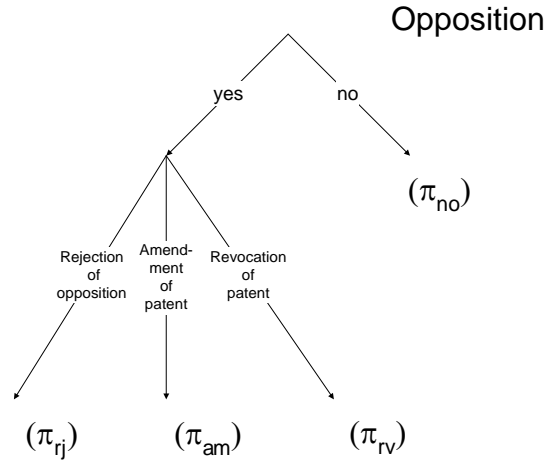
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Figure 1
Decision Tree of the Opponent



Legend:

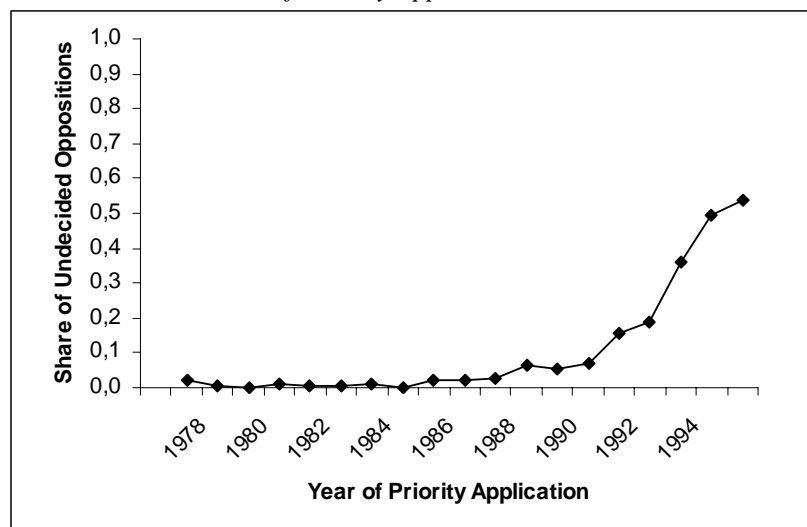
π_{no} : Profits of the potential opponent in the case of no opposition (=0)

π_{rj} : Profits of the opponent if the opposition is rejected (=c)

π_{am} : Profits of the opponent if the patent is amended (=c)

π_{rv} : Profits of the opponent if the patent is revoked
(=f(novelty, inventive step, other factors, c))

Figure 2
Share of Undecided Oppositions²⁷ among All Opposition Cases in Polymers vs. Year of Priority Application



²⁷ As can be reconstructed from electronic sources. See the text for details.

Table 1
Indicators of Patent Value

Variable	Hypothesized Link to Patent Value		Overall Effect on Patent Value
	Measure of technological quality	Technology-unrelated value measure	
Backward References to the Non-Patent Literature	+	-	?
Backward References to the Patent Literature	+	++	++
Number of Designated States (Family Size)	+	++	++
Number of Forward Citations	++	++	++
Number of Applicants / Number of Inventors	+		+
Indicators referring to the filing strategy (Accelerated Examination Request, PCT indicators)		+	+

Legend: - : negative / + : positive / ++ : highly positive / missing: no link or hypothesized effect

Table 2
Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
Opposition (1: yes, 0: no) ¹⁾	0.12		0	1
Rejection of Opposition (1: yes, 0: no) ²⁾	0.26		0	1
Amendment after Opposition (1: yes, 0: no) ²⁾	0.28		0	1
Revocation of Patent after Opposition (1: yes, 0: no) ²⁾	0.39		0	1
Opposition Procedure Closed (1: yes, 0: no) ²⁾	0.05		0	1
Opposition Outcome not Definable (1: yes, 0: no) ²⁾	0.02		0	1
Number of Backward Citations to the Patent Literature (incl. international search) ¹⁾	3.48	1.90	0	53
Number of Backward Citations to the Non-Patent Literature (incl. international search) ¹⁾	0.48	0.93	0	13
Number of Designated States (Family Size) ¹⁾	7.46	3.20	1	15
Number of Applicants ¹⁾	1.04	0.23	1	5
Number of Inventors ¹⁾	2.71	1.46	1	18
Number of Forward Citations (3-year frame) ¹⁾	0.66	1.19	0	18
Accelerated Examination Request (1: yes, 0: no) ¹⁾	0.01		0	1
PCT I (1: yes, 0: no) ¹⁾	0.01		0	1
PCT II (1: yes, 0: no) ¹⁾	0.06		0	1
Time Dummy (priority dates 1978-1980)	0.15		0	1
Time Dummy (priority dates 1981-1985)	0.35		0	1
Time Dummy (priority dates 1986-1990)	0.50		0	1

Legend: 1): Entire sample comprising N=16,980 patents.
 2): Sample of opposed patents comprising N=2,024 patents.

Table 3
Probability Estimations in the Reduced Form
A. Likelihood of an Opposition
B. Likelihood of Patent Maintenance Following Opposition (Full Sample)
C. Likelihood of Patent Maintenance Following Opposition (Restricted Sample)

Variable ³⁾	Column A (S.D.) ¹⁾		Column B (S.D.) ¹⁾		Column C (S.D.) ²⁾	
	3.A.I.	3.A.II.	3.B.I.	3.B.II.	3.C.I.	3.C.II.
Number of Backward Citations to the Patent Literature	0.22*** (0.06)	0.22*** (0.06)	-0.12 (0.08)	-	0.10 (0.14)	-
Number of Backward Citations to the Non-Patent Literature	-0.61*** (0.15)	-0.61*** (0.15)	0.52*** (0.20)	0.48** (0.20)	0.07 (0.36)	-
Number of Designated States (Family Size)	0.31*** (0.04)	0.32*** (0.04)	-0.21*** (0.06)	-0.22*** (0.06)	0.08 (0.10)	-
Number of Applicants	0.23 (0.57)	-	-0.49 (0.74)	-	-0.82 (1.31)	-
Number of Inventors	0.17** (0.09)	0.18** (0.09)	0.03 (0.12)	-	0.40** (0.20)	0.39** (0.20)
Number of Forward Citations (3-year frame)	0.71*** (0.10)	0.71*** (0.09)	-0.40*** (0.13)	-0.41*** (0.13)	0.32 (0.22)	-
Accelerated Examination Request (1: yes, 0: no)	3.03** (1.38)	3.03** (1.38)	-1.08 (2.03)	-	2.55 (3.12)	-
PCT I (1: yes, 0: no)	0.34 (1.14)	-	0.42 (1.63)	-	1.50 (2.65)	-
PCT II (1: yes, 0: no)	-0.18 (0.55)	-	-0.98 (0.71)	-	-2.45** (1.26)	-2.30* (1.24)
Time Dummy (priority dates 1981-1985)	-2.65*** (0.35)	-2.65*** (0.35)	2.35*** (0.44)	2.37*** (0.44)	0.59 (0.72)	-
Time Dummy (priority dates 1986-1990)	-6.65*** (0.37)	-6.66*** (0.36)	6.26*** (0.47)	6.20*** (0.47)	2.07*** (0.79)	2.04*** (0.61)
Constant	-12.03*** (0.77)	-11.79*** (0.52)	15.84*** (1.01)	15.00*** (0.53)	0.40 (1.75)	1.16* (0.62)
LR χ^2 -test (11;8;11;3;11;3)	471.81	471.45	217.80	211.97	24.90	18.55
P-Value	<0.001	<0.001	<0.001	<0.001	<0.01	<0.001

Legend: 1): Entire sample comprising N=16,980 patents.
2): Sample of opposed patents comprising N=2,024 patents.
3): All coefficients are multiplied by factor 10.

*** Significant at 10%/5%/1% levels (two-tailed tests)

Table 4
Probability Estimations in the Structural Form
X: Indicators of Technology-Related Patent Value
Z: Indicators of Technology-Unrelated Patent Value

I: Partly Disjunct Parameterization (Theory-driven)
II. Full Parameterization (Exploratory)

Variable		I.		II.	
		Column (S.D.)		Column (S.D.)	
X ¹⁾ (‘Technical Quality’)	Number of Backward Citations to the Patent Literature	-		0.23** (0.11)	
	Number of Backward Citations to the Non-Patent Literature	-0.42	(0.27)	-0.49 **	(0.24)
	Number of Designated States (Family Size)	-		0.27*** (0.09)	
	Number of Applicants	0.06	(0.46)	-0.29	(1.00)
	Number of Inventors	0.18	(0.19)	0.34**	(0.15)
	Number of Forward Citations (3-year frame)	0.51 ***	0.18)	0.82***	(0.15)
	Accelerated Examination Request (1: yes, 0: no)	-		4.31**	(2.18)
	PCT I (1: yes, 0: no)	-		2.13	(2.22)
	PCT II (1: yes, 0: no)	-		-1.37	(1.00)
	Time Dummy (priority dates 1981-1985)	0.47	(0.78)	-1.46	(1.05)
	Time Dummy (priority dates 1986-1990)	1.29	(0.93)	-3.57	(2.51)
	Constant	-0.43	(2.28)	-13.99***	(4.83)
	Z ¹⁾ (‘Market Potential’)	Number of Backward Citations to the Patent Literature	0.09*	(0.05)	6.56
Number of Backward Citations to the Non-Patent Literature		-		-16.71	(40.05)
Number of Designated States (Family Size)		0.13*	(0.07)	8.60	(20.60)
Number of Applicants		-		4.77	(19.48)
Number of Inventors		-		5.85	(14.38)
Number of Forward Citations (3-year frame)		0.10	(0.26)	23.21	(55.42)
Accelerated Examination Request (1: yes, 0: no)		1.27	(0.91)	102.94	(249.43)
PCT I (1: yes, 0: no)		0.17	(0.50)	29.90	(80.55)
PCT II (1: yes, 0: no)		-0.04	(0.23)	-8.71	(26.88)
Time Dummy (priority dates 1981-1985)		-1.41**	(0.64)	-68.39	(163.86)
Time Dummy (priority dates 1986-1990)	-3.56***	(1.38)	-170.33	(406.97)	
ρ	-0.91***	(0.09)	0.84***	(0.31)	
Costs ¹⁾	2.45**	(1.09)	242.03 (599.25)		
σ_n	1.04***	0.06)	21.91	(52.96)	
Wald χ^2 (22;14)	25.93		106.67		
P-Value	=0.02		<0.001		

Legend: Entire sample comprising N=16,980 patents.
1): Coefficient multiplied by factor 10.
*/**/** Significant at 10%/5%/1% levels (two-tailed tests).