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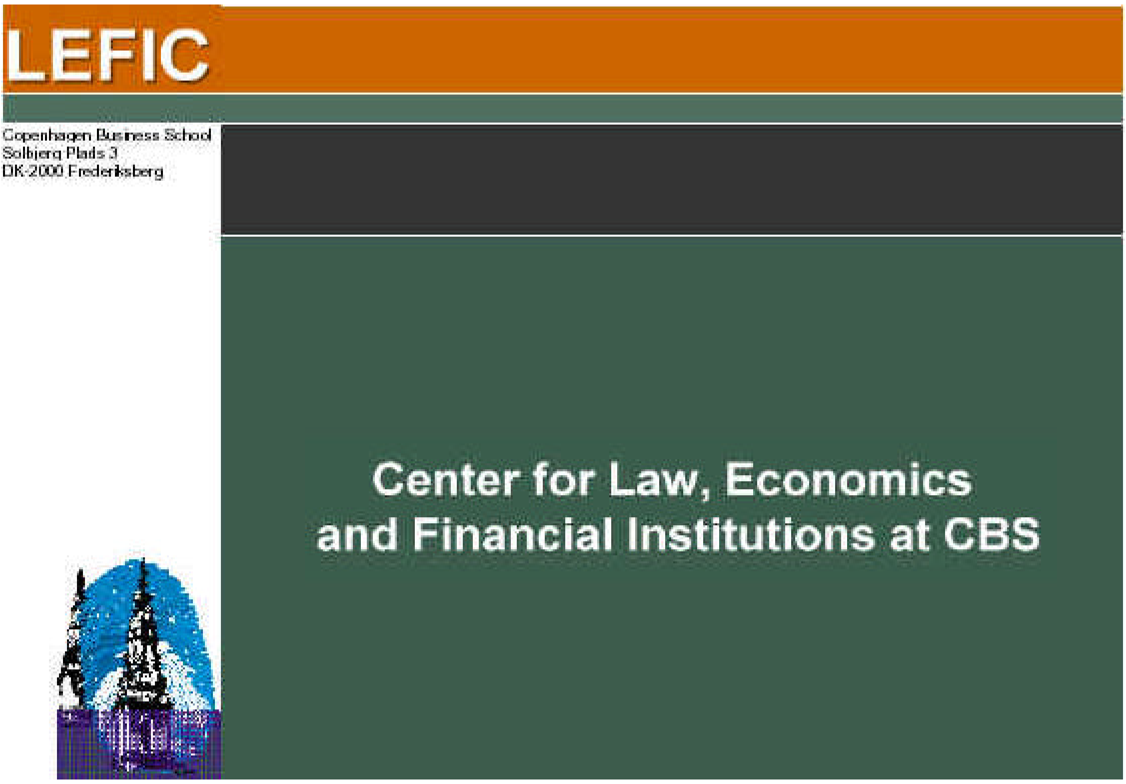

LEFIC WORKING PAPER 2003-1

What Do Patent Indicators Really Measure?
–
Testing Current Theory on Value Drivers of Innovations Within a Structural Two-Stage Discrete Choice Simultaneous Equation Model

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Testing Current Theory on Value Drivers of Innovations Within a Structural Two-Stage Discrete Choice Simultaneous Equation Model

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Preliminary, changes possible, comments welcome!

Abstract:

Patent indicators are widely used to assess innovative output. Despite the large variety of empirical studies in the field, however, the precise meaning of these indicators and their obvious relation to patent value is still based on assumptions and intuitions. This paper provides the first empirical test of patent indicators as value measures in the structural form. It disentangles the different effects reflected in patent indicators and enhances our understanding why inventions are valuable at all. Using a newly assembled data set on European polymer patents, current assumptions on the innovation incentives set by patentability requirements (novelty, inventive activity) are tested. The estimations are carried out using a custom-tailored two stage discrete choice probit model yet unknown in the literature. The results support the assumptions that novelty and inventive activity enhance a patent's value. They confirm the importance of backward citations, family size, and forward citations as value indicators. However, they expand on and partly break with the respective explanations why patent indicators correlate with profitability.

Keywords: Patents, opposition/litigation, indicators, discrete choice estimations

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

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1. Introduction

In 1965, Frederic Scherer drew economists' attention to the importance of patent data as output measures of industrial innovation. In the following 25 years, an unprecedented stream of research evolved that used patent information as economic indicators. The main results of these two and a half decades of empirical patent economics – mainly studies on industrial productivity – are summarized in Griliches' (1990) widely quoted survey article. Since then, however, activities in the field have not stalled. On the opposite, they have branched out in various directions and the use of patent information has entered into diverse economics and management disciplines. Inspired by the rising electronic availability of patent data and increasing processor speed and memory of personal computers during the last fifteen years, economists have spent extensive time on developing more sophisticated patent indicators than simple patent counts. Major efforts concentrated on the compilation and interpretation of procedural legal information published together with the disclosure of the technical invention underlying the patent. Nowadays, backward citations, forward citations, family size, and claims (to mention but a few) are standard indicators used to qualify patents and weight patent counts. The application of these indicators is no longer restricted to research questions associated with the original difficulty of measuring innovative output (Griliches, 1981; Conolly, Hirsch et al., 1986; Conolly and Hirschey, 1988; Megna and Klock, 1993; Cockburn and Griliches, 1988; Hall, Jaffe et al., 2000). Economists have also applied patent indicators to determine the likelihood of litigation (Lanjouw, 1998; Lanjouw and Schankerman, 2000; Harhoff and Reitzig, 2000), to study patterns of industrial organization (Bekkers, Duysters et al., 2002), and technology spillovers (Verspaargen and Loo, 1999). Management scholars use patent indicators to identify lucrative market segments (Ernst, 1996), for competition analysis (Ernst, 1998), and most recently even to study knowledge flows within corporations (Trajtenberg, Henderson et al., 1997; Rosenkopf and Nerkar, 2001; Argyres and Silverman, 2002). Looking at this rapid development it seems as if the applicability of patent information to the measurement of economic phenomena was straight forward.

This impression, however, may prove to be deceptive at second sight. The reason is that the information contents of patent indicators is complex and the diversity of its potential meanings is far from being understood in all detail. The main caveat is that the information contained within patents (and respective indicators) is legal of nature and therefore first of all operationalizes (latent) legal variables. Only through an additional body of theory can these indicators ultimately be linked to economic phenomena. During the last 30 years, patent economists have drawn a complex picture of assumptions which *latent variables* drive a patent's economic value both from a welfare and an individual perspective and which trade-offs they are subject to (Scotchmer and Green, 1990, 1995; Scotchmer, 1996; Gallini, 1992), Klemperer, 1990; Gilbert and Shapiro, 1990). Our theoretical understanding of the correlations between a patent's *observable* legal characteristics and their economic effects, however, is still very limited in part. By saying so I am not only referring to the most recent applications of patent indicators to knowledge management where little or no hard theory-based empirical evidence exists that patent measures operationalize the latent constructs they are supposed to operationalize. Even in the 'classical' field of indicator based assessments of intellectual property rights we still often rely on various plausible assumptions and widely accepted connotations when interpreting estimation results. Undisputedly it is true that a large variety of respective studies in this field (see Appendix A) has convincingly demonstrated the general suitability of procedural patent data to operationalize a patent's economic value. To the best of my knowledge, however, no empirical study exists that allows to interpret coefficients of patent indicators as patent value correlates in the structural form (with the exception of the pioneering work on simple patent counts by Pakes, 1986). From a scientific and an applied perspective, however, this is dissatisfying for one major reason. The reason is that for a variety of theoretical and practical problems we are not only interested *if* an invention is of commercial value but *why* it is of commercial value. Industrial economists, for example, often would like to know if sector performances can be attributed to the quality of the underlying technology or to sth. else. Policy makers need to understand how the adjustment of patentability requirements affects innovation incentives all other variables being equal. Finally, management scholars are interested in the potential of markets independent of the technical value of individual patent rights.

This paper addresses the problem of validating indicators of patent value in the structural form for the first time in the literature. By doing so, it seeks to disentangle the multitude of effects reflected in patent indicators and explain if and why they operationalize the economic value of patent rights. At the same time, it serves as an empirical test of our current theoretical understanding how patentability requirements affect innovation incentives. As a further side-effect it presents a novel discrete choice estimator suitable for testing decision problems in which the anticipated outcome in the second stage affects the decision in the first stage. The remainder of the paper is structured as follows. Section two provides the theoretical framework and section three presents the hypotheses, the research design, and the underlying econometrics. Part four presents the data and empirical estimation results that are discussed in part five. Section six concludes.

2. Theoretical Framework

During the last two decades, at least two different research directions related to the valuation of patents have developed in parallel. Even though they have occasionally been linked, no systematic approach has yet been chosen to bring the two together until most recently (Reitzig, 2002a). These two research streams are described in the (mainly) theoretical literature on the optimal design of patent systems and the (dominantly) empirical literature on patent indicators.

Latent variables of patent value

The theoretical literature has assumed that the following (latent) variables should affect a patent's value for his/her owner: *Patent duration, novelty and inventive activity (non-obviousness), breadth, disclosure, difficulty in inventing around, and dependence on complementary assets*.[3] Since at least the first three of them fall into the category of legal patentability requirements, most of the respective literature in the field stems from economists interested in the design of innovation systems. Already Nordhaus (1967) started from the premise that the economic value of a patent for its holder increases with the patent's duration. Younger models (see for example Matutes, Regibau et al., 1996) differ from their predecessors mainly in that they make more realistic assumptions as to the distribution of returns-per-period over time.[4] Green and Scotchmer (1995) introduced the impact of 'novelty' and 'non-obviousness' (inventive activity) on patent value to the discussion. They assumed both variables to increase the value of the patent right. Klemperer (1990) and Gilbert and Shapiro (1990) were the first to propose that the degree to which a patent protects an invention, namely the patent's breadth, affects the patent's value positively. It was again Green and Scotchmer (1995) who modeled disclosure as a value driver of patents assuming that disclosing technical information conferred a positive externality on the patent-holder's competitors. Consequently they assumed that disclosure should diminish the economic value of a patent for his/her owner. Also, as patents may be used for blocking competitors in certain industries, their values should rise the more difficult it becomes to circumnavigate the protected invention with a new technology. Gallini (1992) introduced this idea into a formal model for the first time. Finally, it was Teece (1986) who reminded us that oftentimes,

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3 See Reitzig (2003) for an overview.

4 Consistent with the literature on technology cycles (see for example Kotler and Bliemel, 1995) the younger models do not assume that returns-per-period are constant but that returns-per-period are subject to the life stage of the underlying technology.

complementary technology and other complementary assets are needed to commercialize the patent protected invention.

More recently, these *latent* variables have been referred to in the management literature as 'value drivers' of the underlying technology in real-option frameworks (Reitzig, 2002b/2002c) that are currently extended to patent valuations (Pitkethly, 1999). Within these frameworks, the influence of technical (Gilbert and Newberry, 1982), market (Gilbert and Newberry, 1982), and legal (Lanjouw, 1998, Harhoff and Reitzig, 2000) uncertainty on a patent's present value is discussed as the patent's volatility. Whereas the first two types of uncertainty should theoretically enhance a patent's value for his/her owner, the latter one can only reduce it.

Little direct empirical evidence from *primary data* exists on the validity of the above assumptions. The only existing questionnaire-based study in the field stems from the semiconductor industry (Reitzig, 2003). Its findings are consistent with the theoretical assumptions apart from the effect of the disclosure.

Indicators of patent value

Comprehensive empirical studies using *secondary data* have been carried out trying to validate procedural legal information referring to the granting procedure or to litigation details as value indicators. Appendix A provides a synopsis of the most important large-scale empirical studies ordered by indicators.

The meaning of these indicators as well as their theoretical and empirical degree of validity has been extensively discussed in the literature (see Reitzig, 2002b/2002c for a comprehensive overview). Readers are kindly addressed to the relevant sources for the detailed discussion of the current knowledge on value indicators. For the purpose of this paper, only the most important findings relevant for the derivation of the hypotheses are summarised briefly.

Backward citations – these are quotations of prior art relevant to the patentability of an invention during the granting procedure – are supposed to be positively correlated with value. In the case of quotations to prior *patent* literature the common rationale is that the citations operationalize existing market potential. In the case of quotations to the *non-patent* literature – especially scientific publications – economists often argue that the link of the patent's invention to basic research indicates high technological quality and therefore economic value (Carpenter, Cooper et al., 1980). Backward citations to both patent and non-patent literature belong to the fairly well validated indicators.

Forward citations, that is the number of quotations a patent receives itself during subsequent granting procedures of younger patents, turn out to be positively correlated with a patent's value in all known studies. Various rationales are put forth. One is that forward citations are supposed to operationalize market potential of a the patent independent of the technological sophistication or quality of the underlying invention. This rationale holds especially – but not exclusively – true for citations made by an applicant. At the same time, however, forward citations are also suspected to operationalize the *legal value drivers* novelty and inventive activity. This appears particularly plausible if the quotations were inserted by the patent examiner.

'Family size' is an indicator that measures the size of the territory in which the patent holder enjoys exclusivity. Most times it is argued that it is a measure of the market size of the invention which is not necessarily correlated with technical sophistication. The family size indicator is also fairly well validated.

A series of other indicators has been tested as value indicators in earlier studies, too. Among those are the 'Scope' variable, the ownership variable, the litigation indicators, indicators referring to the filing strategy, the number of applicants, the number of cross-boarder research co-operations, the accelerated examination request, and the claims. The empirical evidence of their validity as of today varies, however, they still all belong to the extended set of weighting measures for patent counts applied in the field today. More interesting for the purpose of this paper are the differences in their theoretical foundation. Whereas claims and scope are supposed to operationalize a patent's breadth, the number of applicants and the number of cross-boarder research co-operations should reflect a high degree of technological sophistication; i.e. the technology should be novel and highly inventive. The filing strategy variables and the accelerated examination request are deemed to be mainly signs of market size for the invention. Finally, the meaning of the litigation indicator depends on its compilation. Counting unsuccessful oppositions or challenge suits *ex-post* yields a pure value indicator. Counting legal attacks *ex-ante* before the outcome of the opposition procedure or the trial is over has a more complicated meaning that is not discussed here but in the section on the research design.

3. Open research questions, hypotheses, and research design

In the introduction I identified one major research goal in the field, namely to understand *why* inventions are of commercial value with the help of indicators. One important application of this general goal was an empirical test of the assumption that patentability requirements such as novelty and inventive activity affect the economic value of a patent right. Based on the current understanding, the following hypotheses should therefore be tested.

Hypotheses

H1: Novelty and inventive activity (non-obviousness) affect the economic value of a patent protected invention positively.

H2: Indicators such as backward citations to the non-patent literature, forward citations, the number of inventors, and the number of applicants (from now on referred to as indicator set $\sum xb$) operationalize novelty and inventive activity.

H3: Indicators such as backward citations to the patent literature, forward citations, family size, indicators referring to the filing strategy, and the accelerated examination request (from now on referred to as indicator set $\sum zg$) are positively correlated with a patent's value. However, they do not operationalize novelty and inventive activity.

The following section describes the research design chosen for the test of H1 through H3.

The research design

In principle, two generically different approaches can be chosen to test H1 through H3. One potential research design relates indicators to custom tailored *primary data*, namely expert assessments on the latent variables of patent value. This paper pursues the other approach using *secondary data*. Based on a simplified theoretical decision making problem it analyzes observable oppositions in the European patent system in the light of their expected outcomes by the parties.

The theoretical decision making problem

In the European patent system, third parties can attack a patent within nine months after its grant by filing a so-called opposition. The opposition procedure differs slightly from the challenge suit procedure in the US (see Reitzig 2002c for the details). For the purpose of this paper, these differences can be neglected though. There are three potential outcomes of an opposition procedure. Either the patent is upheld and remains unchanged (1), or the patent is amended (2), or it is revoked (3).[5] According to Art. 100 of the European Patent Convention

[5] Graham, Hall et al. (2002) note that there is a 'forth' outcome category, i.e. the opposition procedure is

(EPC) the ruling on the outcome is given by the European patent office based on a (re)assessment of the patentability requirements, the main ones being: novelty, inventive activity, commercial applicability. Finally, insufficient disclosure of the invention can lead to a revocation or an amendment of the patent, too. Since an opposition procedure is costly and since the alternative option to an opposition is a settlement agreement, one can assume that

A1: The incentives to file an opposition are determined by the value at stake and the parties' subjectively perceived likelihoods of the patent being upheld, amended, or revoked.

In the economic literature on litigation an analogous assumption has been used extensively (Priest, 1984; Waldvogel, 1998) and appears to be commonly accepted. Lanjouw and Lerner (1997) also showed the suitability of this premise in the case of *patent* litigations. For the specific case of an *opposition* Harhoff and Reitzig (2000) emphasize the particular importance of settlement costs, but in principle they also agree on the above assumption.

Thus, the opponent's rationale to file an opposition can be illustrated by the decision tree in Figure 1.

Insert Figure 1 about here

"closed". The way they define this category 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". In default of better information they suggest to consider these cases as successful challenges of the patent's validity. Whilst there may be explanations to do so this paper takes a different approach based on intense discussions with senior representatives at the 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 by the opponent and most likely a 'retreat' from the legal attack.

Legend:

π_{no}: Profits of the 'opponent' in the case of no opposition.

π_{rj}: Profits of the opponent if the opposition is rejected.

π_{am}: Profits of the opponent if the patent is amended.

π_{rv} : Profits of the opponent if the patent is revoked.

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

$$p(opp.) = 1 \; if$$

$$p_{rj} \cdot p_{opponent}(rejec.|opp.) + p_{am} \cdot p_{opponent}(amend|opp.) + p_{rv} \cdot p_{opponent}(revoc.|opp.) > p_{no}$$

$$and \qquad (1)$$

$$p = 0 \quad else$$

The estimation problem and its relation to the hypotheses tests

To turn the system of equations (1) into an estimation problem that allows for a test of H1 through H3, some further assumptions and simplifications are necessary. The assumptions are mostly unproblematic. Thus, they are only briefly described and vindicated in the following.

A2: The opponent's profits can theoretically be driven by both patentability requirements (novelty, inventive activity) and other factors.

This assumption is straight forward. Any alternative assumption would falsify H1, H2, and H3 *per definitionem*.

A3: The opponent can reasonably anticipate the decision of the opposition procedure by the EPO. The EPO bases its ruling on the opposition solely on two criteria, namely the fulfillment of novelty and inventive activity.

This assumption is necessary to infer from observable outcomes of opposition decisions (see below) on the opponent's estimation of novelty and inventive activity. The first part of the assumption is entirely unproblematic because it reflects the dogmatic guideline of the EPO. But also the second part is very plausible given the large litigation experience of most opponents (see also Harhoff and Reitzig, 2001). In a formalized fashion, this assumption states that

$$p_{opponent}(outcome \mid opp.) = f(novelty, inventive\ step) \qquad (2)$$

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:

$$p_{no} = 0; p_{rj} = p_{am} = -c; p_{rv} = f(novelty, inventive\ activity, other\ \ factors, -c)$$

and

A5: The opponent's decision is not determined by his/her possibility to appeal against the EPO ruling on the opposition procedure.

Assumption four is the most simplifying of all. It states that the opponent almost completely internalizes the value of the patent for his/her holder which might not be entirely true for all competitive scenarios.[6] It also contains a simplification in that is 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, however, it seems as if this simplification also reflected reality sufficiently well in certain industries (see also section four). Finally, assumption five potentially simplifies the opponent's rationale in that it does not consider subsequent appeal or litigation possibilities any more.[7]

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

$$\begin{aligned} &With \quad p = p(amendment \,|\, opp.) + p(rejection \,|\, opp.) \\ &p(opp.) = 1 \; if \;\; p(p_{am,rj} - p_{rv}) > (p_{am,rj} - p_{rv}) \\ &and \\ &p(opp.) = 0 \quad else \end{aligned} \qquad (3)$$

To test H1 through H3, a maximum likelihood estimator based on equation system (3) is now needed. Using a respective ML-estimator and operationalizing novelty and inventive activity by indicator set $\sum xb$ (and error term e) and other factors by indicator set $\sum zg$ (and error term h) could disentangle the multitude of effects measured by indicators. It could finally help to explain *why* patent indicators measure patent value. Despite the great variety of various two stage discrete choice models described in the econometric literature, however, no

6 In a sector in which patents are mainly used as bargaining chips, this assumption could lead to a distraction from the 'real' results. For the industry analyzed in this paper the assumption should hold well though (see also the following section four).

7 The simplification, however, seems inevitable. Neither does a three stage model accounting for appeal

standard estimator suitable for this decision problem exists. For this reason, a custom-tailored estimator was developed for the present problem.[8] The likelihood function is given below, its derivation is described in Appendix B.

$$\log L = (1-W)\cdot\log\left(\Phi\left(-\frac{a}{s_x}\right)\right) + W\cdot\left[V\cdot\log\left(\Phi^2\left(\frac{a}{s_x}, \sum xb, r_{x,e}\right)\right) + (1-V)\cdot\log\left(\Phi^2\left(\frac{a}{s_x}, -\sum xb, -r_{x,e}\right)\right)\right] \quad (4)$$

where

$W = 1$ *denotes the occurence of an opposition* ($W = 0$ *else*),

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

$a = \left(1-\Phi\left(\sum xb\right)\right)\cdot\left(\sum xb + \sum zg\right) - c,$

$x = \left(1-\Phi\left(\sum xb\right)\right)\cdot(e+h),$ *and*

$$r_{x,e} = \frac{\left(1-\Phi\left(\sum xb\right)\right)\cdot\left(1+r_{h,e}\right)}{\left(1-\Phi\left(\sum xb\right)\right)\cdot\sqrt{\left(2+2\cdot r_{h,e}\right)}}$$

The estimator described in equation (4) maximizes the likelihood of an opposition including the opponent's anticipated probability of winning or losing his case.[9] The value of the patent is modeled by novelty, inventive activity, and other value determining parameters; the opponent's anticipation of the patent being upheld (revoked) is modeled by novelty and inventive activity (consistent with assumption 3).

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or other litigation possibilities appear feasible, nor does a further truncation of the data (see section four) appear reasonable.

8 Full identification of the estimator was positively tested using simulated data.

9 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 text books (see e.g. Maddala, 1983) report on an estimator of the above kind.

Finally, the data prerequisites of the chosen research design and the consequences for the sample selection are briefly elucidated in the last part of this section.

Data prerequisites

The model underlying the estimator starts from 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 fulfilled best in markets where patent holders enjoy temporary monopoly profits and would have to share duopoly profits if they did not have legal protection. Therefore it seems inevitable to run the empirical test on patent data from a discrete product industry.

Besides, a 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 opponent's or plaintiff's rationale.[10] In the present paper, *observable outcomes* of opposition procedures are used to model the opponent's anticipation. Thus, the data need to comprehend the sets of value indicators as described in H2 and H3, 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 that are described in the next section.

4. Empirical results

[10] To the best of my knowledge the study by Graham, Hall 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.

Sample selection

The sample chosen for the analysis contains European polymer patents for two reasons.[11] First, it seems as if in polymers individual patents could protect most of the technology inherent in the final product (see e.g. Cohen, Nelson, et al., 2000). Thus it is plausible to assume that the value of a patent revocation to the opponent is highly correlated with the value of the valid patent for its owner. Secondly, to the best of my knowledge there is no large-scale empirical study on European polymer patents. Below its primary goal, by presenting the data this paper therefore also extends our knowledge base of this industry in a more general fashion.

The selection of the industrial field was based on an updated version of the OST INPI ISI classification by Schmoch (1998, personal note). Polymer patents were identified as belonging to the following IPC subclasses: C08B, F, G, H, K, L; C09D, J. As of September 2002 (date of the data extraction) the European patent register contained 27,635 patents in these areas. At this point, 2,762 (9.99%) patents of the patent in the sample had been opposed. For 2,150 of these opposed patents, a decision by the *first instance* at the EPO – the opposition chamber – was observable in September 2002. For the remaining part of the patents I could not identify any clear ruling by the opposition chamber at that date. Figure 2 shows the share of undecided oppositions among the total sample versus the year of patent grants.

Insert Figure 2 about here

Figure two shows a steep ascent of undecided oppositions after the year 1990. Pending better explanation I take it that this increase can be attributed to the share of opposition cases still to be decided in September 2002 by the *first* instance at the EPO, namely the opposition chamber.[12] As this paper (see Assumption 5) does focus on the decision of the opposition chamber *only* (no further appeals, no subsequent litigation), I cut off the tail of patents granted from 1991 onwards and did not further inquire on the history of the residual percentage of approx. 10% of undecided opposition cases between 1978 and 1990. It is most likely that these latter patents have lapsed or are still under opposition.[13] Thus, the final data for the analysis comprises 16.711 EP patents granted between 1978 and 1990.

Descriptive statistics

Table 1 shows the descriptive statistics for the sample.

Insert Table 1 about here

The most interesting findings are briefly discussed. With 11.5% the rate of opposition in the polymer chemistry industry is significantly increased over the total population of EP patents granted in this period. It almost takes on the same value as in the litigious pharmaceutical and biotechnological industry (10.79% and 10.24% opposition between 1978 and 1990). This preliminarily confirms the assumption that patents in polymers are used as 'exclusion rights'. In about 38% of all oppositions, third parties attack holders successfully according to the notion of this paper; i.e. the patent is revoked by the opposition chamber. In about 21% 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.[14] In the remaining roughly 15% of the oppositions the

[11] The patents were identified via the OST INPI ISI classification based on IPCs.

[12] 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 (after/pre 1991 applications). Adding the average granting time of 4.3 years for patents in the same area (Reitzig, 2002b) 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 10 to 11 year old patents as is the case here.

[13] See "Descriptive Statistics" for a discussion of the resulting effects for this analysis.

[14] The reason is that in a discrete product industry such as polymer chemistry amendments can

procedure was either closed (4.9%) or no outcome can yet be identified (10.3% pending). The latter two cases are also regarded as defeats for the opponent.[15]

The explaining variables are not conspicuous in that their order of magnitude corresponds to various earlier studies in related industries, in particular to the study by Reitzig (2002a). On average, three references to patents of prior art were made by the EPO examiners during the European search procedure. On average, every second patent cites a non-patent literature reference as relevant state of the art. The patents were applied for in 7.47 states on average, and almost three inventors (2.7) were involved in each application. The relatively high number of designation states and the high inventor-to-applicant ratio supports the assumption that most of the patents in this industry are held by corporations and not by individual inventors. This observation is in concordance with the high opposition rate given that oppositions are costly. The mean for accelerated examination requests lies fairly low. Not even one percent of all patents are applied for following the PACE program. This observation supports the view that lead-time advantages in this industry may be less important than in other industries. It also supports the assumption, however, that the applicants are experienced in interacting with the EPO and can anticipate the office's reactions well (see Assumption 3).[16] Interestingly then, however, the percentage of PCTII filings is high compared to Reitzig (2002a) and the ratio of PCTII to PCTI is stunning. The latter findings indicate that applicants are delaying cost intense decisions in more than 7% of the applications by choosing the PCTII route. While this may be a sign of uncertainty (and therefore be at odds with the low acceleration request rate) an explanation for the observation lies in the applicant structure of this sample. Given that the applicant-to-inventor ratio hints at a dominating corporate

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, 2002b). Thus, it is likely that amendments are less harmful for the patent owner than in other industries.

15 It is unlikely that this will lead to an important selection bias since there is neither an indication that these patents – if lapsed – were lapsed *because* of the opposition procedure, nor that – if not lapsed – patents involved in extremely time-taking opposition procedures are revoked significantly more often than other patents.

16 Acceleration of examination if oftentimes requested if the decision of the EPO can not be anticipated at

applicant structure it may well be that the applicants are simply cost insensitive. Finally, the average number of forward citations (three years time window after publication) in subsequent EPO search procedures is 0.55. This figure is fairly low compared to Lanjouw and Schankerman (2000) or Harhoff and Reitzig (2000) indicating that the average scientific impact of a polymer patent on subsequent applications may be lower than in pharmaceuticals or biotechnology. But after all, these considerations remain speculative until a certain point. Thus, in the following the structural estimation seeks to contribute to a somewhat better understanding what the indicators really measure. Before that, however, estimations in the reduced form are presented.

Estimations in the reduced form

Table 2 shows the results of two simple probit estimations. In column A the likelihood of an opposition is modeled by the set of indicators based on the entire sample. In column B the conditional probability of the patent being upheld after opposition is modeled by the same set of indicators. However, regression B is carried out on the sample of opposed patents only.

Insert Table 2 about here

Overall, the model of the likelihood of an opposition presented in column A is highly significant. Individually significant coefficients in column A are found for the backward citations to the patent literature and to the non-patent literature, the family size, forward citations, and the PCTI indicator. The remaining variables are individually and jointly insignificant ($\chi^2(4)$-test: 2.45; P>0.65). Looking at column B, only the number of inventors is significantly and negatively correlated with the maintenance of the patent in an opposition procedure. The remaining variables are individually and jointly insignificant ($\chi^2(8)$-test: 6.78; P>0.56). Correlations among the independent variables are moderate overall (-0.37 until 0.12)

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a point where investments have to be made (see Reitzig, 2002b).

and are therefore not reported separately here. On the basis of the simple estimation results in column A it is impossible to test H1, H2, and H3. The reason is that it is impossible to distinguish between the *different effects* that the individually significant variables exert on the likelihood of an opposition. Whilst it may be – as has been excessively discussed in the literature – that the backward citations to the patent literature hint at the existing market and that the negative coefficient for the non-patent literature references hints at 'low' technical quality of the patent, various other explanations may also hold true. By no means is it possible to make a clear statement as to whether novelty and inventive activity enter the value of the patent positively or not. Looking at the regression results of column B it would also be difficult to reject or sustain hypothesis H2. First of all, the model is overall insignificant. Surprisingly, only the number of inventors is significantly correlated with the maintenance of the patent but exerts a negative effect on the likelihood of the patent surviving opposition. The latter finding is certainly counterintuitive. Aside from this, however, the estimations carried out in column B do not really appear suited for a test of H2. The reason is basically the same as mentioned above for the results of column A. The indicators may potentially operationalize various effects, including effects that are unrelated to the degree of novelty and inventive activity. Thus, to test H1, H2, and H3 only the estimations in the structural form can shed further light on the research questions.

Estimations in the structural form

Table 3 shows the results of the new simultaneous equation estimator that reflects the decision making rationale of the opponent in stage one (opposition) depending on his anticipated outcome in stage two (EPO ruling on the opposition outcome)

Insert Table 3 about here

According to the above notation XB denotes the set of indicators that are supposed to operationalize novelty and inventive activity. To test H1 and H2, however, I use the full set of potential indicators and compare the individually significant variables to the set of indicators as specified in H2 afterwards. Correspondingly, ZG denotes the set of indicators that are supposed to be value correlates of the patent without operationalizing novelty and inventive activity. Again, I start from the full set of available explanatory variables when testing H3. The results are not counterintuitive though surprising at various points. First of all it is important to note that the model is overall significant. From a purely statistical standpoint it models the likelihood of an opposition worse than the simple probit in column 2 B though. As was argued above, however, this simple measure does not reflect the economic suitability of the results. Interestingly, all the individually significant variables in XB, namely the backward citations to the patent literature, the family size, and the forward citations contribute positively to the likelihood of an opposition and to the likelihood of a patent being upheld. The remaining variables in XB are individually and jointly insignificant ($\chi^2(6)$-test: 6.91; P>0.33). If and why this result can be regarded as preliminary empirical evidence for H1 will discussed in more detail in the following.

Coming to individual levels of significance among the variables specified in XB the finding for the forward citations is consistent with the expectation. The number of inventors is almost significant (P=0.12). On the other hand, however, I find no empirical evidence that the number of backward citations to the non-patent literature operationalizes novelty or inventive activity. Interestingly, however, the references to the patent literature are significant regressors in the XB set of indicators. To what extent this sustains H2 or not will be discussed in the next part.

Finally, the results for the coefficients in ZG are also interesting. The only significant coefficient here is the one of the backward citations to the non-patent literature. The remaining variables in ZG are individually and jointly insignificant ($\chi^2(6)$-test: 5.53; P>0.70).

Again, the question as to what this means for the validity of H3 will be discussed in the following.

5. Discussion

The results from the multivariate estimations require further interpretation before conclusions can be drawn with respect to the validity of the hypotheses H1 through H3. At first it seems feasible to concentrate on the potential meanings of the regression results in the structural form.

In principle, the sheer fact that all the individually significant variables in XB contribute positively to the likelihood of an opposition can be regarded as strong evidence to support hypothesis H1. The reason is that the estimator uses the indicators in XB simultaneously for both estimating the likelihood of an opposition and the likelihood of patent maintenance. Thus, variables with significant and positive coefficients in XB operationalize novelty and inventive activity and contribute positively to the patent's value.[17] The finding appears to be of consierable relevance with respect to the large amount of theoretical literature in the field designing patent systems on the assumption that H1 holds true.

Following the same line of thought I therefore also find strong empirical evidence that forward citations made by the examiner operationalize novelty and inventive activity as was hypothesized in H2. Almost significant (P=12.7) is also the coefficient for the number of inventors as was again hypothesized in H2. Interestingly, however, none of these indicators could have been validated as correlates of novelty and inventive activity in the simple estimations in the reduced form due to the selection bias there (Table 2, column B). Unexpectedly, both the family size and the number of citations to the patent literature are

[17] Note that theoretically the result can still be an artifact if the indicators operationalized further

significant in XB. The result is consistent with the reduced form estimations in Table 2 (column A), however, at odds with hypotheses H2 and H3. The latter two variables were suspected to contribute to a patent's value without necessarily operationalizing technical quality. Apparently, this is not the case for the polymer patents in this sample. The estimations in the structural form clearly indicate that the two variables contribute to a patent's value and operationalize technical quality at the same time. Obviously, a causal link between these two observations must not be established on the basis of this research design, however, would be very intuitive. Finally, the estimation result for the references to the non-patent literature is striking for three reasons: their coefficient is not significant among the set of XB regressors (a), it is significant among the set of ZG regressors (b), and it is negative (c). Due to the structural form of the estimation it is unambiguous that at least for this sample patent references to the non-patent literature affect a patent's value independently of their suitability to operationalize technical quality. This 'non-technical' effect has a negative impact on the patent's value which is not counterintuitive given the industry analyzed. Cycle times in polymer chemistry are supposed to be shorter than in pharmaceuticals and biotechnology. Thus, the scientific linkage as partly expressed by non-patent quotations should be less of a value indicator. Besides, the corporate applicant structure in the industry (see above) also supports the view that patenting in this industry is more important than publishing. Thus, in this particular industry references to non-patent literature should be less important and maybe even hint at a technological dead end street that has not been exploited before (negative coefficient).

Coming to the end of this discussion it seems qualified to ask as to what extent the regression results from that novel estimator are robust. First of all the overall significance ($P<0.01$) is high allowing to draw conclusion from the estimation results at all. More importantly, however, the correlation coefficient between the first and the second stage is

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contingency variables not inherent in the model. There is no reason to believe that this is the case significantly different from 1.[18] This and the fact that the individual results found are highly plausible makes me believe that the estimator has passed the test of suitability for this type of estimation problem.

6. Summary and future research

This paper started from the premise that various intuitions and assumptions exist as to what determines the value of a patent and how the value of a patent can be assessed using indicators. Despite the existing large-scale empirical evidence in the field it argued that tests of these assumptions still deserve further attention by empirical economists. It lay out that an answer to the question *why* inventions generate profits at all is crucial for various reasons, namely to understand how patentability requirements related to novelty and inventive activity affect innovation incentives and how non-technical factors drive profitability. Ultimately, the question as to how these different *latent* value drivers can be assessed through indicators is of importance to empirical industrial economists. To enhance our understanding, this paper presented an empirical study based on 16.711 EP polymer patents granted between 1978 and 1990. Applying a novel two stage discrete choice simultaneous equation estimator to the data I could – within my framework of assumptions – support the hypothesis that novelty and inventive activity contribute positively to a patent's value from an individual perspective. Contrasting the structural estimation results to regressions carried out in the reduced form I could sustain the common notion that forward citations are a measure of the patent's technical quality. However, I also found that both family size and patent backward citations are value correlates and (because they?) are correlated to the technical quality of the invention. Interestingly, in the field of polymer chemistry backward citations exert a negative effect on

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though.

18 Local maxima can be found at $r_{x,e} = 1$ and $r_{x,e} = -1$, however, their interpretation becomes

the patent's value which is not related to the patent's novelty or inventive activity. The results are relevant in that they sustain the theoretical literature on the design of patent systems that patentability requirements such as novelty and inventive activity can be important setscrews for innovation incentives in certain industries. In the sample of polymer patents technical sophistication seems to be the crucial element for patent value – a result that was not necessarily to be expected and may well be falsified in other industries. The results also enhance empirical economists' understanding as to what they really measure when using patent indicators. Finally, the paper contributed a new estimator to the field of empirical economics that shows a special feature in that it simultaneously estimates a discrete choice problem in the first stage conditional on the outcome of the decision in the second stage. This type of estimator may be useful for various analogous applications as well.

At this point I see various directions into which to proceed with this research. I only want to mention the two most important ones in my eyes. First of all the estimator can be applied to various other industries so that inter industry comparisons become possible. It is very likely that these comparisons will supply us with interesting novel insights as to how innovation is driven in different industries. It might well be that the existing decision making model which is based on the assumption that patents are used as exclusion rights will fail in other technical fields such as semiconductors and needs adjustment. Secondly, relaxations of the assumptions by refining the model structure would be worthwhile. For example, the aggregation of different outcomes in opposition procedures to two generic categories, namely success or defeat, can be defined and might enhance the estimation quality. To do so, suitable proxies for the breadth of a patent would have to be derived, too.

redundant in that it basically confirms the estimation results from the reduced form estimations only. At $r_{x,e} = 1$ and $r_{x,e} = -1$ one of the two set of indicators, XB or ZG, dominates the other and the various effects at work can not be disentangled any more.

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Appendix A

Validation Studies of Patent Value Indicators in the Reduced Form

Indicator	Study (Authors)	Methodology: - Number of Observations / Industrial Sector	- Dependent Variable (if Multivariate Test)	- Type of Validity	Results (Significance/Sign)
Backward Citations[#]	Carpenter, Cooper et al. (1980)	- N=399 US patents on prostaglandines	- None	- Face validity	-
	Narin, Noma et al. (1987)	- N=17 Pharmaceutical companies	- Indicators of corporate technological strength	- Construct validity	- Patent citations to the scientific literature significant - Positive correlation
	Lanjouw and Schankerman (2000)	- N=10.378 US patents	- Infringement and challenge suits	- Construct validity	- Significant - Negative correlation
	Lanjouw and Schankerman (1999)[♣]	- N= approx. 8000 US patents	- Latent variable of patent quality	- Construct validity	- Forward citations strongest predictor of patent quality, claims and backward citations second, family size forth (all coefficients positive)
	Harhoff, Scherer et al. (1999)	- N=57.782 observations on 778 DE patents	- Patent value	- Direct validity	- Significant - Positive correlation
	Harhoff and Reitzig (2000)	- N=13.389 EP patents	- Opposition	- Construct validity	- Insignificant
	Reitzig (2002a)	- N=813 EP patents	- Opposition	- Construct validity	- Patent references significant - Positive
Forward Citations	Narin, Noma et al. (1987)	- N=17 Pharmaceutical companies	- Sum over the means of six financial variables	- Construct validity	- Significant - Positive
	Trajtenberg (1990)	- N>2.000 (sales of CT scanners to US hospitals)	- Social value computed for the innovation	- Construct validity	- Significant - Non-linear (convex)
	Lanjouw and Schankerman (1999)[♣]	- N= approx. 8000 US patents	- Latent variable of patent quality	- Construct validity	- Forward citations strongest predictor of patent quality, claims and backward citations second, family size forth (all coefficients positive)
	Albert, Avery et al. (1991)	- N=77 Patents	- Patent value	- Direct validity	- Significant - Positive - Non-linear
	Harhoff, Scherer et al. (1999)	- N=57.782 DE patents	- Patent value	- Direct validity	- Significant

	Harhoff and Reitzig (2000)	- N=13.389 EPO patents	- Opposition	- Construct validity	- Significant - Non-linear (convex)
	Hall, Jaffe, Trajtenberg (2000)	- 17,111 US Manufacturing Patents	- Tobin's Q	- Construct validity	- Significant - Positive correlation
Family Size	Lanjouw, Pakes et al. (1996)	- N>20,000 DE patent renewals	- Renewal decision	- Construct validity	- Significant
	Lanjouw and Schankerman (1999)♣	- N= approx. 8000 US patents	- Latent variable of patent quality	- Construct validity	- Forward citations strongest predictor of patent quality, claims and backward citations second, family size forth (all coefficients positive)
	Guellec and van Pottelsberghe de la Potterie (2000)	- N=23.487 EP patent applications	- Patent grant	- Construct validity	- Significant - Positive for G3 patenting
	Harhoff and Reitzig (2000)	- N=13.389 EP patents	- Opposition	- Construct validity	- Significant - Positive correlation
	Reitzig (2002a)	- N=813 EP patents	- Opposition	- Construct validity	- Significant - Positive
Scope	Lerner (1994)	- 535 Venture financed bio-technology firms	- Value of the firm	- Construct validity	- Significant - Linear / positive correlation
	Harhoff, Scherer et al. (1999)	- N=57.782 DE patents	- Patent value	- Direct validity	- Insignificant
	Harhoff and Reitzig (2000)	- N=13.389 EP patents	- Opposition	- Construct validity	- Insignificant
	Lanjouw and Schankerman (2000)	- N=10.378 US patents	- Infringement and challenge suits	- Construct validity	- Significant for infringement suits - Negative correlation
	Reitzig (2002a)	- N=813 EP patents	- Opposition	- Construct validity	- Insignificant
Ownership	Lanjouw and Schankerman (2000)	- N=10.378 US patents	- Infringement and challenge suits	- Construct validity	- Significant - Negative effect of individual ownership
	Harhoff and Reitzig (2000)	- N=13.389 EP patents	- Opposition	- Construct validity	- Significant - Negative effect of individual ownership
	Guellec and van Pottelsberghe de la Potterie (2000)	- N=23.487 EP patent applications	- Patent grant	- Construct validity	- Cross-boarder ownership significant - Positive
Legal Argument	Harhoff, Scherer et al. (1999)	- N=57.782 observations on 778 DE patents	- Patent value	- Direct validity	- Significant - Positive
Patenting Strategy	Guellec and van Pottelsberghe de la Potterie (2000)	- N=23.487 EP patent applications	- Patent grant	- Construct validity	- Significant - PCT II strongly positive
	Reitzig (2002a)	- N=813 EP patents	- Opposition	- Construct validity	- PCT II significant - Positive

Number of Applicants	Guellec and van Pottelsberghe de la Potterie (2000)	- N=23.487 EP patent applications	- Patent grant	- Construct validity	- Significant - Negative
Number of Cross-Boarder Research Co-operations	Guellec and van Pottelsberghe de la Potterie (2000)	- N=23.487 EP patent applications	- Patent grant	- Construct validity	- Significant - Positive
Accelerated Examination Request	Reitzig (2002a)	- N=813 EP patents	- Opposition	- Construct validity	- Significant - Positive
Claims	Tong and Frame (1992)	- N=7.531 US patents	- R&D - GNP	- Construct validity	- Significant - Claim counts outperform patent counts
	Lanjouw and Schankerman (1999)♣	- N= approx. 8000 US patents	- Latent Variable of Patent Quality	- Construct validity	- Forward citations strongest predictor of patent quality, claims and backward citations second, family size forth (all coefficients positive)
	Lanjouw and Schankerman (2000)	- N=10.378 US patents	- Infringement and challenge suits	- Construct validity	- Significant - Positive
	Reitzig (2002a)	- N=813 EP patents	- Opposition	- Construct validity	- Dependent and independent product claims significant and positive - Application claims significant and negative

Note: #: Note that several indicators compiled from backward citations are summarised in this table, e.g. science linkage, patent references or legal quality.
This table contains a selection of studies and is not complete.
♣: In the first part of their paper, (Lanjouw and Schankerman 1999) estimate a latent variable construct for patent quality and assume that forward citations, backward citations, family size and claims contribute to patent value; the results are therefore somehow 'self-referential'. The second part (verification of the results using renewal and litigation data) is not discussed here.

Appendix B: Derivation of the ML estimator

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

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

Using assumptions A1, A2 and A4 yields equation (3)

$$p(-c - f(novelty, inventive\ activity, other\ \ factors)) > (0 + c) \quad (3)$$

that denotes the simplified condition for an opposition being filed.

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

$$p\left[-c - \left(\sum xb + e + \sum zg + h - c\right)\right] > \left(0 - \left(\sum xb + e + \sum zg + h - c\right)\right)$$
$$\Leftrightarrow (1-p)\left(\sum xb + e + \sum zg + h\right) - c > 0$$

$$\Leftrightarrow (1-p)\left(\sum xb + \sum zg\right) - c > (1-p)(e+h) \quad (5).$$

In the following, the observable term $(1-p)\left(\sum xb + \sum zg\right) - c$ is referred to as a, and the unobservable term $(1-p)(e+h)$ is referred to as x.

Modeling (5) as a probit must yield a likelihood function with three distinct probabilities, *p(W=0), p(W=1,V=0),* and *p(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

$$p(W=0) = \Phi\left(-\frac{a}{s_x}\right) \quad (6).$$

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 (2^{nd} stage):

$$p = \sum xb + e \qquad (7).$$

Modeling (7) as a simple probit model (assuming $s_e = 1$) yields the following equation for p:

$$p = \Phi(\sum xb) \qquad (8).$$

Thus, the likelihood of an opposition taking place and the patent being upheld (or amended) is described by the binormal distribution

$$p(W = 1, V = 1) = \Phi^2\left(\frac{a}{s_x}, \sum xb, r_{x,e}\right) \qquad (9),$$

where $r_{x,e}$ is the correlation coefficient between the disturbances of the 1^{st} stage (opposition yes/no) and 2^{nd} stage (patent revoked/upheld or amended) that can be calculated to

$$r_{x,e} = \frac{\left(1 - \Phi\left(\sum xb\right)\right) \cdot \left(1 + r_{h,e}\right)}{\left(1 - \Phi\left(\sum xb\right)\right) \cdot \sqrt{\left(2 + 2 \cdot r_{h,e}\right)}} \qquad (10),$$

assuming that $s_h = 1$. Analogously to (9), the probability of the patent being revoked can be calculated as

$$p(W = 1, V = 0) = \Phi^2\left(\frac{a}{s_x}, -\sum xb, -r_{x,e}\right) \qquad (11).$$

Equations (6), (9), and (11) finally constitute the ML estimator function (4):

$$\log L = (1 - W) \cdot \log\left(\Phi\left(-\frac{a}{s_x}\right)\right) + W \cdot \left[V \cdot \log\left(\Phi^2\left(\frac{a}{s_x}, \sum xb, r_{x,e}\right)\right) + (1 - V) \cdot \log\left(\Phi^2\left(\frac{a}{s_x}, -\sum xb, -r_{x,e}\right)\right)\right].$$

Figure 1
Decision Tree of the Opponent

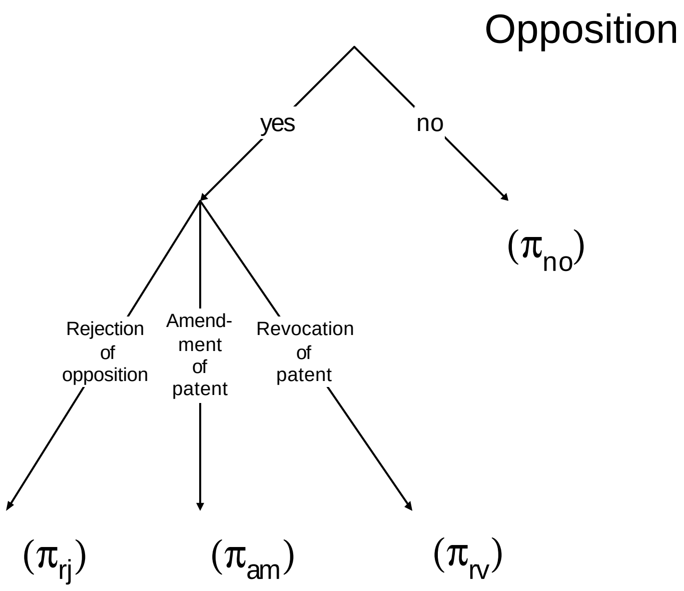

Figure 2
Share of Undecided Oppositions Among All Opposition Cases in Polymers vs. Year of Patent Grant

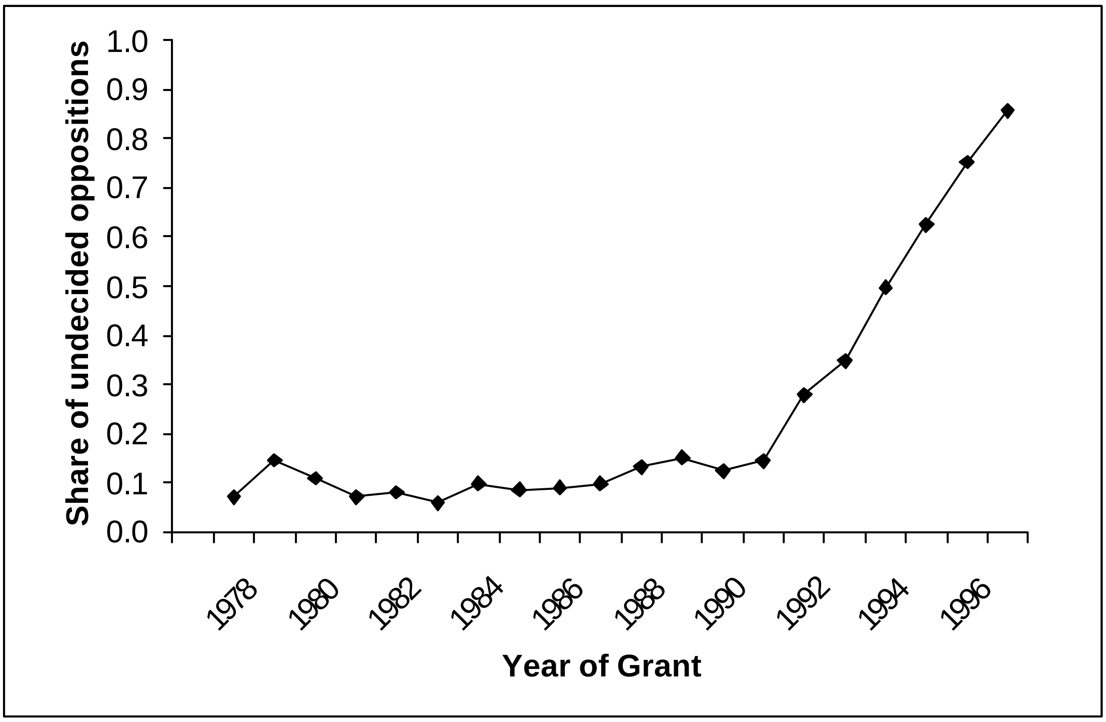

Table 1
Descriptive Statistics

Variable	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Opposition (1: yes, 0: no)[1)]	11.45		0	1
Rejection of Opposition (1: yes, 0: no)[2)]	25.95		0	1
Amendment after Opposition (1: yes, 0: no)[2)]	20.93		0	1
Revocation of Patent after Opposition (1: yes, 0: no)[2)]	38.07		0	1
Opposition Procedure Closed (1: yes, 0: no)[2)]	4.80		0	1
Opposition Outcome not Definable (1: yes, 0: no)[2)]	10.33		0	1
Number of Backward Citations to the Patent Literature[1)]	3.11	1.93	0	24
Number of Backward Citations to the Non-Patent Literature[1)]	0.51	0.92	0	13
Number of Designated States (Family Size)[1)]	7.47	3.21	1	15
Number of Applicants[1)]	1.04	0.22	1	5
Number of Inventors[1)]	2.73	1.48	1	18
Number of Forward Citations (3 years frame)[1)]	0.55	1.06	0	18
Accelerated Examination Request (1: yes, 0: no)[1)]	0.77		0	1
PCT I (1: yes, 0: no)[1)]	0.06		0	1
PCT II (1: yes, 0: no)[1)]	7.11		0	1

Legend: 1): Entire sample comprising N=16,711 patents.
2): Sample of opposed patents comprising N=1,915 patents.

Table 2

Probit Estimations in the Reduced Form
A. Likelihood of an Opposition
B. Likelihood of Patent Maintenance following Opposition

Variable[3)]	**Column A (S.D.)**[1)]	**Column B (S.D.)**[2)]
Number of Backward Citations to the Patent Literature	0.29*** (0.07)	0.17 (0.15)
Number of Backward Citations to the Non-Patent Literature	-0.93*** (0.16)	0.06 (0.37)
Number of Designated States (Family Size)	0.15*** (0.04)	0.16 (0.09)
Number of Applicants	0.13 (0.57)	-0.76 (1.31)
Number of Inventors	-0.01 (0.09)	0.39** (0.21)
Number of Forward Citations (3 years frame)	0.42*** (0.11)	0.24 (0.26)
Accelerated Examination Request (1: yes, 0: no)	1.46 (1.36)	3.03 (3.13)
PCT I (1: yes, 0: no)	2.71* (1.60)	1.14 (3.48)
PCT II (1: yes, 0: no)	0.62 (0.57)	0.11 (1.31)
Constant	-14.07*** (0.75)	0.77 (1.71)
Log Likelihood Ratio Test for s^2*:* c^2 *(9)*	*85.06*	*10.47*
P-Value	<0.001	3.14

Legend:
1): Entire sample comprising N=16,711 patents.
2): Sample of opposed patents comprising N=1,915 patents.
3): All coefficients are multiplied by factor 10.
*/**/*** Significant at 10%/5%/1% level (two-tailed tests)

Table 3
Estimations in the Structural Form
XB: Indicators of Technical Value Drivers
ZG: Indicators of Non-technical Value Drivers

Variable		**Column (S.D.)**
XB[1)]	Number of Backward Citations to the Patent Literature	0.23* (0.12)
	Number of Backward Citations to the Non-Patent Literature	-0.42 (0.34)
	Number of Designated States (Family Size)	0.22** (0.09)
	Number of Applicants	-0.75 (1.15)
	Number of Inventors	0.29 (0.19)
	Number of Forward Citations (3 years frame)	0.43* (0.25)
	Accelerated Examination Request (1: yes, 0: no)	3.71 (2.93)
	PCT I (1: yes, 0: no)	1.67 (3.00)
	PCT II (1: yes, 0: no)	0.47 (1.20)
	Constant	-8.23 (<0.01)
ZG[1)]	Number of Backward Citations to the Patent Literature	0.13 (0.11)
	Number of Backward Citations to the Non-Patent Literature	-0.63** (0.28)
	Number of Designated States (Family Size)	-0.00 (0.01)
	Number of Applicants	0.65 (0.89)
	Number of Inventors	-0.22 (0.14)
	Number of Forward Citations (3 years frame)	0.14 (0.19)
	Accelerated Examination Request (1: yes, 0: no)	-0.56 (1.71)
	PCT I (1: yes, 0: no)	1.52 (2.31)
	PCT II (1: yes, 0: no)	0.32 (0.94)
Rho		-0,51*** (0,16)
Costs[1)]		4,64*** (1,72)
Wald c^2 *(9)*		*22,04*
P-Value		<0.01

Legend: Entire sample comprising N=16,711 patents.
1): Coefficient multiplied by factor 10.
*/**/*** Significant at 10%/5%/1% level (two -tailed tests)