This article was downloaded by: [155.246.103.35] On: 05 April 2017, At: 22:24
Publisher: Institute for Operations Research and the Management Sciences (INFORMS)
INFORMS is located in Maryland, USA

Management Science

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

Conflict Resolution, Public Goods, and Patent Thickets

Dietmar Harhoff, Georg von Graevenitz, Stefan Wagner

To cite this article:
Dietmar Harhoff, Georg von Graevenitz, Stefan Wagner (2016) Conflict Resolution, Public Goods, and Patent Thickets. Management Science 62(3):704-721. http://dx.doi.org/10.1287/mnsc.2015.2152

Full terms and conditions of use: http://pubsonline.informs.org/page/terms-and-conditions

This article may be used only for the purposes of research, teaching, and/or private study. Commercial use or systematic downloading (by robots or other automatic processes) is prohibited without explicit Publisher approval, unless otherwise noted. For more information, contact permissions@informs.org.

The Publisher does not warrant or guarantee the article's accuracy, completeness, merchantability, fitness for a particular purpose, or non-infringement. Descriptions of, or references to, products or publications, or inclusion of an advertisement in this article, neither constitutes nor implies a guarantee, endorsement, or support of claims made of that product, publication, or service.

Copyright © 2016, INFORMS

Please scroll down for article—it is on subsequent pages

INFORMS is the largest professional society in the world for professionals in the fields of operations research, management science, and analytics.
For more information on INFORMS, its publications, membership, or meetings visit http://www.informs.org

MANAGEMENT SCIENCE
Vol. 62, No. 3, March 2016, pp. 704–721
ISSN 0025-1909 (print) | ISSN 1526-5501 (online)

http://dx.doi.org/10.1287/mnsc.2015.2152
© 2016 INFORMS

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

Conflict Resolution, Public Goods, and Patent Thickets

Dietmar Harhoff
Max Planck Institute for Innovation and Competition, D-80539 Munich, Germany,
dietmar.harhoff@ip.mpg.de

Georg von Graevenitz
School of Business and Management, Queen Mary University of London, London E1 4NS, United Kingdom,
g.v.graevenitz@qmul.ac.uk

Stefan Wagner
ESMT European School of Management and Technology, 10178 Berlin, Germany, stefan.wagner@esmt.org

Postgrant validity challenges at patent offices rely on the private initiative of third parties to correct mistakes made by patent offices. We hypothesize that incentives to bring postgrant validity challenges are reduced when many firms benefit from revocation of a patent and when firms are caught up in patent thickets. Using data on opposition to patents at the European Patent Office we show that opposition decreases in fields in which many others profit from patent revocations. Moreover, in fields with a large number of mutually blocking patents, the incidence of opposition is sharply reduced, particularly among large firms and firms that are caught up directly in patent thickets. These findings indicate that postgrant patent review may not constitute an effective correction device for erroneous patent grants in technologies affected by either patent thickets or highly dispersed patent ownership.

Keywords: microeconomic behavior; industrial organization; firm objectives; organization and behavior; market structure; firm strategy; market performance; patent system; patent litigation
History: Received March 28, 2013; accepted October 28, 2014, by Lee Fleming, entrepreneurship and innovation. Published online in *Articles in Advance* August 17, 2015.

1. Introduction

Over the last three decades the demand for patents has been steadily growing at patent offices around the world. A number of researchers have argued that a large proportion of these new patents may be "weak" or marginal in terms of their contribution to the state of the art (Bessen and Meurer 2008, Jaffe and Lerner 2004, Lei and Wright 2009). Mechanisms, such as opposition and litigation, that complement the efforts of patent offices in examining and stripping out weak patent applications should be welfare enhancing in such a context (Choi 2005, Graham and Harhoff 2014, Graham et al. 2003, Hall and Harhoff 2004).

Although these mechanisms are often cost effective (Lemley 2001), several authors have argued that they will be undermined by a public good problem (Farrell and Merges 2004, Harhoff and Reitzig 2004, Levin and Levin 2003). When many parties profit from the revocation or annulment of a patent, private incentives of any single party may no longer be sufficiently strong to initiate such a challenge. We confirm this prediction using data on postgrant review at the European Patent Office (EPO). Additionally, we demonstrate that the presence of patent thickets in complex technologies weakens incentives for filing postgrant reviews and that this effect is strongest for patent applications made by firms at the center of patent thickets as well as for larger firms.

Examination and granting processes are the central quality assurance mechanisms at patent offices, but they are frequently impaired by errors (Lemley 2001, Harhoff and Reitzig 2004). Although patent applicants have various ways of eliminating errors not favorable to them during the examination of their application, errors in their favor are less likely to be corrected by the patent office. Errors made in the granting process are therefore likely to be asymmetric: on average, examination will result in granting exclusion rights that are too strong or broad given the standards that should prevail in the patent system, and therefore the interests of the public and of rival firms are compromised and social welfare is reduced.

Litigation and postgrant validity challenges at patent offices and courts should ideally provide effective mechanisms to correct the erroneous issue of patents (Farrell and Merges 2004, Hall and Harhoff 2004, Levin and Levin 2003). Both mechanisms allow third parties to bring forward additional evidence on

RIGHTSLINK

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

the validity and scope of patent applications. Usually these parties have an interest in reducing the scope of a rival's patent application or having the patent annulled completely, providing a natural counterbalance to the interests of the applicant (Jaffe and Lerner 2004). The United States Patent and Trademark Office (USPTO) is currently introducing a process of postgrant validity review in order to enhance its ability to weed out weak patents within the America Invents Act (AIA) of 2011.[1]

The effectiveness of validity challenges depends on the strength of third-party incentives to challenge a patent. Previous research shows that the likelihood of litigating patents is positively related to patent and firm level characteristics such as the value of patent applications and the opponent's expectation of winning the case (Harhoff and Reitzig 2004, Lanjouw and Schankerman 2001). We extend this line of research by introducing characteristics of the technology space in which patenting takes place. First, we test the strength of the public good effect in post-grant review. Second, we investigate how the presence of and entanglement in patent thickets affects incentives to mount validity challenges. The public good problem arises whenever several firms benefit from the revocation or narrowing of a patent application. The party investing in the invalidation of a granted patent provides a public good to all firms who would see their profits reduced if the patent were to stand. In a technology area with fragmented ownership, an opponent who successfully challenges a patent will profit less on average than in a field with highly concentrated ownership. This reduces incentives to engage in postgrant challenges (Farrell and Merges 2004). Therefore, we expect the incidence of postgrant validity challenges to be positively related to the concentration of patent holdings.

Moreover, in the presence of patent thickets, in which large numbers of patents with overlapping claims (Shapiro 2001) are owned by multiple parties, firms' incentives to file costly postgrant validity challenges may be reduced further. Patent thickets arise when many patents are filed concurrently and patent claims are not clearly delineated, resulting in multiple overlapping claims. In such an environment, firms are exposed to the threat of litigation and of subsequent injunctions, which would hold up production. By threatening countersuits, patent applicants can prevent other producing firms from challenging their patents and from engaging in patent enforcement (Federal Trade Commission 2003). Consequently, firms ensnarled in patent thickets have incentives to create large patent portfolios to protect themselves against litigation and injunctions (Hall and Ziedonis 2001). To avoid an escalation of litigation, firms in patent thickets frequently resolve overlapping claims through nonadversarial means, such as cross licensing, broad settlement agreements, and other out-of-court agreements (Shapiro 2001).

This suggests that the frequency of postgrant validity challenges in patent thickets will be lower than in technology areas not affected by thickets. In particular, the reduction in postgrant validity challenges is likely to be stronger for those firms deeply ensnarled in patent thickets—we refer to these firms as "patent thicket insiders." Studies of these phenomena have been made difficult by a lack of suitable measures regarding the extent and strength of blocking relationships. Drawing on previous research (von Graevenitz et al. 2011), we use citation data to identify and to measure the intensity of such blocking relationships.

We analyze data on opposition proceedings against patents granted at the EPO. Opposition is relatively frequent: historically, 6.2% of all EPO-granted patents have been opposed.[2] Moreover, the time window for oppositions is narrow so that we can apply precisely timed covariates to capture other potential determinants of opposition. Measures of patent ownership concentration and of mutual blocking relationships between patent holders are used to study whether the public good and patent thicket effects are correlated with incidence of postgrant validity challenges. Our empirical results show that incentives to file an opposition against a patent grant are significantly lower if either effect is at work. An increase of one standard deviation in the concentration of patent holdings is related to an increase in the incidence of patent opposition of approximately 8.1% relative to the average unconditional probability. An increase of one standard deviation in our measure of thickets relates to a decrease in the incidence of postgrant validity challenges by 22.2% relative to the average unconditional probability. These findings show that private incentives to invest in postgrant validity challenges in technology areas in which the social value of postgrant validity challenges can be assumed to be particularly high (i.e., where dense patent thickets and/or high

[1] For more information on the America Invents Act of 2011, see http://www.gpo.gov/fdsys/pkg/BILLS-112hr1249enr/pdf/BILLS-112hr1249enr.pdf (last accessed May 3, 2014).

[2] An exact comparison of the incidence of opposition and of validity challenges in court is made difficult by the lack of data on patent litigation in Europe. In the case of Germany, the Federal Patent Court, which has sole jurisdiction on validity issues, had 189 (234) invalidity cases filed in 2000 (2007) (Harhoff 2009, Table 4.4). The number of opposition cases at the EPO was 1998 (2766) in these years (European Patent Office 2004, 2008). Note that in excess of 98% of EPO-granted patents become valid in Germany, whereas the invalidity cases at the Federal Patent Court include validity challenges to patents granted by the national patent office. Although this comparison neglects a number of issues, it appears safe to conclude that opposition is more likely by at least an order of magnitude.

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

fragmentation of patent ownership exist) are weaker than in other technology areas.

The remainder of the paper consists of five sections. In §2, we describe the institutional background of oppositions at the EPO. Section 3 summarizes the theory underlying our hypotheses. Data and descriptive statistics are presented in §4, and §5 presents our empirical results. We discuss implications for the management of intellectual property and for public policy in §6.

2. Opposition at the EPO

2.1. Institutional Background

Since it commenced its operations in 1978, the EPO has offered a harmonized application path for patent applicants that seek patent protection in one or more signatory states of the European Patent Convention (EPC). A patent application granted by the EPO does not lead to a single "European patent," but to a bundle of independently enforceable and revocable national patent rights. However, the grant decision of the EPO is subject to a central postgrant review mechanism, which can be initiated by any third party within nine months of the grant date. If no opposition is filed within this time period, the patent's validity can only be challenged under the legal rules of the respective countries where the patent takes effect. Opponents then have to challenge the national patent rights separately in the national courts for each state, which is significantly more expensive than the centralized opposition proceeding.

The opposition procedure at the EPO is a quasi-judicial process, heard by an Opposition Division consisting of three technically qualified examiners. Opposition may be filed on grounds listed in Art. 100 EPC. These are (i) the subject matter is not patentable under the terms of EPC Art. 52–57,[3] (ii) the patent does not disclose the invention clearly enough or in its entirety so that it could be carried out by a person skilled in the art, or (iii) the subject matter of the European patent extends beyond the content of the original application. An opposition can lead to either a rejection of the opposition and thus the maintenance of the patent as it was granted or the maintenance of the patent in amended form (i.e., with more restricted claims), or it can lead to the complete revocation of the opposed European patent. The outcome of opposition has legal effect for all national rights originating with the EPO patent grant and is subject to appeal to the Technical Boards of Appeal at the EPO.

2.2. Prior Literature

Most of the literature analyzing postgrant validity challenges has focused on U.S. patent litigation, where the vast majority of cases are settled out of court (Lanjouw and Schankerman 2004b).[4] For that context, it is quite appropriate to assume that the parties involved will resolve out of court those cases in which the legal issues are transparent. In the opposition context, this consideration is less likely to hold. Although there is some settlement activity, most cases actually go to "trial" and are resolved in either opposition or appeal proceedings. This is a result of both institutional and financial considerations: settlements during the opposition proceedings are risky because the EPO may pursue the case itself (Rule 84(2) EPC). This restricts settlements to the nine months following the patent's grant, in which an opposition can be filed. Financially, a settlement is unlikely to be much cheaper than attacking or defending the patent in opposition. The average cost of opposing a patent at the EPO has been estimated to range from €6,000 to €50,000 (including patent lawyers' fees) and is therefore considerably lower than the cost of litigating a patent in multiple national courts.[5] Finally, opportunities to drive up the other party's costs are virtually nonexistent in the European setting.

Revoking erroneously granted patents or narrowing patents during opposition proceedings after they have been specified too broadly can prevent welfare losses. These would emerge because of the market power given to a holder of an erroneously granted patent (Graham and Harhoff 2014). If the patent is revoked in opposition, the gain in welfare equals the welfare loss that society would have incurred in the case of the patent being upheld and enforced. The

[3] The EPC, 15th edition, is available at http://www.epo.org/law-practice/legal-texts/epc.html. See EPC Art. 52–57. The subject matter may not be novel (Art. 52(1), 54, and 55 EPC), does not involve an inventive step (Art. 52(1), 56 EPC), cannot be used in an industrial application (Art. 52(1) and 57 EPC), is not regarded an invention (Art. 57 EPC), or is not patentable for reasons stated in Art. 53 EPC.

[4] Note that when patents are subject to litigation this is typically in response to a patent infringement claim by the patent owner. When a patent grant is opposed this is more likely to be used in a preemptive way by a third party. This means that comparisons between work focusing on patent litigation, as is often the case in studies using U.S. data, and work focusing on opposition, as is often the case in studies using European data, should be read bearing this fundamental difference in mind. Note also that the ongoing reform of the U.S. patent system implements a postgrant review institution that is somewhat comparable to the opposition system at the EPO. See 6 of H.R. 1249: America Invents Act, available at https://www.govtrack.us/congress/bills/112/hr1249/text (last accessed April 20, 2014). However, it is unclear how costly postgrant review at the USPTO will be, since it may involve discovery.

[5] An average litigation case will cost approximately €160.000 in Germany. Costs in France and the Netherlands are similar, whereas litigation in the United Kingdom has typically been more expensive. See Harhoff (2009) for estimates of litigation costs in European countries.

RIGHTSLINK

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

revocation of these patents can have two effects: it effectively eliminates the need for subsequent litigation or it reduces the room for extracting excessive rents from competitors or consumers. It is more difficult to assess the welfare effects of a rejection of an opposition. If the opposition is rejected, there is no need to amend the underlying patent and it is less clear that there is a benefit from the opposition having been brought. There is still a benefit from the lower cost of determining the question of validity, and there could be an additional litigation-reducing effect, if opposition has demonstrated the legal robustness of the patent or clarified its boundaries for others. If opposition results in an amendment of the patent, then this can be seen as a convex combination of the two polar cases.

Such benefits from opposition have to be considered in relation to possible costs the institution may give rise to. As noted above, the costs of opposition and appeals are typically lower than those of a case brought to a court. This might have negative effects if more ill-founded cases are brought as opposition cases than would be the case if parties could only resort to a court. Judicial processes take time to resolve, and during that period uncertainty is not resolved. If the parties to an opposition case do not anticipate the outcomes perfectly, their incentives to invest in innovation or the production of a product based on a patent will suffer and welfare gains from the introduction of technology are postponed. Without observing actual investment and R&D decisions, it is difficult to assess the likelihood of this fear, uncertainty, and doubt (FUD) scenario. In addition, if opposition decisions were to be regularly overturned by the courts on appeal, then this could lead to a system in which opposition is just an extra hurdle in the judicial process. Patent owners might then face higher costs of patent litigation and more delays, overturning the benefits stemming from the lower initial costs of opposition proceedings and speedier resolution of disputes. This scenario could arise if opposition chambers are not required to adhere to the same interpretation of the law as patent courts. There is currently no evidence that this is the case in Europe.

Where patents are correctly delineated after opposition, the opposition mechanism should be welfare increasing as long as the expected costs from errors in the granting process are larger than the total social cost of opposition. Empirical work (Harhoff and Reitzig 2004) has shown that valuable patents are more likely to be attacked under opposition than less valuable ones. This indicates that the opposition procedure serves as an information revelation mechanism selecting valuable patents for further scrutiny based on the information that third parties bring to the table. Typically such patents are also more likely to give rise to large welfare losses if granted erroneously. The selection of high-value patents into opposition makes it likely that the overall effect of opposition is welfare increasing. Detailed analyses of the welfare effects of opposition can be found in Levin and Levin (2003) and Graham and Harhoff (2014). Both papers suggest that patent opposition processes may have significant potential for achieving welfare gains.[6]

3. Incentives to Engage in Postgrant Validity Challenges

The empirical analysis of the opposition mechanism provided by this paper is motivated by the expectation that postgrant opposition is not uniformly effective. In this section we set out four hypotheses about opposition, which we test empirically further below. The hypotheses are derived from a simple static model that captures a number of mechanisms that affect firms' incentives to oppose patents granted by a patent office. We analyze a static model and focus only on the decision to oppose or accommodate a granted patent in order to accommodate multiple mechanisms. The model illustrates the logical consistency of our hypotheses in this context. It also serves as a basis for the decision of which variables to include in the empirical model.

The model, which is provided in Online Appendix 1 (online appendices available as supplemental material at http://dx.doi.org/10.1287/mnsc.2015.2152), captures two mechanisms acting on the probability of opposition for a specific patent: first, the patent thicket effect, and second, the public good effect. Our modeling shows that the public good effect will only be at work if the patent thicket effect does not remove private incentives to oppose a patent. Consequently, there are no interactions between the two effects.

In Online Appendix 1, we demonstrate that the existence of a patent thicket changes the calculus of whether to oppose a patent in one of two ways: either the potential opponent is worried about retaliation by the applicant if an opposition case is lodged or the applicant has chosen to simultaneously apply for so many very similar patents that opposition is ineffective. In a patent thicket the threat of retaliation is likely to be high because both firms' patent portfolios cover similar technologies, leading to overlapping patents. The threat of tit-for-tat opposition creates incentives to cooperate. For instance, the CEOs of two central players in the smart phone industry, Apple and Google, have recently attempted to end a sequence of court cases in bilateral negotiations

[6] Graham and Harhoff (2014) point out that this result depends crucially on the assumption that opposition is not too costly.

RIGHTSLINK

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

at the board level.[7] Additionally, the lack of precision in the language used to describe patents in many high-technology industries makes it hard for potential opponents to determine exactly by which patents they may be affected (Federal Trade Commission 2011). If an applicant submits multiple patents that all might affect the potential opponent, we show that opposition may cease to be cost effective. These two mechanisms have similar effects. We set out three hypotheses capturing these effects next.

Hypothesis 1. *Patents in technology areas characterized by patent thickets are less likely to be opposed than patents in other technology areas.*

Within a given technology area we distinguish between firms that are part of patent thickets (insiders) and firms that are outside the thickets (outsiders). Outsiders patent technology that is not closely related to the core technologies of the thicket but that is still patented in the same technology area. Concerns over retaliation should matter less to firms contemplating opposition against these outsiders.

Hypothesis 2. *Patents granted to patent thicket insiders are less likely to be opposed than patents granted to patent thicket outsiders.*

Finally, we expect that the patent portfolio size of an applicant firm will moderate the effect of the patent thicket on the probability of opposition against that firm's patents. An applicant firm with a large portfolio presents a more credible threat of retaliatory opposition or will find it easier to apply simultaneously for multiple patents than a firm with a small portfolio, leading to the third hypothesis.

Hypothesis 3. *Patent portfolio size amplifies the negative effect of patent thickets on the likelihood of opposition.*

Our theoretical analysis shows that, whenever firms have an incentive to oppose a patent application individually, the total probability that the patent application is opposed falls with additional potential opponents. This public good effect is also modeled in Farrell and Merges (2004). Further, Harhoff and Reitzig (2004, footnote 25) point out that the incentives to invest in opposition will be strong when only a small number of firms benefits from the public good, e.g., in tight oligopoly structures, and relatively weak when a large number of firms would benefit from the public good, e.g., in competitive markets. We therefore expect the following.

Hypothesis 4. *Patents granted to firms whose rivals' patent portfolios are more concentrated are more likely to be opposed.*

To test these hypotheses, we include covariates that have been previously identified as affecting the probability of patent litigation. Lanjouw and Schankerman (2001) provide an important analysis of the general features of patent litigation in the United States. They compare the characteristics of litigated patents and their owners to those of a control group of patents and owners. They establish the following empirical results: (i) more valuable patents are more likely to be litigated; (ii) parties with large portfolios are attacked less often, i.e., are presumably able to use settlements instead of litigation; (iii) foreign (non-U.S. patent holders) are less likely to be involved in U.S. litigation; and (iv) litigation risk is much higher in pharmaceuticals than in other technologies.[8] Lanjouw and Schankerman (2004b) confirm that the risk of litigation for patents owned by individuals or firms with small patent portfolios is much higher. They argue that holders of relatively large portfolios of patents are more likely to trade licenses and may engage in other forms of "cooperative" dispute resolution. Hence, these types of patent owners are less likely to pursue infringement suits in court. A significant disadvantage for smaller firms results from this: they face a high risk of litigation and are not as well positioned to resolve cases amicably.

4. Data and Descriptive Statistics

We use data on all patent applications filed at the EPO between 1980 and 2007 to test the hypotheses derived in the previous section. This section provides detailed information on our data sources, a discussion of the variables we derive, and descriptive statistics for these variables.

4.1. Data Sources

Our data set was obtained from the PATSTAT[9] database and contains bibliographic and legal information on patents, as well as information on the identity of the patent applicants. We assign patents to applicants based on the applicant information contained in the ECOOM-EUROSTAT–EPO PATSTAT Person Augmented Table (EEE-PPAT), which provides a harmonized set of applicant names for the PATSTAT

[7] Apple's CEO Tim Cook and Google's CEO Larry Page have been conducting behind-the-scenes talks about a range of intellectual property matters, including the mobile patent disputes between the companies in August 2012 (for more details, see http://www.reuters.com/article/2012/08/30/us-google-apple-idUSBRE87T15H20120830 (last accessed May 3, 2014)).

[8] The average incidence of infringement litigation is approximately 1 case per 100 patents. However, the rate varies between 0.5 cases in chemicals to 2 cases per 100 patents for pharmaceuticals. Lerner (1994) estimates a likelihood of 6 cases per 100 patents in biotechnology in the time period, 1990–1994. Generally, the frequency of litigation decreases as a technical sector matures.

[9] Information on PATSTAT is available at http://www.epo.org/searching/subscription/raw/product-14-24_de.html (last accessed April 20, 2014).

RIGHTSLINK

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

Table 1 Applications, Grants, Pending Cases, and Oppositions by Application Year (1980–2007)

Application year	Applications	Grants	Grant rate (%)	Pending cases	Share of pending cases (%)	Oppositions	Oppostion rate[a] (%)
1980	21,174	14,685	69.35	18	0.09	1,439	9.80
1981	27,182	18,688	68.75	24	0.09	1,890	10.11
1982	30,177	20,961	69.46	40	0.13	2,098	10.01
1983	33,187	22,889	68.97	72	0.22	2,037	8.90
1984	38,930	26,456	67.96	82	0.21	2,307	8.72
1985	41,498	28,054	67.60	41	0.10	2,310	8.23
1986	45,301	30,332	66.96	48	0.11	2,292	7.56
1987	48,258	32,008	66.33	137	0.28	2,268	7.09
1988	55,131	36,099	65.48	288	0.52	2,429	6.73
1989	61,150	39,084	63.91	497	0.81	2,528	6.47
1990	67,722	44,660	65.95	236	0.35	2,676	5.99
1991	63,070	42,319	67.10	52	0.08	2,633	6.22
1992	64,553	43,352	67.16	332	0.51	2,686	6.20
1993	63,973	44,066	68.88	171	0.27	2,572	5.84
1994	65,933	45,200	68.55	367	0.56	2,660	5.88
1995	69,426	46,518	67.00	660	0.95	2,661	5.72
1996	75,947	49,128	64.69	1,195	1.57	2,739	5.58
1997	85,585	52,254	61.06	2,072	2.42	2,722	5.21
1998	96,581	55,436	57.40	3,543	3.67	2,826	5.10
1999	105,203	57,126	54.30	6,093	5.79	3,056	5.35
2000	116,851	60,129	51.46	9,226	7.90	3,035	5.05
2001	123,431	58,489	47.39	15,061	12.20	3,046	5.21
2002	121,559	53,121	43.70	22,032	18.12	2,530	4.76
2003	124,710	48,778	39.11	32,813	26.31	2,357	4.83
2004	130,653	43,205	33.07	46,487	35.58	1,936	4.48
2005	137,899	37,300	27.05	62,795	45.54	1,535	4.12
2006	141,006	29,413	20.86	80,634	57.18	1,089	3.70
2007	138,666	20,032	14.45	97,225	70.11	545	2.72
Total	2,194,756	1,099,782	50.11	382,241	17.42	64,902	5.90

Note. In the case that a patent has been filed by more than one applicant, it is contained multiple times in the data.
[a]The opposition rate reported is the number of oppositions filed divided through patent grants by year of application. For patents granted less than nine months before April 1, 2011, we do not observer whether opposition has been filed or not.

database.[10] We also applied our own harmonization routines including consolidation of subsidiaries to the 100 most important patent applicants ranked by their total number of patent applications.[11]

In total, we observe 2,194,756 patent applications at the EPO between 1980 and 2007 that resulted in a total of 1,099,782 granted patents to date (see Table 1). It should be noted that many applications are still pending. For example, 70% of patent applications in the 2007 application cohort were still under examination in March 2011. For 1,044,292 of the granted patents, we can observe whether there was an opposition by the end of the first quarter of 2011; 64,902 oppositions were filed against granted patents, yielding an average opposition rate of 6.2%. Table 1 shows that, although the annual number of patent applications has steadily increased over time, both the share of patent applications that led to granted patents and the number of oppositions relative to patents granted remained relatively stable until the mid-1990s. The decline in both grant and opposition rates toward the end of the observation period is due to truncation, because the examination of patent applications is lengthy. Grant lags at the EPO are on average approximately 4.5 years (Harhoff and Wagner 2009).

4.2. Variables

4.2.1. Dependent Variable.

Opposition. For each granted (focal) patent in our sample, we observe whether an opposition was filed within the statutory period of nine months after the grant date. This is the dependent variable in our analysis. The reference year t for the dependent variable is the year in which the patent is granted by the EPO. All technology and firm level measures are calculated relative to this grant year, albeit with a lag in some cases. This captures the information set firms have when making a decision to oppose the patent after it is granted. We discuss the lags we adopt in each case below. We deviate from this rule only with respect to the measure of concentration, which captures the public good effect. This measure is calculated on the basis

[10] See Du Plessis et al. (2009), Peeters et al. (2009), and Magerman et al. (2009) for a comprehensive description of the harmonization routines.

[11] Similar results are obtained without the application of our harmonization routine.

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

of the application year *ta* of the focal patent to reflect the concentration of related technology at a time close to the date of invention.

4.2.2. Explanatory Variables.

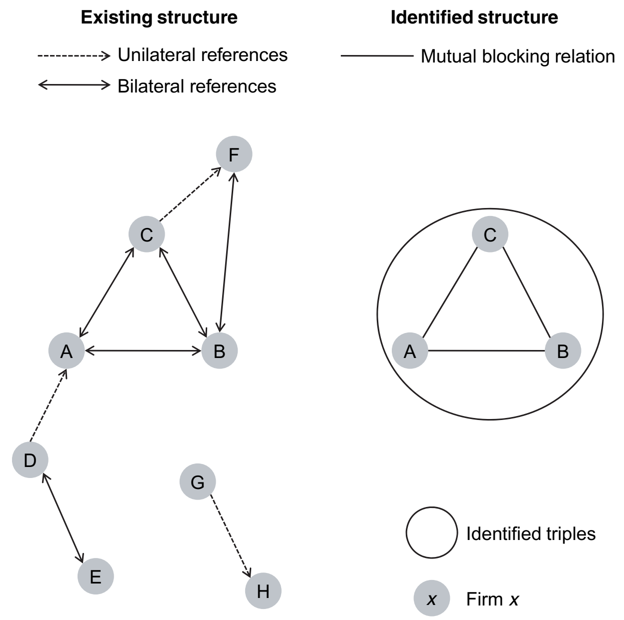
Concentration of patent ownership $C_{f,a,ta}$. This measure is used to capture the public good effect. It is constructed as the Herfindahl index of the concentration of rivals' granted patents in a technology area a, if these patents were applied for in the same year *ta* as the focal patent. Because of this timing, the variable measures concentration in the cohort of technologies submitted to the patent office at the time of application of the focal patent. This choice of timing is based on the assumption that revocation of a patent will primarily benefit applicants of patents applied in the same year and technology area. These applicants will be most affected by a revocation and should be able to extract more value from their own patents if the focal patent is revoked. In calculating the measure, we distinguish 30 different technology areas according to the OST-INPI/FhG-ISI technology classification (OECD 1994). This firm-area-year level variable measures the strength of the public good effect.

Density of patent thickets: Triples of mutually blocking firms $Tr_{a,t}$. This measure is used to capture the patent thicket effect. Our primary measure of the density of patent thickets in a particular technology area a is the "triples" measure introduced by von Graevenitz et al. (2011, 2013). This measure is based on critical references listed in the search reports of the EPO. Critical references point to prior art that limits the patentability of an invention. For example, the existence of an older, but similar, invention can threaten the patentability of a newer invention because the newer invention is not novel or lacks inventiveness. In these cases, critical documents containing conflicting prior art are referenced in search reports at the EPO as X- or Y-type references (Harhoff and Reitzig 2004); X refers to documents showing that a claimed invention cannot be considered novel or cannot be considered to involve an inventive step. When a document has to be combined with one or more other documents to show a lack of inventiveness, it is classified as a Y-type reference.[12]

When the patentability of firm A's inventions is frequently limited by existing patents of firm B, it is reasonable to assume that A is blocked by B to a certain degree. If the inverse is also true, A and B are highly likely to own mutually blocking patents. To capture more complex structures of blocking relationships we follow von Graevenitz et al. (2011) and compute the number of "triples" in which three firms own mutually blocking patents (see Figure 1). Resolving this form of blocking is likely to be costlier and more complex than bilateral bargaining because it may involve three simultaneous bilateral bargaining processes. In such settings any agreement by two parties creates incentives for holdup by the third (Mnookin 2003), and deviation by one party requires coordination on punishment by the others, which makes cooperation harder to attain (Grujić et al. 2012). Even more complex blocking situations can be described as consisting of multiple triples. Triple or triad counts are widely used as a local measure of network density as proposed by Holland and Leinhardt (1976) and Milo et al. (2002).

In our data blocking pairs and triples are identified as follows: for each firm f we analyze all critical patent references contained in search reports pertaining to firm f's patents in a given technology area and grant year t over the current and the two preceding years ($t-2$ to t).[13] Pairs are established if firm A is on firm B's list of referenced firms and, at the same time, if firm B is on firm A's list of referenced firms. Finally, triples

Figure 1 Schematic Presentation of Unilateral and Bilateral Blocking Relationships



Source. Reprinted from von Graevenitz et al. (2011, Figure 1), with permission from Elsevier.

[12] Refer to EPO Guidelines for Examination, Part B, Chapter X, Section 9.2.1, available at http://www.epo.org/law-practice/legal-texts/html/guidelines/e/b_x_9_2_1.htm (accessed May 3, 2014). Approximately 46% of all references contained in the population of European patent applications are critical references, with X references being twice as frequent as Y-type references. Our results remain robust if we use only X-type references for the construction of our triples measure.

[13] We analyze a time span of three years to account for cumulativeness in technological progress. Relying on a three-year window is an arbitrary choice. Although the measure differs in its absolute values depending on the time window chosen, its variation across fields is robust with respect to different time windows.

RIGHTSLINK

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

are formed if firm A and firm B, firm A and firm C, and firm B and firm C form pairs of mutually blocking relationships in the same period (see Figure 1).[14] Having constructed the triples measure at the technology area level, we lag the measure by two periods to capture the fact that patents younger than 18 months are not published by the patent office. The lagged measure reflects firms' ability to measure the density of patent thickets only with delay. This area-year variable measures the strength of the patent thicket effect.

To test the insider–outsider hypothesis (Hypothesis 2), we split the count of triples at the level of a technology area into two components: a firm level count of the number of triples in which the firm itself is involved (insider triples, $Tr\_i_{a,t}$), and the count of triples present in the technology area without the involvement of the focal firm (rivals' triples, $Tr\_o_{a,t}$). These measures are also lagged by two periods.

4.2.3. Covariates.

Fragmentation $Fr_{f,a,t}$. To control for the impact of fragmentation of prior art we use the Ziedonis (2004) fragmentation index. We construct an index of fragmentation based on X and Y references contained in a focal firm f's annual patent applications because $Fr_{f,a,t} = 1 - \sum_{j=1}^{n} s^2_{f,a,j,t}$, where $s_{f,a,j,t}$ is the share of X- and Y-type references in f's patent applications that point to patents owned by patentee j, which are filed in area a and the grant year t of the focal patent. We apply the correction proposed by Hall (2005) for this measure and multiply the fragmentation index by $refs_{f,a,t}/(refs_{f,a,t} - 1)$, where $refs_{f,a,t}$ is the number of references in firm f's patent applications in area a and grant year t. As with the triples measure we use the second lag of the fragmentation measure relative to the grant year of the applicant's patent to account for the fact that patents younger than 18 months are not yet published. The fragmentation measure is frequently used to control for the effects of patent thickets in the literature (Cockburn and MacGarvie 2011, Galasso and Schankerman 2010, Noel and Schankerman 2013, Ziedonis 2004). Ziedonis (2004) argues that high fragmentation of ownership of a technology among the rivals of a patent holder will exacerbate the problem of negotiating access to the technology. This measure provides no information about the complexity of bargaining because it contains no information about linkages between the patent holder's rivals.

We have found this measure to be weakly correlated with the triples measure and include it as a separate covariate. Our results are robust to the exclusion of the variable,[15] but because it is highly significant we report it in our results below.

Size of technology area $S_{a,ta}$. We include the total number of patent applications filed in a technology area in the year in which the application for the focal patent is made. This variable captures the possibility that examination quality suffers as a result of large volumes of applications. If this were the case we might expect a greater volume of applications to increase the probability of opposition. This could counteract the patent thicket effect, making that harder to identify.

Applicant characteristics $F_{f,t}$. For each applicant we compute the natural logarithm of the cumulative number of patent applications filed at the EPO by the year in which the focal patent is granted as a proxy for the size of the applicant's patent portfolio. It is reasonable to assume that the likelihood of patent opposition should decrease with the size of an applicant's patent portfolio. Lanjouw and Schankerman (2001) as well as Harhoff and Reitzig (2004) discuss this effect. Moreover, we include dummy variables for an applicant's country of origin, distinguishing applicants from the United States, Japan, Europe, and the rest of the world. Europe is used as the reference group in the regressions reported below. We also distinguish between four types of applicants: individuals, government institutions, universities, and a reference group that consists mainly of private enterprises.

Patent characteristics X_i. Previous research has shown that the likelihood of postgrant validity challenges depends on a number of patent characteristics: the (private) value of patents is positively related to the likelihood of litigation and opposition (Harhoff and Reitzig 2004, Lanjouw and Schankerman 2001). We include the number of citations a patent receives over a five-year period (in logarithms) as a (noisy) proxy for its private value (Harhoff et al. 1999). Moreover, we include the number of jurisdictions in which equivalent patents have been filed (Lanjouw and Schankerman 2004a) and a variable indicating whether a patent was filed via the Patent Cooperation Treaty (PCT) application path to serve as a proxy for patent value.[16] Following Harhoff and Reitzig (2004) and Lanjouw and Schankerman (2001, 2004b), we include the number of claims and variables describing the composition of backward references contained in a patent's search report as further proxies for patent value. At the EPO, references contained in a patent's search report are classified into different categories.

[14] Note that this measure of triples relies upon all firms referenced on each firm's list of critical references. In contrast, von Graevenitz et al. (2011, 2013) rely on only the top 10 firms on each list.

[15] These results are available from the authors upon request.

[16] A PCT application also allows applicants to postpone decisions regarding the scope of international protection for up to 30 months and might signal the intention to commercialize the protected invention in a large number of national markets.

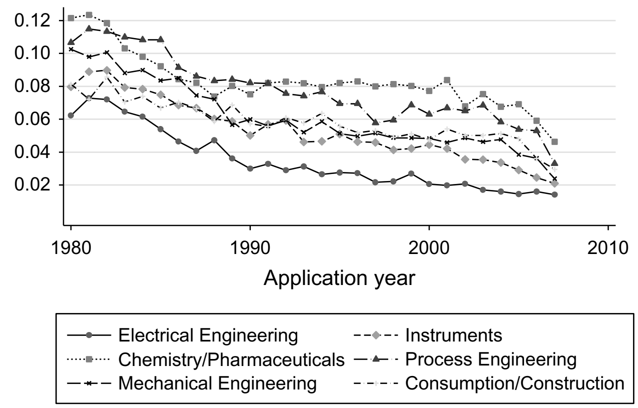
Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

X- and Y-type references are discussed above. A-type references summarize prior art without implying a limitation of novelty or inventive step. We use the latter as a reference group. Finally, we control for the rigor of the examination process using the duration of patent examination: the time between the filing of the application and the publication of the patent grant. The duration of patent examination has been shown to be correlated with the number of citations a patent receives and therefore also been interpreted as value indicator (Johnson and Popp 2003). Harhoff and Reitzig (2004) further show that both the duration of patent examination and the count of X-type references are positively correlated with the likelihood of opposition.

4.3. Descriptive Statistics

Table 2 presents the number of patent grants, the number of oppositions (as well as the average number of triples), and the average concentration of patent holdings for the 30 different technology fields for the period from 1980 to 2007.

Figure 2 Opposition Rates by Main Technology Area (1980–2007)



Although technology areas vary considerably in the numbers of patent applications and grants, we also observe interesting variation in opposition rates, number of triples indicating existence of patent thickets, and the degree of patent ownership concentration.

Figure 2 shows the development of opposition rates over time for six main technology areas. For almost

Table 2 Number of Patent Grants and Oppositions with Mean Values of Opposition Rate, Triples, and Concentration of Rivals' Patent Grants by Technology Area (1980–2007)

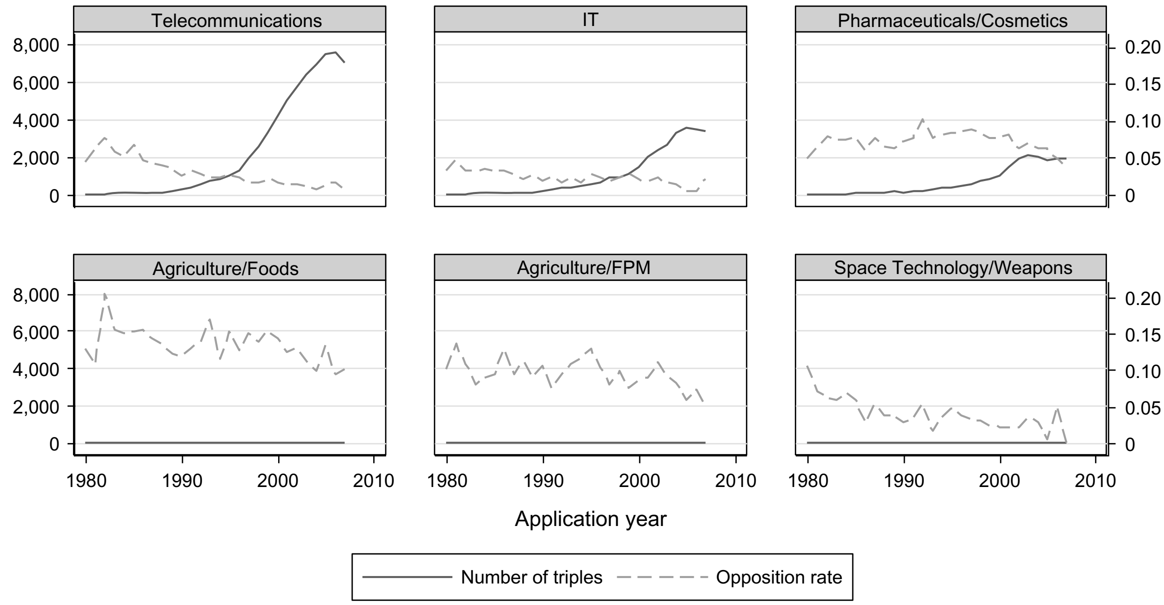
Technology area	Area no.	Grants	Oppositions	Oppostion rate (%)	Triples	Concentration of rivals' patents
Electrical Engineering/Energy	1	62,002	2,780	4.48	648.00	0.0118
Audiovisual Technology	2	31,084	985	3.17	987.33	0.0352
Telecommunications	3	66,629	1,496	2.25	4,726.35	0.0237
IT	4	39,772	827	2.08	1,867.94	0.0248
Semiconductors	5	19,998	442	2.21	745.05	0.0308
Optical	6	36,737	1,054	2.87	607.67	0.0214
Analysis/Measurement/Control Technology	7	67,968	3,461	5.09	342.18	0.0045
Medical Technology	8	57,246	3,557	6.21	352.03	0.0053
Nuclear Technology	9	4,505	247	5.48	3.27	0.0486
Organic Chemistry	10	42,058	1,946	4.63	138.02	0.0114
Polymers	11	46,859	4,413	9.42	476.47	0.0155
Pharmaceuticals/Cosmetics	12	61,050	4,545	7.44	1,164.40	0.0060
Biotechnology	13	16,884	1,109	6.57	14.47	0.0061
Agriculture/Foods	14	11,938	1,608	13.47	10.23	0.0134
Petrol Chem./Materials Chem.	15	27,966	2,621	9.37	135.61	0.0171
Surface Technology	16	20,526	1,764	8.59	20.04	0.0058
Materials	17	29,720	3,095	10.41	22.56	0.0051
Chemical Engineering	18	40,251	2,899	7.20	28.32	0.0039
Material Processing/Textiles/Paper	19	47,778	4,521	9.46	33.58	0.0038
Handling/Printing	20	63,690	3,644	5.72	321.35	0.0073
Agriculture/Food-Processing Machines	21	14,926	1,413	9.47	4.36	0.0118
Environment	22	14,644	1,088	7.43	49.91	0.0069
Machine Tools	23	35,069	2,663	7.59	20.60	0.0034
Motors	24	33,682	1,560	4.63	499.46	0.0189
Thermal Processes	25	13,571	991	7.30	16.07	0.0078
Mechanical Elements	26	39,288	1,937	4.93	82.55	0.0045
Transportation	27	65,168	3,369	5.17	840.53	0.0072
Space Technology/Weapons	28	5,533	206	3.72	0.41	0.0209
Consumer Goods	29	47,820	2,562	5.36	61.15	0.0029
Construction Technology	30	35,420	2,099	5.93	10.79	0.0023
Total		1,099,782	64,902	5.90	668.06	0.0110

Note. In the case that a patent has been filed by more than one applicant it is contained multiple times in the data.

RIGHTSLINK

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

Figure 3 Triples (Left Ordinate) and Rate of Opposition (Right Ordinate) at the EPO (1980–2007) by Application Year and Technology Area



Notes. The figure shows graphs for selected technology areas. Telecommunications, IT, and Pharmaceuticals/Cosmetics have the highest average number of triples between 1980 and 2007. Agriculture/Foods, Agriculture/Food-Processing Machines (FPM), and Space Technology/Weapons have the lowest average number of triples between 1980 and 2007.

all of them, opposition rates have declined since the EPO began its operation with the start of examination in 1978 and the first patent grants in 1980. Opposition rates are lowest for patents in the main technology area of Electrical Engineering. The decline of opposition rates has also been particularly pronounced in this main technology area.

Our measure of the existence and density of patent thickets—the number of triples of mutually blocking relations between patent applicants—is particularly high in complex technologies belonging to the main field of Electrical Engineering, such as Audiovisual Technology, Telecommunications, IT, and Semiconductors.[17] Other studies have suggested that these are the technology areas characterized by overlapping patent rights and patent thickets; see, e.g., Hall and Ziedonis (2001), Noel and Schankerman (2013), and Cockburn and MacGarvie (2011). The areas with the lowest (average) number of triples are Agriculture/Foods, Agriculture/Food-Processing Machines, Construction Technology, Nuclear Technology, and Space Technology/Weapons.

Figure 3 graphs opposition rates and the number of triples over time for the three areas with the highest and the three areas with the lowest triple counts. Increases in the number of triples in Telecommunications and IT are accompanied by a decrease in the respective opposition rates.[18] Both Table 2 and Figure 3 suggest that areas with very dense thickets (high levels of triples) are also characterized by below-average opposition rates. In fact, the coefficient of correlation between the number of triples and the opposition rate is −0.43 and highly significant. We also find a highly significant but somewhat smaller correlation between the concentration of ownership of granted patents and the opposition rate in a technology field, with a coefficient of correlation of −0.24.

In §3 we argue that opposition rates vary between firms within a technology area, depending on the extent to which firms are caught up in the patent thicket. We distinguish between outsiders, whose patents are not part of the thicket, and insiders, who may be more or less affected by the thicket. Figure 4 provides information on the relative numbers of insiders and outsiders (by the size of the circles in the figure) by technology area and period. The figure demonstrates that, even in areas in which thickets are rife, the vast majority of firms are not part of the thicket as measured by the triples measure. However, it is also clear from the figure that significant numbers of firms are caught up in many thickets, whereas only a few firms are caught up in a moderate number of thickets. Over time firms seem to be separating into two groups: one group that is caught

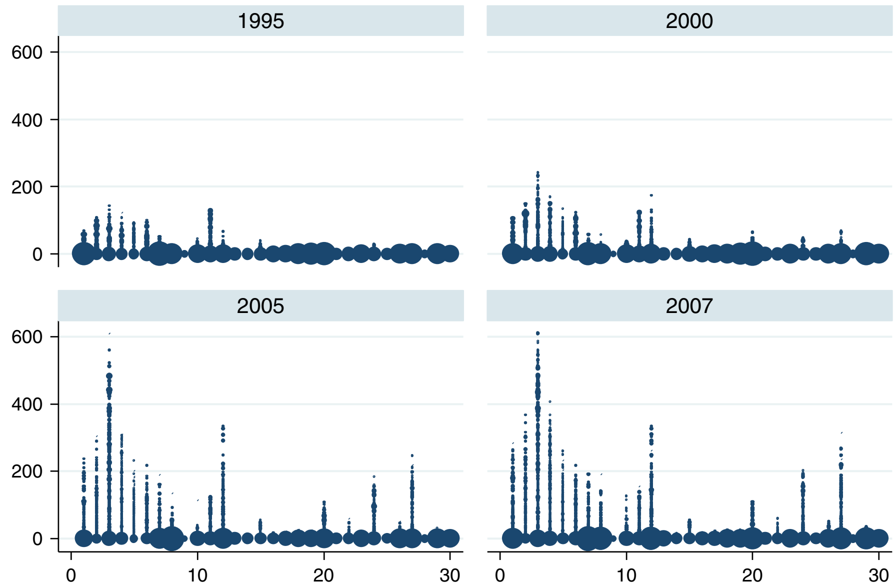
[17] We also find a large number of triples in the field of Pharmaceuticals/Cosmetics.

[18] A similar development can be observed for the Audiovisual as well the Semiconductor areas, which are not separated out in Figure 3. See von Graevenitz et al. (2007) for more complete time series of opposition rates in different technology areas.

RIGHTSLINK

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

Figure 4 (Color online) Structure of Patent Thickets Across Technology Areas for Four Different Periods



Notes. The figure shows graphs by grant year. The area of each circle indicates the number of firms in each category. Compare with Table 2 for technology area labels.

up in patent thickets and one that is not. Figure 4 also demonstrates that, over time, thickets are getting more extensive within particular areas (i.e., firms caught up in triples are caught up in more of them) and that they are becoming more widespread across technological fields. In the regression analysis below, we further pursue the distinction between insiders and outsiders to determine how these two groups of firms are affected by opposition.

5. Empirical Results

In this section we discuss the empirical models we use, present results, and analyze these.

5.1. Empirical Model

We estimate probit models, which relate the probability of opposition against the grant of a focal patent i, to characteristics of the focal patent, the owner of the focal patent, and the technology area to which the focal patent is assigned. Given the absence of a (quasi-)experimental setting, we do not attempt to identify causal effects in our analyses. The specification for the empirical model we estimate is as follows:

$$\begin{aligned}&\Pr(\textit{opposition against patent } i \textit{ in year } t)\\&\quad=\Phi(\beta_0+\beta_C C_{f,a,ta}+\beta_{Tr}Tr_{f,a,t-2}+\beta_{Tr}Fr_{f,a,t-2}\\&\qquad+\beta_S S_{a,ta}+\beta_X' X_i+\beta_F' F_{f,t}+\Psi_a+\Gamma_t).\end{aligned}$$

Above we set out the simplest specification we estimate. In this specification opposition is a function of three explanatory variables and a number of covariates. The explanatory variables are concentration $C_{f,a,ta}$, the number of triples $Tr_{a,t-2}$, and the fragmentation measure $Fr_{f,a,t-2}$. The second main specification we estimate replaces the count of triples at the area level with two measures: the number of triples a firm is involved in $Tr\_i_{f,a,t-2}$ and the number of remaining triples in the technology area $Tr\_o_{f,a,t-2}$ with $Tr_{a,t}=Tr\_i_{a,t}+Tr\_o_{a,t}$.

All models include vectors for patent characteristics X_i and for firm characteristics $F_{f,t}$ as well as the measure of total applications to a technology area in a given year $S_{a,ta}$. In all regressions we cluster standard errors at the level of the firm f, technology area a, and grant year t. Moreover, we capture persistent differences across technologies using technology class fixed effects Ψ_a and time trends and shocks in specific years using time fixed effects at the level of the grant year of a patent Γ_t.

Conditional on the included covariates, any remaining variation in the data allows us to study the effect of changes in the density of patent thickets and in the concentration of patent holdings in specific technical fields on the incidence of opposition. Nevertheless, in these analyses it is important to rule out "endogeneity" of the independent variables. One concern might be that the measure of the patent thicket effect (triples) or the measure of the public good effect might themselves be affected by incidence of opposition, leading to reverse causality. A second concern might be that unobservable determinants of opposition are correlated with the explanatory variables, leading to omitted variables bias. There are two reasons to discount these problems here.

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

The first relates to the time lags between the measures we use for the patent thicket effect and the public good effect. The patent thicket effect measure captures the state of patent thickets two years before opposition, because opponents and applicants will not have more up-to-date information than this from patent data released by the EPO. Therefore reverse causality is highly unlikely for the patent thicket effect. The public good effect measure is based on the size of the cohort of applications made when the focal patent was submitted to the patent office. This date is on average more than four years before the date of a decision to oppose the focal patent (Harhoff and Wagner 2009). The lag and the associated uncertainty about future opponents strongly reduce the potential for reverse causality here. The second reason to discount endogeneity relates to the level of aggregation: the dependent variable in the regressions reported below is measured at the level of the granted patent and will be affected mainly by patent application-specific and firm-specific unobservable effects. The measures of the patent thicket effect and of the public good effect average across all firms in a technology area or at least across several firms in that technology area. As such they are much less likely to correlate significantly with firm-specific unobservable effects. Note that any technology area-specific unobservable effects are captured by time and technology area fixed effects.

5.2. Results and Discussion

In Table 3 we report coefficients and marginal effects from estimation of the specifications outlined above.[19] Table 3 presents only the coefficients and marginal effects of the key variables underlying our hypotheses. The full results, including further controls for fragmentation, the characteristics of the patent applicant, the patent applications, and backward as well as forward references, are reported in Table A.2 in Online Appendix 2. In our regressions the proxies for patent value, such as the number of forward citations and the size of the international patent family (equivalents), have a statistically significant positive effect on the incidence of opposition, as expected. An increase by one logarithmic unit in the citation count is associated with an increased incidence of opposition of 2.4 percentage points (at the sample means of other covariates). One additional international patent filing increases the incidence of opposition by approximately 0.09 percentage points (see columns (1) and (2) of Table A.2). These results are consistent with earlier studies of opposition and of litigation (Harhoff and Reitzig 2004; Lanjouw and Schankerman 2001, 2004a). Also, higher generality and originality of patents are associated with increases in the probability of opposition. This suggests that pioneering patents (with high originality) or widely diffusing patents (with high generality) run a higher risk of opposition than other patents, either for technical or strategic reasons.

Following Harhoff and Reitzig (2004), we use the composition of backward references to proxy patent quality. Although the total count of backward references is associated with a slight decrease in the likelihood of opposition, an increase in the share of X references in the search report has a statistically significant positive effect on the probability of opposition. We find a statistically significant negative effect of PCT filings on opposition: PCT filings have an opposition incidence that is 0.52 percentage points lower than other filings. PCT filings are usually protected in relatively many jurisdictions, suggesting that this is a subset of all patents selected for their value, their strategic relevance, and their high quality. PCT filings provide considerable option value, because the decision of in which countries to file can be delayed by up to 30 months after the priority date, adding 18 months of delay compared to "normal" international patent applications. We suspect that PCT applications are of higher quality (i.e., applicants have more time to abandon applications not worth pursuing), which lowers the chances for potential opponents to be successful in opposition. The likelihood of observing opposition against PCT applications should therefore be reduced.

As expected, firms with large portfolios experience a lower incidence of opposition. Again, this finding confirms earlier results (Lanjouw and Schankerman 2001, 2004b) and is consistent with the view that large firms enjoy advantages in the process of resolving disputes over intellectual property. The median size of an applicant's patent portfolio (cumulative number of patent grants until the end of 2007) across all technology areas is 64; the largest patent portfolio is 20,433. The average marginal effect of an increase of one logarithmic unit in patents is a reduction in opposition by 0.2 percentage points. Non-European applicants are significantly less likely to face opposition than European patent holders. This is not surprising, because patent filings from non-European countries have gone through stronger selection filters than patent filings of the local applicants. Some applicant types (individuals, universities, and government organizations) experience a significantly lower risk of opposition than other (mostly corporate) patent holders. Again, the effect may be driven by relatively low patent value or the preselection of patents of particularly

[19] In Table A.1 in Online Appendix 2, we summarize descriptive statistics for all the variables included in our empirical models. Coefficients for time and area fixed effects are not reported for reasons of brevity. The full regression results can be obtained from the authors upon request.

RIGHTSLINK

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

Table 3 Results from Probit Regressions—Dependent Variable: *Opposition* **(0/1)**

Variables		(1) Coeff.	(2) dx/dy	(3) Coeff.	(4) dx/dy	(5) Coeff.	(6) dx/dy	(7) Coeff.	(8) dx/dy
Number of area triples	YA	−0.0096***	−0.0010***	−0.0027**	−0.0008***				
		[0.001]	[0.000]	[0.001]	[0.000]				
Number of rivals' triples/100	FYA					−0.0069***	−0.0007***	−0.0070***	−0.0008***
						[0.001]	[0.000]	[0.001]	[0.000]
Number of own triples/100	FYA					−0.1051***	−0.0113***	−0.0178	−0.0065
						[0.010]	[0.001]	[0.059]	[0.003]
Number of triples/100× *Number of patents* (log)				−0.0012***					
				[0.000]					
Number of own triples/100× *Number of patents* (log)								−0.0107	
								[0.007]	
Concentration of rivals' patents	FYA	4.7258***	0.5082***	4.6593***	0.5008***	4.1634***	0.4474***	4.1175***	0.4425***
		[0.589]	[0.063]	[0.590]	[0.064]	[0.587]	[0.063]	[0.585]	[0.063]
Cumulative number of patents (log)	FY	−0.0310***	−0.0033***	−0.0243***	−0.0032***	−0.0236***	−0.0025***	−0.0233***	−0.0027***
		[0.002]	[0.000]	[0.002]	[0.000]	[0.002]	[0.000]	[0.002]	[0.000]
Further controls including the following:									
Fragmentation	FYA	Yes		Yes		Yes		Yes	
Applicant characteristics	FY	Yes		Yes		Yes		Yes	
Patent characteristics	P	Yes		Yes		Yes		Yes	
Number and characteristics of forward citations	P	Yes		Yes		Yes		Yes	
Number and characteristics of backward references	P	Yes		Yes		Yes		Yes	
Time fixed effects (application years)		Yes		Yes		Yes		Yes	
Area fixed effects	A	Yes		Yes		Yes		Yes	
Log-likelihood	P	−196,594		−196,047		−195,928		−195,895	
Observations		966,974		966,974		966,974		966,974	

Notes. Standard errors have been clustered by firm, area, and year and are reported in brackets. Source of variation is indicated in the second column: F, firm; Y, year; A, area; P, patent. Marginal effects are average marginal effects calculated by using Stata's margins command. See Table A.2 in Online Appendix 2 for a full list of controls.

$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

high quality. There is evidence that both arguments apply: Gambardella et al. (2008) report that patents from these three types of applicants are usually of lower commercial value than corporate patents. At the same time, the level of novelty when compared to the state of the art of these filings can be above average, making it harder to oppose them on grounds of not reaching the necessary inventive step.

Our main variables of interest are the effects of the triples measure of patent thicket density and the concentration of patent ownership among the applicant's rivals. We report findings regarding these variables in Table 3. In column (1) of Table 3 we just include the main variables: triples as a measure of the patent thicket effect with fragmentation as an additional covariate and concentration as a measure for the public good effect.

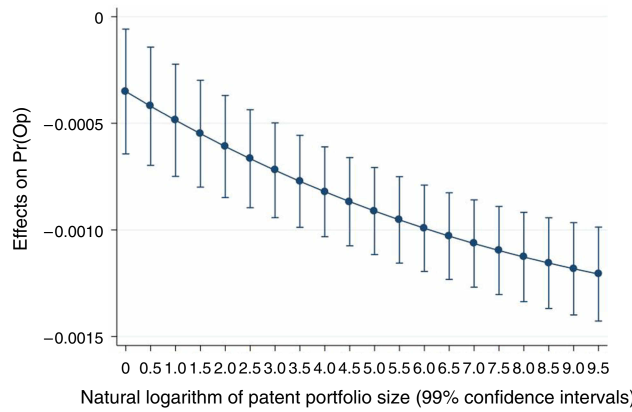
We find support for Hypothesis 1. The count of technology area triples is associated with a significant reduction in opposition incidence with an effect of −0.0010, which is statistically significant.[20] At the median of all variables an increase of one standard deviation in the lagged triples count divided by 100 (13.43) reduces the incidence of opposition by 1.34 percentage points ($13.43 * -0.0010 = -0.0134$). That is a 22.2% reduction relative to the unconditional opposition rate. It is worth noting that these numbers understate the effect of a deepening of the patent thicket, the unconditional probability of opposition in technology areas affected by thickets has been below 5% for the last 20 years.

To test Hypothesis 2 we split the count of technology area triples into two separate measures: own triples, in which the holder of the focal patent is involved, and rivals' triples, in which only other firms in the same technology area are involved. The effect of both variables on opposition is highly significant and negative as is shown in columns (5) and (6) of Table 3. An increase of one standard deviation in own triples reduces the probability of opposition by 14.4% ($0.7689 * -0.0113 = 0.0087$) relative to the unconditional mean, whereas an increase of one standard deviation in rival triples reduces the probability of opposition by 15% ($12.94 * -0.0007 = 0.0091$) relative to the unconditional mean . Note also that one additional own triple reduces the probability of opposition more than if there is an additional triple in the technology area. This means that, ceteris paribus, a patent application submitted by a firm that is a patent thicket insider is less likely to face opposition than a patent application submitted by a firm that is an outsider.

We include the fragmentation variable in our specifications to confirm that the triples variable offers

[20] The number of technology area triples ranges between 0 and 7,526 in our data, with a median value of 63.

Figure 5 **(Color online) Average Marginal Effect of Additional Triples by Size of Patent Portfolio**



a better way of describing the density of patent thickets than the fragmentation measure that is frequently used in the literature to proxy effects of patent thickets. The coefficient of fragmentation is positive[21] and highly significant as can be seen in Table A.2. However, the economic effect of a standard deviation change in fragmentation on opposition is much weaker (0.05% at the median of all variables) than that of triples.

Hypothesis 3 posits that patent applications are less likely to be opposed in technologies affected by patent thickets if they belong to larger firms as opposed to smaller firms. Testing this hypothesis requires us to include an interaction between the measure of patent thickets (triples) and the measure of firm size. We test the hypothesis in the specification that includes only technology area triples (columns (3) and (4) of Table 3) and in the specification that includes both own and rivals' triples (columns (7) and (8) of Table 3). Figures 5 and 6 show that, in both specifications, the interaction term is associated with a significant reduction of the probability of opposition (denoted as Pr(Op) in the figures) for larger firms. We reject the null hypothesis that size does not matter for either model, although Figure 6 indicates that the effect is only significant for firms with patent portfolios that are larger than the median portfolio, when we distinguish between own and rival's triples.

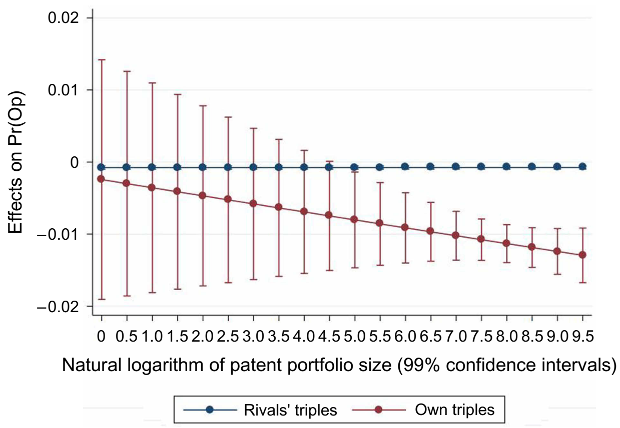
Finally, Hypothesis 4 states that concentration should have a positive sign if there is a public good effect. The average marginal effect of concentration of 0.51 is statistically significant, lending support to this

[21] If the fragmentation measure is also a measure of the patent thicket effect, conditional on the triples measure we would expect it to have a negative sign. In unreported results we have found that the square of the fragmentation measure has a significant negative effect on the probability of opposition. For high values of fragmentation the overall effect is negative but economically very weak as indicated above.

RIGHTSLINK

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

Figure 6 (Color online) Average Marginal Effect of Additional Own Triples by Size of Patent Portfolio



hypothesis. At the median of all variables, an increase of one standard deviation (0.0096) of concentration leads to an increase in the probability of opposition by 0.49 percentage points ($0.096 * 0.51 = 0.0049$). This effect is also economically important because it translates to an 8.1% increase in the opposition rate relative to the unconditional opposition rate.

Overall, we find that the hypotheses set out in §3 are supported using the data we employ here. The results indicate that patent thickets have a strong dampening effect on the incidence of opposition; the public good effect has a dampening effect, too, but it is much smaller in effect size.

5.3. Robustness Tests

The results reported above are robust to a number of changes in the specification of the empirical model conducted to probe various possible sources of unobserved heterogeneity. We report detailed results from these robustness tests in Online Appendix 2 (which contains Tables A.1–A.8). There are two principal forms of test: (i) we analyze changes in the composition of the sample to ensure that our results are not primarily driven by a specific set of firms or a specific period of time, and (ii) we add further covariates to ensure that our findings are not affected by omitted variable bias.

We change the sample by dropping all patents granted after 2000, which does not alter our findings substantially (see Table A.4). Additionally, Tables A.7 and A.8 show that neither the removal of the largest applicant in each technology field, nor the removal of all noncorporate patent applicants from the sample alters our findings significantly.

Returning to the full sample, we add variables characterizing each applicant's patent portfolio at time t. This is done to capture firm level differences in patenting strategies and capabilities that we do not directly observe. The additional covariates include the averages of each applicant firm's (i) grant duration, (ii) number of forward citations, (iii) number and composition of backward references, (iv) number of claims per patent, (v) duration of the examination period, and (vi) share of PCT applications in year t. Results reported in Table A.3 show that our key findings are qualitatively unchanged. Next, adding the average rate of opposition in a technological area a in year t leaves our main findings unchanged (see Table A.5), as does the inclusion of four-, five-, and six-year lags of the technology area opposition rate (see Table A.6).

Finally, Online Appendix 3 provides a further analysis that is based on a policy shock affecting the value of some national patents during the period we analyze. We focus on the "Spider in the Web" doctrine, created by the High Court in The Hague in 1998. This increased the probability that Dutch patents would be opposed and also moderated the patent thicket effect. Although the shock affected only 1.87% of patents in our sample, it does allow us to test a number of additional hypotheses that apply if the doctrine affected the strategic value of Dutch patents. Because the shock was exogenous, we can test whether our results change in a predictable way. We can reject the null hypothesis that the "Spider in the Web" doctrine had no effect for regressions using area triples, but not for regressions using own and rivals' triples. Moreover, the pattern of interaction effects we observe in the first of these regressions is entirely consistent with our theoretical analysis. This suggests that our results are not driven by unobserved heterogeneity at the technology or the patent portfolio level (see Table A.9 in Online Appendix 3). Overall, these tests provide additional confidence in the stability of the results we report in Table 3.

6. Conclusions and Further Research

Strong demand for patent rights combined with errors in patent offices' examination and grant procedures result in increasing numbers of "weak" and overlapping patent rights. As a result companies are increasingly confronted with serious challenges when trying to develop and commercialize technology in the presence of patent thickets. Litigation and postgrant validity challenges have been considered as a way of eliminating erroneously granted patent rights, with postgrant patent review typically being cheaper than litigation. Discussing the America Invents Act (AIA), enacted at the end of 2011, Graham and Vishnubhakat (2013) highlight three avenues for post-grant validity challenges that have recently been introduced in the United States with the explicit aim of raising patent quality. These are postgrant review, "covered

RIGHTSLINK

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

business method patents" (or third-party) review, and *inter partes* (or third-party) review.[22]

We argue, as do previous studies, that postgrant opposition is likely to lose its effectiveness when multiple opponents fail to engage in opposition because of a public good effect. This study is the first to document the empirical importance of this effect. Moreover, the patent thicket effect, which we propose and document, results in fewer patent opposition cases in technologies affected by patent thickets. The rate of patent opposition at EPO has been stable for 20 years at approximately 8% in the technology area of Chemistry, which is characterized by a relatively high concentration of patent ownership and is thus less likely to be affected by the public good effect. As in other discrete technologies, the incidence of triples is low in Chemistry. Meanwhile the opposition rate in Electrical Engineering has fallen by 50% in the same period, from a starting level of 5.5% in 1990. Electrical Engineering is the technology area most affected by patent thickets, and ownership concentration is low. Our results indicate that the public good and patent thicket effects are at work in increasing numbers of technology areas.

These findings are of high relevance for the users of patent systems and for those concerned with the governance of such systems. Unfortunately, our results show that in complex technologies, in which the need for a corrective seems to be highest, private incentives to engage in postgrant validity challenges are particularly low. This demonstrates that a focus on examination quality is especially important for such complex technologies and that "rational ignorance" of patent offices (Lemley 2001) is not a particularly effective approach in these technologies. Moreover, our analysis suggests that it will have to be smaller applicants who contribute to ensuring that weak patents are kept off the register or removed from it when first asserted. Collectively, their interests in an opposition mechanism working are much stronger than those of larger firms at the heart of thickets whose cooperative actions through cross licensing do not remove weak patents from the patent register. Further work on whether the interests of the many patent thicket outsiders can be harnessed in their collective interest and the interest of society seems warranted.

Our results also raise important questions for the management of patent rights at the firm level. The choice between adversarial and collaborative means of conflict resolution becomes blurred when the problems discussed in this study arise. "Navigating thickets" can require considerable brinkmanship. To date, scholarly research can provide little guidance for firms' operational or strategic patent management in such a context. Although we have not studied the dynamics of opposition, it is conceivable that periods of collusion are sometimes terminated by "patent wars." The analogy to collusive price setting and intermittent price wars is obvious. In our case, controversies surrounding singularly important patents or divergent opinions about optimal firm strategy may lead patent holders to resort to court interaction in some cases, possibly triggering counteractions by other parties. Such breakdowns in collaborative "thicket management" may be occurring currently in the mobile telephony industry. The current dispute between the major players (most notably between Apple and Google) can be seen as a telling example of firms trying to find the right balance between confrontational and collaborative conflict resolution in an industry characterized by patent thickets. We suggest that research regarding the factors that trigger patent wars, which can be socially and privately detrimental, should receive particular attention in future work on patent management.

To summarize, our study underscores the challenging nature of innovation management in complex technologies. The dense interaction between holders of mutually blocking patents can render postgrant review rather ineffective in technology areas impacted by thickets. Mechanisms like opposition, which are meant to ensure that strong patents survive on the register while weak patents are eliminated, lose some of their appeal in this context. Our study cannot offer any strong results as to how the problem of weak patents in complex technologies can be addressed, but it shows that once firms have adopted the logic of patent portfolio races, the incentives to patent more and litigate less against holders of large patent portfolios spread even to firms initially not caught up in the thicket but active in the same technology. This tendency of patent thickets to self-perpetuate and grow is worrisome. It remains to be seen whether the instruments soon to be available at the USPTO or postgrant mechanisms relying on independent parties other than the directly affected firms, such as an ombudsman who acts in the public interest, can alleviate this problem, or whether a much greater emphasis on examination quality is required. These are important questions for future work.

[22] The new postgrant review mechanism at the USPTO allows opponents to challenge patents on all grounds, including eligibility and clarity. The "covered business method" review procedure allows third parties that face the threat of litigation (or are actually sued) to challenge a patent's validity independently of the issue date of the potentially infringed-upon business method patent. Finally, the *inter partes*, or third-party submission, allows any member of the public to participate by submitting documents and commentary for use by patent examiners. See Graham and Vishnubhakat (2013) for details.

RIGHTSLINK

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.

Supplemental Material

Supplemental material to this paper is available at http://dx.doi.org/10.1287/mnsc.2015.2152.

Acknowledgments

The authors acknowledge comments by Mark Schankerman, Alberto Galasso, Gerry George, Pierre Regibeau, Stefan Bechtold, and Uwe Walz. The authors also acknowledge comments by participants of the "Conference on Patents, Entrepreneurship and Innovation" at the USPTO in Washington, DC; at the European Policy for Intellectual Property (EPIP) 9th Annual Conference 2014 in Brussels; and at seminars in Frankfurt, Germany; Imperial College London; Leipzig, Germany; Maastricht, Netherlands; University of East Anglia, Norwich, United Kingdom; St. Andrews, Scotland; Oxford, United Kingdom; London; and Zurich. Research for this paper received support from the German Research Foundation (DFG) [Collaborative Research Project SFB/TR 15, Project C2] and the Economic and Social Research Council (ESRC) [Grant RES-578-28-0002] to the Centre for Competition Policy at the University of East Anglia.

References

Bessen JE, Meurer MJ (2008) *Patent Failure* (Princeton University Press, Princeton, NJ).

Choi JP (2005) Live and let live: A tale of weak patents. *J. Eur. Econom. Assoc.* 3(2–3):724–733.

Cockburn IM, MacGarvie MJ (2011) Entry and patenting in the software industry. *Management Sci.* 57(5):915–933.

Du Plessis M, Van Looy B, Song X, Magerman T (2009) Data production methods for harmonized patent indicators: Assignee sector allocation. Working paper, Eurostat, Luxembourg.

European Patent Office (2004) Annual report 2004. Accessed June 22, 2015, http://www.epo.org/about-us/annual-reports-statistics/annual-report/2004.html.

European Patent Office (2008) Annual report 2008. Accessed June 22, 2015, http://www.epo.org/about-us/annual-reports-statistics/annual-report/2008.html.

Farrell J, Merges RP (2004) Incentives to challenge and to defend patents: Why litigation won't reliably fix patent office errors and why administrative patent review might help. *Berkeley Tech. Law J.* 19(3):943–970.

Federal Trade Commission (2003) To promote innovation: The proper balance of competition and patent law and policy. Report, Federal Trade Commission, Washington, DC.

Federal Trade Commission (2011) The evolving IP marketplace: Aligning patent notice and remedies with competition. Report, Federal Trade Commission, Washington, DC.

Galasso A, Schankerman M (2010) Patent thickets, courts, and the market for innovation. *RAND J. Econom.* 41(3):427–503.

Gambardella A, Harhoff D, Verspagen B (2008) The value of European patents. *Eur. Management Rev.* 5(2):69–84.

Graham S, Harhoff D (2014) Separating patent wheat from chaff: Would the U.S. benefit from adopting a patent post-grant review? *Res. Policy* 43(9):1649–1659.

Graham S, Vishnubhakat S (2013) Of smart phone wars and software patents. *J. Econom. Perspectives* 27(1):67–86.

Graham S, Hall BH, Harhoff D, Mowery DC (2003) Post-issue patent quality control: A comparative study of U.S. patent re-examinations and European patent oppositions. Cohen WM, Merrill SA, eds. *Patents in the Knowledge-Based Economy* (National Academies Press, Washington, DC), 74–119.

Grujić J, Eke B, Cabrales A, Cuesta JA, Sánchez A (2012) Three is a crowd in iterated prisoner's dilemmas: Experimental evidence on reciprocal behaviour. *Scientific Reports* 2:638.

Hall BH (2005) A note on the bias in Herfindahl-type measures based on count data. *Revue d'Économie Industrielle* 110(2): 149–156.

Hall BH, Harhoff D (2004) Post grant review systems at the U.S. patent office: Design parameters and expected impact. *Berkeley Law Tech. J.* 19(3):989–1016.

Hall BH, Ziedonis RH (2001) The patent paradox revisited: An empirical study of patenting in the U.S. semiconductor industry, 1979–1995. *RAND J. Econom.* 32(1):101–128.

Hall BH, Helmers C, von Graevenitz G, Rosazza-Bondibene C (2013) A study of patent thickets. Report, Intellectual Property Office, Newport, Wales, UK.

Harhoff D (2009) Economic cost-benefit analysis of a unified and integrated European patent litigation system. Report, European Commission, Brussels. http://ec.europa.eu/internal_market/indprop/docs/patent/studies/litigation_system_en.pdf.

Harhoff D, Reitzig M (2004) Determinants of opposition against EPO patent grants: The case of biotechnology and pharmaceuticals. *Internat. J. Indust. Organ.* 22(4):443–480.

Harhoff D, Wagner S (2009) The duration of examination at the European patent office. *Management Sci.* 55(12):1969–1984.

Harhoff D, Narin F, Scherer FM, Vopel K (1999) Citation frequency and the value of patented innovation. *Rev. Econom. Statist.* 81(3):511–515.

Holland PW, Leinhardt S (1976) Local structure in social networks. Heise DR, ed. *Sociological Methodology* (Jossey-Bass, San Francisco), 1–45.

Jaffe AB, Lerner J (2004) *Innovation and Its Discontents: How Our Broken Patent System Is Endangering Innovation and Progress, and What to Do About It* (Princeton University Press, Princeton, NJ).

Johnson DKN, Popp D (2003) Forced out of the closet: The impact of the American Inventors Protection Act on the timing of patent disclosure. *RAND J. Econom.* 34(1):96–112.

Lanjouw JO, Schankerman M (2001) Characteristics of patent litigation: A window on competition. *RAND J. Econom.* 32(1): 129–151.

Lanjouw JO, Schankerman M (2004a) Patent quality and research productivity: Measuring innovation with multiple indicators. *Econom. J.* 114(495):441–465.

Lanjouw JO, Schankerman M (2004b) Protecting intellectual property rights: Are small firms handicapped? *J. Law Econom.* 47(1): 45–74.

Lei Z, Wright B (2009) Why weak patents? Rational ignorance or pro-"customer" tilt? Working paper, Pennsylvania State University, University Park.

Lemley M (2001) Rational ignorance at the patent office. *Northwestern University Law Rev.* 95(4):1495–1529.

Lerner J (1994) The importance of patent scope: An empirical analysis. *RAND J. Econom.* 25(2):319–333.

Levin J, Levin R (2003) Benefits and costs of an opposition process. Cohen WM, Merrill SA, eds. *Patents in the Knowledge-Based Economy* (National Academies Press, Washington, DC), 121–144.

Magerman T, Grouwels J, Song X, Van Looy B (2009) Data production methods for harmonized patent indicators: Patentee name harmonization. Working paper, Eurostat Luxembourg.

Milo R, Shen-Orr S, Itzkovitz S, Kashtan N, Chklovskii D, Alon U (2002) Network motifs: Simple building blocks of complex networks. *Sciencee* 298(5594):824–827.

Mnookin RH (2003) Strategic barriers to dispute resolution: A comparison of bilateral and multilateral negotiations. *J. Institutional Theor. Econom.* 159(1):199–220.

Noel M, Schankerman M (2013) Strategic patenting and software innovation. *J. Indust. Econom.* 61(3):481–520.

OECD (1994) Using patent data as science and technological indicators. Patent Manual, Organization for Economic Cooperation and Development, Paris.

RIGHTSLINK

Peeters B, Song X, Callaert J, Grouwels J, Van Looy B (2009) Harmonizing harmonized patentee names: An exploratory assessment of top patentees. Working paper, Eurostat, Luxembourg.

Shapiro C (2001) Navigating the patent thicket: Cross licenses, patent pools and standard setting. Jaffe A, Lerner J, Stern S, eds. *Innovation Policy and the Economy* (MIT Press, Cambridge, MA), 119–150.

von Graevenitz G, Wagner S, Harhoff D (2011) How to measure patent thickets: A novel approach. *Econom. Lett.* 111(1):6–9.

von Graevenitz G, Wagner S, Harhoff D (2013) Incidence and growth of patent thickets: The impact of technological opportunities and complexity. *J. Indust. Econom.* 61(3):521–563.

von Graevenitz G, Wagner S, Hoisl K, Hall B, Harhoff D, Giuri P, Gambardella A (2007) The strategic use of patents and its implications for enterprise and competition policies. Report, European Commission, Brussels.

Ziedonis RH (2004) Don't fence me in: Fragmented markets for technology and the patent acquisition strategies of firms. *Management Sci.* 50(6):804–820.

Downloaded from informs.org by [155.246.103.35] on 05 April 2017, at 22:24 . For personal use only, all rights reserved.