Paper to be presented at the

DRUID Society Conference 2014, CBS, Copenhagen, June 16-18

Conflict Resolution, Public Goods and Patent Thickets

Dietmar Harhoff
MPI
MPI
dietmar.harhoff@ip.mpg.de

Georg Von Graevenitz
UEA
UEA
G.Graevenitz@uea.ac.uk

Stefan Wagner
ESMT
ESMT
stefan.wagner@esmt.org

Abstract

Post-grant 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 post-grant 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 against 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 post-grant 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.

Jelcodes:L10,M20

Conflict Resolution, Public Goods and Patent Thickets

February 25th, 2014

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 (Jaffe and Lerner, 2004; Bessen and Meurer, 2008; 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 (Graham et al., 2003; Hall et al., 2004; Hall and Harhoff, 2004; Choi, 2005; Graham and Harhoff, 2009).

While these mechanisms are often cost effective (Lemley, 2001), several authors have argued that they will be undermined by a public goods problem (Levin and Levin, 2003; Farrell and Merges, 2004; Harhoff and Reitzig, 2004). 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 post-grant review at the European Patent Office. Additionally, we demonstrate that the presence of patent thickets in complex technologies further weakens incentives for filing post-grant 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 mechanism at patent offices, but they are frequently impaired by errors. While 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 interests of the public and of rival firms are compromised and social welfare is reduced.

Litigation and post-grant validity challenges at patent offices and courts should provide effective mechanisms to correct the erroneous issue of patents (Levin and Levin, 2003; Farrell and Merges, 2004; Hall and Harhoff, 2004). Both mechanisms allow third parties to bring forward additional evidence on 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 post-grant validity review in order to enhance its ability to weed out weak patents within the America Invents Act (AIA) of 2011.[1]

[1] For more information on the America Invents Act of 2011 see http://judiciary.house.gov/issues/issues_patentreformact2011.html, latest visit on 16th of October 2012.

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 (Lanjouw and Schankerman, 2001; Harhoff and Reitzig, 2004). 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 goods 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 goods 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 post-grant challenges (Farrell and Merges, 2004). Therefore, we expect the incidence of post-grant 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, 2000) are owned by multiple parties, firms' incentives to file costly post-grant 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)[2]. Consequently firms engulfed in patent thickets have incentives to create large patent portfolios to protect themselves against litigation and injunctions (Ziedonis, 2004). To avoid an escalation of litigation, firms in patent thickets frequently resolve overlapping claims through non-adversarial means, such as cross-licensing, broad settlement agreements and other out-of-court agreements (Shapiro, 2000).

This suggests that patent thickets will reduce the incidence of post-grant validity challenges, even if the cost of such challenges is low. In particular, the reduction in post-grant validity challenges is likely to be stronger for those firms deeply enmeshed 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 (Graevenitz

[2] These two forms of litigation may constitute separate or related institutions. Post-grant reviews (called opposition in Europe) only address issues of validity. In some jurisdictions (e.g. in Germany), questions of validity may also be treated by dedicated courts while infringement issues are addressed separately. In the USA, an infringement suit may be answered by an invalidity attack on the plaintiff's patent(s), or by a countersuit alleging infringement by the plaintiff himself, as in the case of *Yahoo vs. Facebook*.

et al., 2011), we use citation data to identify and to measure the intensity of such blocking relationships.

To the best of our knowledge, the main hypotheses of this paper have not been tested empirically before. This study uses data on opposition proceedings against patents granted at the European Patent Office (EPO). Opposition is relatively frequent – historically, 6.2% of all EPO-granted patents have been opposed. 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 identify the public goods and patent thicket effects on the incidence of post-grant validity challenges. Our empirical results show that incentives to file an opposition against a patent grant are significantly reduced by these two effects: a one standard deviation increase in the concentration of patent holdings reduces the incidence of patent opposition by roughly 12.5% relative to the average unconditional probability. A one standard deviation increase in our measure of thickets reduces the incidence of post-grant validity challenges by 22.2% relative to the average unconditional probability. These findings show that technology areas in which the social value of post-grant validity challenges can be assumed to be particularly high (i.e., where dense patent thickets and/or high fragmentation of patent ownership exist), private incentives to invest in post-grant validity challenges are lower than in other technology areas.

2 Institutional Background and Effects of Opposition against Granted Patents at the EPO

Since it commenced operating 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. The EPO's activities are based on the European Patent Convention (EPC) signed in 1973. A patent application granted by the EPO does not lead to a single "European patent" that grants protection in the designated states chosen by the applicant, but to a bundle of independently enforceable and revocable national patent rights. However, the grant decision of the EPO is subject to a central post-grant 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 it takes effect.[3] Third parties will have to challenge the national patent rights in the responsible national courts for each state separately which will be extremely costly as compared to the centralized opposition proceeding.

The opposition procedure at the EPO is a quasi-judicial process taking place in front of an Opposition Division consisting of "three technically qualified examiners, at least two of whom shall not have taken part in the proceedings for grant of the patent to which the opposition relates" (Art. 19 (2) EPC).

[3] Note that the procedural design proposed by the America Invents Act of 2011 is almost identical, see http://judiciary.house.gov/issues/issues_patentreformact2011.html, last accessed on 16th of October 2012.

Opposition may be filed on grounds listed in Art. 100 EPC. These are (i) the subject matter is not patentable under the terms of the EPC Art. 52 to 57[4], (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. If not rejected according to Art. 102(1) EPC, an opposition can lead to either the maintenance of the patent as it was granted, the maintenance in amended form or the revocation of the opposed European patent (and therefore all resulting national patent rights) as specified in Art 102 (3) EPC. The outcome of the opposition procedure is subject to appeal of the patent holder and the opponent to the Technical Boards of Appeal at the EPO.

Most of the literature analyzing post-grant validity challenges has focused on U.S. patent litigation where the vast majority of cases are settled out of court (Lanjouw and Schankerman, 2004a)[5]. For that context, it is quite appropriate to assume that the parties involved will resolve all those cases out of court in which the legal issues are transparent. In the opposition context, this consideration is less likely to hold. While there is some settlement activity, most cases actually go to "trial" and are resolved in either opposition or appeal proceedings. This is due both to institutional and financial considerations: settlements during the opposition proceedings are risky as the EPO may pursue the case of its own motion according to Rule 84(2) EPC. That restricts settlements to the pre-filing period, which is exogenously set to nine months following the grant. On the financial side, it is unlikely that settlement is much less expensive than attacking or defending the patent in opposition. Moreover, an opposition proceeding is the only centralized way to challenge European patents and its cost is comparably low. 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.[6] Finally, strategic opportunities to drive up the other party's costs are virtually nonexistent in the European setting.

Revoking erroneously granted or narrowing patents during opposition proceedings after they have been specified too broadly can prevent welfare losses. These would emerge due to the market power given to a holder of an erroneously granted patent (Graham and Harhoff, 2009). If the patent is

4 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 according to Art. 53 EPC.

5 The ongoing reform of the US patent system will implement a post-grant review institution which is somewhat comparable to the opposition system at the EPO as described here, See Section 6) of H.R. 1249: America Invents Act, available at http://www.gpo.gov/fdsys/pkg/BILLS-112hr1249enr/pdf/BILLS-112hr1249enr.pdf?__utma=37760702.727769229.1315824201.1315824201.1315824201.1&__utmb=37760702.4.9.1315824230757&__utmc=37760702&__utmx=-&__utmz=37760702.1315824201.1.1.utmcsr=google|utmccn=(, last accessed on September, 12th, 2011). However, it is unclear how costly post-grant review at the USPTO will be, since it may involve discovery.

6 An average litigation case will cost around 160.000 EUR in Germany. Mejer and van Pottelsberghe (2009) also provide examples with costs as high as €2 to €10 Mio EUR, but these are exceptional and not representative. See Harhoff (2009) for estimates of litigation costs in other European countries.

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 revocation of these patents can have two effects – it effectively eliminates the need for subsequent litigation - or it reduces the room for extracting licensing fees from competitors. It is more difficult to assess the welfare effects of a rejection of an opposition. If the opposition is rejected, then the patent was presumably correctly specified and there is no benefit from the opposition. Conceivably, there could still be a litigation-reducing effect if opposition has demonstrated the legal robustness of the patent. The intermediate outcome of opposition — an amendment of the patent by which the original patent is modified and restricted in scope or breadth – can be seen as a convex combination of the two polar cases. In both cases, the benefits from opposition have to be compared to the resource costs of the opposition and appeals process.

Leaving aside the resource costs of the trial, there are potential social costs of opposition. Judicial processes take time to resolve and during that period uncertainty is not resolved. If the parties to a trial 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 the FUD (fear, uncertainty and doubt) scenario. One indication might be the likelihood of opposition against small patent applicants such as start-ups, SMEs or independent inventors. Assuming that these agents do not have a "deep purse", they would be likely to become particularly attractive targets of opposition procedures (Lanjouw and Schankerman, 2004b). This effect is likely to be pronounced, if the private costs of opposition are high.

Assuming that the patent is correctly delineated from the prior art after opposition, the opposition mechanism should be welfare increasing as long as the expected reductions in welfare losses from errors in the granting process are larger than the total social cost of opposition. Particularly valuable patents have been shown to be more likely attacked under opposition than less valuable ones (Harhoff and Reitzig, 2004). This indicates that the opposition procedure also serves as an information revelation mechanism as valuable patents (those causing potentially high welfare losses) are selected based on the information third parties bring to the table. This 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 the analysis of the introduction of a post-grant opposition system in the U.S. undertaken by Levin and Levin (2003) as well as Graham and Harhoff (2009). Both papers suggest that there is significant potential for positive welfare gains from the introduction of a patent opposition process.[7]

---

[7] Graham and Harhoff (2009) point out that this result depends crucially on the assumption that opposition is not too costly.

3 Incentives to Engage in Post-grant Validity Challenges

In this paper we analyse whether individual patents are opposed post-grant. In doing so we focus on characteristics of the patent, the applicant and the technology area. Our aim is to identify which factors increase or decrease the incidence of opposition, so as to establish whether post-grant opposition serves applicants patenting different kinds of technology equally well. In this section we review related literature and develop a number of hypotheses that guide our empirical analysis below.

Lanjouw and Schankerman (2001) provide an important analysis of the general features of patent litigation in the USA. They compare the characteristics of litigated patents and their owners to those of a control group of patents. Litigation risk is distributed in a heterogeneous manner across firm types and technologies. They establish the following empirical results: i) more valuable patents are more likely to become involved in litigation; ii) parties with large portfolios are attacked less often, i.e., are presumably able to use settlements instead of litigation; iii) foreign (non-US patent holders) are less likely to be involved in US litigation; iv) litigation risk is much higher in pharmaceuticals than in other technologies.[8] Lanjouw and Schankerman (2004a) also show 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 less well positioned to resolve cases amicably. Their work is based on the assumption that only highly controversial cases or cases with high settlement costs will be filed or even adjudicated at court. Given the institutional setup of opposition and its relatively low costs, our own work below takes as given the incidence of disputes and the inability of some parties to settle their disputes outside of court. The very advantage of opposition data lies in the fact that the selection effects are less pronounced than in the case of US litigation.[9]

The first main hypothesis we test is based on Farrell and Merges (2004). They consider the effectiveness of litigation as a mechanism to weed out granted patents that are either weak or excessively broad. They develop a theoretical model and show that when a weak patent affects the prospective payoffs of more than one potential infringer, litigation activity by any one of the infringers becomes a (partial) public good. Harhoff and Reitzig (2004, fn. 25) also point out that the incentives to invest in opposition will be strong when only a small number of firms benefits from the public good,

[8] The average incidence of infringement litigation is about one case per 100 patents. But the rate varies between 0.5 cases in chemicals to 2 cases per hundred patents for pharmaceuticals. Lerner (1995) estimates a likelihood of six cases per hundred patents in biotechnology in the time period 1990-1994. Generally, these authors point out that the frequency of litigation decreases as a technical sector matures.

[9] We note here that this result cannot be confirmed in our analysis of opposition data. Individuals are less likely to be attacked under opposition even once the value of the patent has been taken into account.

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 assume here that the concentration of patent ownership (among potential opponents) is positively related to concentration in product markets so that we can derive the following hypothesis:

Hypothesis 1: Patents granted to firms whose rivals' patent portfolios are more concentrated are more likely to be opposed.

Bessen and Meurer (2006) argue that innocent infringement may be an important source of disputes between patent owners. In this setting a firm may include a technology already patented by a rival in their own application because they are not aware of the earlier patent. If the patent examiner also misses the earlier patent, then the owner of that patent can challenge the later patent through post-grant review. Innocent infringement is more likely to arise where patents are poorly delineated and where overlap of patent rights is highly likely. Consequently, we might expect more opposition cases to arise in technology areas affected by patent thickets or between firms caught up in these thickets.

There is an important countervailing effect. In the 1980s dense patent thickets emerged in the semiconductor industry after a number of firms successfully obtained injunctions against their rivals (Grindley and Teece, 1997; Hall and Ziedonis, 2001; Hall, 2005). In order to avoid costly settlements or shut down of business activity, firms in the industry sought to extend their own patent portfolios such as to be able to file a countersuit against potential attackers. This logic led to races between firms in the course of which large patent portfolios were built (Hall and Ziedonis, 2001; Federal Trade Commission, 2003). This process has been compared to the cold-war arms race between the USA and the USSR.

In such an environment, unilateral hostile actions can trigger counter-attacks. Within a patent thicket we expect a firm to be very careful when using patent opposition against applicants that are in a strong position to oppose one or more of the firm's own patent applications, which reduces the incidence of patent opposition between firms caught in the same thicket. This effect will become particularly pronounced as the number of potential actions increases in very dense patent thickets. Based on this discussion we hypothesize that the effect of avoiding a scenario of mutually assured destruction (MAD) is typically stronger than the effect of innocent infringement:

Hypothesis 2: Patents granted to firms active in technology areas characterized by dense patent thickets are less likely to be opposed than patents of firms without such involvement.

This is the second main hypothesis we test empirically. We now turn to two additional hypotheses that capture effects specific to patent thickets.

Within a given technology area we can distinguish between firms that are *directly* affected by patent thickets, because their own patents are part of the thicket, and other firms that are affected indirectly. The former we label *insiders*, the latter *outsiders*. Outsiders are likely to own technology that is not closely related to the core technologies of the thicket. Concerns of reciprocity should matter less to firms contemplating opposition against these patent-applicants, as they are not strongly involved in the technologies around which thickets have evolved. We would therefore expect that the MAD effect discussed above is less likely to protect outsiders against opposition. Insiders on the other hand have incentives to resolve conflicts arising within patent thickets cooperatively. For instance, the CEOs of two central players in the smart phone industry, Apple and Google, have attempted to end a situation of suits and subsequent counter-suits in bilateral negotiations at the board level.[10] This leads us to expect that:

Hypothesis 3: Patents granted to patent thicket "insiders" will be opposed less frequently than patents granted to patent thicket "outsiders".

Finally, we note that patent portfolio size of a firm is likely to moderate the effect of patent thicket density on incentives to oppose the firm's patent applications. Larger firms will find it easier to obtain broad cross-licensing agreements (Lanjouw and Schankerman, 2001), reducing their exposure to opposition from large rivals. Cross-licensing is frequently adopted in technologies affected by patent thickets. The denser a patent thicket the more likely it is that an applicant with a large portfolio will have patents covering much of the technology area, increasing the possibility that a large applicant can retaliate against an opposition by a small applicant. This will reduce incentives of smaller applicants to oppose patents filed by large applicants in patent thickets as well. Based on this reasoning we expect that dense patent thickets will reduce the likelihood of observing opposition against patents of holders of large-portfolios further:

Hypothesis 4: The density of patent thickets negatively moderates the effect of patent portfolio size on the likelihood of opposition.

4 Data and Descriptive Statistics

4.1 Data Sources

Our analysis is undertaken at the level of individual patents. A firm's patenting activities are split into technical areas for which we derive patent thicket and ownership concentration measures. Our data include all patent applications filed at the EPO between 1980 and 2010. This data set was obtained from the PATSTAT[11] database and contains bibliographic and legal information on patents, as well as information on the identity of the patent applicants, which has been combined with the ECOOM-

---

[10] 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 18th of December 2012).

[11] Information on PATSTAT is available at http://www.epo.org/searching/subscription/raw/product-14-24_de.html (last accessed on Sep. 18th, 2011).

EUROSTAT–EPO PATSTAT Person Augmented Table (EEE-PPAT).[12] From these data, we obtained information whether an opposition was filed for each granted patent. This binary variable is the dependent variable in our regression analysis.

In total, we observe 2,196,980 patent applications at the EPO between 1980 and 2007 that resulted in a total of 1,099,553 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 1,044,069 granted patents, we can observe whether there was an opposition by the end of the first quarter of 2011. 64,946 oppositions were filed against granted patents, which yield an average opposition rate of 6.04%. Table 1 shows that while the annual number of patent applications has steadily increased over time, both the share of patent applications that led to granted patents, as well as the number of oppositions relative to patents granted remained relatively stable until the late 90s. The decline in both grant and opposition rates towards the end of the observation period is due to truncation as the examination of patent applications is lengthy. Grant lags at the EPO are on average longer than 4 years and vary considerably (Harhoff and Wagner, 2009).

INSERT TABLE 1 ABOUT HERE

4.2 **Variables**

Dependent variable

Opposition. For each granted patent in our sample, we observe whether an opposition was filed within the statutory period of 9 months after the grant date. This is the dependent variable in our analysis.

Independent variables

Concentration of patent ownership. We measure the overall concentration of patent ownership as the Herfindahl index of rivals' granted patents (i.e., all patents excluding the focal firm's own patents) in a given technology area in a given year. In calculating the measure, we distinguish 30 different technological areas according to the OST-INPI/FhG-ISI technology classification (OECD, 1994). We use this firm-area-year level variable as an independent measure of the importance of the public goods effect. If a few rivals dominate an area, the benefit from successfully challenging a patent is higher, and opposition should be more likely to occur.

[12] We use the applicant names provided by the ECOOM-EUROSTAT–EPO PATSTAT Person Augmented Table (EEE-PPAT) which provides harmonized applicant names for the PATSTAT database. See Du Plessis et al. (2009), Peeters et al. (2009) and Magermann et al. (2009) for a full description. We further applied harmonization routines to the important patent applicants.

Density of patent thickets – Triples of mutually blocking firms. Our primary measure of the density of patent thickets in a particular technology area is the "triples" measure introduced by (Graevenitz et al., 2011; 2012). 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 references (Harhoff et al., 2006). If 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 in a mutually blocking relationship. To capture more complex structures of blocking relationships we follow (Graevenitz et al., 2011) and compute the number of "triples" in which three firms mutually block each other's patents (see Figure 1). They argue that in such a setting, the complexity of blocking relationships increases, and resolution of blocking becomes increasingly costly. Then, the triples measure can be taken as a proxy measure of the density of a patent thicket that reflects the likelihood that further overlaps between firms' patents exist.

INSERT FIGURE 1 ABOUT HERE

From a computational perspective, blocking pairs and triples are identified using the following approach: for each firm *i* we analyze all critical patent references contained in search reports pertaining to firm *i*'s patents in a given technology area over the current and the two preceding years (t−2 to t).[13] In the next step, we keep the most frequently referenced firms (top 10) yielding annual lists of firms which are blocking firm *i*.[14] Pairs are then established if firm A is on firm B's list of most frequently referenced firms and, at the same time, if firm B is on firm A's list of most frequently referenced firms. Finally, triples 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).

In order to test our insider-outside hypothesis (Hypothesis 3), we split the count of triples at the level of a technical area into two components: a firm-level count of the number of triples in which the firm itself is involved (insider triples), and the count of triples present in the technological area without the involvement of the focal firm (rivals' triples).

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. While the measure differs in its absolute values depending on the time window chosen, its variation across fields is robust w.r.t. different time windows.

14 Taking only the top 10 blocking firms is an arbitrary choice to easy computational burden. Choosing different cut-off levels does not affect our results significantly.

Fragmentation. To control for the impact of fragmentation of prior art we use Ziedonis' (2004) fragmentation index and apply the correction proposed by Hall (2005b). She argues that high fragmentation of ownership among the rivals of a patent holder would exacerbate the problem of negotiating access to those technologies. This measure is frequently used to control for the effects of patent thickets in the literature (Ziedonis, 2004; Schankerman and Noel, 2006; Galasso and Schankerman, 2010; Cockburn and MacGarvie, 2011).

Covariates

Applicant characteristics. For each applicant we compute the logarithm of the cumulative number of patent applications filed at the EPO as a proxy for the size of the patent portfolio. It is reasonable to assume that the likelihood of patent opposition should decrease with the size of an applicant's patent portfolio.[15] Moreover, we include dummy variables for an applicant's country of origin, distinguishing applicants from the United States of America, 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, which consists mainly of private enterprises.

Patent characteristics. Previous research has shown that the likelihood of post-grant validity challenges depends on a number of patent characteristics. Most notably, it has been shown that the (private) value of patents is positively related to the likelihood of litigation and opposition (Lanjouw and Schankerman, 2001; Harhoff and Reitzig, 2004). 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 also include the number of jurisdictions in which equivalent patents have been filed to control for patent value in our regressions (Lanjouw and Schankerman, 2004b) and a variable indicating whether a patent was filed via the Patent Cooperation Treaty (PCT) application path.[16] Following prior work (Lanjouw and Schankerman, 2001; Harhoff and Reitzig, 2004; Lanjouw and Schankerman, 2004a), we also include the number of claims and variables describing the composition of backward references contained in a patent's search report as they can be expected to determine the likelihood of patent opposition. At the EPO, references contained in a patent's search report are classified into different categories. A-type references merely summarize prior art without implying a limitation of novelty or inventive step. X-type references indicate that a single prior patent is in conflict with the applications claims. Y-type reference may do the same in combination with each other. (Harhoff and Reitzig, 2004) show that the number of X references is positively related to the

15 See Lanjouw and Schankerman (2001) and Harhoff and Reitzig (2004) for discussions of this effect.

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.

likelihood of an opposition being filed. (Harhoff and Wagner, 2009) show that patents with a high number of such references are less likely to be granted.

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.

INSERT TABLE 2 ABOUT HERE

While the different technology areas vary considerably in their number of patent applications and grants, we also observe interesting variation in the opposition rates, as well as the existence of patent thickets and the degree patent ownership concentration.

Figure 2 shows the development of opposition rates over time for six main technology areas. For almost 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 technological field of electrical engineering, and the decline of opposition rates has been particularly pronounced in this main technology area, which also subsumes technology areas for information and telecommunications technology.

INSERT FIGURE 2 ABOUT HERE

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 for instance Hall and Ziedonis (2001), Schankerman and Noel (200) and Cockburn and MacGarvie (2011). The areas with the lowest (average) number of triples are Agriculture/Food, Thermal Processes, and Space Technology/Weapons.

[17] We also find a large number of triples in the field of Pharmaceutical and Cosmetics. See evidence for strategic patenting behavior in cosmetics by Hall and Harhoff (2002).

INSERT FIGURE 3 ABOUT HERE

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 triples counts. Increases in the number of triples in Audiovisual Technology and Telecommunications 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 (coefficient of correlation -0.24).

INSERT FIGURE 4 ABOUT HERE

In Section 3 we argued that opposition rates vary between firms within a technical 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 (size of circles) 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, while 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 which is caught up in patent thickets and one which is not. Figure 4 also demonstrates that over time, thickets are both getting more extensive within particular areas (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.

[18] A similar development can be observed for the IT as well the Semiconductor areas which are not included in Figure 2, see von Graevenitz et al. (2007) for more complete time series of opposition rates in different technology areas.

5 Empirical Results

This section provides results from regressions in which we test whether opposition becomes a public good if the number of potential opponents increases and in which we study the effects of patent thickets on opposition at the EPO. Using the cross-section of all granted patents at EPO between 1980 and 2007 we estimate five probit models. The results are set out in Table 4. In all regressions we capture persistent differences across technologies using technology class fixed effects and time trends and shocks in specific years using time fixed-effects. Additionally, we include covariates capturing the legal strength of a patent and the economic value of the underlying invention. These covariates include the number and the composition of backward references included in a patent's search report, which have been shown to be correlated to the legal strength of patent rights (Harhoff and Reitzig, 2004; Harhoff and Wagner 2009), as well as the number of citations a patent receives, as a proxy of its value (Harhoff et al., 1999). Conditional on these covariates, any remaining variation in the data allows us to identify the effect of changes in the density of patent thickets and in the numbers of potential opponents to applications in specific technical fields on the incidence of opposition.

In this analysis it is important to rule out endogeneity of the independent variables. One concern might be that the patent thicket proxy (triples) or the measure of the public goods 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 independent variables, leading to omitted variables bias. There are two reasons to discount these problems here. The first relates to the time lag between current patent applications and an ultimate grant decision by the patent office (which puts patents at risk of being opposed by a third party) is on average more than 4 years (Harhoff and Wagner, 2009). This lag decouples opposition today and the measures of patent thickets and public goods effects, which are based on patents granted before the date on which today's granted patents were submitted to the patent office. 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 at the level of the granted patent application and will be affected mainly by patent application specific and firm specific unobservable effects. The variables capturing the effects of patent thickets 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.

In Table 3, we summarize descriptive statistics for the dependent and the independent variables.

INSERT TABLE 3 ABOUT HERE

INSERT TABLE 4 ABOUT HERE

In Table 4 we report coefficients and marginal effects.[19] Columns 1 and 2 of Table 4 present a specification including only covariates. As discussed in Section 4 their effects in this specification are expected to be driven either by patent value (higher value is likely to attract more opposition) or factors impacting the outcome of the case (a higher anticipated likelihood of having a patent revoked will attract more opposition). Moreover, other variables (such as the size of the patent portfolio) are expected to impact the likelihood of pre-opposition settlement or considerations of reciprocity and may therefore lead to more or fewer oppositions.

Value-related variables such as the number of forward citations, the size of the international patent family (equivalents) and claims have a positive impact 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 2.7 percentage points (at the sample means of other covariates). One additional international patent filing increases incidence of opposition by about 0.1 percentage points. Ten additional claims are associated with about the same impact. These results are broadly consistent with earlier studies of opposition and of litigation (Lanjouw and Schankerman, 2001; Harhoff and Reitzig, 2004; Lanjouw and Schankerman, 2004b). Higher generality and originality of patents are associated with an increase in the likelihood of opposition. This may indicate that pioneering patents (with high originality) or widely diffusing patents (with high generality) attract more attention (and thus run a higher risk of opposition) than other patents, either for technical or monetary reasons.

Following Harhoff and Reitzig (2004), we use the composition of backward references to characterize patent quality. While the total number of backward references is uninformative, an increase in the share of X-classified references listed in the search report leads to an increase in the likelihood of opposition. Conversely, A-classified references (which do not indicate any state of the art that might cast doubt on the patent's novelty and inventive step) reduce the likelihood of opposition.

We find a significant negative effect of PCT filings on opposition – PCT filings have an opposition incidence that is 1 percentage point lower than other filings. PCT filings are relevant for two reasons. First, this is a common filing path for patents protected in many jurisdictions. Hence, particularly valuable patents are likely to be filed via the PCT. On the other hand, PCT filings also enjoy considerable option value, since the decision which regions to enter can be delayed by up to 30 months after the priority date, adding 18 months of delay compared to "normal" international applications.

As expected, firms with large portfolios experience a lower incidence of opposition. Again, this finding confirms earlier results (Lanjouw and Schankerman, 2001; 2004a) and is consistent with the view that large firms enjoy advantages in the process of resolving disputes over IP. The median size of

[19] We do not report the estimated coefficients for the time and area fixed effects here for reasons of brevity. The regression results can be obtained from the authors upon request.

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 a one logarithmic unit increase in patents is a reduction in opposition by 0.3 percentage points.

Non-European applicants are significantly less likely to face opposition than European patent holders. This is not surprising, as patent filings from non-European countries have gone through stronger selection filters than patent filings of the local applicants – a lower opposition rate for the patents granted to this group of applicants is therefore not surprising. Finally, 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 pre-selection of patents of particularly high quality. There is evidence that both arguments apply – Gambardella, Harhoff and Verspagen (2008) report that patents from these three types of applicants are usually of lower commercial value than corporate patents. At the same time, the "inventive step" of these filings can be above average.

Our main variables of interest are the concentration of patent ownership among the applicant's rivals and the effects of the triples measure of patent thicket density. In column (3) we just include the two main variables: concentration as a measure for the public goods effect and triples as a measure of thicket density. Hypothesis 1 states that concentration should have a positive sign if there is a public goods effect. We cannot reject this hypothesis: the average marginal effect of concentration is 0.82 which is highly significant. At the median of all variables a one standard deviation increase (0.0106) of concentration leads to an increase in the probability of opposition by more than 0.75 percentage points (0.0106*0.7113=0.0075). This effect is also economically important as it translates to a 12.5% increase in the opposition rate relative to the unconditional opposition rate of 6.04%. Second, Hypothesis 2 cannot be rejected. The count of technology area triples is associated with a significant reduction in opposition incidence. The number of technology area triples ranges between zero and 87 in our data, with a median value of 5. The average marginal effect of technology area triples on opposition is -0.0009 which is highly significant. At the median of all variables a one standard deviation increase in the triple count (16.90) reduces the incidence of opposition by 1.34 percentage points (16.89*-0.00079=0.0134). That is a 22.2% reduction relative to the unconditional opposition rate.

We use the fragmentation variable in our regressions to confirm that higher-order dependencies (such as captured by the triples variable) offer a better way of describing the density of patent thickets than the fragmentation measure that was previously used in the literature to approximate the density of patent thickets (Ziedonis, 2004). The coefficient is positive[20] and highly significant. However the

[20] If fragmentation of patent ownership is used as a proxy measure of patent thickets we should expect a negative coefficient for this variable. We find that in unreported specifications the variable has a negative coefficient as long as size is measured in levels. However, the effects are not significant or only at the 10%

economic effect of fragmentation on opposition is much weaker (2.8% at the median of all variables) than that of triples or of the public goods effect.

To test whether Hypothesis 3 can be rejected we split the number of technology area triples into two groups: 1) triples which the holder of the focal patent is involved in - own triples; 2) triples which other firms in the same technical area are involved in. In unreported results we find that the effects of own triples are not significant unless we include a quadratic effect for own triples. Then the linear and the quadratic terms are highly significant as is shown in columns 7 and 8. Interpreting this functional form analytically is complex, so we plot the average marginal effects of own and rivals' triples for all values of own triples in Figure 5. In Figure 6 we also provide the predicted probability of opposition for all values of own triples. Both Figures indicate that at very low values of own triples the probability of opposition increases or is constant, but beyond 6 own triples this effect is reversed. At the median of all other variables a firm that is part of 14 own triples experiences a reduction in the probability of opposition by 0.18% from an additional own triple whereas an additional rival triple only reduces the probability of opposition by 0.08%. Both effects are statistically highly significant but relatively modest economically. Note that the 98th percentile of own triples is 12, so only a small number of patent applicants are affected by this reduction in the probability of opposition.

Hypothesis 4 posits that patent applications of larger firms are likely to encounter opposition less frequently in patent thickets. This leads to 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 5 and 6) and in the specification that includes both own and rivals' triples (columns 9 and 10). In both cases we find that the interaction term has a statistically significant negative effect. We cannot reject Hypothesis 4 in either specification. Nor does the introduction of Hypothesis 4 lead to a rejection of Hypothesis 3. At the median of all variables a one standard deviation increase in the number of rivals' triples changes the marginal effect of the logarithm of firm size by 0.07% of the unconditional probability of opposition.

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 post-grant validity challenges have been considered as a way of eliminating erroneously granted patent rights - with post-grant patent review typically being cheaper than litigation. Discussing the America Invents Act (AIA) which was enacted at the end of 2011, Graham and Vishnubhakat (2013) highlight three avenues for

level, depending on which other variables are included. We transform the size variable using the logarithm to improve the fit of our regressions.

post-grant validity challenges that have recently been introduced in the United States with the explicit aim of raising patent quality. These are post-grant review, "covered business method patents" (or third party) review, and *inter partes* (or third party) review.[21]

We argue, as do previous studies, that post-grant opposition is likely to lose its effectiveness where multiple opponents fail to engage in opposition due to a public goods effect. Moreover, the logic of mutually assured destruction in patent thickets will result in fewer patent opposition cases there than in technologies not affected by patent thickets. The rate of patent opposition at EPO has been stable for 20 years at around 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 a public goods problem. 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 these relationships go beyond these two exemplary technologies - the broad trends in our data can be shown to be associated with the aforementioned public goods problem and with the presence of patent thickets. Moreover, opposition rates decline with the size of an applicant's portfolio, and the more so the denser the patent thicket. Finally, the likelihood of opposition is affected by the position of firms within patent thickets.

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 post-grant 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 et al. 2001) is not a particularly effective approach in these technologies. It remains to be seen whether the relatively recent establishment of defensive patent aggregators (Hagiu and Yoffie, 2013) will reverse the public goods effect in complex technology areas and will lead to effective use of the mechanisms created by the America Invents Act. This act certainly has created scope for more collective activity of this kind. However, 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 such a 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

---

[21] The new post-grant opposition mechanism at the USPTO allows to challenge patents on all grounds, including eligibility and clarity. The "covered business method" review procedure allows third parties that face the threat (or are actually sued) to challenge its validity independently of the issue date of the potentially infringed 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.

from the patent register. Further work on whether the interests of the many patent thicket outsiders can be harnessed in their and the interests 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. While 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 break-downs 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.

References

Bessen, J. E. and Meurer, M.J. (2006): "Patent Litigation with Endogenous Disputes", *The American Economic Review,* Vol. 96(2), 77–81.

Bessen, J.E. and Meurer, M. J. (2008): Patent Failure, Princeton University Press.

Choi, J. P. (2005): "Live and Let Live: A Tale of Weak Patents", *Journal of the European Economic Association,* Vol. 3(2–3), 724–733.

Cockburn, I.M. and MacGarvie, M.J. (2009): "Patents, Thickets, and the Financing of Early-Stage Firms: Evidence from the Software Industry", *Journal of Economics & Management Strategy,* Vol. 18(3), 729-773.

Cockburn, I.M., and MacGarvie, M.J. (2011): "Entry and Patenting in the Software Industry", *Management Science,* Vol. 57(5), 915–933.

Cooter, R. and Rubinfeld, D. (1989): "Economic Analysis of Legal Disputes and Their Resolution", *Journal of Economic Literature*, Vol. 27, 1067-1097.

Du Plessis, M., Van Looy, B., Song, X. & Magerman, T. (2009): "Data Production Methods for Harmonized Patent Indicators: Assignee sector allocation", EUROSTAT Working Paper and Studies, Luxembourg.

Farrell, J. and Merges, R. P. (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 Technology Law Journal*, Vol. 19 (3), 943-970.

Federal Trade Commission (2003): "To Promote Innovation - The Proper Balance of Competition and Patent Law and Policy", Report, GPO.

Galasso, A. and Schankerman, M. (2010): "Patent thickets, courts, and the market for innovation", *RAND Journal of Economics*, Vol. 41(3), 427-503.

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

Graevenitz, G. von, 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 for the European Commission.

Graevenitz, G. von, Wagner, S. and Harhoff, D. (2011): "How to measure patent thickets – A novel approach", *Economics Letters*, Vol. 111(1), 6-9.

Graevenitz, G. von, Wagner, S. and Harhoff, D. (forthcoming): "Incidence and Growth of Patent Thickets - The Impact of Technological Opportunities and Complexity", forthcoming in: *Journal of Industrial Economics*.

Graham, S. and Vishnubhakat, S., (2013): "Of Smart Phone Wars and Software Patents", *Journal of Economic Perspectives*, Vol. 27, 67–86.

Graham, S. J. H. and Harhoff, D. (2009): "Separating Patent Wheat from Chaff: Would the U.S. Benefit from Adopting a Patent Post-Grant Review?" Available at SSRN: http://ssrn.com/abstract=1489579 or http://dx.doi.org/10.2139/ssrn.1489579

Graham, S., Hall, B.H., Harhoff, D. and Mowery, D. C. (2003): "Post-Issue Patent Quality Control: A Comparative Study of US Patent Re-Examinations and European Patent Oppositions," in: W. M. Cohen and S. A. Merrill (eds.), *Patents in the Knowledge-Based Economy*. The National Academies Press, Washington, D.C., 74-119.

Grindley, P. C. and D. J. Teece (1997): "Managing Intellectual Capital: Licensing and Cross-Licensing in Semiconductors and Electronics", *California Management Review*, Vol. 29, 8-41.

Hagiu, A. and Yoffie, D.B. (2013): "The New Patent Intermediaries: Platforms, Defensive Aggregators, and Super-Aggregators", *Journal of Economic Perspectives*, Vol. 27, 45–66.

Hall, B. H. (2005a): "Exploring the Patent Explosion", *Journal of Technology Transfer,* Vol. 30, 35–48.

Hall, B. H. (2005b): "A Note on the Bias in Herfindahl-Type Measures Based on Count Data", *Revue d'Économie Industrielle*, Vol. 110 (2). 149-156.

Hall, B. H. and Ziedonis, R. (2001): "The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995", *RAND Journal of Economics*, Vol. 32 (1), 101-128.

Hall, B. H. and D. Harhoff (2004): "Post Grant Review Systems at the U.S. Patent Office – Design Parameters and Expected Impact," *Berkeley Law Technology Journal*, 19 (3), 989-1016.

Hall, B. H. and Harhoff, D. (2004). "Post Grant Review Systems at the U.S. Patent Office – Design Parameters and Expected Impact," *Berkeley Law Technology Journal*, Vol. 19(3), 989-1016.

Hall, B.H., Helmers, C., von Graevenitz, G. and Rosazza-Bondibene, C. (2012): "A Study of Patent Thickets", Final Report to IPO UK.

Harhoff, D. (2009): "Economic Cost-Benefit Analysis of a Unified and Integrated European Patent Litigation System," Final Report to the European Commission. (available at http://ec.europa.eu/internal_market/indprop/docs/patent/studies/litigation_system_en.pdf)

Harhoff, D., Hoisl, K. and Webb, C. (2006): “European patent citations – how to count and how to interpret them?”, Working paper, University of Munich, CEPR and OECD.

Harhoff, D., Narin, F., Scherer, F.M. and Vopel, K. (1999): “Citation frequency and the value of patented innovation”, *Review of Economics and Statistics,* Vol. 81(3), 511 –515.

Harhoff, D. and Reitzig, M. (2004): “Determinants of Opposition against EPO Patent Grants – The Case of Biotechnology and Pharmaceuticals”, *International Journal of Industrial Organization*, Vol. 22(4), 443-480.

Harhoff, D. and Wagner, S. (2009): “The Duration of Examination at the European Patent Office”, *Management Science*, Vol. 55(12), 1969-1984.

Jaffe, A. B. and Lerner, J. (2004): Innovation and Its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What to Do About It., Princeton, N.J.: Princeton University Press.

Lanjouw, J. and Lerner, J., (1998): “The enforcement of intellectual property rights: a survey of the empirical literature” *Annales d'Economie et de Statistique,* 223–246.

Lanjouw, J. O. and Schankerman, M. (2001): “Characteristics of patent litigation: a window on competition"” *RAND Journal of Economics*, Vol. 32 (1), 129-151.

Lanjouw, J. O. and Schankerman, M. (2004a): “Protecting Intellectual Property Rights: Are Small Firms Handicapped?” *The Journal of Law and Economics*, April, 45-74.

Lanjouw, J. O. and Schankerman, M. (2004b): “Patent Quality and Research Productivity: Measuring Innovation with Multiple Indicators” *The Economic Journal* Vol. 114, 441–465.

Lei, Z., and Wright, B. (2009): Why Weak Patents? Rational Ignorance or Pro-‘Customer’ Tilt?, Mimeo.

Lemley, M. (2001): “Rational Ignorance at the Patent Office”, *Northwestern University Law Review*, Vol. 95(4), 1495-1529.

Levin, J., Levin, R., (2003): “Benefits and Costs of an Opposition Process”, in: Cohen, W.M., Merrill, S.A. (eds), *Patents in the Knowledge-Based Economy*. National Academies Press, pp. 121–144.

Magerman T., Grouwels J., Song X. & Van Looy B. (2009). “Data Production Methods for Harmonized Patent Indicators: Patentee Name Harmonization”, EUROSTAT Working Paper and Studies, Luxembourg.

Mejer, M. and van Pottelsberghe de la Potterie, B. (2009): “Economic incongruities in the European patent system”, CEPR Discussion Paper no. 7142. London, Centre for Economic Policy Research. (available at http://www.cepr.org/pubs/dps/DP7142.asp).

Noel, M. and Schankerman, M. (2006): “Strategic Patenting and Software Innovation”, CEPR Discussion Paper No. 5701, CEPR London.

OECD (1994): Using patent data as science and technological indicators. Patent Manual.

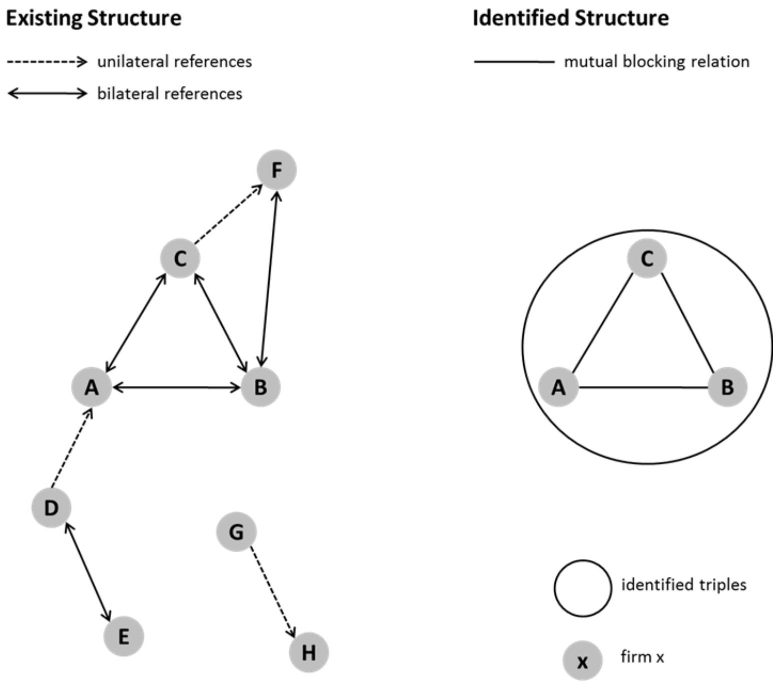
Peeters B., Song X., Callaert J., Grouwels J., Van Looy B. (2009): “Harmonizing harmonized patentee names: an exploratory assessment of top patentees”, EUROSTAT Working Paper and Studies, Luxembourg.

Shapiro, C. (2001): “Navigating the Patent Thicket: Cross Licenses, Patent Pools and Standard Setting”, in: Jaffe, A. and Lerner, J. and Stern, S. (eds.), *Innovation Policy and the Economy*. Cambridge, MA, MIT Press.

Waldfogel, J. (1998): “Reconciling Asymmetric Information and Divergent Expectations Theories of Litigation”, *Journal of Law and Economics,* Vol. 41, 451–476.

Ziedonis, R. (2004): “Don’t fence me in: Fragmented Markets for Technology and the Patent Acquisition Strategies of Firms.”, *Management Science*, Vol. 50(2004), 804-820.

Figure 1 Schematic Presentation of Unilateral and Bilateral Blocking Relationships



Note: Adopted from von Graevenitz et al. (2011), Figure 1.

Figure 2 Opposition Rates by Main Technological Area – 1980-2009

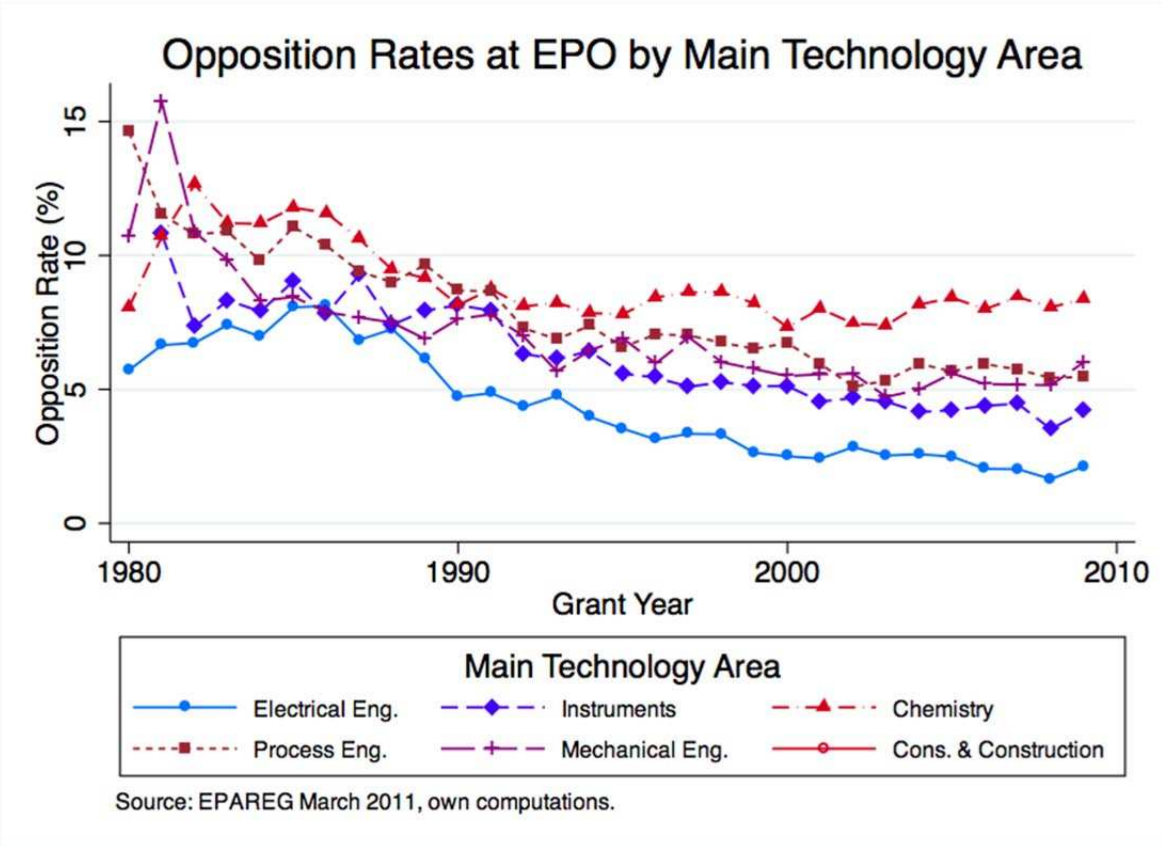
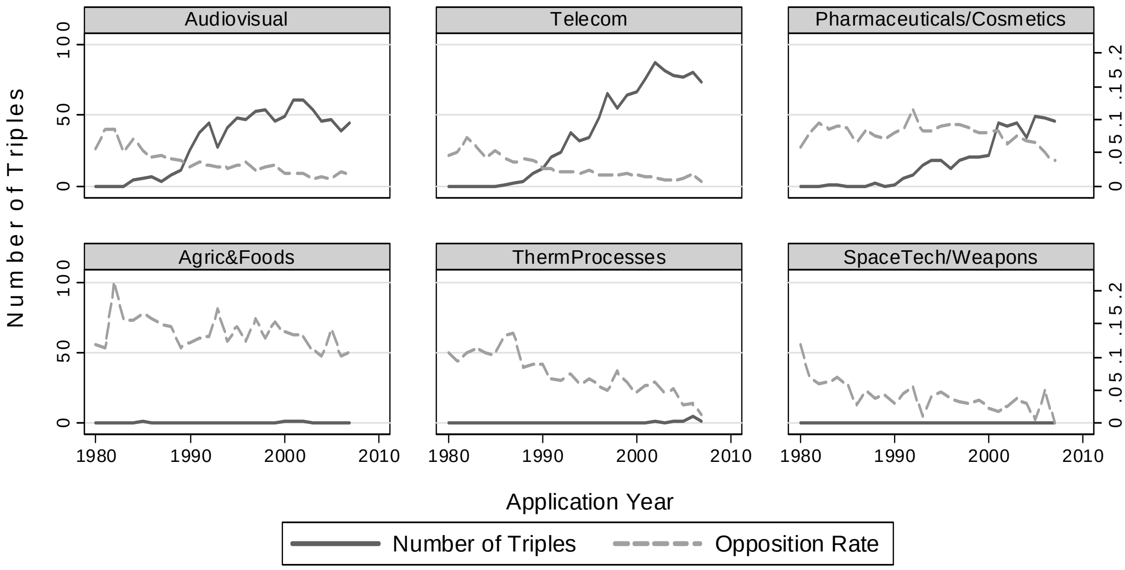


Figure 3 Triples (left ordinate) and Rate of Opposition (right ordinate) at the EPO (1980 to 2007) by Application Year and Technological Area



Note: Audiovisual, Telecommunication and Pharmaceuticals/Cosmetics have the highest average number of triples between 1980 and 2007. Agriculture/Food, Thermal Processes and Space Technology/Weapons have the lowest average number of Triples between 1980 and 2007.

Figure 4 Structure of Patent Thickets Across Technology Areas for four different periods

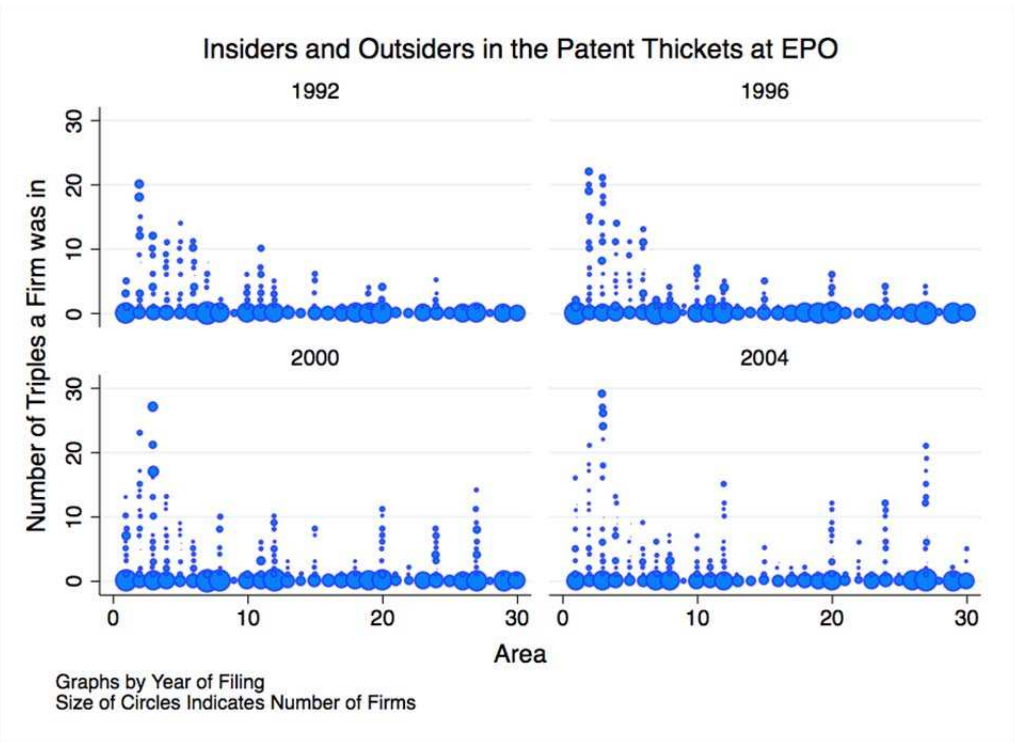


Figure 5 Average Marginal Effects of Additional Own and Rivals' Triples by Number of Own Triples

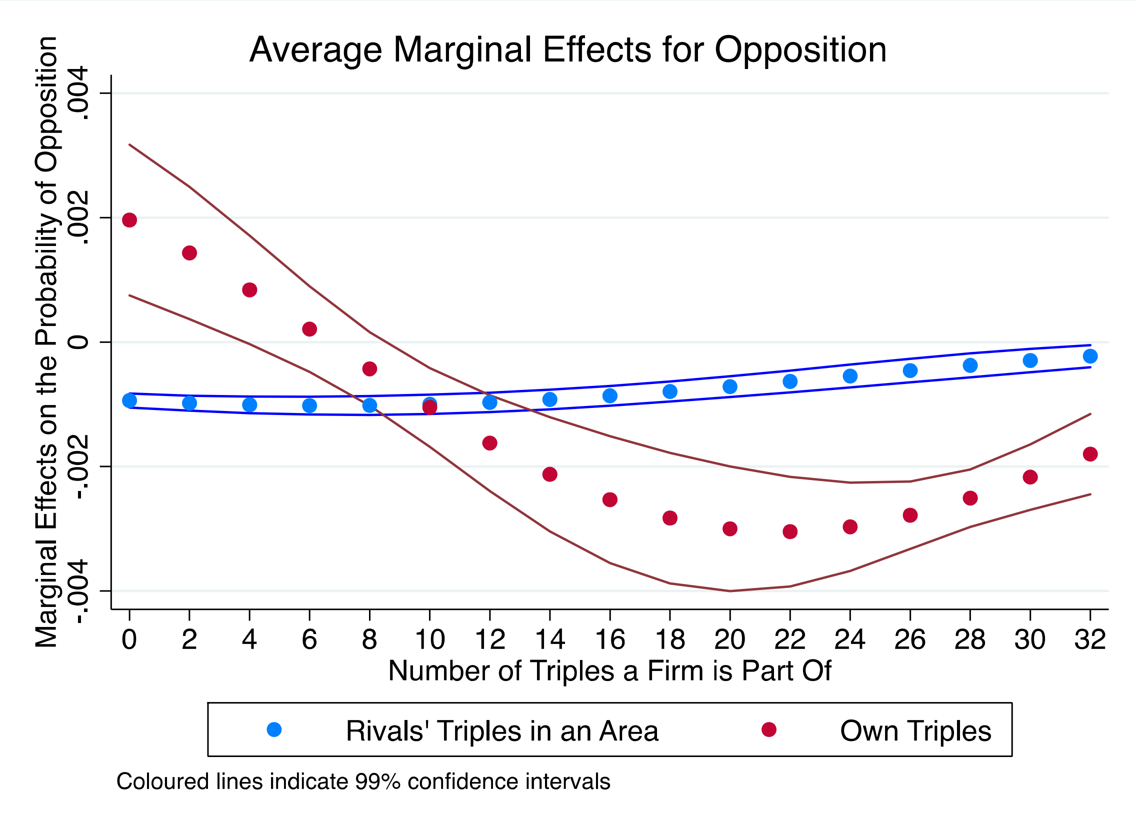


Figure 6 Probability of Opposition by Number of Own Triples

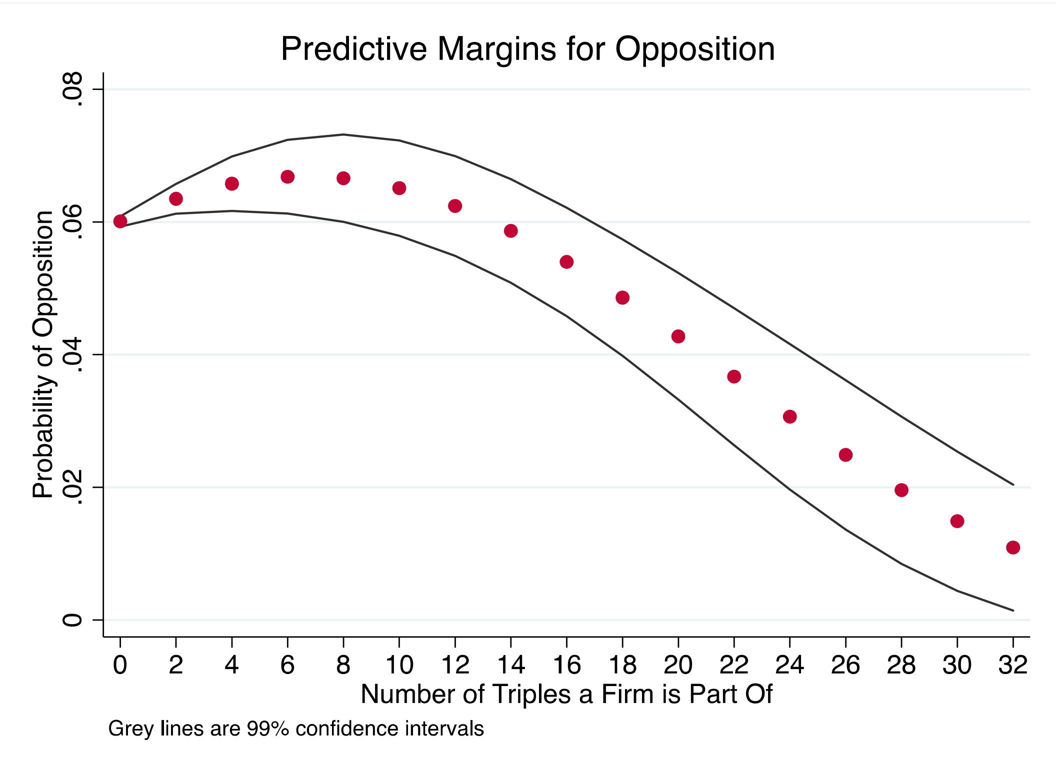


Table 1 Applications, Grants, Pending Cases and Oppositions by Application Year (1980-2007)

Application year	Applications	Grants	Grant rate	Pending cases	Share of pending cases	Oppositions	Opposition rate
1980	21,174	14,685	69.35%	18	0.09%	1,439	9.80%
1981	27,179	18,686	68.75%	24	0.09%	1,890	10.11%
1982	30,174	20,960	69.46%	40	0.13%	2,097	10.00%
1983	33,187	22,888	68.97%	72	0.22%	2,037	8.90%
1984	38,927	26,455	67.96%	82	0.21%	2,307	8.72%
1985	41,495	28,051	67.60%	41	0.10%	2,308	8.23%
1986	45,292	30,325	66.95%	48	0.11%	2,291	7.55%
1987	48,251	32,002	66.32%	137	0.28%	2,268	7.09%
1988	55,124	36,096	65.48%	288	0.52%	2,429	6.73%
1989	61,132	39,068	63.91%	496	0.81%	2,526	6.47%
1990	67,714	44,651	65.94%	236	0.35%	2,676	5.99%
1991	63,062	42,314	67.10%	52	0.08%	2,633	6.22%
1992	64,536	43,341	67.16%	332	0.51%	2,686	6.20%
1993	63,954	44,052	68.88%	170	0.27%	2,572	5.84%
1994	65,921	45,191	68.55%	367	0.56%	2,660	5.89%
1995	69,419	46,516	67.01%	659	0.95%	2,661	5.72%
1996	75,930	49,119	64.69%	1,195	1.57%	2,739	5.58%
1997	85,556	52,238	61.06%	2,070	2.42%	2,720	5.21%
1998	96,548	55,421	57.40%	3,538	3.66%	2,826	5.10%
1999	105,158	57,104	54.30%	6,089	5.79%	3,056	5.35%
2000	116,787	60,107	51.47%	9,215	7.89%	3,033	5.05%
2001	123,391	58,472	47.39%	15,058	12.20%	3,045	5.21%
2002	121,510	53,105	43.70%	22,023	18.12%	2,529	4.76%
2003	124,682	48,768	39.11%	32,807	26.31%	2,357	4.83%
2004	130,627	43,203	33.07%	46,478	35.58%	1,936	4.48%
2005	137,877	37,297	27.05%	62,783	45.54%	1,535	4.12%
2006	140,983	29,407	20.86%	80,626	57.19%	1,089	3.70%
2007	138,638	20,031	14.45%	97,202	70.11%	545	2.72%
Total	**2,194,228**	**1,099,553**	**50.11%**	**382,146**	**17.42%**	**64,890**	**5.90%**

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

Table 2 Patent Grants, Oppositions, Opposition Rate, Triples and Concentration of Rivals' Patent Grants by Technology Area (1980 - 2007)

Application year	Grants	Oppo-sitions	Opposition rate	Triples	Concentration of Rival's Patents
Electrical Engineering/Energy	64,479	2,927	4.54%	17.56	0.0109
Audiovisual	40,313	1,321	3.28%	40.72	0.0279
Telecom	58,379	1,199	2.05%	61.95	0.0273
IT	40,209	879	2.19%	25.94	0.0186
Semiconductors	20,130	412	2.05%	18.97	0.0241
Optical	36,359	1,035	2.85%	16.85	0.0200
Analysis/Measurement/Control Techn.	67,140	3,361	5.01%	8.91	0.0045
Medical Technology	55,032	3,412	6.20%	17.49	0.0068
Nuclear Technology	4,475	253	5.65%	0.80	0.0472
Organic Chemistry	52,776	2,273	4.31%	6.66	0.0117
Polymers	49,624	4,675	9.42%	12.42	0.0149
Pharmaceuticals/Cosmetics	56,060	4,550	8.12%	28.27	0.0059
Biotechnology	17,363	1,166	6.72%	2.03	0.0056
Petrol Chem./Materials Chem.	26,495	2,649	10.00%	12.57	0.0162
Surface Technology	20,674	1,762	8.52%	1.37	0.0056
Materials	29,226	3,006	10.29%	1.44	0.0051
Chemical Engineering	41,972	3,112	7.41%	3.33	0.0034
Material processing/Textiles/Paper	46,831	4,467	9.54%	1.75	0.0041
Handling/Printing	64,913	3,737	5.76%	17.19	0.0067
Agriculture & Food Process-Machines	14,226	1,365	9.60%	0.73	0.0134
Environment	8,484	543	6.40%	3.43	0.0130
Machine Tools	34,085	2,617	7.68%	0.96	0.0035
Motors	34,067	1,590	4.67%	19.59	0.0198
Thermal Processes	14,473	1,052	7.27%	0.69	0.0089
Mechanical Elements	41,708	2,048	4.91%	1.10	0.0048
Transportation	62,214	3,240	5.21%	22.80	0.0074
Space Technology/Weapons	5,504	213	3.87%	0.00	0.0211
Consumer Goods	46,106	2,433	5.28%	3.66	0.0033
Construction Technology	35,282	2,094	5.94%	2.10	0.0024
Total	1,099,553	64,890	5.90%	16.59	0.0113

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

Table 3 Descriptive Statistics

VARIABLES	MEAN	S.D.	MEDIAN	MIN	MAX
Opposition (0/1)	0.06	---	0.00	0.00	1.00
Number of area triples	12.17	16.89	5.00	0.00	87.00
Number of own triples	0.91	3.26	0.00	0.00	32.00
Number of rivals' triples	11.26	15.74	5.00	0.00	87.00
Concentration of rivals' patents x100	1.06	0.98	0.70	0.15	11.72
Fragmentation x100	68.92	42.91	95.04	0.00	100.00
Cum. number of patents /1000	1.09	2.55	0.06	0.00	20.44
Company applicant (0/1)	0.89	---	1.00	0.00	1.00
Individual applicant (0/1)	0.07	---	0.00	0.00	1.00
University applicant (0/1)	0.01	---	0.00	0.00	1.00
Government applicant (0/1)	0.02	---	0.00	0.00	1.00
Generality	0.10	0.20	0.00	0.00	1.00
Originality	0.29	0.34	0.20	0.00	1.00
Total references	3.89	2.83	4.00	0.00	123.00
Citations received within 5 years	0.82	1.61	0.00	0.00	100.00
Share of X relative to total references	0.19	0.30	0.00	0.00	1.00
Share of Y relative to total references	0.10	0.22	0.00	0.00	1.00
Share of A relative to total references	0.49	0.38	0.50	0.00	1.00
Number of equivalents	7.52	5.96	6.00	1.00	346.00
PCT filing (0/1)	0.35	---	0.00	0.00	1.00
Number of claims	13.49	10.45	11.00	0.00	476.00
EU applicant (0/1)	0.54	---	1.00	0.00	1.00
US applicant (0/1)	0.23	---	0.00	0.00	1.00
Japanese applicant (0/1)	0.19	---	0.00	0.00	1.00
Applicant ROW (0/1)	0.04	---	0.00	0.00	1.00

Note: A correlation table for all independent and the dependent variable is available from the authors upon request.

Table 4 **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	(9) Coeff.	(10) dx/dy
Number of area triples	ya			-0.0082***	-0.0009***	-0.0065***	-0.0009***				
				[0.000]	[0.000]	[0.000]	[0.000]				
Number of rivals' triples	fya							-0.0083***	-0.0009***	-0.0097***	-0.0009***
								[0.000]	[0.000]	[0.001]	[0.000]
Number of own triples	fya							0.0173***	0.0018***	0.0191***	0.0020***
								[0.004]	[0.000]	[0.004]	[0.000]
Number of own triples squared	fya							-0.0013***		-0.0013***	
								[0.000]		[0.000]	
Number of triples x						-0.0003***				-0.0005***	
number of patents (log)						[0.000]				[0.000]	
Concentration of rivals' patents	fya			7.2972***	0.8280***	7.1644***	0.8129***	7.4818***	0.8487***	7.4440***	0.8444***
				[0.499]	[0.057]	[0.502]	[0.057]	[0.504]	[0.057]	[0.504]	[0.057]
Fragmentation	fya			0.0416***	0.0047***	0.0396***	0.0045***	0.0448***	0.0051***	0.0429***	0.0049***
				[0.006]	[0.001]	[0.006]	[0.001]	[0.006]	[0.001]	[0.006]	[0.001]
Cum. number of patents (log)	fy	-0.0267***	-0.0030***	-0.0272***	-0.0031***	-0.0235***	-0.0030***	-0.0311***	-0.0035***	-0.0267***	-0.0035***
		[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]
Individual applicant (0/1)	f	-0.2706***	-0.0308***	-0.2615***	-0.0297***	-0.2585***	-0.0293***	-0.2667***	-0.0303***	-0.2640***	-0.0300***
		[0.009]	[0.001]	[0.009]	[0.001]	[0.009]	[0.001]	[0.009]	[0.001]	[0.009]	[0.001]
University applicant (0/1)	f	-0.2630***	-0.0299***	-0.2692***	-0.0305***	-0.2694***	-0.0306***	-0.2658***	-0.0302***	-0.2657***	-0.0301***
		[0.021]	[0.002]	[0.021]	[0.002]	[0.021]	[0.002]	[0.021]	[0.002]	[0.021]	[0.002]
Government applicant (0/1)	f	-0.2941***	-0.0335***	-0.2970***	-0.0337***	-0.2974***	-0.0337***	-0.2915***	-0.0331***	-0.2907***	-0.0330***
		[0.016]	[0.002]	[0.016]	[0.002]	[0.016]	[0.002]	[0.016]	[0.002]	[0.016]	[0.002]
Generality	p	0.2320***	0.0264***	0.2316***	0.0263***	0.2307***	0.0262***	0.2341***	0.0266***	0.2338***	0.0265***
		[0.011]	[0.001]	[0.011]	[0.001]	[0.011]	[0.001]	[0.011]	[0.001]	[0.011]	[0.001]
Originality	p	0.0929***	0.0106***	0.0802***	0.0091***	0.0804***	0.0091***	0.0816***	0.0093***	0.0824***	0.0093***
		[0.007]	[0.001]	[0.007]	[0.001]	[0.007]	[0.001]	[0.007]	[0.001]	[0.007]	[0.001]
ln(1+total references)	p	0.0021	0.0002	-0.0047	-0.0005	-0.0047	-0.0005	-0.0056	-0.0006	-0.0057	-0.0006
		[0.004]	[0.000]	[0.004]	[0.001]	[0.004]	[0.001]	[0.004]	[0.001]	[0.004]	[0.001]

Table 4 **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	(9) Coeff.	(10) dx/dy
ln(1+ citations received within 5 years)	ya	0.2342***	0.0267***	0.2339***	0.0265***	0.2340***	0.0265***	0.2338***	0.0265***	0.2337***	0.0265***
		[0.004]	[0.000]	[0.004]	[0.000]	[0.004]	[0.000]	[0.004]	[0.000]	[0.004]	[0.000]
Share of X relative to total references	fya	0.0491***	0.0056***	0.0451***	0.0051***	0.0461***	0.0052***	0.0445***	0.0050***	0.0457***	0.0052***
		[0.010]	[0.001]	[0.010]	[0.001]	[0.010]	[0.001]	[0.010]	[0.001]	[0.010]	[0.001]
Share of Y relative to total references	fya	-0.0256*	-0.0029*	-0.0385**	-0.0044**	-0.0374**	-0.0042**	-0.0385**	-0.0044**	-0.0370**	-0.0042**
		[0.012]	[0.001]	[0.012]	[0.001]	[0.012]	[0.001]	[0.012]	[0.001]	[0.012]	[0.001]
Share of A relative to total references	fya	-0.1217***	-0.0138***	-0.1131***	-0.0128***	-0.1130***	-0.0128***	-0.1118***	-0.0127***	-0.1113***	-0.0126***
		[0.009]	[0.001]	[0.009]	[0.001]	[0.009]	[0.001]	[0.009]	[0.001]	[0.009]	[0.001]
Number of equivalents		0.0096***	0.0011***	0.0094***	0.0011***	0.0094***	0.0011***	0.0094***	0.0011***	0.0094***	0.0011***
		[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]
PCT filing (0/1)	fya	-0.1028***	-0.0117***	-0.1001***	-0.0114***	-0.1004***	-0.0114***	-0.0999***	-0.0113***	-0.1005***	-0.0114***
		[0.006]	[0.001]	[0.006]	[0.001]	[0.006]	[0.001]	[0.006]	[0.001]	[0.006]	[0.001]
Number of claims	fya	0.0006**	0.0001**	0.0008**	0.0001**	0.0008**	0.0001**	0.0008**	0.0001**	0.0008**	0.0001**
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
US applicant (0/1)	fy	-0.1512***	-0.0172***	-0.1623***	-0.0184***	-0.1627***	-0.0185***	-0.1614***	-0.0183***	-0.1612***	-0.0183***
		[0.007]	[0.001]	[0.007]	[0.001]	[0.007]	[0.001]	[0.007]	[0.001]	[0.007]	[0.001]
Japanese applicant (0/1)	f	-0.2534***	-0.0288***	-0.2638***	-0.0299***	-0.2634***	-0.0299***	-0.2625***	-0.0298***	-0.2619***	-0.0297***
		[0.008]	[0.001]	[0.008]	[0.001]	[0.008]	[0.001]	[0.008]	[0.001]	[0.008]	[0.001]
Applicant ROW (0/1)	f	-0.2863***	-0.0326***	-0.2805***	-0.0318***	-0.2810***	-0.0319***	-0.2813***	-0.0319***	-0.2812***	-0.0319***
		[0.018]	[0.002]	[0.019]	[0.002]	[0.019]	[0.002]	[0.019]	[0.002]	[0.019]	[0.002]
Time fixed effects (Grant years)	f	YES		YES		YES		YES		YES	
Area fixed effects		YES		YES		YES		YES		YES	
Log-likelihood	p	-225200		-224382		-224362		-224311		-224275	
Observations		1,044,069		1,044,069		1,044,069		1,044,069		1,044,069	

Note: Standard errors in parentheses. SEs have been clustered by firm, area and year and are reported in brackets. *** p<0.001, ** p<0.01, * p<0.05
Source of variation is indicated in the second column: f - firm, y - year, a - area, p – patent.
Marginal effects are average marginal effects calculated using STATA’s margins command.