Why most patents are invalid –
Extent, reasons, and potential remedies of patent invalidity

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Abstract: The legal stability of granted patents is uncertain, a fact that entails inefficiencies for the patentee as for third parties. It is an important question for intellectual property policy and management how severe this problem is. Few patents are litigated, and those that are are not a random selection. We thus ask: if a randomly picked patent underwent revocation proceedings, what would be the odds of it being invalidated? We address this question for the case of Germany, where revocation proceedings are separate from infringement suits. Based on court decisions, expert interviews, and a survey among patent lawyers, we find that patents in revocation proceedings that conclude with a decision are, on average, more robust than the average patent. Thus, the share of court decisions that declare the patent in suit partially or fully invalid—in the first instance, 75% for 2000 to 2012 and 79% for 2010 to 2012—is a conservative estimate of the share of all patents that would be partially or fully invalidated if challenged in court. An econometric analysis of 305 court decisions between 2010 and 2012 supports this finding, predicting for a sample of randomly drawn patents an average probability of (partial or full) invalidation of around 82%. We show that our arguments carry over to other legislations. To address the problem that many patents are latently invalid we suggest a significant increase of the inventive step required for grant combined with smaller increase of the inventive-step standard in litigation.

Keywords: Patent, Patent Validity, Patent Invalidation, Inventive Step

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1. Introduction

The possibility to enforce patents is essential for the patent system to work. However, enforcement will fail if the litigated patent is invalidated. In fact, most infringement litigation is decided by invalidation of the patent in suit, an observation that Lemley and Shapiro (2005) aptly capture with their notion of "probabilistic patents." This uncertainty about a patent's legal robustness entails inefficiencies for the patentee, who cannot fully rely on its patents; for third parties, who are facing more exclusion rights than legally should have been granted; and for policy makers concerned about incentives to innovate. Patents that are "latently invalid"—i.e., are valid but would be invalidated if challenged in court—unduly restrict innovative activities of third parties, expose them to the risk of infringement litigation, impose a cost burden for invent-arounds or licensing, and obfuscate the patent system, making patent search and monitoring more difficult.

The degree of severity of this problem is an important question for intellectual property (IP) policy makers and management. Only a very small fraction of all patents are litigated, and this fraction is not by random selection. It may be that those patents that lack legal robustness are litigated, in which case the problem of probabilistic patents would be less severe for the universe of all patents. But it may also be that patents in suit are more robust than the average patent: invalidity decisions are mostly triggered by infringement proceedings, and given the choice a patentee is more likely to enter these with robust patents.

We thus ask a simple yet important question. If a randomly picked patent underwent revocation proceedings, what would be the odds of it being invalidated? Are these odds higher or lower than the share of patents that, after being challenged in court with a decision reached, actually are declared invalid? In other words, do the selection effects at work lead to patents whose validity is tested and decided in court being more robust or less robust than the average patent?

Miller (2013) addresses this question for the U.S., analyzing 980 patents that received a court decision on innovation-based validity between 2000 and 2010. He finds that 37% of these patents were partially or fully invalidated due to either anticipation or obviousness (Table 2), and estimates for the entirety of all patents applied for on the same days as the adjudicated patents a share of 28% of partial or full invalidation (p. 45).[1]

[1] Miller's (2013) focus on patents that received a decision on "innovation-based validity" rather than on validity in general implies that the numbers he reports cannot be directly compared to overall invalidation rates.

Our study addresses a similar question for the case of Germany, while differing from Miller's (2013) in its focus on validity in general (rather than innovation-based validity), methodological triangulation, and the set of explanatory variables employed. The German patent system is characterized by a bifurcation between infringement and revocation proceedings (e.g., Cremers et al., 2013), which facilitates a focused analysis of the latter. We also go beyond Miller's (2013) study by combining several data sources and methods: a descriptive analysis of all decisions in invalidity suits by the Federal Patent Court (*Bundespatentgericht* or *BPatG*) and the court of second (and last) instance (the Federal Court of Justice, *Bundesgerichtshof* or *BGH*) from 2000 until 2012; 19 hours of expert interviews; a survey among 320 patent lawyers; and a multivariate analysis of first and second instance judgements issued between 2010 till 2012, accounting for the litigants' revenues.

On a descriptive level, we find that 54% of invalidity suits before the Federal Patent Court between 2000 and 2012 settled, while 46% concluded with a decision. Of these, 69% were appealed. At the Federal Patent Court between 2010 and 2012, the decision was "fully invalid" in 45%, and "partially invalid" in 34% of all cases. Thus, only 21% of the cases ended in decisions that the patent was held fully valid. Statistics of final instance decisions are similar.

Interviewees and survey participants alike consider patents that enter invalidity suits to be of average robustness. However, the patents in those 54% of suits that settle are seen as significantly less robust—the logic being that, anticipating invalidation, the patentee would offer the plaintiff a free license in exchange for withdrawal of the suit. Furthermore, the plaintiff's budget was seen as having a positive effect on the likelihood of invalidation. Given the patent office's requirement of absolute novelty, the standard for testing validity of a patent should be a very thorough search for prior art, which can best be performed with a large budget. Thus, assuming that a large budget was spent by the plaintiff in the hypothetical suit involving a randomly picked patent, the likelihood of invalidation would be further increased compared with the sample of actual decisions. It thus seems safe to conclude that a randomly picked patent would be invalidated, partially or fully, with a probability above that found for actual invalidation decisions.

An econometric analysis of court decisions between 2010 and 2012 supports the above conclusion. We find that the plaintiff being in the top revenue tercile has the strongest and most highly significant effect on the likelihood of full invalidation both in the first and in the final instance decision, which we interpret as indication that the plaintiff's budget matters. While the actual shares of partially and fully invalidated patents in the first instance are 33.3% and 45.3% respectively, totaling 78.6%, we obtain in out-of-sample predictions for randomly drawn

patents point estimates of around 32% for partial, 48% to 51% for full, and 80% to 84% for either partial or full invalidation. Predictions for final instance decisions are even slightly higher. Assuming, as a proxy for a very thorough search for prior art, that all plaintiffs are large increases the prediction for partial or full invalidation in the first instance to values between 88% and 91%. We conclude that around 80% or more of all active German patents are latently invalid, either fully or partially.

We argue that the same logic holds for other legislations. In fact, in countries such as the U.S. where validity is tested within the infringement proceedings rather than separately as in Germany, the incremental robustness of patents whose validity is challenged over the average patent should even be higher since the counteracting selection effect that goes along with the filing of a nullity suit in Germany is largely absent.

Various measures against the abundance of latently invalid patents have been proposed, though none of them appears effective. We also concur with Farrell and Merges (2004) and others in considering Lemley's (2001) argument unsatisfactory that patent offices are "rationally ignorant" of the objective validity due to resource restrictions in the examination of patents. As a solution, we suggest a significant increase of the required inventive step in the examination procedure (including, if applicable, opposition proceedings) combined with an unchanged inventive-step standard when a patent is challenged in court. Such a measure would reduce the likelihood of grant mostly for patents that, in the current system, are latently invalid, while maintaining validity of most of those that are currently valid. We discuss the benefits and challenges of such a measure.

The paper is organized as follows. In the next section, we review the literature on the determinants of patent infringement and patent validity. Section 3 presents method and data, and Section 4, results of the interviews and survey. An econometric analysis of court decisions is provided in Section 5. The final section provides a discussion of our findings and conclusions.

2. Background

A common defense against an infringement action is to challenge validity of the underlying patent (Lanjouw and Schankerman, 2001), such that patents facing a revocation action are usually preselected at the infringement stage. Thus, it is necessary to examine patent infringement and its determinants before addressing the factors influencing revocation.

2.1. Patent infringement

One of the inefficiencies caused by latently invalid patents is that they may unduly expose other parties to the risk of being sued for infringement. This is more of a cause for concern the

more widespread infringement is in general. So, how frequent is patent infringement? Infringement *litigation*, in any case, is rare—according to Lemley (2001), only about 1.5% of all U.S. patents are ever asserted in court.[2] For Germany, Stauder (1989) estimates a share of 1% of all patents. However, actual litigation is only the tip of the iceberg as patentees might not find out about the infringement, might not react to it, or might settle with the infringer (Weatherall and Webster, 2014). Also, since patents do not fulfill their notice function properly as argued by Bessen and Meurer (2008), it is plausible that much patent infringement is inadvertent and also goes unnoticed by the patentee. For Australia, Weatherall and Webster (2010) find that 28% of the patents in the sample were perceived by the respective inventor as having been infringed.[3] Considering that most inventors do not actively search for infringement, the actual number will likely be higher.

Various surveys, recently reviewed by Weatherall and Webster (2014), study the incidence of infringement on the level of firms. Kingston (2001) and Rodwell et al. (2007) find that two-thirds to three-quarters of the European SMEs in their sample faced some kind of IP infringement. By surveying UK SMEs and micro-firms, Greenhalgh et al. (2010) discovered that roughly 35% of the respondents had already faced a patent dispute. While firm-level results are not directly informative of the incidence of infringement on the patent level, they do support the notion that patent infringement is far more widespread than patent litigation. This, in turn, implies that the risk of being sued for infringement of latently invalid patents is a serious cause of concern.

To understand the selection effects that lead to patents being involved in revocation actions, we now review the factors that affect the likelihood of a patent being involved in infringement litigation (which in turn triggers most revocation actions). The most obvious of these factors is the patent's commercial value. The more valuable the underlying invention, the more likely it is that third parties will pursue similar research and design products or processes that inadvertently, or even consciously, infringe on the patent. This economic reasoning is confirmed by empirical observations showing that patents with a higher number of forward citations—an established indicator of patent value—are more likely to enter infringement actions (Allison et al., 2004; Cremers, 2004; Lanjouw and Schankerman, 2001, 2004; Somaya,

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[2] This number varies strongly by industry and reaches six percent for the biotechnology sector (Lerner, 1995).

[3] While the authors mostly use "copying" instead of "infringement," they make clear that they do not differentiate between the terms. They use "copying" to mean "conduct the inventor perceives as involving use of their idea/invention" (Weatherall and Webster, 2010: 24) without implying intent on the part of the presumed copier.

2003).[4] The same is true for patents that are part of a larger patent family (Cremers, 2004; Harhoff et al., 2003), which also indicates patent value (as perceived by the applicant). Furthermore, a patent being involved in litigation, which causes considerable cost[5], constitutes in itself a signal of value (Lemley and Shapiro, 2005).

Several studies find a positive relationship between the number of backward citations of a patent and the likelihood of it being involved in infringement litigation (Allison et al., 2004; Cremers, 2004; Harhoff et al., 2003; MacGahee, 2011). In contrast, Lanjouw and Schankerman (2004) find a negative relationship, arguing that backward citations are an indicator of a well-developed field of technology where uncertainty (which favors legal disputes) is lower. Further, a positive relationship has been identified with the number of claims (Allison et al., 2004; Lanjouw and Schankerman, 2001; MacGahee, 2011), the application-to-grant lag (Allison et al., 2004; Somaya, 2003), young patent age (Allison et al., 2004), and the patent having survived opposition or re-examination (Cremers, 2004; Harhoff et al., 2003).

Of interest in our study is if patents entering infringement actions are more robust than the average patent. The correlations reported above are mostly inconclusive in this regard, though. Value should increase with both the patent's inventive step and with its breadth; legal robustness, however, should increase with the former but decrease with the latter. Any predictions regarding a correlation between robustness and backward citations, number of claims, grant lag, or age appear even more speculative. The same is true for characteristics of the patent holder, which various authors have studied as potential correlates of infringement litigation.[6]

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[4] See Cooter and Rubinfeld (1989) as well as Lanjouw and Schankerman (2001) for an overview of the key determinants of litigation in general and with respect to patent litigation, respectively.

[5] According to the American Intellectual Property Law Association (2013) each party in a litigation proceeding faces median costs of $700,000 for patents worth < $1 million. Those costs can increase to up to $5.5 million for patents valued at more than $25 million (American Intellectual Property Law Association, 2013). According to practitioners' estimates, the costs for German first instance proceedings are typically in between €75,000 to €230,000 for values in dispute from €500,000 to €5,000,000. In rare cases the litigation value might increase up to $30,000,000, raising the cost at risk to €1,380,000. Costs for the second instance proceeding are roughly 15% higher (Bardehle Pagenberg Partnerschaft, 2013b). Total costs (including nullity action) can be as high as €2 million for €10 million in dispute (IP Campenhausen, 2004; Mejer and van Pottelsberghe de la Potterie, 2012). Moreover, an estimation by Bessen and Meurer (2012) for U.S. public firms on proceeding related costs for alleged infringers exceeds $16 billion a year.

[6] Foreign-owned patents seem to be less likely involved in a patent infringement action than domestic-owned patents, likely due to the higher costs foreign parties would face as well as cultural and language differences (Allison et al., 2004; Lanjouw and Schankerman, 2001; MacGahee, 2011; Moore, 2003; Weatherall and Jensen, 2005). Analyzing U.S. proceedings between 1978 and 1999, Lanjouw and Schankerman (2004) find that patents assigned to individuals and domestic firms

What is relevant in our context is the positive correlation between a patent being involved in infringement proceedings and its having survived opposition or re-examination (Cremers, 2004; Harhoff et al., 2003). Such patents have shown a certain legal robustness, by virtue of which they increase the average robustness of all patents involved in infringement proceedings. A second argument pointing in the same direction is based on the patentee's decision situation. Legal action is not an automatic reaction to detecting infringement. A patentee will be more likely to file suit if it perceives the allegedly infringed patent as robust; and in cases where a product is seen to infringe on several patents, the patentee will ceteris paribus select those it perceives as most robust for its legal action. Summarizing, we posit that patents involved in infringement proceedings are more robust than the average patent.

2.2. Patent validity

2.2.1. Patents entering invalidity proceedings

About 1% of all granted patents find their validity challenged in court, both in Germany (e.g., Keukenschrijver, 2014; Lanjouw and Schankerman, 2001) and in the U.S. (e.g., Keukenschrijver, 2014; Lanjouw and Schankerman, 2001). For Germany, Stauder and Luginbuehl (2009) identify a steady upward trend. Nearly all of these validity challenges are triggered by infringement proceedings (Keukenschrijver, 2014, pp. 83–84, 2014, pp. 73–74; Stauder, 1989, p. 39; Stauder and Luginbuehl, 2009, p. 296). In turn, one third to half of all patents that are involved in infringement proceedings are subsequently subject to validity challenges instituted as a defense by the alleged infringer.[7] In countries where validity is

with small patent portfolios are more likely part of infringement proceedings than firms holding larger patent portfolios. This finding has been confirmed by other scholars analyzing similar settings (e.g., Allison et al., 2004; Ball and Kesan, 2009; Bessen and Meurer, 2005; Somaya, 2003). The outcomes are similar for Germany (Cremers, 2004) and Australia (Weatherall and Webster, 2010). Greenhalgh et al. (2010), however, come up with a contrary finding. According to their study on UK cases between 2003 and 2009, large foreign firms were prominent among the litigants. Weatherall and Webster (2014) summarize possible explanations for the finding that small firms are more likely to be involved in patent litigation: they only have a small number of patents available for possible cross-licensing and therefore a reduced bargaining power; they have more at stake and hence more to lose; they have mistaken expectations and are more confident of winning a dispute; and they may face issues of asymmetric information as larger firms are typically more experienced about patents and how to litigate them. With respect to the business model of parties involved, several scholars find a steadily increasing share of non-practicing entities (NPEs) in infringement proceedings (Ball and Kesan, 2009; Chien, 2009; Freedman, 2010). This is in line with the fact mentioned earlier that more valuable patents are more likely to enter those proceedings and NPEs tend to own more valuable patents (Fischer and Henkel, 2012; Risch, 2012).

[7] For the period of 1972 to 1974 Stauder (1989) reports a share of 44% to 57%. Averaging over the years of 2000 to 2008 (filing year of the respective infringement action), Cremers et al. (2014: 24) find that "slightly less than a third of infringement cases (counted at the patent level) are associated with a revocation action."

challenged within infringement proceedings, this share is considerably higher: Stauder (1989) reports 81% for France and 93% for the UK. For the U.S., the share is estimated to be above 90%.

Which characteristics of a patent correlate with the likelihood of it entering invalidation proceedings? Obviously, since most invalidation proceedings are triggered by infringement proceedings, the selection effects at work for the latter also come to bear for the former if the reference group is the universe of all patents. We are aware of two studies that address this question. For suits before the Federal Patent Court, Fischer (2015) finds that a patent's forward and backward citations, its having been contested in opposition, the number of its family members and claims—all indicators of a patent's value—as well as being owned by an individual correlate positively with a selection into a revocation proceeding. In contrast, the number of assigned IPC classes, a higher grant lag, and examination at the EPO (as opposed to the German Patent and Trademark Office) correlate negatively with the likelihood of the patent entering invalidation proceedings. Using U.S. data, Miller (2013) shows among other things that patents owned by individuals or by foreign firm are less likely, and those owned by licensing firms more likely to be challenged in court.

Of these results, Fischer's (2011) finding of a positive relationship with the patent's forward citations might indicate that the patents in German invalidation proceedings that conclude with a decision are more robust than the average patent. Beyond that, based on economic reasoning we had identified a selection of more robust patents into infringement proceedings in Section 2.1. In a bifurcated system as in Germany this selection effect is counteracted at the invalidation stage by the fact that the alleged infringer will be more likely to challenge the patent the less robust it is perceived to be. Thus, compared with all patents in infringement proceedings, those in invalidity proceedings should, on average, be less robust. To judge the net effect of both selections, relative to the population of all patents, on the basis of earlier research and economic arguments alone appears unfounded. We will address this issue empirically in our Results section.

The counteracting selection effect described above is largely absent in legal systems such as the U.S. where validity is challenged in most infringement proceedings. In such countries, patents whose validity is tested in infringement proceedings should thus be more robust than the average patent.

2.2.2. Outcomes of invalidity proceedings

When invalidity proceedings in Germany are concluded with a decision, significantly more than half of all patents are either partially or fully invalidated. For the period 1963 to 1971,

Liedel (1979) finds a rate of partial or full invalidation of 71% in the first as in the second instance. Keukenschrijver (2014) reports for the first instance a rate of 66% for 1961 to 1980 and 52% for 1980 to 1990. In the same range, Fischer (2015)finds a rate of 65% in the first instance for the period of 1985 to 1999, and Stauder and Luginbuehl (2009) even report a rate of 76% for 2000 till 2008. This number is in line with our own analysis, reported below, for 2000 till 2010. In the most recent study, Hess et al. (2014) report, for the years 2010 to 2013, a rate of partial or full invalidation in the first instance of 79%.[8]

High rates of invalidation are not specific to Germany. Early studies on U.S. patent litigation unveil an invalidation rate of 60% to 70% for the period 1948 to 1954 (Federico, 1956) and roughly 65% from 1953 to 1978 (Koenig, 1980). Allison and Lemley (1998) report an overall invalidation rate of 46% for the period of 1989 to 1996. More recently, Mann and Underweiser (2012) find that for the years 2003 through 2009 the Federal Circuit held 60% of the patents in the cases it adjudicated not valid. In other countries, invalidation rates are in similar ranges. For Australia, Weatherall and Jensen (2005) report a rate of full or partial invalidation of 53% (first and second instance) for the period of 1997 to 2003. Oyama (2012) finds an invalidation rate of 73% at the Japanese district courts, and a UK study examining the years 2000 to 2008 indicates an overall rate of about 50% partially or fully invalid in the first instance (Helmers and McDonagh, 2013). France seems to be special case, with according to Véron (2010) only 27% of the cases before the court of first instance in Paris between 2000 und 2009 resulting in a revocation decision.

Given that globally more than half of all invalidation proceedings that conclude with a decision lead to partial or full invalidation of the patent, the question arises which factors correlate with, or even drive, the likelihood of invalidation. We address in turn factors relating to the granting process, the patent, and the parties in suit.

Granting process. Henry and Turner (2006) trace how the establishment of the Court of Appeals for the Federal Circuit (CAFC) affected the decision of invalidity. Analyzing the years 1953 through 2002, they show that the CAFC significantly decreased the rate of revocation and overruled the first instance invalidity decision three times more often. As a result, the lower courts halved their revocation rulings and patentees appealed more likely in cases of a first instance invalidity. Cockburn et al. (2002) analyzed the CAFC rulings during the period 1997 to 2000 with respect to examiners' characteristics, but found no correlation between the

[8] The authors further find that 75% of all (partial or full) invalidation rulings in revocation proceedings are based on a lack of patentability due to newly introduced prior art.

examiners' experience, his or her workload, or the age of the patent and the outcome of the invalidation proceedings. Further, Marco (2006) estimated the probability of wrongful validity and invalidity rulings by district and appellate courts. Allison and Lemley (1998) find that juries are more patentee friendly and patents in jury trials are therefore more likely upheld. Atkinson et al. (2009) show that patents in patentee-defendant cases—where the patent challenger initiates litigation—are less likely ruled valid. According to MacGahee (2011), this effect significantly increases for cases involving continuations. Finally, Cockburn et al. (2002) and MacGahee (2011) find a positive relationship between the time a patent spends in examination and the probability of invalidation, while Fischer (2015) identifies a negative correlation.

Patent characteristics. Various patent characteristics have been analyzed regarding their correlation with the likelihood that a patent would be ruled invalid. Results have been partly contradictory. For the number of backward citations, MacGahee (2011) finds a negative relationship analyzing U.S. cases between 1929 and 2006, while Fischer (2015) finds a positive correlation for German invalidity suits between 1985 and 1999. Whereas Miller (2013), who analyzes litigated patents subject to obviousness and anticipation decisions in the U.S. between 2000 and 2010, finds no significant effect, Fischer (2015) identifies a positive correlation of the number of forward citations and the probability that a patent survives a revocation attempt partially or fully. Fischer (2015) and MacGahee (2011) show a negative relationship with the number of claims (Fischer, 2015; MacGahee, 2011). Fischer (2015) further specifies that a larger number of claims positively correlates with partial, but not with complete survival—a plausible finding since a larger number of claims makes it more likely that at least one is upheld in invalidation proceedings. Equally plausible, Fischer (2015) finds a positive correlation between the number of IPC classes a patent is assigned to and its surviving invalidity proceedings without any amendments. Results on the effect of an application-to-grant lag are contradictory. Whereas MacGahee (2011) shows a positive correlation between the time a patent spends in the examination procedure and the likelihood of an invalidation, Fischer (2015) reveals a positive relationship of grant lag and the probability of a complete survival. Finally, Atkinson et al. (2009), MacGahee (2011), and Miller (2013) find that older patents are less likely to be ruled invalid, while Cockburn et al. (2002) find no such correlation.

Characteristics of the parties in suit. There is little research on how characteristics of the parties in suit correlate with invalidation probability. Using patent portfolio size as a proxy for company size, Fischer (2015) finds no effect on the outcome of a revocation proceeding on

plaintiff and defendant side. Miller (2013), using a binary coding of small vs. large firms[9], did not find any size effects. Further, there is evidence that corporate as well as foreign patentees are more likely to win, i.e., to have their patents upheld (MacGahee, 2011). In addition, while an invalidation ruling is less likely if the defendant in the infringement suit is a foreign firm, patents owned by licensing firms seem to face a higher probability of being ruled invalid (Miller, 2013). Table 1 provides an overview of the aforementioned studies including the determinants influencing selection into a revocation proceeding as well as the outcomes.

Table 1 here

2.2.3. Oppositions

During the first nine month after grant of a patent by the European Patent Office (EPO), or the German Patent and Trademark Office, the patent's validity can be challenged by any third party through an opposition (post-grant review) before the respective patent office. Just as revocation actions before the Federal Patent Court, oppositions may be triggered by an infringement suit[10], but in the majority of cases are filed as a preventative action against "potentially dangerous patents of competitors" (Bardehle Pagenberg Partnerschaft, 2013a). Doing so is an attractive option not least because the fees for an opposition are rather low. Cost estimates for each instance and party reach from €15,000 to € 25.000 (Harhoff and Reitzig, 2004) to € 50,000, depending on the complexity of the case (Bardehle Pagenberg Partnerschaft, 2013a).

We focus in our study on invalidation proceedings rather than including oppositions as well, for the following reason. The fact that they are initiated by third parties (while nearly all revocation actions are triggered by infringement suits) implies that patents perceived as weak should be opposed more often. Since a relatively large share of all granted patents are opposed (roughly 5%)[11], this suggests that the opposition procedure weeds out quite a few weak patents.

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[9] "Large" companies are product firms that are publicly traded or listed on the Forbes' list of the largest private companies.

[10] During the opposition period, invalidation of the patent can only be effected through an opposition; a suit before the Federal Patent Court is possible only after that period. Accordingly, a defendant in an infringement suit filed during the opposition period needs to resort to an opposition (or to wait until the end of the opposition period) if it wants to take legal steps to invalidate the patent.

[11] See, e.g., Bardehle Pagenberg Partnerschaft (2013a), Calderini and Scellato (2004), Caviggioli et al. (2013), Harhoff et al. (2007), Scellato et al. (2011). Oppositions are significantly more frequent than invalidation proceedings (Harhoff et al.,

In fact, approximately one-third each are fully revoked, maintained with amendments, and fully maintained.[12] Accordingly, those still in force after the end of their respective opposition period should be more robust. By focusing on invalidation proceedings rather than also including oppositions we thus obtain a more conservative estimate of the share of all patents that would be invalidated if challenged.[13] Nonetheless, due to the obvious parallels between invalidation actions and oppositions it is appropriate in the context of our study to review existing research on the latter. Specifically, we report findings on the correlates of the incidence and outcome of oppositions, related to the patent and to the parties involved.

Regarding the patent, studies have demonstrated that more valuable patents are more likely to be challenged in opposition proceedings. Empirical research identified among others that the number of forward and backward citations, the number of claims, and the size of the patent family are positively correlated with the probability of facing an opposition (Caviggioli et al., 2013; Graham et al., 2002; Hall et al., 2009; Harhoff and Reitzig, 2004; Jerak and Wagner, 2006; Schneider, 2011). Evidence on correlates of opposition outcomes is mixed. Caviggioli et al. (2013) report a positive correlation with patent value indicators such as backward citations and number of claims on the survival likelihood. Family size, however, shows a positive correlation with a revocation probability. Furthermore, Graham et al. (2002) identified a higher amendment probability for highly cited patents and patents with many claims.

With respect to characteristics of the parties involved, Harhoff and Hall (2002) were able to show that oppositions in the haircare industry repeatedly occur between larger firms. Contrary to this finding, Calderini and Scellato (2004) provide evidence from the telecommunication industry that larger firms more likely oppose patents of smaller companies, whereas the probability of opposition between two larger players is significantly lower. In his study on cases in the plant biotechnology sector, Schneider (2011) discovered that patents of companies with larger patent portfolios more likely face an opposition. However, there seems to be no statistical difference between large firms and small firms as measured by the number of employees (Schneider, 2011).

2003; Harhoff and Reitzig, 2004). Out of 24,116 granted patents with the priority year 1979, 2,036 were opposed and only 73 of them were subject to a revocation proceeding (Harhoff et al., 2003).

[12] See Caviggioli et al. (2013), Harhoff et al. (2007), Scellato et al. (2011). The outcomes of German national cases are quite similar to the EPO cases (cf. Caviggioli et al., 2013; Scellato et al., 2011).

[13] One could also consider oppositions as part of the granting process. In this sense, our study focuses on those patents whose granting process is fully completed.

Thus, the identified correlates of invalidation probability are by and large consistent between oppositions and invalidity actions. The key difference, as explained, resides in the way either is initiated, which should select more robust patents into invalidity actions than into oppositions.

2.3. Revocation proceedings in Germany

Before illustrating the methods and data used, we provide a brief description of German revocation proceedings. Once the opposition period has expired, the validity of a German patent or the German part of a European patent can be challenged through revocation proceedings. Such proceedings can be initiated by any legal entity, both for its own and for a third party's purpose (Keukenschrijver, 2014). Nevertheless, a revocation suit is usually filed as a counterclaim to an ongoing infringement dispute (Keukenschrijver, 2014). Due to the German bifurcated patent litigation system, questions regarding infringement and invalidation are not subject to the same proceeding. Whereas district courts (*Landgerichte*) are responsible for the first instance of infringement proceedings, the first instance jurisdiction over revocation disputes lies with the Federal Patent Court. The district courts examine alleged infringement assuming validity of the patent in suit.[14] However, according to §148 ZPO the court can stay an infringement proceeding (even ex officio) if it expects a (partial) revocation of the patent in a co-pending revocation proceeding (Keukenschrijver, 2014).[15]

Once a revocation proceeding has been filed with the Federal Patent Court, the judges (who are technically trained) have to decide on whether the patent at stake is valid, partially invalid, or invalid. The reasons for a patent revocation are based on §22 PatG in conjunction with §21 PatG and can be classified as follows: non-patentability of the subject-matter; lack of sufficiently clear and complete disclosure of the invention, enabling a person skilled in the art to carry out the invention; usurpation of essential contents of the patent by the patentee; inadmissible extension of the subject matter beyond the content of the application as originally filed; and extension of the scope of protection (Keukenschrijver, 2014). Liedel (1979) identified non-patentability based on a lack of inventive step as the predominant reason for an invalidation ruling. An action is dismissed—and the patent therefore maintained as granted—if the claim is inadmissible or the examination shows that the claimed invention is patentable.

[14] Invalidity of the patent-in-suit is an inadmissible defense. A revocation proceeding has to be filed with the Federal Patent Court.

[15] Practically this is done quite rarely and only if the probability of a (full or partial) revocation is considered to be high.

Whereas “invalid” and “valid” are unambiguous decisions, a partial invalidity ruling is not. However, it can usually be interpreted as either “invalid” or “valid” in the context of the infringement case that triggered it, depending on the fate of the claims relevant in that case. The parties in the revocation case may also restrict their challenge, or defense respectively, to a subset of all claims. The plaintiff may request a partial invalidation of the patent, contesting only certain claims. The court then only examines those claims the plaintiff filed invalidation for. A “partial invalid” ruling in line with the plaintiff’s filing effectively amounts to a full invalidation from the plaintiff’s point of view (Liedel, 1979). In turn, the defendant has the option to restrict its defense to a limited number of claims. Only these claims will be subject to the court action, while the non-defended claims become by operation of law invalid (Keukenschrijver, 2014). In this case the patent can only be ruled partial invalid—if some or all of the defended claims are upheld—or invalid if the defended claims are ruled invalid. An indication of whether a “partial invalid” decision means a success for the plaintiff or the defendant is the filing of an appeal by one or the other party.

In total approximately two-third of the first instance decisions on the merits are appealed before the Federal Court of Justice (Stauder and Luginbuehl, 2009) where five legally trained judges of the X. Senate decide on the validity of the patent within one oral hearing (Keukenschrijver, 2014). The Federal Court of Justice ruling is final and cannot be appealed. If the first-instance plaintiff withdraws its claim in a Federal Court of Justice proceeding, the patent remains valid notwithstanding the first instance ruling. A withdrawal of the appellate proceeding will result in a legally binding first instance decision.

The central question addressed in this study concerns the selection effects that lead from the population of all active patents to those that enter revocation proceedings which end with a decision (see Figure 1). In this population there is an unknown number of infringed patents (1). Some of these infringed patents and some of the non-infringed patents get involved into infringement proceedings (2). A certain share of these patents (plus very few others) are subject to a revocation proceeding (3). Cases that are not settled reach a first instance decision at the Federal Patent Court (4). Some of these rulings are appealed before the Federal Court of Justice and result in a final ruling unless they are settled (5). On each stage there are several legal, patent related and party specific determinants influencing the probability that a patent proceeds to the next level.

Figure 1 here

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3. Method and Data

3.1. Interviews

To gain further insights into the nature of patent revocation proceedings as well as the factors influencing these proceedings at the various stages of the process, we conducted 12 semi-structured interviews with 15 different interviewees, three by phone and nine face-to-face. Interview partners were selected to be experienced in our field of study, i.e., familiar with infringement and revocation proceedings and senior with respect to professional experience. Furthermore, the interviews should provide a comprehensive view of the topic, thus, interviewees were selected from different professions as well as different technological backgrounds. Among them are judges from the Federal Patent Court and Federal Court of Justice, representatives of the patent office, and lawyers and patent attorneys—both with and without former industry experience.

As a framework we used an interview guideline based on the invalidation process and the various selection stages (see 3.1.). We started with general questions related to infringement and revocation proceedings. With respect to our research questions we guided the interviewees through the whole process and asked for determinants influencing each stage. We further asked the participants to assess the importance of these factors. The questions had an open form and often initiated lively discussions. In total we conducted 19 hours of interviews, corresponding to an average duration of 1h 35min. The interviews were fully recorded, transcribed, encoded and evaluated using QRS's nVivo 10 software.

3.2. Survey

Based on the interview results and research questions, we developed a five page paper-based questionnaire to gain further insights into the proceeding's selection process. The first part of the survey contains personal questions on the participants' professional career. The second and third part address the determinants of infringement and revocation proceedings. The survey concludes with questions on the participants' employers. We mainly use closed-ended questions with default response options on a five-point Likert scale, complemented by some open questions.[16] Before the launch, we performed pre-tests with five patent attorneys and two patent scholars.

Potential participants were identified using a ranking of patent law firms in the field of patent litigation as well as a list of further recommended patent law firms, both provided by the

[16] For some of the questions we allowed for a "no answer possible" response.

JUVE publishing house's "JUVE Handbook German Commercial Law Firms 2013".[17] By thoroughly searching and analyzing the ranked law firms' websites, we were able to identify patent attorneys and lawyers engaged in infringement and in particular in revocation related proceedings. This approach resulted in a list of 1,165 potential participants (among them are 74% patent attorneys and 26% lawyers) working for 100 different national and international law firms with offices in Germany. Following an announcement in the newsletter of the chamber of patent attorneys in Germany, we sent out the paper-based questionnaire including cover letter, survey and a postpaid envelope. Besides, we set up an online version of the survey to provide a choice of medium to the participants. After two follow-ups (four and seven weeks after the initial distribution), we achieved an overall response rate of 28%. The survey demographics show that 64% of the respondents are patent attorneys, 36% lawyers. The median participant was involved into 6-10 revocation proceedings and shows 11-15 years of revocation suit experience.[18] Nearly 40% of the respondents work in law firms with more than 150 employees.

3.3. Court decisions

In order to examine the factors influencing a patent's likelihood of revocation we set up a unique dataset of case, party, and patent specific variables merging different data sources. The dataset contains all decisions connected to patent validity by the Federal Patent Court between 2000 and 2012 as well as the corresponding appellate decisions by the Federal Court of Justice from 2000 until January 13, 2015.

We sourced the first instance decisions including a wide range of case specific information from the Federal Patent Court's decision database, which provides online access to all its decisions since 2000.[19] We complemented the first instance data with the related second instance decisions using the online judgment database of the Federal Court of Justice providing access to all its decisions (by the X. Senate) since 2000.[20]

We verified our findings by comparing them with a list of all patent validity cases (including their outcomes) filed at the Federal Court of Justice within the last two centuries, which was provided by the Federal Court of Justice's X. Senate. This information allowed us to identify

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[17] See http://www.juve.de/handbuch/de/2013/ranking/24450#ranking-24450; http://www.juve.de/handbuch/de/2013/weiterekanzleien/24450#weiterekanzleien-24450.

[18] To preserve anonymity, these variables were asked as categories.

[19] See: http://www.bundespatentgericht.de/cms/index.php?option=com_wrapper&view=wrapper&Itemid=77&lang=en.

[20] See:http://juris.bundesgerichtshof.de/cgi-in/rechtsprechung/list.py?Gericht=bgh&Art=en&Datum=Aktuell&Sort=12288.

the appellate cases without a final decision on the merits, yet with out of court settlements or withdrawals.

For a multivariate analysis of court decisions, we enriched the dataset with a wide range of party specific characteristics for the years 2010 to 2012.[21] Further, to control for a possible influence that the parties' law firms might have on the outcomes, we collected a variety of information regarding each law firm involved in the cases under consideration.[22] Finally, patent level data was collected from both the *PATSTAT* database and the *INPADOC* as well as from the German patent office's *DPMAregister* and the European patent office's *Espacenet*.

To test for differences between the challenged patents and patents not involved in revocation proceedings we constructed a control group by matching a randomly selected granted patent (that had not been subject to revocation proceedings) to every patent in the database using filing month as the matching criterion.[23] In Section 5.2 we provide a more detailed view on the variables employed in the multivariate analysis.

4. Results: Interviews and Survey

4.1. Legal stability of patents in revocation suits

In order to draw conclusions for the population of all patents from the observed invalidity decisions, we need to identify the selection effects at work (see Figure 1). As discussed earlier, economic reasoning suggests that patents involved in infringement cases should be more robust than the average patent, while the subsequent selection stage—in most cases the filing of an invalidity suit by the alleged infringer—should favor less robust patents. This reasoning is confirmed by our interviews, from which we report specific quotes for illustration:

21 We restricted the dataset to the period of 2010 to 2012 for two reasons. First, availability of company specific data for earlier years is limited. Second, court decisions are anonymized, so that we had to identify the parties in a time-consuming process from other sources. Whereas the defendant in a patent revocation proceeding is basically the owner of a patent at the time of the case filing (van Hees and Braitmayer, 2010), to identify the corresponsing plaintiff we sourced the relevant information from the global IP case law database darts-ip, performed internet searches, asked defendants to provide the respective plaintiff's name, and requested access to the Court's case records for the remaining proceedings. As sources for party specific information we used Bureau van Dijk's Orbis database, Thomson Reuters's Thomson ONE, LexisNexis's Nexis, Bisnode's Hoppenstedt Firmendatenbank für Hochschulen, and the German Federal Gazette.

22 Analyzing the law firms' homepages as well as the JUVE publishing house ranking on patent law related law firms we identified characteristics such as employee count, specialization and awards such as a listing on the JUVE ranking.

23 To be able to control for technology as well as patent office specific differences, we did not base the matching on IPC classes or on whether the patent was granted by the DPMA or the EPO.

I wouldn't have proceeded on the basis of a non-robust patent [...]. (Patent attorney)

As expected, our interviews reveal that the positive selection at the first stage is counteracted by the next step leading to revocation proceedings:

"Well, I assume after all that there would have been some sort of tangential result, affecting the granted patent [...] And this in turn indicates to me that the suits which are filed are not without any prospect of success." (Patent attorney)

These findings are in line with our survey results. As Table 2 shows, survey participants perceive patents involved in infringement proceedings as slightly more robust than the average (mean on a scale from -2, "significantly less valid", to +2, "significantly more valid": 0.20; test median=0: p=0.000). The net effect of both selection stages is seen to be zero (mean: 0.05; test median=0: p=0.206). That is, both interviewees and survey participants consider patents that enter invalidity suits to be of average robustness.

4.2. Influence of firm size and budget

Liedel (1979) reports estimates that the share of invalidations could be increased to up to 95% if the plaintiff sued without time and budget restrictions. While this is clearly a bold estimate, it is plausible that invalidation becomes more likely the more time and budget is spent on searching for prior art. According to our interviews, firm size by itself does not have an influence, but—unsurprisingly—does correlates with budget spent on the case:

"The little guy has an even chance if he deploys equal means. And what is unfortunately observable time and again is that they do not do this. Either they are poorly represented or they're not willing to invest the money in decent research." (Patent attorney)

"Not necessarily. Well, size doesn't really confer any premium in itself." (Judge)

Budget spent is seen to matter, though:

"If you search long enough and with sufficiently large amounts of money that you put into the thing, you'll eventually find something." (Patent attorney)

"Well, as regards the success of revocation suits, I do think that the investment in good lawyers pays off to some extent" (Patent attorney)

Survey results are mostly in line with interview findings (Table 2). Plaintiff size is seen to increase the probability of an invalidation ruling slightly (mean: 0.19; test median=0: p=0.000), whereas defendant size is considered to have no effect (mean: 0.00; test median=0: p=0.892). Regarding budget, survey participants clearly believe that a larger budget will strongly increase the probability of finding new prior art suitable to achieve an invalidation ruling (mean: 1.41; test median=0: p=0.000).

4.3. Revocation suits that settle

As already shown in Section 4.1., a large share of revocation suits settle (55% of the first instance proceedings). Economic reasoning suggests that these settlements would have ended in (partial of full) invalidations had they been brought to a decision. By settling when invalidation is imminent, and the patent holder providing a free license to the plaintiff, the parties in suit save on costs while maintaining the patent as a barrier against outsiders.[24] In contrast, when a "valid" ruling is to be expected, the patentee improves its position vis-à-vis third parties by receiving the confirmation of validity of its patent.

Interview results are consistent with this argument:

"In my opinion, this means that behind these very high figures there are, in essence, potentially successful revocation suits." (Patent attorney)

"They would probably also all have been revoked, or many would have been revoked." (Judge)

"These certainly are the weak patents. If one is pretty sure of one's position, then one sees it through." (Patent attorney)

[24] Lemley and Shapiro (2005: 76) note in this context: "Indeed, virtually every patent licensing and cross-licensing agreement can be seen as the settlement of a patent dispute. However, the frequency or form of such private settlements may not serve the public interest, because litigating patent disputes to completion tends to generate positive externalities, by clarifying the limits of patent protection if the patent is upheld or encouraging wider use of the innovation if the patent is invalidated."

Survey participants confirm the interview results that settled proceedings would more likely have led to a partial revocation (mean: 0.57; test median=0: p=0.000) as well as a full revocation decision (mean: 0.18; test median=0: p=0.002) than proceedings that ended with a decision.

4.4. Newly found prior art vs. differing evaluation standards

Invalidation decisions on German patents are taken by the Federal Patent Court or the Federal Court of Justice, while the grant decision is taken by the EPO or the German Patent and Trademark Office. In our context, the respective court's decision is relevant since it *defines*, by law, validity of the litigated patent. Nonetheless, in order to suggest policy measures that could address the issue of latently invalid patents, it is important to understand if the large number of invalidations by the German courts is due to newly found prior art or to differing evaluation standards. According to our interviews, the former clearly matters:

> *"Well, in those cases I spontaneously recall now, new prior art was virtually always submitted." (Patent attorney)*

> *"I do believe, however, that in most cases new prior art will be found or submitted." (Patent attorney)*

Yet, differing evaluation standards also play a role:

> *"And here, the thing is that, in my view – this is just my personal estimation now – 50 percent of the decisions taken by the Federal Patent Court would have reached the opposite conclusion at the European Patent Office." (Patent attorney)*

> *"That happens, too. That is, that prior art was not considered as relevant in the examination procedure by the EPO as it was before the Federal Patent Court in a revocation suit - that happens a lot." (Patent attorney)*

The survey (Table 2) clarifies that newly found prior art is seen as the predominant invalidation reason at the Federal Patent Court (mean: 4.46, between "important" (4) and "very important" (5)), while differing evaluation standards (Federal Patent Court vs. DPMA/EPO) are considered as being between "somewhat important" (3) and "important" (4), with a mean of 3.49.

4.5. Resulting selection bias

Overall, patents in first-instance invalidation proceedings that conclude with a decision should be more robust than the average patent: the net selection effect of patents in infringement suits, followed by the selection of a share of these patents (and very few others) into invalidation suits is seen to be neutral, while the selection into decisions by the Federal Patent Court (as opposed to settlements) favors more robust patents.

Since the subsequent selection into the second instance (see Figure 2) is fairly symmetric among the first-instance outcomes, and the second-instance decisions show largely the same distribution as those in the first instance, there is no indication of a selection bias in the step from first to second decision. However, the logic that settlements are more likely to occur if an invalidation appears imminent applies equally at the second instance. Again, thus, patents in invalidation cases concluding with a decision should be more robust than the average patent.

5. Results: Analysis of court decisions

5.1. Descriptive analysis

We base our study on a descriptive analysis of all final decisions by the German Patent Court (BPatG) and the court of second instance (BGH) during the course of patent revocation proceedings in Germany between 2000 and 2012. In total we analyzed 1,125 different first instance decisions and 355 corresponding BGH rulings on 1,092 different German Patents.[25] Figure 2 illustrates the process of a German revocation action including first and second instance proceedings and statistics.

Figure 2 here

Due to data restrictions we only consider those proceedings that reached a judgment on the merits (in line with Liedel (1979) as well as van Zeebroeck and Graham (2014)). During the analyzed period, on average roughly 46% of the first instance revocation proceedings reached such a final ruling.[26] Fifty-four percent of the proceedings were concluded with a withdrawal

[25] Number includes 789 German parts of European patents as well as nine supplementary protection certificates (SPC) and ten patents granted in the German Democratic Republic.

[26] We calculated this number by analyzing the yearly statistics of the Federal Patent Court on revocation proceedings reported in the respected March issues of the Blatt für Patent-, Muster- und Zeichenwesen (Blatt für PMZ).

of the revocation action or settlements between the parties. According to the Federal Patent Court decisions in our dataset, 25% of the cases were dismissed and the patent therefore upheld. The court partially revoked the patent in 37% of the cases and decided on a full revocation in 38%. Analyzing the partial revocations reveals that 45% of them conform to the plaintiff's claim. Effectively, thus, we can consider these rulings as full revocations in the context of the corresponding infringement suit, increasing the share of fully revoked patents from 38% to 55%.[27] Also, a certain share of those "partial invalid" decisions where the plaintiff had claimed a full invalidation may be tantamount to an effective full invalidation, though we cannot determine this share precisely.

Sixty-nine percent of the first instance decisions on the merits are appealed at the Federal Court of Justice. 45% of these appellate proceedings reach a final decision (the split being 24% fully valid, 43% partially revoked and 33% fully revoked).28 The outcomes of the cases reaching their final judgment at the first or second instance are 26% "valid", 40% "partially revoked", 34% "fully revoked". Revocation rates at the first, second and first or second instance are roughly the same for patents granted by the European Patent Office and for patents granted by the German Patent Office. Table 3 summarizes the decisions at each stage as well as the final decisions of the first or second instance.

Table 3 here

According to Table 4, the majority of patents in revocation proceedings protect inventions in the mechanical engineering sector (35%), a finding in line with Cremers et al. (2013). A closer look at the outcomes for each industry reveals that the (partial) revocation rate is almost equal to or higher than 70% across all industries. The highest number of (partial) revocation judgments is pronounced in the Instrumental and Chemistry sectors (83%).

Table 4 here

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[27] See Section 3.1.

[28] Fifty-five percent of the cases did not reach a final decision due to the following reasons: 36% withdrawal of the appeal; 49% withdrawal of the claim; 4% settlements at court; 6% pending as of March, 2015; 5% other.

5.2. Multivariate Analysis

Tables (5) and (6) provide the content and the descriptive statistics of the variables that we use in a multivariate analysis of decisions issued 2010 to 2012. In order to control for potential correlation between the unobserved determinants of the selection in revocation proceeding and its outcome we ran a set of Heckman regressions.[29] For identification, we used the size of the defendant since (a) the respective variables are highly significant in the selection equation and insignificant in the outcome equation, and (b) based on economic consideration should have an effect in the selection stage (since in most cases the defendant had triggered the revocation proceeding by filing an infringement suit) but not in the outcome stage (where the plaintiff's ability to find additional prior art is critical). In none of the specifications did we find a significant effect of the Heckman correction, in line with Miller (2013). We thus report separate models for the selection and the outcome stage (Tables 7, 8).

Table 5 and Table 6 here

We start with a probit model of the selection into a revocation proceeding. Using various patent characteristics as well as patent owner attributes as explanatory variables, we compare patents that have entered a revocation action to a randomly drawn sample of matched patents that have not been involved in revocation proceedings (see 5.2.1).[30] In a second step, we analyze correlates of the revocation likelihood for the adjudicated patents (see 5.2.2) in the first instance (Table 7) and in the final instance (Table 8) using ordered probit and standard probit models.

Table 7 and Table 8 here

5.2.1. Correlates of entering a revocation proceeding

Patent characteristics. With respect to the factors describing the patents' economic value, our findings are in line with Fischer's (2015). The selection models in Table 7 and Table 8 consistently indicate that a higher number of a patent's forward citations as well as family

[29] Specifically, we employ the STATA command "heckprob" if the outcome variable is binary (as in Models II and III) and the "heckoprobit" command if it is ordinal (as in Model I).

[30] See 3.3 for the matching criterion applied.

members go along with a higher likelihood of being challenged in a revocation proceeding. Our findings further confirm that patents that had been subject to opposition proceedings (and were maintained in part or in full) are more likely to be subject to a revocation proceeding. The number of referenced non-patent literature is negatively correlated with the probability of being challenged in an invalidation proceeding, whereas broader patents (measured by their number of claims) more likely enter a revocation suit. Regarding technology fields, patents related to electrical engineering are more likely to enter invalidation proceedings.

Patent owner characteristics. We find a negative correlation ($p<0.01$) of company size and the probability of the patent being contested. In Table 7, but not in Table 8, we observe a negative correlation with foreign ownership ($p<0.05$), in line with Miller (2013).

5.2.2. Correlates of patent revocation likelihood

Models Ia/b in Table 7 and Table 8 employ an ordinal dependent variable that equals 0 when the patent was fully upheld, 1 if it was ruled partially invalid, and 2 if it was fully invalidated. The dependent variable in models IIa/b equals 1 if the patent was ruled fully invalid and 0 otherwise. In models IIIa/b, the dependent variable equals 1 if the court decided on partial or full revocation.

Characteristics of the parties in suit. As assumed, defendant size does not show any influence on an invalidation ruling. In contrast, Models Ia/b and IIa/b show a highly significant effect of plaintiff size on the probability of a full revocation ruling, both in the first (Table 7) and in the final instance (Table 8).[31] The patent owner's country of residence has mostly no effect. For the plaintiff, not being headquartered in Germany has no effect in the first instance, but interestingly a highly significant positive effect in the final instance.

Patent characteristics. In line with Miller (2013), our analysis of the first instance decisions (Table 7) indicates a negative relationship between the number of backward citations and the probability of the patent being ruled fully invalid (Models Ia/b, and IIa/b).[32] As in Miller (2013), none of our models reveals a significant correlation between the number of forward citations and the invalidation likelihood. The same holds for the number of claims, a result contrary to the work by Fischer (2011a) and MacGahee (2011).[33] In contrast, examination at the EPO, having survived an opposition, and the IPC class "Instruments" correlate positively with the

[31] According to Models IIIa/b (Table 7) there seems to be no significant effect on a (partial) invalidation decision.

[32] This finding, however, does not hold for the models IIIa/b controlling for an influence on a (partial) invalidation.

[33] In line with Miller (2013) our findings indicate a negative, however not significant, relationship.

likelihood that the patent is fully upheld (models IIIa/b). Finally, all our models show that older patents are less likely to be ruled invalid, in line with Atkinson et al. (2009), MacGahee (2011), and Miller (2013).

The results on the final instance decisions (Table 8) are in line with those in Table 7 regarding backward citations, opposition and, partly, EPO examination. Differences exist mainly with respect to IPC classes, IPC4 class counts (in models IIIa/b), backward citations to NPL, and patent age.

5.3. Predictions

Based on our estimates (Tables (7) and (8)) we ran out-of-sample predictions for the set of matched patents, setting plaintiff size variables to the average values of the adjudicated patents (which, by construction of the size categories, equal 0.33). Table 9 summarizes the predictions.

Table 9 here

For the first instance, we find the unconditional mean of the probability of a partial or full invalidation of a randomly drawn patent to be between 80.9% and 82.8%, corresponding to an increase of about 5% over the actual rate of 78.7% in 2010 to 2012. For the final decision, we find an unconditional mean of roughly 79%. The average out-of-sample prediction for the probability of a full revocation in the first instance is around 47%, compared with a share of 45.2% in actual decisions. For the final instance, average predicted probabilities are around 45%, compared with the actual rate of 41%.

We further perform the same set of predictions by assuming to have only large plaintiffs in our regressions, a situation that comes closer to the ideal of a perfectly thorough search for prior art and thus to fulfillment of the (theoretical) requirement of absolute novelty. In this alternative specification, the average predicted probability of a partial or full invalidation in the first instance increases to 87% (86% in Model IIIa, 87% in Model IIIb, 87% in Model Ia, and 88% in Model Ib), while that of a full revocation becomes 61% (58% in Model Ia, 59% in Model Ib, and 63% in Models IIa/b). For a final decision in the first or second instance, the average predicted probability of a (partial or full) invalidation increases to 86% (85% in Model IIIa, 84% in Model IIIb, and 88% in Models Ia/b), and that of the full revocation to 62%.

How do our predictions perform on the level of individual observations within the sample? We predict, for each observation, the most likely outcome and compare this prediction with the

actual outcome in contingency tables (Table 9, Appendix A1).[34] Comparing the share of correct predictions with that of the null model (which predicts for all observations the most frequent outcome) shows that our model performs relatively well in predicting full invalidation: compared with the null model, it predicts 13.8% (I. instance, A1.3) and 15.0% (final instance, A1.4) more observations correctly. It performs badly in predicting "partial or full invalidation," with an improvement over the null model by only 0.7% (A1.5) and 0.9% (A1.6). As expected, the performance of the ordered probit model lies between those of the two probit models, with improvements over the null model by 5.9% (A1.1) and 11.9% (A1.2). Thus, our model is not particularly accurate in predicting individual outcomes. This comes as no surprise, however; given the complexity and diversity of legal cases the goal of making accurate predictions on the level of the observation would be presumptuous. We thus stick to the more modest goal of predicting average outcomes on an aggregate level.

6. Discussion

Invalidation rates of litigated patents are high in most countries, and in particular in Germany. Our qualitative and quantitative studies consistently indicate that the average invalidation rate for randomly drawn patents would even be above the actual rate for adjudicated patents. While the numbers are specific to Germany, we conjecture—based on our qualitative study—that the finding of a higher invalidation rate out-of-sample than in-sample carries over to other legislations. And even if this is not the case—Miller (2013) predicts for innovation-based validity decisions an out-of-sample invalidation rate of 28% compared with 37% in-sample—latent invalidity rates are likely high in any country.

Are these findings worrisome? Lemley (2001) argues that patent offices are "rationally ignorant" of the objective validity of patents because examining each patent in detail would be far too costly: "Because so few patents are ever asserted against a competitor, it is much cheaper for society to make detailed validity determinations in those few cases than to invest additional resources examining patents that will never be heard from again." This view has been criticized, among others, by Farrell and Merges (2004) on the grounds that the incentives to challenge and defend issued patents are strongly skewed. We concur with their critique. While we follow Lemley's (2001) argument that a more detailed examination of each patent application would not solve the problem, and an examination as thorough as in a court case would be unfeasible

[34] Comparing the average predicted probability of each outcome with the actual frequency of this outcome in the sample is not informative since the two are, by construction of the estimator, identical (e.g., Train, 2003, p. 72).

for patent offices, we do not consider "rational ignorance" a satisfactory explanation. Also patents that are never litigated but latently invalid create inefficiencies: they unduly deter third parties from using the patented invention, create a risk for others of being litigated, cause cost for their application, examination, grant, and monitoring, and obscure the patent system by their sheer quantity. Needless to say, the error of denying patents that would have deserved grant also occurs, and setting the priorities correctly between avoiding one or the other type of error is non-trivial (Meurer, 2009). Yet, the error of omitting relevant prior art can only work toward granting too many patents, and so it appears more relevant to us.

So how could the problem that the majority of German patents—and also large shares of all patents in other countries—are latently invalid be addressed? Increasing fees for examination and grant may go some way in reducing the number of legally weak patent applications, though only to the extent that patent value as perceived by the applicant correlates with robustness. However, this measure would likely affect financially constrained applicants more than legally weak patents.

To address the issue that most patents are latently invalid, we suggest increasing the required inventive step in the examination procedure significantly (including, where applicable, potential opposition proceedings), while increasing the inventive step required for upholding a patent in later validity challenges only to a smaller degree. Essentially, we thus propose a certain "presumption of validity," but with a different rationale than the correspondent doctrine in U.S. patent law. That doctrine requires courts to regard a granted patent as valid unless the opposing party provides "clear and convincing evidence," a standard that favors the patentee in a validity dispute (e.g., Jaffe and Lerner, 2006, p. 50).[35] Lichtman and Lemley (2007) criticize the presumption of validity as inappropriate, given the patent office's resource and informational constraints. We concur with their view, and suggest a presumption of validity as a purely pragmatic mechanism: to ensure that most granted patents clear the intended inventive step hurdle of s even in the light of additional prior art found after grant, one stipulates a significantly larger inventive step for grant—say, $2s$—but increases the threshold for upholding patents in validity challenges only to a smaller extent (1.5 s, say).

The measure we propose would reduce the likelihood of grant mainly for those patents that under the current system are latently invalid: since the main reason for invalidation is newly submitted prior art (Hess et al., 2014), patents that are latently invalid will, on average, have a

[35] A parallel in German patent law is that a pending invalidity suit may be a reason to stay simultaneous infringement proceedings regarding the same patent only if invalidation of the patent in suits appears highly likely.

smaller inventive step than other patents. In Appendix A2, we illustrate our argument with a mathematical model of patent invalidation. Importantly, rejecting these patents on the grounds of an increased inventive step standard would be far simpler for examiners than finding the prior art that makes them latently invalid. A desirable side effect of the proposed measure would be a reduction in the overall number of patents. At the same time, requiring an inventive step significantly higher for grant than that required for upholding a patent in a validity challenge makes it harder to invalidate granted patents, thus providing much-needed legal certainty to patentees and other parties alike. While such double standards may be unsatisfactory from a dogmatic point of view, they would be an effective measure against the serious problem that most patents, certainly most German patents, are latently invalid.

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Figures and Tables

Figure 1: Invalidation process and selection stages

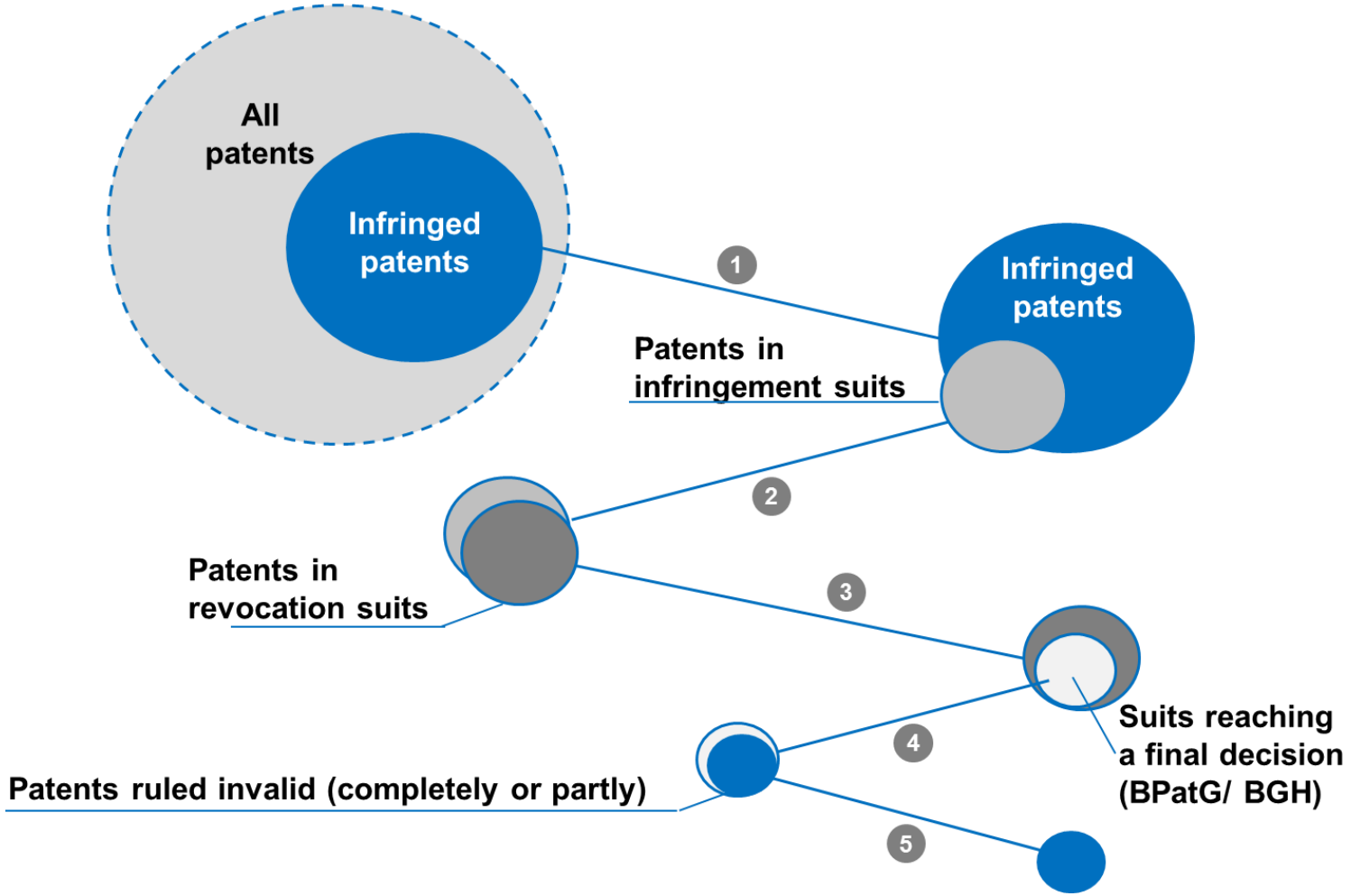
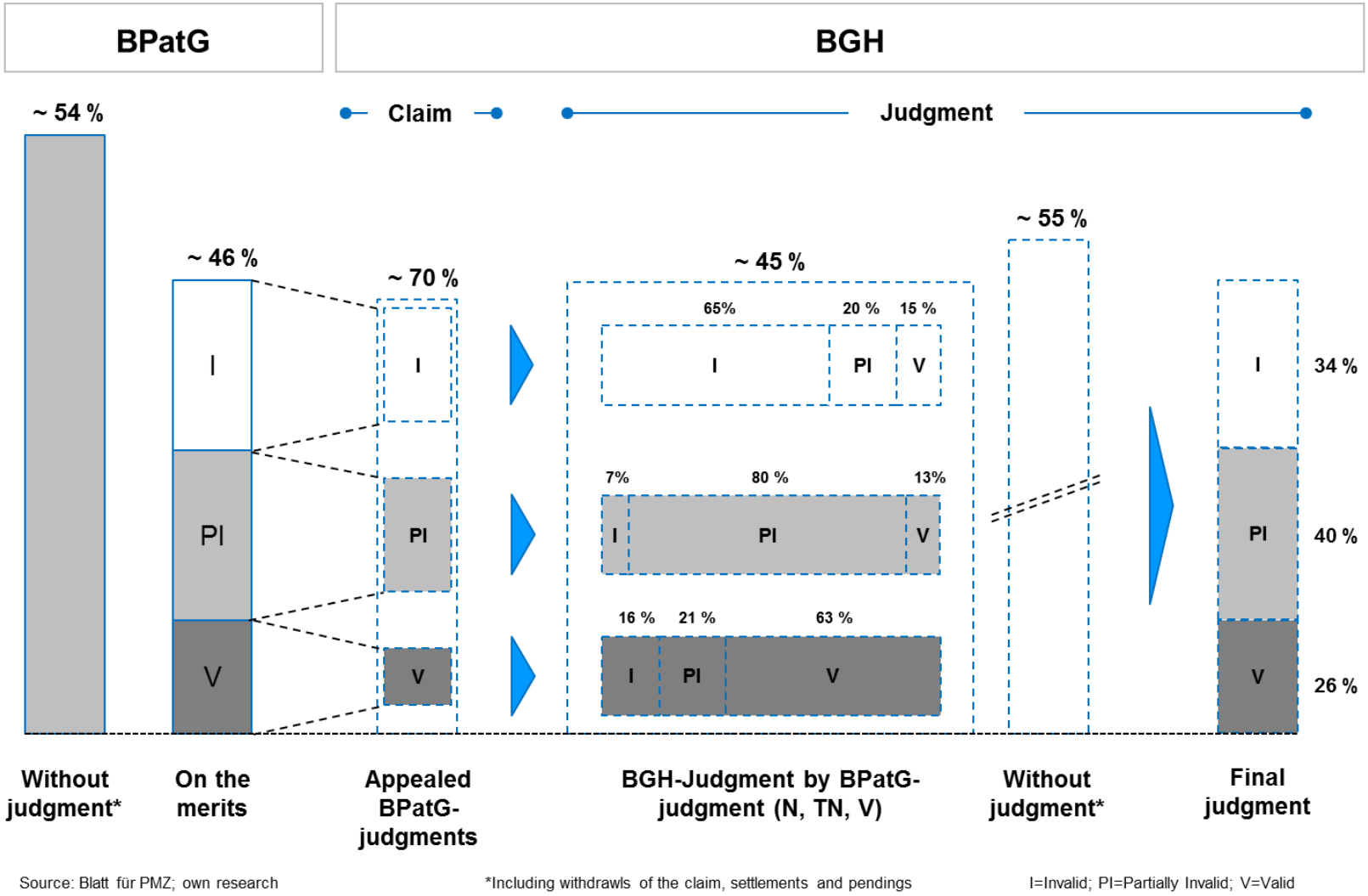


Figure 2: Process and statistics of German revocation actions



*Including withdrawals of the claim, settlements and pendings I=Invalid; PI=Partially Invalid; V=Valid

Table 1: Studies on determinants of patent revocation

Determinant	Study	Multivariate correlation
Selection into revocation proceeding		**….with selection into proceeding**
Patent characteristics		
Number of patent forward citations	Fischer (2015)	+
Number of patent backward citations	Fischer (2015)	+
Number of patent claims	Fischer (2015)	+
Number of assigned IPC classes	Fischer (2015)	-
Contested in opposition proceeding	Fischer (2015)	+
Number of family members	Fischer (2015)	+
Examination at the EPO	Fischer (2015)	-
Application-to-grant lag	Fischer (2015)	-
Patent owner characteristics		
Patent Owner = Individual	Fischer (2015) Miller (2013)	+ -
Patent Owner = Foreign firm	Miller (2013)	-
Patent Owner = Licensing Firm	Miller (2013)	+
Determinants of revocation likelihood		**…with revocation likelihood**
Patent characteristics		
Number of forward citations	Fischer (2015) Miller (2013)	- not sign.
Number of backward citations	Fischer (2015) MacGahee (2011)	+ -
Number of claims	Fischer (2015) MacGahee (2011)	- -
Number of assigned IPC classes	Fischer (2015)	-
Contested in opposition proceeding	Fischer (2011b)	not sign.
Examination at the EPO	Fischer (2015)	not sign.
Application-to-grant lag	Fischer (2015) MacGahee (2011)	- +
Patent Age	Atkinson et al. (2009) MacGahee (2011) Miller (2013)	- - -
Patent owner characteristics		
Company Size (size of patent & trademark portfolio)	Fischer (2015)	not sign.
Patent Owner = Corporate	MacGahee (2011)	-
Patent Owner = Foreign firm	MacGahee (2011)	-
Patent Owner = Licensing Firm	Miller (2013)	+

Table 2: Survey results

***Legal robustness**: Patents in infringement/ revocation proceedings, compared to average patent:*

	significantly less valid (-2)	somewhat less valid (-1)	roughly same validity (0)	somewhat more valid (+1)	significantly more valid (+2)	N	Median	Mean	Wilcoxon signed-rank test
Infringement proceedings	3%	5%	66%	22%	4%	297	0	0.20	0.000
Revocation proceedings	2%	11%	70%	14%	3%	295	0	0.05	0.206

***Firm size/budget:** Influence of parties' size on likelihood of invalidation: The likelihood of invalidation…*

	significantly decreases (-2)	considerably decreases (-1)	does not increase (0)	somewhat increases (+1)	significantly increases (+2)	N	Median	Mean	Wilcoxon signed-rank test
Size Plaintiff	0%	4%	76%	16%	4%	231	0	0.19	0.000
Size Defendant	0%	9%	82%	8%	1%	232	0	0.00	0.892

***Firm size/budget:** Influence of plaintiff's budget on likelihood of finding relevant prior art:*

Plaintiff's budget	0%	0%	6%	47%	47%	296	1	1.41	0.000

***For cases that settle:** what would have been the outcome in case of a decision compared to proceedings ending with a decision?*

	significantly less likely (-2)	somewhat less likely (-1)	roughly same probab. (0)	somewhat more likely (+1)	significantly more likely (+2)	N	Median	Mean	Wilcoxon signed-rank test
Probability of partial invalidation	0%	9%	39%	35%	17%	206	1	0.57	0.000
Probability of complete invalidation	6%	15%	41%	33%	5%	206	0	0.18	0.002

***Newly found prior art vs. differing evaluation standards**: Reasons for invalidation by Federal Patent Court after grant by patent office:*

	not at all important (1)	low importance (2)	somewhat important (3)	important (4)	very important (5)	N	Median	Mean	One-sample t test
Newly found prior art	0%	1%	2%	47%	50%	297	4	4.46	0.000
Differing Evaluation Standards	1%	4%	44%	46%	5%	285	4	3.49	0.000

Table 3: Revocation rates across the instances (2000 – 2012)

	I. Instance			II. Instance			I. Instance or II. Instance		
	DE	EP	**Total**	DE	EP	**Total**	DE	EP	**Total**
Decision									
Valid	25%	25%	**25%**	22%	24%	**24%**	24%	27%	**26%**
Partially Revoked	39%	36%	**37%**	43%	43%	**43%**	41%	40%	**40%**
Fully Revoked	36%	39%	**38%**	35%	33%	**33%**	35%	33%	**34%**

Table 4: Revocation rates across industries (2000 – 2012)

	Industries					
	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields	**Total**
Decision						
Valid	24%	17%	18%	31%	29%	**25%**
Partially Revoked	32%	45%	40%	36%	34%	**37%**
Fully Revoked	44%	38%	43%	33%	37%	**38%**
Total	**18%**	**14%**	**18%**	**35%**	**15%**	**100%**

Table 5: Description of variables used in the empirical study

Variables	Description
Plaintiff	
Plaintiff size large (Revenue)	Dummy variable=1 if plaintiff revenue (at date of case filing) can be assigned to the largest tercile
Plaintiff size medium (revenue)	Dummy variable=1 if plaintiff revenue (at date of case filing) can be assigned to the middle tercile
Plaintiff size small (revenue)	Dummy variable=1 if plaintiff revenue (at date of case filing) can be assigned to the smallest tercile
Plaintiff individual	Dummy variable=1 if plaintiff is an individual
Plaintiff headquarter not Germany	Dummy variable=1 if plaintiff's country of residence (headquarter) is not Germany
Defendant/Patent Owner	
Defendant/Owner size large (Revenue)	Dummy variable=1 if defendant/owner revenue (at date of case filing) can be assigned to the largest tercile
Defendant/Owner size medium (revenue)	Dummy variable=1 if defendant/owner revenue (at date of case filing) can be assigned to the middle tercile
Defendant/Owner size small (revenue)	Dummy variable=1 if defendant/owner revenue (at date of case filing) can be assigned to the smallest tercile
Defendant/Owner individual	Dummy variable=1 if defendant/owner is an individual
Defendant/Owner NPE	Dummy variable=1 if defendant/owner can be classified as a non-practicing entity
Defendant/Owner headquarter not Germany	Dummy variable=1 if defendant's/owner's country of residence (headquarter) is not Germany
Patent characteristics	
IPC: Electrical Engineering	Dummy variable=1 if patent can be assigned to the electrical engineering industry (based on IPC-class)
IPC: Instruments	Dummy variable=1 if patent can be assigned to the instruments industry (based on IPC-class)
IPC: Chemical Engineering	Dummy variable=1 if patent can be assigned to the chemical industry (based on IPC-class)
IPC: Mechanical Engineering	Dummy variable=1 if patent can be assigned to the mechanical engineering industry (based on IPC-class)
IPC: Others	Dummy variable=1 if patent can't be assigned to one of the industries mentioned above
IPC: Complex industry	Dummy variable=1 if patent can be assigned to a complex industry (based on IPC-class)
IPC4 class count	Number of different IPC subclasses on a 4 digit level (logarithm)
Number of claims (log)	Number of patent claims (logarithm)
Family size (log)	Number of the patent's docdb-family members (logarithm)
German Part of EP patent	Dummy variable=1 if patent is German part of an European patent
Grant lag (log)	Number of days between the application and the grant date (logarithm)
Opposition	Dummy variable=1 if patent was restricted or fully upheld during an opposition procedure
Forward citations, 5 years (log)	Number of citing patents until 5 years after publication (logarithm)
Backward citations (log)	Number of references to patent literature (logarithm)
Backward citations to NPL (log)	Number of references to non-patent literature (logarithm)
Patent Age at Case Filing (1000 days)	Patent age at date of the case filing (divided by 1000)

Table 6: Descriptive statistics and test of equality of means/proportions

	I: Involved patents					II: Matched patents					p-values[1]
	Mean	*Median*	*Std. dev*	*Min*	*Max*	*Mean*	*Median*	*Std. dev*	*Min*	*Max*	*I vs. II*
Plaintiff											
Plaintiff size large	0.334	0	0.473	0	1						
Plaintiff size medium	0.334	0	0.473	0	1						
Plaintiff size small	0.331	0	0.471	0	1						
Plaintiff individual											
Plaintiff not German	0.557	1	0.498	0	1						
Defendant/Patent Owner											
Def./Own size large	0.226	0	0.419	0	1	0.439	0	0.497	0	1	0.000
Def./Own size medium	0.334	0	0.473	0	1	0.334	0	0.473	0	1	1.000
Def./Own size small	0.439	0	0.497	0	1	0.226	0	0.419	0	1	0.000
Def./Own individual	0.049	0	0.217	0	1	0.075	0	0.264	0	1	0.180
Def./Own NPE	0.039	0	0.195	0	1	0.003	0	0.057	0	1	0.002
Def./Own not German	0.570	1	0.496	0	1	0.702	1	0.458	0	1	0.001
Patent characteristics											
IPC: Electrical Engineering	0.262	0	0.441	0	1	0.180	0	0.385	0	1	0.015
IPC: Instruments	0.151	0	0.354	0	1	0.125	0	0.331	0	1	0.347
IPC: Chemical Engineering	0.164	0	0.371	0	1	0.249	0	0.433	0	1	0.009
IPC: Mechanical Engineering	0.292	0	0.455	0	1	0.334	0	0.473	0	1	0.256
IPC: Others	0.131	0	0.348	0	1	0.111	0	0.315	0	1	0.457
IPC: Complex industry	0.741	1	0.439	0	1	0.649	1	0.478	0	1	0.014
IPC4 class count	1.997	2	1.268	1	9	1.931	2	1.248	1	8	0.520
Number of claims (log)	2.495	2.485	0.616	0.693	4.143	2.392	2.398	0.622	0.693	4.234	0.039
Family size (log)	1.968	2.079	1.022	0	4.419	1.602	1.792	0.805	0	4.277	0.000
German Part of EP patent	0.734	1	0.442	0	1	0.705	1	0.457	0	1	0.417
Grant lag (log)	7.386	7.409	0.553	5.796	8.660	7.347	7.411	0.554	5.252	8.583	0.382
Opposition	0.190	0	0.393	0	1	0.043	0	0.202	0	1	0.000
Forward citations, 5 years (log)	0.612	0	0.835	0	3.367	0.406	0	0.636	0	2.944	0.000
Backward citations (log)	1.570	1.609	0.596	0	3.258	1.452	1.386	0.574	0	3.219	0.013
Backward citations to NPL (log)	0.384	0	0.592	0	2.639	0.447	0	0.569	0	3.434	0.177
Patent Age at Case Filing (1k days)	4.273	4.038	1.505	0.675	8.56						
Observations			**305**					**305**			**610**

[1] t-test and test of proportions, respectively

Table 7: Correlates of selection into BPatG revocation proceedings with decisions, and of outcomes (2010 – 2012; probit / ordered probit)

	Selection		Ia – 3 stages		Ib – 3 stages		IIa – fully inv.		IIb – fully inv.		IIIa – partly/fully		IIIb – partly/fully	
	Coef.	*S.E.*	*Coef.*	*S.E.*	*Coef.*	*S.E.*	*Coef.*	*S.E.*	*Coef.*	*S.E.*	*Coef.*	*S.E.*	*Coef.*	*S.E.*
Plaintiff														
Plaintiff size large			0.396**	(0.198)	0.450**	(0.187)	0.598***	(0.227)	0.640***	(0.214)	0.124	(0.260)	0.202	(0.250)
Plaintiff size medium			-0.047	(0.169)	-0.022	(0.165)	0.102	(0.202)	0.138	(0.198)	-0.218	(0.217)	-0.194	(0.216)
Plaintiff individual			-		-		-		-		-		-	
Plaintiff not German			0.171	(0.143)	0.166	(0.142)	0.138	(0.169)	0.129	(0.167)	0.184	(0.183)	0.171	(0.181)
Defendant/Patent Owner														
Def./Own. size large	-0.942***	(0.159)	0.161	(0.200)	0.119	(0.194)	0.079	(0.228)	0.037	(0.222)	0.336	(0.274)	0.293	(0.270)
Def./Own. size medium	-0.505***	(0.154)	-0.189	(0.180)	-0.210	(0.174)	-0.204	(0.203)	-0.210	(0.196)	-0.167	(0.219)	-0.227	(0.213)
Def./Own. individual	-0.431	(0.278)	-0.168	(0.384)	-0.168	(0.386)	0.142	(0.397)	0.169	(0.398)	-0.591	(0.425)	-0.655	(0.433)
Def./Own.: NPE	0.226	(0.580)	0.215	(0.490)			0.075	(0.485)			0.310	(0.620)		
Def./Own. not German	-0.323**	(0.139)	0.199	(0.163)	0.174	(0.154)	0.117	(0.188)	0.085	(0.179)	0.265	(0.204)	0.279	(0.196)
Patent characteristics														
IPC: Electrical Engineering	0.502**	(0.209)	0.126	(0.255)	0.141	(0.243)	0.134	(0.269)	0.110	(0.261)	0.055	(0.301)	0.117	(0.286)
IPC: Instruments	0.198	(0.225)	0.229	(0.239)	0.215	(0.239)	0.010	(0.289)	-0.052	(0.286)	0.761**	(0.339)	0.830**	(0.337)
IPC: Chemical Engineering	-0.116	(0.280)	-0.102	(0.365)	-0.079	(0.364)	-0.350	(0.401)	-0.369	(0.403)	0.372	(0.451)	0.479	(0.436)
IPC: Mechanical Engineering	0.023	(0.201)	-0.279	(0.239)	-0.286	(0.238)	-0.350	(0.274)	-0.378	(0.274)	-0.146	(0.280)	-0.130	(0.272)
IPC: Complex industry	0.057	(0.188)	-0.410	(0.273)	-0.387	(0.275)	-0.533*	(0.296)	-0.460	(0.294)	-0.152	(0.309)	-0.193	(0.311)
IPC4 class count	-0.057	(0.051)	0.038	(0.054)			-0.015	(0.064)			0.140	(0.085)		
Number of claims (log)	0.156*	(0.092)	-0.090	(0.120)			-0.151	(0.139)			-0.053	(0.152)		
Family size (log)	0.495***	(0.088)	0.000	(0.085)			-0.010	(0.094)			0.014	(0.104)		
German Part of EP patent	-0.272	(0.166)	-0.271	(0.194)	-0.266	(0.168)	-0.128	(0.217)	-0.156	(0.188)	-0.527**	(0.255)	-0.473**	(0.228)
Grant lag (log)	0.143	(0.106)	0.241*	(0.138)	0.261*	(0.136)	0.250	(0.158)	0.251	(0.156)	0.236	(0.179)	0.291	(0.182)
Opposition	0.910***	(0.215)	-0.111	(0.198)	-0.133	(0.191)	0.133	(0.205)	0.109	(0.202)	-0.414*	(0.226)	-0.401*	(0.212)
Forward citations, 5 years (log)	0.239***	(0.078)	0.118	(0.084)	0.113	(0.082)	0.156	(0.096)	0.127	(0.093)	0.084	(0.108)	0.103	(0.105)
Backward citations (log)	0.050	(0.103)	-0.313**	(0.119)	-0.312***	(0.116)	-0.337**	(0.137)	-0.331**	(0.135)	-0.251	(0.172)	-0.257	(0.160)
Backward citations to NPL (log)	-0.210**	(0.106)	-0.068	(0.127)			-0.128	(0.144)			0.042	(0.157)		
Patent Age at Case Filing (1k days)			-0.161***	(0.058)	-0.161***	(0.058)	-0.154**	(0.065)	-0.146**	(0.065)	-0.183***	(0.071)	-0.193***	(0.070)
Constant	-1.650*	(0.846)					-0.153	(1.234)	-0.654	(1.154)	0.352	(1.391)	0.118	(1.342)
Constant cut 1			-0.650	(1.065)	-0.323	(0.995)								
Constant cut 2			0.369	(1.064)	0.693	(0.994)								
Observations	610		305		305		305		305		305		305	
F-Test	0		0.000		0.000		0.014		0.003		0.000		0.000	
Pseudo Likelihood	-343.9		-296.1		-296.8		-187.7		-188.9		-133.3		-135.1	
Wald's chi-squared	124.6		51.34		49.13		40.43		38.75		55.33		50.88	
Degrees of freedom	19		23		18		23		18		23		18	
Pseudo R-squared	0.187		0.074		0.077		0.107		0.101		0.156		0.145	

*** p<0.01, ** p<0.05, * p<0.1

Table 8: Correlates of selection into revocation proceedings with final decisions at BPatG or BGH, and of outcomes (2010 – 2012; probit / ordered probit)

	Selection		Ia – 3 stages		Ib – 3 stages		IIa – fully inv.		IIb – fully inv.		IIIa – partly/fully		IIIb – partly/fully	
	Coef.	*S.E.*	*Coef.*	*S.E.*	*Coef.*	*S.E.*	*Coef.*	*S.E.*	*Coef.*	*S.E.*	*Coef.*	*S.E.*	*Coef.*	*S.E.*
Plaintiff														
Plaintiff size large			0.565**	(0.239)	0.598***	(0.227)	0.844***	(0.285)	0.898***	(0.274)	0.231	(0.302)	0.263	(0.286)
Plaintiff size medium			-0.077	(0.200)	-0.048	(0.195)	-0.041	(0.248)	0.007	(0.241)	-0.103	(0.252)	-0.064	(0.245)
Plaintiff individual			-		-		-		-		-		-	
Plaintiff not German			0.529***	(0.174)	0.505***	(0.171)	0.561***	(0.209)	0.538***	(0.204)	0.493**	(0.217)	0.472**	(0.213)
Defendant/Patent Owner														
Def./Own. size large	-1.049***	0.190	0.192	(0.243)	0.180	(0.240)	0.241	(0.288)	0.226	(0.284)	0.185	(0.318)	0.162	(0.312)
Def./Own. size medium	-0.617***	0.177	-0.186	(0.201)	-0.168	(0.198)	-0.081	(0.238)	-0.069	(0.234)	-0.282	(0.246)	-0.278	(0.243)
Def./Own. individual	-0.471	0.308	0.039	(0.400)	0.056	(0.396)	0.524	(0.455)	0.532	(0.452)	-0.444	(0.476)	-0.420	(0.470)
Def./Own.: NPE														
Def./Own. not German	-0.198	0.160	-0.220	(0.189)	-0.224	(0.188)	-0.358*	(0.228)	-0.359*	(0.226)	-0.130	(0.237)	-0.138	(0.234)
Patent characteristics														
IPC: Electrical Engineering	0.685***	0.237	-0.558**	(0.298)	-0.551**	(0.295)	-0.318	(0.346)	-0.312	(0.341)	-1.024***	(0.411)	-1.015***	(0.407)
IPC: Instruments	0.416	0.260	-0.594**	(0.322)	-0.602**	(0.321)	-0.624*	(0.377)	-0.635*	(0.374)	-0.665*	(0.453)	-0.678*	(0.450)
IPC: Chemical Engineering	0.121	0.324	-0.416	(0.419)	-0.412	(0.415)	-0.407	(0.501)	-0.357	(0.493)	-0.663	(0.557)	-0.635	(0.547)
IPC: Mechanical Engineering	0.162	0.238	-0.799***	(0.303)	-0.808***	(0.303)	-0.781**	(0.373)	-0.778**	(0.371)	-1.032***	(0.410)	-1.032***	(0.409)
IPC: Complex industry	0.075	0.221	-0.404	(0.290)	-0.372	(0.285)	-0.579	(0.363)	-0.505	(0.353)	-0.322	(0.355)	-0.275	(0.346)
IPC4 class count	-0.076	0.059	0.095	(0.077)	0.090	(0.075)	0.014	(0.094)	0.008	(0.091)	0.225**	(0.108)	0.215**	(0.103)
Number of claims (log)	0.183*	0.110	-0.041	(0.147)			-0.114	(0.181)			-0.077	(0.188)		
Family size (log)	0.492***	0.104	-0.056	(0.107)			-0.046	(0.123)			-0.055	(0.133)		
German Part of EP patent	-0.242	0.196	-0.386	(0.238)	-0.437**	(0.199)	-0.375	(0.277)	-0.408*	(0.232)	-0.461	(0.305)	-0.522**	(0.257)
Grant lag (log)	0.135	0.120	0.131	(0.170)			0.155	(0.200)			0.063	(0.214)		
Opposition	0.826***	0.260	-0.390*	(0.235)	-0.384*	(0.235)	-0.037	(0.287)	-0.031	(0.285)	-0.758***	(0.286)	-0.744***	(0.285)
Forward citations, 5 years (log)	0.226**	0.088	0.030	(0.100)	0.012	(0.098)	0.084	(0.120)	0.053	(0.117)	-0.036	(0.124)	-0.050	(0.122)
Backward citations (log)	0.039	0.118	-0.292**	(0.143)	-0.291**	(0.140)	-0.482***	(0.174)	-0.487***	(0.172)	0.023	(0.193)	0.011	(0.191)
Backward citations to NPL (log)	-0.294**	0.122	-0.205	(0.151)	-0.208	(0.149)	-0.485***	(0.190)	-0.495***	(0.189)	0.131	(0.192)	0.128	(0.191)
Patent Age at Case Filing (1k days)			-0.103	(0.069)	-0.076	(0.060)	-0.110	(0.081)	-0.070	(0.068)	-0.093	(0.085)	-0.077	(0.075)
Constant	-1.724*	0.959					1.004	(1.492)	1.590**	(0.668)	1.809	(1.609)	1.954***	(0.721)
Constant cut 1			-1.624	(1.265)	-2.287***	(0.567)								
Constant cut 2			-0.614	(1.261)	-1.281**	(0.558)								
Observations	454		227		227		227		227		227		227	
F-Test	0.000		0.000		0.000		0.000		0.000		0.003		0.004	
Pseudo Likelihood	-259		-218.7		-219.3		-123.9		-124.6		-111.1		-111.4	
Wald's chi-squared	93.11		57.09		57.09		59.40		60.34		44.84		45.39	
Degrees of freedom	18		22		19		22		19		22		19	
Pseudo R-squared	0.177		0.111		0.109		0.191		0.187		0.153		0.150	

*** p<0.01, ** p<0.05, * p<0.1

Table 9: Out-of-sample predictions of invalidation probabilities

	I. instance decision (BPatG)				Final (I. or II.) instance decision (BPatG/BGH)			
	Out-of-sample prediction			Actual shares in-sample	Out-of-sample prediction			Actual shares in-sample
	Obs.	*Mean*	*Std. Dev.*		*Obs.*	*Mean*	*Std. Dev.*	
Ia -Full Model: 3 Stages								
Patent fully valid	305	0.188	0.113	0.213	227	0.213	0.132	0.265
Patent partially invalid	305	0.330	0.061	0.334	227	0.330	0.060	0.330
Patent fully invalid	305	0.482	0.163	0.452	227	0.457	0.179	0.405
Patent partially or fully invalid	305	0.812		0.787	227	0.787		0.735
Ib - Reduced Model: 3 Stages								
Patent fully valid	305	0.191	0.116	0.213	227	0.218	0.131	0.265
Patent partially invalid	305	0.329	0.061	0.334	227	0.332	0.058	0.330
Patent fully invalid	305	0.480	0.165	0.452	227	0.450	0.175	0.405
Patent partially or fully invalid	305	0.809		0.787	227	0.782		0.735
IIa - Full Model: Fully invalid								
Patent fully invalid	305	0.462	0.152	0.452	227	0.439	0.214	0.405
IIb - Reduced Model: Fully invalid								
Patent fully invalid	305	0.455	0.148	0.452	227	0.433	0.217	0.405
IIIa - Full Model: Partly/Fully invalid								
Patent partially/fully invalid	305	0.828	0.140	0.787	227	0.802	0.129	0.735
IIIb - Reduced Model: Partly/Fully invalid								
Patent partially/fully invalid	305	0.827	0.143	0.787	227	0.796	0.128	0.735

Note: Plaintiff size variables for matched patents are set to average values of litigated patents. In-sample predictions are identical (with differences below 0.004) to actual shares in-sample.

Appendix A1: In-Sample Predictions by Observation

A1.1: Ia – 3 stages: I. Instance decision (BPatG)

Actual decision	Prediction				Correctly predicted…
	Valid	*Partially Revoked*	*Fully Revoked*	*Total*	
Valid	7	51	7	**65**	**by model: 51.1%**
Partially Revoked	0	69	33	**102**	**by null model: 45.2%**
Fully Revoked	2	56	80	**138**	**Improvement: 5.9%**
Total	**9**	**176**	**120**	**305**	

A1.2: Ia – 3 stages: I. or II. Instance decision (BPatG/BGH)

Actual decision	Prediction				Correctly predicted…
	Valid	*Partially Revoked*	*Fully Revoked*	*Total*	
Valid	17	36	7	**60**	**by model: 52.4%**
Partially Revoked	8	54	13	**75**	**by null model: 40.5%**
Fully Revoked	2	43	48	**92**	**Improvement: 11.9%**
Total	**27**	**132**	**68**	**227**	

A1.3: IIa – fully invalid: I. Instance decision (BPatG)

Actual decision	Prediction			Correctly predicted…
	Valid / Partially Revoked	*Fully Revoked*	*Total*	
Valid / Partially Rev.	131	36	**167**	**by model: 68.5%**
Fully Revoked	60	78	**138**	**by null model: 54.8%**
Total	**191**	**114**	**305**	**Improvement: 13.8%**

A1.4: IIa – fully invalid: I. or II. Instance decision (BPatG/BGH)

Actual decision	Prediction			Correctly predicted…
	Valid / Partially Revoked	*Fully Revoked*	*Total*	
Valid / Partially Rev.	115	20	**135**	**by model: 74.4%**
Fully Revoked	38	54	**92**	**by null model: 59.5%**
Total	**153**	**74**	**227**	**Improvement: 15.0%**

A1.5: IIIa – partially/fully invalid: I. Instance decision (BPatG)

Actual decision	Prediction			Correctly predicted…
	Valid	*Partially / Fully Revoked*	*Total*	
Valid	12	53	**65**	**by model: 79.3%**
Partially / Fully Rev.	10	230	**240**	**by null model: 78.7%**
Total	**22**	**283**	**305**	**Improvement: 0.7%**

A1.6: IIIa – partially/fully invalid: I. or II. Instance decision (BPatG/BGH)

Actual decision	Prediction			Correctly predicted…
	Valid	*Partially / Fully Revoked*	*Total*	
Valid	12	48	**60**	**by model: 74.4%**
Partially / Fully Rev.	10	157	**137**	**by null model: 73.6%**
Total	**22**	**205**	**227**	**Improvement: 0.9%**

Appendix A2: A model of patent grant and invalidation

We consider a certain time period and all inventions for which patent protection is sought during this period. The number of these inventions is normalized to unity. Each invention is characterized by its inventive step (s_i) relative to the state of the art known to the examiner at the time of application (which we normalize to $s = 0$). We denote the minimum inventive step required for grant by s_g. The inventions under consideration are distributed along the *s* axis according to a distribution density $\varphi(s)$, so that the number of granted patents obtains as $\int_{s_g}^{\infty} \varphi(s)\, ds$.

We assume that, in case a patent is challenged, the plaintiff finds relevant prior art with probability p. We abstract from other reasons for invalidation and from variations in the plaintiff's effort. If the plaintiff does find prior art, then the piece of newly found prior art with the highest inventive step is characterized by s_p. This prior art invalidates the patent under consideration if the invention's adjusted inventive step, $s_i - s_p$, is below the threshold for upholding the patent, s_u. (Typically, this threshold equals that for grant, s_g. However, we are interested in the effects of introducing different thresholds.) Conditional on new prior art being found, the distribution of s_p along the s axis is described by the distribution density $\psi(s_p)$. Thus, the probability that a patent with inventive step s_i is invalidated in litigation is given by $p \int_{s_i - s_u}^{\infty} \psi(s_p)\, ds_p$. For the share of all latently invalid patents (i.e, those that would be invalidated in litigation) we then obtain:

$$S_{inv} = \int_{s_g}^{\infty} \varphi(s_i) \int_{s_i - s_u}^{\infty} p\, \psi(s_p)\, ds_p\, ds_i \Big/ \int_{s_g}^{\infty} \varphi(s_i)\, ds_i$$

Differentiation with respect to s_u yields

$$\frac{dS_{inv}}{ds_u} = \int_{s_g}^{\infty} \varphi(s_i)\, p\, \psi(s_i - s_u)\, ds_i \Big/ \int_{s_g}^{\infty} \varphi(s_i)\, ds_i \; > \; 0.$$

A lengthier, but equally straight-forward calculation yields:

$$\frac{dS_{inv}}{ds_g} = -\frac{\varphi(s_g)\, p}{\left(\int_{s_g}^{\infty} \varphi(s_i)\, ds_i\right)^2} \left[\int_{s_g}^{\infty} \varphi(s_i) \left(\int_{s_g - s_u}^{\infty} \psi(s_p)\, ds_p - \int_{s_i - s_u}^{\infty} \psi(s_p)\, ds_p \right) \right] < \; 0.$$

This expression is negative because the first integral in the inner brackets stretches over a larger interval, and thus is greater, than the second (since $s_g \leq s_i$). Thus, increasing the required

inventive step for grant while keeping constant the required inventive step for upholding a patent in litigation reduces the share of patents that are invalidated in litigation. The same result is achieved by decreasing the inventive step required for upholding a patent in litigation while keeping the inventive step required for grant constant; however, this measure would inflate the number of granted patents.

As an illustrative example, consider $\varphi(s) = \psi(s) = e^{-s}$. Evaluating the above equation for S_{inv} yields $S_{inv} = \frac{p}{2} e^{s_u - s_g}$, which shows the counteracting effects of raising s_u and raising s_g. This result also demonstrates that changes in the two thresholds which leave the difference $s_u - s_g$ unchanged have, in this example, no effect; in the general case, the effect is ambiguous. In particular, "raising the bar" while leaving s_u equal to s_g has no clear effect on the share of latently invalid patents. Developing the example further, assume $s_u = s_g = 1$ and $p = 0.8$. Then, raising s_g from 1 to 2 reduces the share of latently invalid patents from 0.4 to 0.147.