Protection Heterogeneity in a Harmonized European Patent System

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This paper seeks to investigate to what extent European patent litigation has been harmonized across the Member States of the European Patent Convention. We introduce a divergent expectation model for patent infringement disputes, where both litigation and settlement are driven by patent quality, a function of both broadness and definiteness of the patent, with the technology-specific factor determining the relative weights. Under our model, patent holders and patent infringers decide whether to settle or litigate based on differences in perception of the patent's quality whereas at the trial stage it is the assessment of the absolute patent quality by the judge which decides the outcome of the case. We evaluate 1117 patent infringement and counterclaim decisions rendered by courts in the three largest patent-granting European countries – Germany, France and the United Kingdom – between 2008 and 2012 to empirically test the hypotheses flowing from our model at the trial stage. Our preliminary findings point to significant differences in patent litigation outcomes by technology, industry and jurisdiction. We particularly find evidence that patent litigation is technology-specific within and between countries. We seek to explain our results through an assessment of the value-specific patterns of the patent conflicts and thereby, find that the patent quality proxy we use significantly predicts the litigation outcome.

I. Introduction

The European policy target in patent laws over the last decades has been harmonization. A European patent is granted in a uniform examination system with a central opposition system during a nine-month period. This cornerstone was set in 1973, with the inauguration of an examination and grant system by the European Patent Office, based upon the European Patent Convention. Nevertheless, the European patent then moves in a country-by-country enforcement regime,

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where differences in patent enforcement systems and application of uniform substantial patent laws by the national courts may reflect the lack of an integrated jurisdiction. The Unified Patent Court, which is expected to receive its first cases in 2017, shall, thus, avoid or reduce intra-Community trade barriers, high costs of parallel litigation, and inconsistent decisions or strategic litigation that may follow from a fragmented court system.

From the perspective of social welfare, harmonization translates into a trade-off between the benefits of harmonization and the costs associated with it – in other words, the values of legal diversity. Whereas harmonization is driven mainly by the externalities argument, where countries with weak patent systems free ride off the positive externalities created by the stronger systems, it precludes competition amongst legal systems and experimentation. The benefits of harmonization are considered to outweigh its costs in patent laws, when balancing the two.

Of late, divergences between the uniform rules applicable to patents and their application by the judges to different industries in the United States have led to the debate on whether patent law is becoming technology-specific. Whereas in theory, patent law is governed by a general set of legal rules that does not distinguish between technologies, Burk and Lemley (2002) found evidence that courts were applying the catch-all rules differently to different industries, and hence, that patent law was technology-specific in application . The sharpness of the division was underlined by J. Allison, Lemley, and Schwartz (2015) finding that the differences in outcome before courts by both technology and industries were dramatic. Despite its crucial importance in a harmonized setting, this question has not been studied in Europe so far. Recent European studies, such as Graham and Van Zeebroeck (2014) and Cremers et al. (2013), have shown a variance in the distribution and outcome patterns of litigation across countries, but the determinants of heterogeneity were not the subject of research.

We propose a model where both litigation and settlement are driven by patent quality. We assume that patent quality depends on both broadness of the patent claim and definiteness of the patent. In our model, patent holders and patent infringers decide whether to settle or litigate based on differences in the perception of the patent's quality, i.e. based on *relative* patent quality assessments. We assume that technology-specific differences in patent definiteness exist, leading to different settlement and litigation rates across technologies. At the trial stage, the divergent expectations of the parties are no longer material, it is rather the assessment of the *absolute* patent quality by the judge, i.e. the composite of both patent broadness and definiteness, which decides the outcome of the case. The model predicts that technologies where the patent definiteness attribute can be estimated with high accuracy will have higher settlement rates. Furthermore, according to the model, the absolute patent quality will be determinative of case outcome only at the litigation stage. Therefore, in contrast to Priest and Klein (1984), the model predicts that patent litigation cases where high quality patents are under dispute will have a higher probability of success and, thus, we expect to find higher win rates in our empirical dataset.

II. Theory

A. Litigated Patents: the Tip of the Iceberg

Most patents have little monetary value[1] and, therefore, expire uninfringed[2]. Patent litigation data can always only be a subsample of both patent disputes and the entire patent universe. It is, therefore, subject to a strong selection bias. Early law and economics scholars, in particular Priest and Klein (1984) with their seminal paper, have suggested that the cases which are litigated are the hardest ones, namely those with a 50 % chance of winning and losing. The Priest-Klein hypothesis has since been extended and/or rejected by numerous authors[3]. As a result of this strong selection bias, it is suggested that no inferences can be made about legal standards from plaintiff trial win rates. We introduce a divergent expectation model for patent infringement disputes which uses building blocks of the Priest-Klein theorem and integrates these into a subjective expected utility model. We build our model in three steps: Firstly, we model the trade-off of the patent holder between settlement and trial in an expected utility setting; secondly we introduce a divergent expectations framework; and lastly, we dive deeper into the dimensions of patent quality. Under our model, and in contrast to Priest-Klein, the cases at trial do not necessarily have a 50 % chance of winning, but because of divergent expectations of the parties, a population of patent cases of different quality will end before the courts, and the latter quality will be determinative of the final outcome by the judge.

B. A Microeconomic Model of Patent Disputes

Patent holders whose patents are infringed have a discrete choice between settling or litigating such claims. Rubinfeld and Scotchmer (1993) have modeled success and defeat in litigation as two mutually exclusive states of the world in an expected utility setting. Building on this framework, we represent the patent holder's choice set in patent infringement cases as a function of patent broadness and patent definiteness – with the technology-specific factor determining the relative weights. We define broadness as the scope of coverage of a patent and definiteness as the precision of the claims specifications.

The starting point of our model is the occurrence of a patent infringement dispute. At the principal node, the patent holder can decide whether to settle or litigate his respective patent claim. By settling, he endogenizes an otherwise risky

[1] Moore (2005) and Lemley (2001)(both finding that the majority of patents lapse because of a failure of the patent holders to pay the renewal fee, indicating that there is no economic value to the protection).

[2] See Lemley (2001)(estimating that of about two million U.S. patents in force, only about 2,000 different patents are subject to court disputes and, of that, about 100 cases per year actually make it to trial).

[3] See Clermont (2009); Clermont and Eisenberg (2002); Kessler, Meites, and Miller (1996).

outcome, since he obtains certainty over the payoff at settlement – not leaving it to an exogenous decision body. As such, the settlement option appears deterministic rather than probabilistic. However, we assume that the decision agent deploys backward induction across the decision tree depicted in figure 1. Therefore, the settlement decision is ultimately rendered dependent on the uncertain trial outcome as set out below.

We first assume that the patent holder will litigate with probability $p_S(\theta)$ and settle with probability $1 - p_S(\theta)$. If he decides to litigate, he enters the ligitation lottery, where he can either win or lose. We further assume that each patent is endowed with a patent quality θ, which determines both the success probability in a patent infringement trial, denoted as $p_L(\theta)$, and the probability of an adverse outcome, i.e. the probability that the claim is not upheld at trial, denoted by $1 - p_L(\theta)$. Since the patent holder makes his decision by backward induction, we assume that the success probability at trial is determinative of the patent holder's initial settlement choice[4].

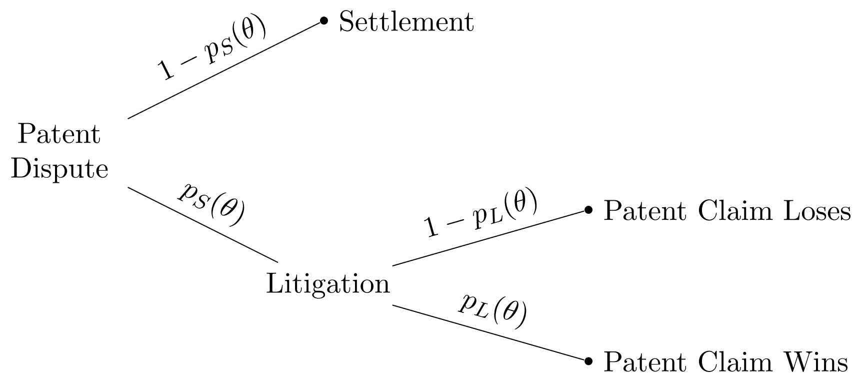

Figure 1. Litigation vs. Settlement Decision Tree

We can, therefore, model the trade-off between settlement and trial using a von Neumann-Morgenstern expected utility framework. The patent holder's utility function is, thus, given by:

$$U^{\theta}(S, L) = (1 - p_S(\theta))u(S - c_S) + p_S(\theta)u(L - c_L) \tag{1}$$

Figure 2 depicts the claimant's indifference curve: the vertical axis, labeled S, represents the patent holder's expected payoff upon settlement, whereas the horizontal axis, labeled L, represents his expected payoff upon litigation, with the

[4]A microfoundation concerning these assumptions can be derived inspired by Priest and Klein (1984), but this goes beyond the scope of this paper.

latter being the weighted sum of the win/lose state payoff. The costs associated with negotiating the settlement are denoted as c_S, while the costs of going to trial are denoted as c_L. The settlement and litigation payoff, S and L, respectively, must exceed c_S and c_L, respectively, for there to be some utility for the agent $u(\cdot) > 0$. We further assume that the costs of going to trial exceed those of settlement, $c_L > c_S$. The indifference curves I_n further to the northeast represent greater expected utility and are, thus, preferred by the patent holder, i.e. $u(I_3) \succ u(I_2) \succ u(I_1)$.

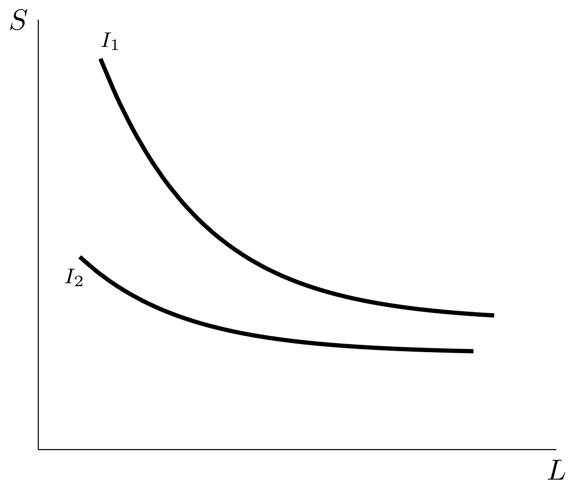

Figure 2. Litigation vs. Settlement Indifference Curves

The slope of the patent holder's indifference curve reflects the patent quality and, thus, the probability of winning a potential infringement suit $p_L(\theta)$. The slope is the marginal rate of substitution:

$$MRS = -\frac{p_S(\theta)}{(1 - p_S(\theta))} \frac{u'(S)}{u'(L)} \tag{2}$$

Therefore, the lower the patent quality, θ, the flatter the patent holder's indifference curve and the larger the patent holder's relative preference for the settlement option, since for a given settlement amount, the holder of the lower quality patent requires in return more litigation payoff units to render him indifferent.

Divergent Expectations

Both plaintiff and defendant hold different subjective expectations of the success probability at trial $p_L(\theta)$. We assume, for now, that patents are classified by agents as either high quality patents, H, or low quality patents, L, so that $\theta \in \{L, H\}$ at this stage. If no settlement is agreed, the patent quality will be assessed by the judge, resulting in the assignment of a judicial patent quality, J, which then determines the success probability at trial and defines the agents expected utility function at trial. Negotiation occurs in a bargaining zone, denoted by Z, determined by (i) the patent holder's estimation of $p_L(\theta)_H$, (ii) the patent infringer's estimation of $p_L(\theta)_I$[5] and (iii) a range of expected litigation outcomes between L_{min} and L_{max}[6].

Figure 3 illustrates a scenario where the patent holder perceives the patent to be of low quality and, therefore, as having relatively low success probability in adjudication, resulting in a relatively flat indifference curve I_l. On the other hand, the patent infringer's assessment of the patent is that it is a patent of high quality, leading to a steep settlement curve I_h. While only formed at the trial stage, I_j denotes the indifference curve using the judicial success probability. In this set-up, it would be pareto-efficient for the patent holder and the patent infringer to reach a settlement at all litigation payoff levels, L_n. This is because a bargaining zone exists in the north-east and the south-west of the patent holder and the patent infringer, respectively, i.e. in the utility-enhancing zone (represented by the gray area in figure 3).

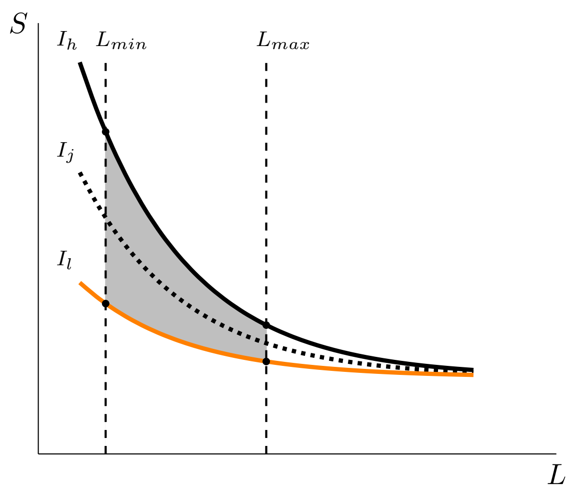

Figure 3. Patent Infringement Bargaining Area

[5]This can be plotted as a second, *quasi* indifference curve of the patent holder. It can also be thought of as the patent infringer's subjective assessment of what the patent holder's fair indifference curve should look like given his estimation of the success probability.

[6]Whereby $L_{min} = \min(L_{\text{patent holder}}, L_{\text{patent infringer}})$ and $L_{max} = \max(L_{\text{patent holder}}, L_{\text{patent infringer}})$

Patent Quality Parameters

Relaxing our assumption that patent quality can only take two discrete states to $\theta \in \{\mathbb{N}\}$, we now assume that the patent quality is a function of the patent's broadness, denoted as B, and the patent's definiteness, denoted as D, with the technology-specific factor, denoted as α^j, determining the relative weights:

$$\theta(B, D) = B^{(1-\alpha^j)} D^{\alpha^j} \tag{3}$$

Figure 4 represents $\theta(B, D) = \overline{B}^{(1-\alpha^j)} D^{\alpha^j}$, i.e. the patent value as a function of the patent's definiteness, D, with the patent's broadness held constant at different initial endowment levels. The technology-specific factor, α^j, determines whether patent broadness or definiteness has more influence on patent quality and adjudication success probability[7].

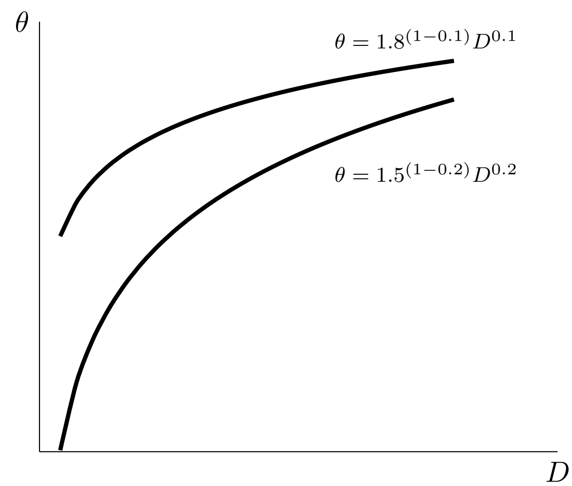

Figure 4. Patent Quality Function

We further assume that patent broadness and the technology factor are observable exogenous variables and that differences in the parties' estimation of patent quality θ are solely due to patent definiteness. We assume that the accuracy of estimating the patent's true level of definiteness is technology-specific and that

[7] To illustrate this by analogy, patent disputes can be compared to boundary disputes in land law – with the land owner and trespasser being the equivalent to the patent holder and infringer, respectively. Patent broadness can in this analogy be thought of as the size of the land protected, while patent definiteness is the equivalent of the land's fencing or trespassing detection system. The larger the size of the land, the higher the likelihood of trespassing and the easier it is for the land owner to prove in court that trespassing has occurred, the smaller the land the more important his fencing/detection systems and the evidential threshold established by courts become.

the standard error of estimate of the patent's definiteness can be denoted as:

$$\sigma^j_{est} = \sqrt{\frac{\sum_{k=1}^{N_j} (D^j_k - \overline{D}^j)^2}{N_j}} \tag{4}$$

These differences in the standard errors of estimates across technologies lead to different respective settlement rates. Put formally, if two technologies, A and B, exist with agents having more trouble to ascertain the boundaries of a patent in technology A (due to lower prediction accuracy of the patent definiteness attribute), then the initial bargaining zone is larger for this technology and the likelihood of reaching a settlement decreases.

$$\sigma^A_{est} > \sigma^B_{est} \Rightarrow Z^A > Z^B \tag{5}$$

Thus, we summarize our propositions as follows.

Proposition 1. The patent value is a function of the patent's definiteness and broadness with the technology-specific factor as a scaling factor.

Proposition 2. Only patent disputes where it is difficult for the parties to reach agreement over patent quality (and, by extension, on the success chances at trial) defined with regard to patent definiteness will proceed to trial. Where the parties can agree on the merits of the case, irrespective of whether this entails a high or a low absolute success probability, settlement will be preferred. Thus, it is only relative success probability that determines the settlement vs. litigate decision, i.e. the estimation of the success probability of the patent holder versus that of the patent infringer.

Proposition 3. If no settlement is reached, the divergent expectations of the success probability are no longer determinative of the final outcome. Rather, the key factor is the judge's assessment of patent quality and, thereby, of the adjudication success probability $p(\theta)$. It is, thus, the absolute value of $p_L(\theta)$ that matters at the adjudication stage.

Since the selection of cases proceeding to adjudication is made on relative patent quality, this does not tell us anything about absolute case quality and success likelihood at trial. Since patent quality, as determined by the judge, depends on patent broadness, definiteness and technology factor, the litigation sample does not allow us to make inferences as to the population of contiguous cases. In other words, heterogeneity in case outcomes among technologies would be in line with our model's predictions, as success probability at trial depends on a host of factors in patent disputes.

Relation with the Priest-Klein hypothesis

In relating our model to Priest and Klein (1984), we rely on the Priest-Klein model formalization of Klerman and Yoon-Ho (2014). Like our model, Priest and Klein is a divergent expectation model, where the litigation condition depends on the relative estimate of the plaintiff's versus the defendant's success probability, denoted as P_P and P_D respectively. In particular, the litigation condition, also known as the Landes-Posner-Gould condition, can be stated as follows:

$$(P_P - P_D)J > C - S$$

Thereby, J is equivalent to the litigation payout L in our model. C are the litigation costs, while S are the settlement costs, c_L and c_S in our model. In line with our assumptions, settlement will occur where the plaintiff's estimate of the success probability is below that of the defendant. Under Priest-Klein, as formalized by Klerman and Yoon-Ho (2014), the success probability estimates are further modeled as follows:

$$P_P = F_P \left[\frac{Y' + \epsilon_P - Y^*}{\sigma_P} \right]$$

and

$$P_D = F_D \left[\frac{Y' + \epsilon_D - Y^*}{\sigma_D} \right]$$

Thereby, Y' relates to the defendant's degree of fault, its equivalent in our model is patent quality θ, which determines whether the patent holder's fault can be proven in court. Both plaintiff and defendant under Priest and Klein make an estimate of Y', with an error ϵ_P and ϵ_D. This error has a mean of zero and a standard deviation of σ_P and σ_D. The judicial/legal threshold fault level is denoted a Y^*. F_P and F_D denote the standardized cumulative density functions. Therefore, under Priest and Klein, in the limit, i.e. if σ_P and σ_D approach zero, no cases will go to trial as the parties will have certainty over litigation outcome and will always settle. In turn, if σ_P and σ_D rise, there will be fewer settlements and more cases proceeding to trial. This is in line with our model of the parties estimate of patent definiteness σ_{est}, the less definite the patents get, the more litigation is to expected. As a result, since only the cases with a high estimation variance will proceed to trial, it will be difficult to empirically show a concentration of cases at the 50% win rate.

Notably, our model further differs from Priest and Klein in so far as in addition to the estimation factor (patent definiteness in our case) there are further patent dispute specific components influencing the parties estimate of success probability, namely patent broadness and precedent level. Lastly, since we adopt a two-stage model, where the judicial standard of θ is itself subject to fuzziness, we do not include it in the model of the parties estimates.

III. Hypotheses

We formulate the following hypotheses flowing from our theoretical model. We predict that the outcome of court decisions over patents is predicted by the quality and, therefore, of the technology and industry of the patent at stake.

Hypothesis 1 *The quality of the litigated patent is directional for the outcome of patent litigation.*

Explanation. Hypothesis 1 follows directly from Proposition 3. In the absence of settlement, the patent quality will be determined by the judge, resulting in the assignment of a judicial patent quality which determines the success probability at trial. The higher the quality of a patent, the more likely it is to win.

Hypothesis 2 *The technology and industry of the litigated patent is directional for the outcome of patent litigation.*

Explanation. Our model predicts that the success probability at trial depends on patent quality (see Proposition 3), a function of the patent's definiteness and broadness with the technology-specific factor determining the relative weights (see Proposition 1), which imply variations in patent quality across technologies and industries.

IV. Data

We have compiled a novel dataset comprising 1117 individual patent litigation infringement and counterclaim decisions rendered between 2008 and 2012 across Germany, France and the United Kingdom. Thus, we explicitly excluded revocation decisions and infringement counterclaims, or non-infringement declarations.

A. Germany

Because Germany operates a bifurcated system, i.e. patent infringement and patent validity cases are dealt with by different courts, we collected the patent infringement and nullity data separately. Due to this particularity, a revocation decision falling within 2.5 years after an infringement decision is artificially determined as a counterclaim[8]. Since the majority of infringement cases in Germany are heard in Dsseldorf[9], we have currently limited our collection of German infringement cases to that court. There were 468 Dsseldorf infringement cases from the Landgericht, which were gathered from the official online North Rhine-Westphalia case database[10] by filtering all cases with the keyword patent

[8]In facts, we can confirm for 120 of 123 revocation cases that it is the potential infringer that challenged the validity of the (arguably) infringing patent. Inversely, if a revocation decision occured within the same timespan before the infringement decision, the case was excluded and considered as revocation with infringement counterclaim. The latter cases are rare, Hees and Braitmayer (2010) estimate that 90% of all revocation actions are filed in response to an infringement action.

[9]In fact, the regional court in Dsseldorf hears the largest number of cases in Europe: Cremers et al. (2013, p. 43).

[10]Available under http://www.justiz.nrw.de.

appearing in the judgment. A total of 164 appellate cases were traced from the same database for the Oberlandesgericht and final appeals at the Federal Court of Justice of Germany (Bundesgerichtshof) from their online database[11]. Thereafter, we extracted the patent codes from the database of the German Patent and Trade Mark Office and from Darts-IP. Nullity actions are handled by the German Federal Patent Court (Bundespatentgericht) in Munich with appeal to the Federal Court of Justice of Germany (Bundesgerichtshof). Basing our search on the patent codes, we have gathered 90 invalidity cases from the official Federal Patent Court and 15 from the Federal Court of Justice online database[12] and compared our results with the nullification actions listed in the Patent Gazette (Patentblatt)[13]. We estimate that our dataset covers two-third of all German patent decisions rendered between 2008 and 2012[14].

B. *France*

In the absence of an official register for patent suits in France, we have built our dataset of 304 cases resp. 401 decisions from the IP data platform Darts-IP, the most exhaustive database in the field[15]. This is underlined by the fact that, apart from the French Patent Office (INPI), Véron & Associés is the main supplier of IP case data to the platform[16]. Véron & Associés has aggregated all decisions rendered by the Tribunal de Grande Instance (TGI) de Paris, the Cour d'Appel de Paris and the Cour de Cassation from the 1 January 2000 – therefore, covering all three appellate levels. Notably, the TGI provides the richest data source for French case data, since, even prior to the centralization of patent litigation in 2009 and the exclusive first instance jurisdiction of the TGI, the Parisian Court was already the most prominent patent court in France – hearing more than 50 % of all cases[17].

C. *United Kingdom*

The overwhelming majority of patent suits are heard in England and Wales[18], with a shared jurisdiction of the Patents Court (PHC), part of the High Court of England and Wales, and the Intellectual Property Enterprise Court (IPEC; formerly the Patent County Courts). While the Patent County Courts historically dealt with smaller claims of less complex variety, with a market share of less than 10 %[19], the IPEC has become, after some restructuring in the court system, an

[11]Available under https://www.bundesgerichtshof.de.
[12]Available under https://www.bundespatentgericht.de.
[13]Available under https://register.dpma.de/DPMAregister/Uebersicht.
[14]We will contact Darts-IP in this regard.
[15]Cremers et al. (2013, p. 39).
[16]Cremers et al. (2013, p. 39).
[17]*Towards an Enhanced Patent Litigation System and a Community Patent How to Take Discussions Further* (2007).
[18]Hence, we excluded the by far less important litigation in Scotland and Northern Ireland.
[19]See Helmers and McDonagh (2013) and Graham and Van Zeebroeck (2014).

effective forum for IP disputes in England and Wales[20]. Our dataset is based on the PCH and the IPEC Diary, basically listing all cases scheduled for a hearing or an application.[21] Thus, starting from the Diaries, we were able to collect 89 infringement casees from the website of the British and Irish Legal Information Institute[22], Thomson Reuter's Westlaw[23] database and on Darts-IP [24]

V. Data Coding

A. Decision Coding

We hand-coded all decisions, categorizing them across numerous dimensions, mainly by technology and industry, but also by the level of jurisdiction (first instance, intermediate appeal level and supreme court) and the nature of the ruling rendered (infringement vs. invalidity). The patent case was our unit of analysis: each outcome was coded separately for each patent, even when they were assessed in the same verdict. A win was reported if the patent holder could enforce its infringement claim before the courts, i.e. at least one of the claims was found to be infringed and that claim was, if challenged, upheld as valid.

We increased granularity by further differentiating between the arguments behind negative decisions, e.g. we coded whether an invalidity judgment resulted from the absence of a patentable subject matter (due to either the absence of novelty, an inventive step, an industrial application or a patentability exception), an insufficient disclosure or an impermissible extension of the subject matter of the patent.

B. Patent Quality

The degree of quality of patents is not directly observable, and thus can at best be inferred from patent metrics or using survey methods[25]. To circumvent the problem, we use an econometric factor model developed by Lanjouw and Schankerman (2004) that observes multiple metrics and seeks to capture the patent quality[26].

[20]Our evaluation indicates that, based on the 69 available court decisions listed on the IPEC Diary as per January 2011 on July 2015, the main share of rulings are issued in patent related cases (32.4 %) dominated by infringement trials (19.1 %), followed by copyright (20.6 %), trademark and design(19.1 % each), goodwill (2.9 %) and unavailable litigation (5.8 %).

[21]Available for the PHC under https://www.justice.gov.uk/courts/court-lists/list-patents-court-diary and for the IPEC under https://www.justice.gov.uk/courts/court-lists/intellectual-property-enterprise-court-diary.

[22]Available under https://www.bailii.org.

[23]Available under https://www.westlaw.co.uk.

[24]While the Diaries intend to be as accurate as possible, they do not furnish an exhaustive overview of UK patent litigation. Some settled cases are not listed and parties may, in some cases, request to not be listed (information derives from calls with the clerks in charge of keeping the IPEC and PHC Diaries).

[25]e.g. Harhoff, Scherer, and Vogel (1999); Gambardella, Harhoff, and Verspagen (2008).

[26]See also Hall, Thoma, and Torrisi (2007), and Dumont (1234) for a recent use of the factor model to capture patent quality and link it to the damages in French patent lawsuits and Knoll, Baumann, and Riedel (2014) for a quality-adjusted count of patent applications. In addition, see OECD (2005) for a graphic view of the evolution of patent quality proxied by two composite indexes.

We thus use the general factor model denoted:

$$y_{ki} = \lambda_k q_i + \beta X_i + \epsilon_{ki} \tag{6}$$

where y_{ki} is the observation of the k'th patent indicator for the i'th patent, q is the common factor patent quality with factor loading λ_k and X_i is any control variable. The variance of q is normalized by setting its variance to one $q \sim N(0, 1)$. Any uncommon variation which is not related to the other 'quality' indicators is captured by an idiosyncratic error ϵ_{ki}, which is assumed to be independently drawn from a $N = 0, \sigma_k^2$.

Thus, the common factor q is the unobserved characteristics of a patent that influences positively all indicators, representing our multidimensional quality measure. We use the number of forward citations over 5 years, backward citations, number of claims, and family size as indicators[27]. A principle-components factor analysis, using varimax rotations was conducted, with the four factors explaining 36% of the variance. The factor loading matrix for this final solution is presented as follows:

TABLE 1—FACTOR LOADINGS

Variable	European Patents
Number of Claims	0.79
Backward Citations	0.59
Family Size	0.65
Forward Citations 5y	-0.0

Thus, we obtain a normalized patent quality index. We can map the distribution of the patent quality in our data as follows in Figure 5.

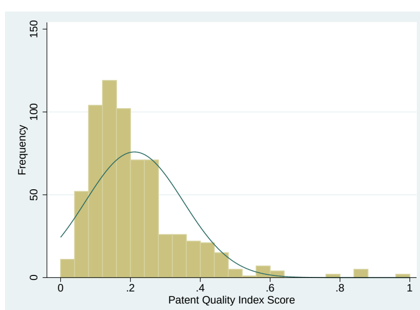

FIGURE 5. DISTRIBUTION OF THE PATENT QUALITY SCORES

[27]These four measures have all been found to be positively associated with patent value, see Lanjouw and Schankerman (2004) for a discussion on the common factor quality on all these four indicators.

C. Technology Coding

Due to the limitations of the PTO or the International Patent Classification in capturing patents at a conceptual level[28], measuring the patent breadth requires hand-coding by technology field[29].

We followed the classification developed by J. Allison et al. (2015) displayed hereafter. Each patent was first assigned to a technology area. For ten percentage of the patents, we also identified a secondary technology area. Thus, we obtain 833 patent-case pairs leading to 946 technology areas. We use this aggregated count in our econometric analysis, but additionally report the results when the primary technology area is taken by itself. We decided to reflect accurately the technology of the patented inventions at the cost of the duplication of c. 100 cases.

1) ***Mechanical:*** *An invention in which the claims cover the use of mechanical parts, either solely or predominantly, sometimes combined with heat, hydraulics, pneumatics, or other power sources or power transfer techniques.*

2) ***Electronics:*** *An invention in which the claims cover the use of traditional electronic circuitry or the storage or transmission of electric energy.*

3) ***Chemistry:*** *An invention in which the claims cover chemical reactions, chemical compounds with specific elements and proportions, and chemical processes specifying specific elements and amounts or proportions. Closely related inventions such as those on purportedly novel metal alloys and non-metallic composites are also included when the claims cover the specific components and proportions of such amalgams. This technology area includes small-molecule chemistry; DNA, antibodies, and other large molecules are included in the biotechnology category instead. Although many of the chemistry technology patents were assigned to the pharmaceutical industry category, they are also found in other industry categories such as semiconductors.*

4) ***Biotechnology:*** *An invention in which the claims cover processes involving advanced genetic techniques intended to construct new microbial, plant, or animal strains; a product created from such a process; or the way such a process or product is used in biotechnology research. Although there are a number of different genetic-engineering techniques, for several reasons we decided not to disaggregate these techniques into separate technology areas.*

[28]The classifications are inadequate for delimiting technologies since they were designed with the purpose of identifying the function of the patent to facilitate prior art searches, see J. R. Allison, Lemley, Moore, and Trunkey (2004, p. 28-29).

[29]In the words of J. R. Allison et al. (2004, p. 28-29): *if economists want to measure patent breadth, they will have to hand-code the patents by technology area or at least find a better measure than the ones that exist today.*

5) ***Software:*** *An invention in which the claims cover data processingthe actual manipulation of data (and not merely transmission, receipt, or storage of data), regardless of whether the code carrying out such data processing is on a magnetic storage medium, embedded in a chip (firmware), or resident in flash memory.*

6) ***Optics:*** *An invention in which the claims cover the use of light waves or light energy. We also assigned certain patents in the primary software classification to one of that technologys subsets, namely, software business methods. As we defined it, the software business method category includes software patents that cover models, methods, and techniques for conducting business transactions. Business-method patents are notoriously difficult to define, with possible definitions varying greatly in scope.*

D. Industry Coding

By determining the industries, we aim at assessing a further dimension of patent litigation. As such the industry classification allows us to isolate technologies that are used in several industries, or to aggregate industries relying on inventions in several technologies. The communications or transportation industries illustratively both rely on inventions in the field of electronics, software and mechanics. We follow the industry classification of J. Allison et al. (2015) and assigned each patent to one of the following industries:

1) ***Computer and Other Electronics:*** *This industry encompasses inventions of all kinds that purport to advance the state of the art in computing or computer device manufacturing, or to enhance users experiences in employing computing technology. The category includes software and computer hardware inventions that seek to serve the aforementioned purposes. Also included are inventions predominated by the use of traditional electronic circuitry when those inventions purport to advance the art in that technology or enhance users experiences in employing electronics technology. In contrast with our prior studies, here we combine the computer and traditional electronics industries because we find fewer and fewer patents covering traditional electronics without also including significant data processing elements. Traditional electronics inventions without data processing elements do continue to exist, but their frequency and importance is rapidly decliningthe industries clearly have been merging for quite some time.*

2) ***Semiconductor:*** *The semiconductor industry category includes inventions of any kind intended to advance the state of the art in researching, designing, or fabricating semiconductor chips. Technologies employed in semiconductor industry inventions may include software, chemistry, optics, and mechanical.*

3) ***Pharmaceutical:*** *The pharmaceutical industry category includes patents on drugs for treating diseases or other abnormal conditions in humans or animals, as well as processes for producing or using such drugs. The technologies found in pharmaceutical industry inventions are overwhelmingly chemistry or biotechnology.*

4) ***Medical Devices, Methods, & Other Medical:*** *This industry category includes , non-biotechnology inventions of any kind used for research on, or for the diagnosis or treatment of, diseases or other abnormal conditions in humans or animals. Patents on processes and products for pharmaceutical purposes are not included in this category. All of the different technology fields are represented in the medical industry category.*

5) ***Biotechnology:*** *This category includes those inventions that are in the biotechnology technology category that do not relate to the production of pharmaceutical compositions or medical diagnostics or treatment, but that instead purport to advance the science of biotechnology itself.*

6) ***Communications:*** *The communications industry category includes inventions of all kinds intended to advance the state of the art in communications. Technologies represented in the communications industry include software, electronics, optics, and mechanics.*

7) ***Transportation:*** *This category includes patents on any type of invention related to the production of automobiles or vehicles of any other kind intended for transporting people or cargo, and inventions related to the provision of transportation services. Several different technology areas are represented in this industry category.*

8) ***Construction:*** *The construction industry category includes inventions of all kinds related to the erection or maintenance of structures, or to excavation.*

9) ***Energy:*** *This category includes inventions of any kind associated with power generation, transportation, or consumption.*

10) ***Goods & Services for Industrial & Business Uses:*** *This category includes patents on products and services of all kinds intended for industrial and business purposesi.e. goods and services for wholesale uses that are not in another, more specific category. Many software-implemented business method inventions are included in this category..*

11) ***Goods & Services for Consumer Uses:*** *This category includes patents on products and services of all kinds intended for personal consumer purposesi.e. goods and services for retail uses that are not in another, more specific category. Many software-implemented business method inventions are included in this category.*

E. Econometric Specification

We model the plaintiffs (discrete) success in case i, denoted as Y_i, as a function of technology T, industry I, country C and patent value V to study the data on patent litigation. Our specification is

$$Y_{i,t,j,k} = \alpha + \beta_j T_{i,t} + \beta_j I_{i,j} + \beta_k C_{i,k} + \beta_v V_i + \epsilon_{i,t,j,k} \tag{7}$$

where the dependent variable is the case outcome, with Y_i equal to 1 if the claim is successful at trial and 0 if the claim is not upheld. T, I and C are indicators to control for level differences across these factors. V is the OECD patent quality index, a continuous variable between 0 and 1, for the patent under dispute in case i. Furthermore, α is the constant, subscript t indicates technology t, subscript j indicates industry j, subscript k indicates country k and subscript v indicates the coefficient for patent value. We estimate β coefficients for the different factors using logit regression. Finally, $\epsilon_{i,t,j,k}$ is an error term with the usual distributional assumptions. Following J. Allison et al. (2015), we consistently use chemistry as the contrast dummy for technology, "goods and services for consumer uses for industry and Germany as the contrast dummy for the country indicator.

VI. Results

We now turn to the empirical testing of the hypotheses developed previously. We begin by presenting the heterogeneity of litigation across the three countries we studied, Germany, France and the UK. Second, we analyze the technology of the patented invention as a predictor for the outcomes at trial, thirdly the industry of the patent. Finally, we move to the main point of our theoretical model, the assessment of the patent quality as predictor for the outcome at trial.

A. Country Specificity of Litigation

The picture painted by our data is complex. Overall patent litigation win rates appear to be highest in Germany, with an average of about 52 %, followed by France, where an average of 37% of the claims in our sample have been successful. Lastly, in line with the subjective perception that the United Kingdom is the most patent-unfriendly country in Europe[30], our dataset reveals that less than one of four cases won by patentholders in the UK (see Table 2 for an overview). A logit regression was calculated to predict litigation outcome based on the country of litigation solely. A significant regression equation was found, $LR\chi^2(2) = 34.25, p < .01$. The likelihood of success of patentholders was significantly lower in both France ($\beta = -.6$, $p < .01$ and in the UK ($\beta = -1.2$, $p < .01$) compared to Germany[31].

[30] See for instance Elmer and Stacy (2010).
[31] The country variable remained strongly significant in the three models depicted in the Appendix, that integrate the technology, industry and quality predictors.

Table 2—Win Rates by Country

Technology	**Overall Win Rate by Country**					
	Germany		**France**		**UK**	
	Frequency	Win %	Frequency	Win %	Frequency	Win %
Overall	519	52.2	349	37.5	77	23.4
Infringement	519	59.3	237	55.7	77	64.9
Validity	102	47.1	254	54.3	76	34.2

When increasing granularity, we find that there was no significant effect of the country variable on infringement outcomes. As shows Table 2, the variation between infringement rates across countries, varying from about 56 % to 65 %, was smaller than in invalidity rates – where the variance went from 34 % to 54 %. In line with this, a logit regression found indeed that the country variable significantly predicted invalidation at trial. In particular, patents at stake in France and in Germany had a significantly lower likelihood of being invalidated compared to patents in the UK ($\beta = -.82$, $p < .01$ for France, and $\beta = -.63$, $p < .05$ for Germany)[32].

We dive one level deeper and analyze the validity challenges on which the courts ruled. In short, lack of inventiveness was the most frequent and successful challenge across all three countries. In the UK and in Germany, approximately half of the patents challenged for obviousness were invalidated, in France the rate was of 40%. It is striking that in the UK, half of all patents brought by patentholders in infringement cases resulted in an invalidation for lack of inventiveness[33]. Novelty was the second most litigated argument, and reached a success rate of two third in the UK compared to higher levels in France and Germany of approximately four out of five novelty cases won by the patenholder. Finally, it can be noted that other arguments such as unsufficiency of disclosure slightly varied across countries, but ranged in similar high rates[34].

[32]Also, a one-way ANOVA was conducted to compare the effect of the country variable on the outcomes. There was a significant effect of country on the overall outcome at the $p < .01$ (F(2,942) = 17.194). Post hoc comparisons using the Tukey test indicated that the mean score for Germany (M=0.52, SD = 0.48) was significantly different than for the UK (M= 0.23, SD= 0.43) and France (M=0.38, SD=0.49). However France did not significantly differ from the UK (the mean difference was not significant at the 0.05 level). When increasing granularity with further ANOVA, we find that there was no effect of the country variable on infringement outcomes. For invalidity outcomes on the other hand, there was a significant effect at the $p < .01$ ((F(2,443) = 4.81). Post hoc comparisons using the Tukey test indicated that the mean score for France (M=0.46, SD = 0.5) was significantly different than for the UK (M= 0.66, SD= 0.55), whereas there were not significant for the other pairwise comparisons. These results should be taken with caution since ANOVA is not common practice with binary dependent variables because of violations of the assumptions of homogeneity of variances and normally distributed errors.

[33]37 patents were nullified for obviousness from a total pool of 77 patents, or when counting the primary technology area only 30 of a total pool of 60 invalidity cases.

[34]With win rates of c. 70% in the UK, 75% in France, 87% in Germany.

B. Technology Specificity of Litigation

When comparing win rates between technologies among jurisdictions, we find mixed evidence of protection heterogeneity. At first, we observe in Figure 6 that the share of the litigated technologies varied across country. Mechanical patents dominated litigation in the three countries – whereas J. Allison et al. (2015) show that software had taken the lead in the litigated cases in the United States. In all three countries, more than two third of the cases were mechanical or electronics cases, even reaching a share of 85% in France. When adding chemistry, the third largest litigated technology, the pool of these three technologies accounted for over four fifth of all decisions. Of the remaining technologies, biotechnology represented the smallest share.

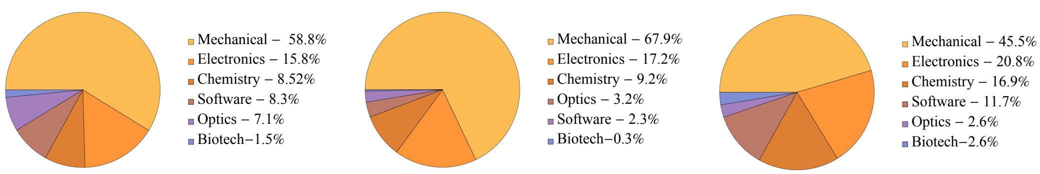

Figure 6. Technology Distribution in Germany, France and in the UK

From a descriptive perspective, we observe in Table 3 that the win rates by technology concealed remarkable variation by technologies, across and cross-country. Illustratively, patents in the electronics overperformed in France, but fare very poorly in the UK.

Table 3—Overall Win Rate by Technology

	Overall Win Rate by Technology					
Technology	**Germany**		**France**		**UK**	
	Frequency	Win %	Frequency	Win %	Frequency	Win %
Mechanical	305	53.8	237	35.9	35	31.4
Electronics	82	48.8	60	51.7	16	12.5
Chemistry	44	43.2	32	21.9	13	38.5
Software	43	44.2	8	25.0	9	0.0
Optics	37	62.2	11	54.5	2	0.0
Biotechnology	8	75.0	1	0.0	2	0
Total	519	52.2	349	37.5	77	23.4

We have conducted a logit regression to test for the effects of technologies on the likelihood of overall success of patentholders. Although the model was statistically significant, adding the technology variable does not provide us with a better forecast of the litigation outcome. Indeed, when comparing the two predictive models –with the country variable only versus with both country and technology – we find that the former constituted the better relative fit[35]. Of the technologies, we nevertheless find that optics patents were a significant predictor of the overall win rate, and fare much better before the courts than chemistry patents.

When moving to the infringement and invalidity level, a more refined picture emerges. Similarly as to the situation across countries, the descriptive statistics presented in Table 4 and Table 5 seem to indicate that there is greater variance across technologies in invalidation than in infringement rates. As a result, we conjecture that the overall differences in the win rates are driven mainly by protection heterogeneity among technologies on the invalidity side. We have conducted logit regressions for the effect of technologies on both infringement and invalidity outcome to confirm this conjecture. For infringement disputes, the relative fit of the model only increased very marginally[36], and the model was found significant at the lowest level ($p < .1$). Again, it was the technology Optics that significantly predicted the success likelihood at trial.

Table 4—Infringement by Technology

Technology	Infringement by Technology					
	Germany		France		UK	
	Frequency	Win %	Frequency	Win %	Frequency	Win %
Mechanical	305	57.4	162	64.4	35	60.0
Electronics	82	58.5	45	66.7	16	81.3
Chemistry	44	59.1	20	45.0	13	53.8
Software	43	58.1	2	100.0	9	88.9
Optics	37	75.7	7	85.7	2	50.0
Biotechnology	8	75.0	1	0.0	2	0.0
Total	519	59.3	237	55.7	77	64.9

On the other hand, for the validity decisions taken by the courts on the counterclaims suits, the fit of the model increases when integrating the technology predictor. We had found that the country variable UK significantly predicted a higher likelihood of the patents of being invalidated. This effect holds, although its level of significance slightly decreases. It also appears that one technology,

[35]See the two Akaike Information Criterion (AIC) in the Appendix, and lower (better) AIC score of the country model

[36]From an AIC score of 1132.5 for the model with the country as predictor to 1132.3 for the model with both

software, was much more likely to be invalidated by the courts. When we take software patents as indicator variable, we find that they faced a significantly higher likelihood of losing on validity grounds compared to mechanical, electronics, chemistry or optics patent. This results should be taken with caution due to the small sample size of software patents. Also, when we aggregate software, electronics and chemistry patents in one class, we find that mechanical patents were significantly more likely to be found valid than this pool[37].

Table 5—Invalidity by Technology

	Invalidity by Technology					
Technology	**Germany**		**France**		**UK**	
	Frequency	Win %	Frequency	Win %	Frequency	Win %
Mechanical	55	58.2	178	56.2	35	54.3
Electronics	25	52.0	39	61.5	16	12.5
Chemistry	11	27.3	23	43.5	12	41.7
Software	8	25.0	6	0.0	9	0.0
Optics	13	38.5	8	50.0	2	0.0
Biotechnology	3	66.7	0	0.0	2	0
Total	102	47.1	254	54.3	76	34.2

The grounds for nullification in our dataset provide some additional explanations as to the variance in the invalidity decisions. Among the notable differences that can be read in Table 6, the latter pool chemistry, software and electronics patents performed very poorly in arguments based on inventiveness and on novelty. Again, when we perform a logit regression also controlling for the country of litigation, we find that this pool of technologies was significantly more likely to lose on these grounds than mechanical patents at the $p < 0.01$ level.

Table 6—Win Rate of Invalidity Challenges

	Win Rate of Invalidity Challenges									
Technology	**Chemistry**		**Electronics**		**Software**		**Mechanical**		**Optics**	
	Freq.	Win %	Freq.	Win %	Freq.	Win %	Freq.	Win %	Freq.	Win %
Novelty	26	61.5	35	77.1	9	33.3	166	83.1	9	33.3
Inventiveness	36	41.7	51	51.0	11	18.2	224	60.3	16	56.3
Disclosure	17	64.7	14	92.9	3	33.3	64	76.6	7	71.4
Patentability	3	33.3	5	20.0	2	0.0	-	-	1	100.0
Extension	6	83.3	15	60.0	5	60.0	54	76.6	4	25.0

[37]With optics and biotechnology patents in a third class.

Finally, at the individual country level, when we run multiple logit regressions, we find that some technologies significantly influence litigation outcome, although to a different degree. In all three countries, optics patents were significantly more likely to prevail than chemistry patents ($p < .05$ in France and the UK, $p < .1$ in Germany). In France additionally, patents in the electronics technology area were also significantly more likely to win at the $p < .05$ level. And in the UK and in Germany, patents in the mechanical area were significantly less likely to be found invalid than chemistry patents ($p < .05$).

C. Industry Specificity of Patent Litigation

We now focus on the industry, thus on the use rather on the nature of the patent. This is illustratively enables us to disentangle chemistry patents, which may differ whether they are deployed in the pharmaceutical industry or in the industrial chemical or cosmetics industry. Table 7 shows that only the patentees in consumer goods and services overperformed, and in pharmaceutical underperformed consistently across the three countries. By contrast, most of the win rates differed: patentees were winning many cases in one country (patents in communications in France, industrial goods and medical devices in Germany) and performed poorly in the two other.

Table 7—Overall Win Rate by Industry

Technology	Overall Win Rate by Industry					
	Germany		France		UK	
	Frequency	Win %	Frequency	Win %	Frequency	Win %
Goods & Services for Industrial & Business Uses	161	51.6	90	27.8	21	33.3
Construction	72	47.2	67	26.9	2	100.0
Transportation	55	54.5	59	42.4	7	42.9
Goods & Services for Consumer Uses	50	54.0	59	52.5	3	33.3
Medical Devices, Methods & Other Medical	45	60.0	16	12.5	11	9.1
Computer and Other Electronics	57	49.1	17	35.3	4	0.0
Communications	24	37.5	18	94.4	19	5.3
Pharmaceuticals	15	33.3	15	33.3	10	30.0
Semiconductor	7	28.6	1	0.0	-	-
Biotechnology	14	85.7	-	-	-	-
Total	519	52.2	349	37.5	77	23.4

When testing for the effects of industries on the overall success likelihood among all three countries using logit regressions, we find that the model was statistically significant (see Model 3 in the Appendix, with the country and industry as predictors). Overall, the model integrating the industry variable showed a better predictive fit than the technology model[38] This would suggest that there

[38]This is confirmed by a decrease in the AIC score, whereas the latter increased for the technology

were larger differences for patents from different industries than for patents from different technologies. Compared to patents in the consumer goods industry, patentholders in the pharmaceutical, computer and electronics, construction and semiconductor industry were significantly less likely to definitively win. By contrast, patent owners in biotechnology were significantly more likely to prevail at trial, although it must be noted that all cases took place in Germany.

The industry-model also showed a better predictive fit than the technology-model in infringement disputes. By contrast, the technology-model was superior in predicting invalidity decisions[39]. Thus, this would indicate that there was greater variance across industries in the disputes over the violation of the patent itself, and across technologies in the rulings on the question of whether the enforced patent was valid.

Pharmaceutical and construction patents were less likely – and communications and biotechnology patents more likely – to be found infringed than consumer goods. The level of significance increased in invalidity disputes, where pharmaceutical, communications and construction patents were significantly more likely to be held invalid. Also, when we assess the results on a individual national level, we find that certain industries significantly predicted the litigation outcome. This was the case for communications patents in France, that fare significantly better compared to consumer goods, while patents covering construction and goods for industrial and business uses were more significantly more likely to lose (all at $p < .01$). The effect disappeared when considering the infringement level only, but was also present at nullification, where patents in the construction, pharmaceutical and industrial and business use fare significantly worse (all at $p < .05$ minimum). In Germany, only biotechnology patents predicted the litigation outcome, being more likely to definively win at the $p < .05$ level. In the U.K., where we dispose of the smallest dataset, we find that three industries fare significantly worse in infringement disputes compared to our dummy consumer goods: patents in the pharmaceutical, transportation, and medical devices industry ($p < .01$).

D. Patent Quality in Patent Litigation

In line with our hypothesis, we find that our quality proxy significantly predicts litigation outcome at the $p < .01$ level in our full specification, where we control for the county of litigation, the technology and the industry of the patent (see the regression model 4 in the Appendix). The higher the quality of a patent, the higher was its likelihood of prevailing at trial. This result holds when we separate infringement and invalidation outcomes: patents of higher quality were more likely to be found infringed and less likely to be invalidated (with both $p < .1$) . Similarly, at the individual country level, the quality of the patent significantly predicted the definitive outcome at trial in Germany ($p < .05$), as

model, as explained previously.

[39]See the AIC scores in the regression tables in the Appendix

well as the infringement and invalidity results ($p < .1$)[40]. By contrast, in the UK and in France, the patent quality did not predict definitive win, infringement or validity outcomes with any level of significance.

When comparing the patent quality across the three countries, a one-way ANOVA indicates that there was a significant effect of the country variable on the quality on the patent (F(2,662) = 6.3, $p < .01$). In Germany, the quality scores were the lowest (M = 0.20, SD =0.12), and this difference was signficant compared to both quality scores in France (M =0.23, SD = 0.162 and in the UK (M= 0.24, SD = 0.14) according to post hoc comparisons using the Tukey test. In addition thereto, the differences in patent quality across technologies, and also across industries, were significant[41]. The mean score of chemistry patents (M = 0.27, SD = 0.09) was significantly higher than of electronics (M = 0.19, SD = 0.14), mechanical (M=0.2, SD = 0.13) and software patents (M = 0.17, SD = 0.11). Also, patents in the optics technology area (M = 0.26, SD =0.19) ranked significantly higher than software patents (see also the boxplots depicted in the Appendix). Further results at the individual country level reveal that optics patents were of significantly higher quality in France and in the UK[42]. However there was no significant difference across the industries themselves. Taken together, these results suggest that the quality of the patents varied across countries and technology mainly, with a mean quality that was the highest in France, and for chemistry patents.

VII. Discussion

These findings confirm our prior that significant cross-country differences between the national patent litigation systems still exist in the run-up of the institutional unification of the European patent system through the Unified Patent Court.

A. Homogeneity in Infringement – Heterogeneity in Invalidation

Our results suggest that there exist larger differences across countries, technologies and to some extent industries in the counterclaims decisions over the validity of the patents than over the infringement disputes. In the latter, in all three constellations, the econometric models were either not predicting the outcome with any statistical relevance, or at a lower level of significance. Specifically, the heterogeneity in the enforcement of patents seems driven by differences in how the courts decide over patents of different technologies. In particular, patentholders in the software, electronics and chemistry pool technology fare signifcantly worse than mechanical patents. Originally, the patent system was designed for mechan-

[40]The regression model includes both patent technology and quality as independent variables.
[41]For technology, (F(5,660) = 5.2, $p < .01$) for industry (F(10,665) = 2.6, $p < .01$)
[42]The quality of optics patents was significantly higher than mechanical patents in both countries, and of electronics and software in the UK.

ical inventions[43]. Compared to the new technologies that branched out such as biotechnology or software, mechanical patents are considered as simpler, which may explain its strength at trial[44]. When we put this result in contrast with the findings on litigation in the United States, it is surprising to see that chemical and mechanical patents shared inverse paths: chemical patents were strong performers before the US courts but weak in our three countries, while mechanical patents were more often than not invalidated in the US, while mostly held valid in Europe.

For the infringement of patents, where the enforcement appears more homogeneous across countries and technologies, there were larger differences in the outcomes by industry. Mostly, patentees in the pharmaceutical and construction industry were more likely to lose at trial, while the communication and biotechnology patentholders were more likley to win. Whether this results from systematic variations in the judges assessment of different industries or from selection – with industries bringing different type of cases up to adjudication – remains unclear.

Patent defenses in infringement and in invalidity correspond to two different side of the bargain between an inventor and the society: on invalidity, the defense focuses on the contribution of the inventor to the world (the disclosure of a novel and nonobvious invention); on infringement on the monopoly the inventor obtains (whether the infringers product or process falls within that scope)[45]. Our findings suggest that disputes on the monopoly are industry-specific, but technology-specific for the contribution itself[46].

B. *Technology as Predictors*

Although there were great variances in the outcomes of technologies across countries, only a few of them ultimately could be identified as predicting the outcome with statistical strength. Mainly, optics patents were more likley to prevail at trial than their chemistry counterparts. This can be explained by the fact that they achieved the second highest win rate amongst technologies in Germany, and were of significantly higher quality in both France and in the UK. Other technologies, such as the mechanical patents also were very strong at invalidation trial, whilst software was very weak. Since we integrated both the technology and country variable, this may not only be explained by high shares of software litigation in the UK, but rather by systematic weak performances of software before the courts of all three countries.

In the United States, J. Allison et al. (2015) have presented evidence that owners of chemistry and pharmaceutical patents have much greater success in litigation

[43]See Burk and Lemley (2002) for this discussion.

[44]J. Allison and Lemley (2002), for instance showing that mechanical patents spend relatively little time in patent prosecution.

[45]See Ford (2013).

[46]On the contrary, Wagner (2002) argues for the existence of rather case-specific than industry-specif differences.

than their counterparts. The authors link this result with the classical representation that pharmaceutical patents are strong and valuable, and are perceived as critical to protect R&D investments. On the other hand, the players in the computer industries share a diametrically opposed view of patents as promoters of innovation, reflected in low win rates of software and computer patents. In our dataset, chemistry patents are of higher quality than patents in the electronics, mechanical and software universe. Nevertheless, they performed relatively poorly before the courts: being more likely to definitively win in France, and to be invalidated in Germany and in the UK, compared to patents in the mechanical area. Combined with the results by industry, showing that pharmaceutical patents performed poorly across all three countries, it seems that the picture presented by litigation is very different from the situation in the United States. Whether this results from a selection of different type of patents, or from differences in the application of legal standards such as the inventive threshold remains unclear. As to patents in the software area, they represented a much smaller share of patents – also due to very different patentability standards – but similarly performed poorly before the courts; and the same was true for patents in the computer and electronics industry.

C. Patent Quality

Finding that patent quality significantly predicts the outcome at trial enables us to confirm the prediction in our model, and to provide further insight on the fragmentation of the enforcement system. As discussed above, we hypothesis that the patent quality will be determined by the judge, resulting in the assignment of a judicial patent quality which determines the success probability at trial. We acknowledge that our perspective focuses on the quality of the patent referring to itself only, not on its prosecution history or to the characteristics of the applicant, inventor or of the judges[47]. Nevertheless, our patent quality measure was a predictor that consistently had a significant relation with the outcome at trial. By contrast, this was not the case for any other of our predictors. Patents of higher quality were more likely to prevail definitively before the courts, but also independently to be found infringed or valid.

Interestingly, the country where the patents were of the highest quality scores was the UK, where the definitive win rate was much lower than in France and in Germany. This may be put in relation to the substantially higher patent litigation costs in the UK than in the other two countries[48]. For inventions of lower quality, the parties may prefer to settle the dispute or even to renounce to the enforcement

[47]In the United States, Mann and Underweiser (2012) found statistically significant relations between validity decisions and ex ante aspects of the prosecution history such as the existence of internal patent office appeals.

[48]In in the UK, the costs are estimated to reach an aggregate of between 1million and 6 million (Helmers and McDonagh (2013, p. 384)) in comparison to EUR 50'000 to 200'000 in France (Helmers and McDonagh (2013, p. 384)) and of EUR 25 to EUR 91'456 for the court fees and of EUR 40'000 to EUR 100'000 for attorney fees in Germany (Cremers et al. (2016, p. 16)).

of their rights since the expected payoff from trial may be too low. Ultimately, this situation may lead to a market distortion by discouraging the enforcement of (valid) patents[49]. Hence, these costs of enforcing patents could lead to a 'tax' on innovation, with UK innovators having lower incentives to invest in low quality innovation – that they cannot enforce[50].

D. *The UK as Anti-Patent Court*

The reputation of the UK as "anti-patent", due to low win rates, has lead to the perception that courts in London constitute a propitious jurisdiction for challenging the validity of patents or requesting declarations of non-infringement[51]. Similarly, patentees should avoid the forum when bringing infringement claims. Illustrating this, an empirical study of the enforcement of patents in the UK from 2000 to 2008 showed that the infringement of a valid patent was ultimately found in 15% of all infringement cases (including non-infringement)[52].

Our data focus on the latter infringement disputes only, excluding the selection of plaintiffs that may strategically bring non-infringement claims to London. On the question of the violation of the patent itself, we surprisingly find that the win rate if infringement disputes was the highest across all three countries. Two third of the patents of our dataset were infringed or would have been infringed, if one considers it independently of the patent's validity. But on the validity counterclaims, two third of the patented inventions were found invalid. Considering the fact that we focus on cases where the patentholder selected the courts in London and to enforce his patent, this is very surprising[53]. It is generally considered that patentholders have better access to information about the patent and prior art. On the contrary, this asymmetric level of access is inversed for information relating to non-infringement, since the infringer develops, manufactures or uses the infringing products or processes[54]. When we dive into the variance of the nullification rates across technologies, it was mainly the technology pool chemistry, electronics and software patents that performed extremely poorly. This may either be a result of selection with different cases of these three technologies being challenged, or of different inventiveness threshold for these technologies in the UK.

[49]Ellis (1999) "It is, simply put, that the escalating, indeed skyrocketing litigation costs of the 1970's and 1980's have distorted patent markets and patent economics. Put another way, it is my observation that the escalating costs associated with litigating patent infringement and validity issues discourage challenges to patents, thereby essentially equating the entry barriers for presumptively valid, but weaker patents with those entry barriers associated with strong or judicially tested patents.").

[50]See Bessen and Michael (2007) for costly litigation as tax on innovation when it flows from the risk of unavoidable infringement.

[51]See Moss, Jones, and Lundie-Smith (2010) for instance.

[52]Helmers and McDonagh (2013).

[53]This result is similar to ed by results from 2000 to 2008 where the revocation rate amongst cases alleging infringement was of 82%, see Cremers et al. (2013).

[54]See also Ford (2013) for more details.

VIII. Conclusion

This paper investigates county-, technology- and industry-specificity of the European patent enforcement system. We develop a model of patent litigation which predicts that both settlement and litigation are driven by patent quality. We test the prediction of the model at the litigation stage using a dataset that covers litigation data from Germany, France and the United Kingdom during the period 2008 to 2012.

We find evidence that the European patent enforcement system is heterogeneous across country, technologies and industry, mostly at the invalidation stage. Our results indicate that protection heterogeneity in nullification decisions among countries and technologies exists. For infringement disputes, we find a more homogeneous situation across countrie and technologies, and the variance only emerged when comparing the success rates of litigants across industries. Furthermore, we find that our quality proxy significantly predicted the outcome at trial: patent of higher quality were more likely to definitely prevail before the courts, more likley to be found infringed and to be found valid. Hence, we see the future role of the Unified Patent Court as crucial, since it will be in a position to decide whether it wants to set European patent litigation on a path of further unification.

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Appendix

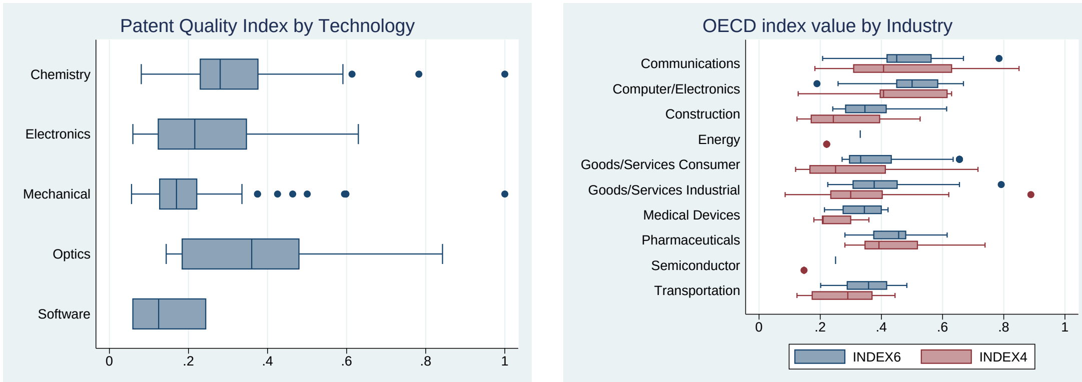

FIGURE 7. QUALITY BOXPLOT FRANCE

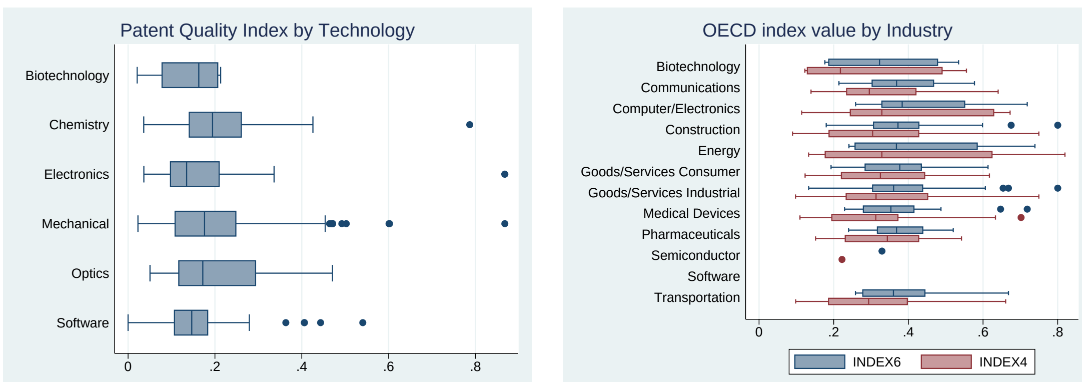

FIGURE 8. QUALITY BOXPLOT GERMANY

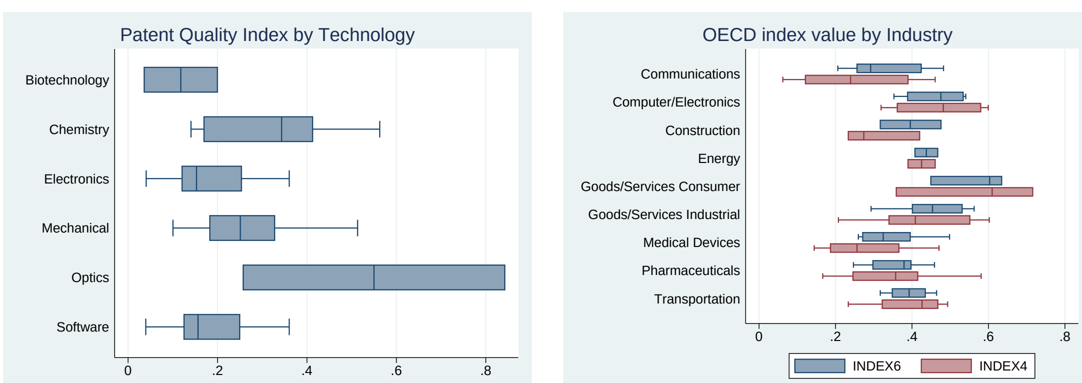

FIGURE 9. QUALITY BOXPLOT UNITED KINGDOM

FIGURE 10. DEFINITIVE OUTCOMES – FULL SAMPLE CROSS-COUNTRY REGRESSION RESULTS

	(1)	(2)	(3)	(4)
Country				
FRANCE	-0.598***	-0.611***	-0.617***	-0.424**
	(0.141)	(0.144)	(0.147)	(0.190)
UK	-1.276***	-1.232***	-1.276***	-1.884***
	(0.283)	(0.286)	(0.296)	(0.368)
Technology				
Biotechnology		0.720		0.260
		(0.664)		(0.842)
Electronics		0.454		0.643
		(0.279)		(0.438)
Mechanical		0.377		1.053***
		(0.243)		(0.365)
Optics		0.770**		1.289***
		(0.369)		(0.489)
Software		-0.130		0.179
		(0.358)		(0.544)
Industry				
Biotechnology			1.323*	1.771*
			(0.792)	(0.915)
Communications			-0.138	0.562
			(0.337)	(0.457)
Computer and Electronics			-0.540*	0.268
			(0.305)	(0.436)
Construction			-0.648**	-1.005***
			(0.260)	(0.340)
Energy			0.174	0.472
			(0.452)	(0.664)
Industrial & Business Uses			-0.494**	-0.231
			(0.231)	(0.281)
Medical Devices			-0.499	-0.336
			(0.315)	(0.372)
Pharmaceuticals			-0.694*	0.373
			(0.399)	(0.559)
Semiconductor			-1.501*	-1.050
			(0.844)	(1.215)
Transportation			-0.182	0.0838
			(0.267)	(0.323)
Quality				
new_factor				1.675***
				(0.627)
Constant	0.0887	-0.259	0.469**	-0.917**
	(0.0879)	(0.235)	(0.208)	(0.459)
chi2	34.25***	42.78***	56.02***	75.55***
Pseudo R^2	0.026	0.033	0.043	0.082
AIC	1270.1	1271.6	1268.3	883.8
BIC	1284.7	1310.4	1331.4	969.3
Observations	945	945	945	666

Standard errors in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$

Figure 11. Infringement Outcomes – Full Sample Cross-Country Regression Results

	(1)	(2)	(3)	(4)
Country				
FRANCE	-0.149	-0.104	-0.134	-0.187
	(0.158)	(0.161)	(0.166)	(0.210)
UK	0.238	0.261	0.149	-0.274
	(0.255)	(0.258)	(0.272)	(0.309)
Technology				
Biotechnology		-0.0210		-0.862
		(0.649)		(0.896)
Electronics		0.399		0.0634
		(0.288)		(0.431)
Mechanical		0.0900		0.400
		(0.248)		(0.342)
Optics		0.997**		1.098**
		(0.417)		(0.524)
Software		0.407		0.156
		(0.368)		(0.550)
Industry				
Biotechnology			1.920*	2.588**
			(1.062)	(1.229)
Communications			0.735*	1.289**
			(0.392)	(0.527)
Computer			-0.264	0.266
			(0.325)	(0.460)
Construction			-0.700**	-1.110***
			(0.281)	(0.358)
Energy			0.0760	0.0228
			(0.484)	(0.672)
Industrial & Business Uses			-0.312	-0.166
			(0.252)	(0.300)
Medical Devices			-0.399	-0.305
			(0.339)	(0.389)
Pharmaceuticals			-0.822**	-0.249
			(0.406)	(0.547)
Semiconductor			-0.358	0
			(0.796)	(.)
Transportation			-0.354	-0.295
			(0.287)	(0.339)
Quality				ref.
new_factor				1.256*
				(0.652)
Constant	0.378***	0.166	0.645***	0.0210
	(0.0894)	(0.238)	(0.226)	(0.450)
Pseudo R^2	0.002	0.011	0.029	0.062
chi2	2.217	12.36*	32.76***	51.80***
AIC	1132.5	1132.3	1121.9	820.6
BIC	1146.7	1170.1	1183.4	900.3
Observations	833	833	833	621

Standard errors in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$

FIGURE 12. INVALIDITY OUTCOMES – FULL SAMPLE CROSS-COUNTRY REGRESSION RESULTS

	(1)	(2)	(3)	(4)
Country				
FRANCE	-0.191	-0.0122	0.0107	-0.337
	(0.225)	(0.238)	(0.246)	(0.319)
UK	0.637**	0.615*	0.312	0.718*
	(0.305)	(0.318)	(0.332)	(0.399)
Technology				
Biotechnology		-0.128		-0.462
		(0.978)		(1.343)
Electronics		-0.362		-0.906
		(0.379)		(0.609)
Mechanical		-0.626*		-0.781
		(0.330)		(0.481)
Optics		0.0997		-0.200
		(0.532)		(0.677)
Software		1.853**		1.012
		(0.804)		(1.049)
Industry				
Biotechnology			0.0238	-0.469
			(1.269)	(1.598)
Communications			2.307***	1.708**
			(0.575)	(0.764)
Computer and Electronics			0.738	-0.168
			(0.462)	(0.728)
Construction			0.767**	0.804
			(0.375)	(0.523)
Energy			0.710	0
			(0.860)	(.)
Industrial & Business Uses			0.647**	0.153
			(0.323)	(0.421)
Medical Devices			0.836*	0.480
			(0.435)	(0.530)
Pharmaceuticals			1.966***	0.945
			(0.630)	(0.843)
Semiconductor			0.714	0.962
			(1.044)	(1.309)
Transportation			0.0541	-0.587
			(0.386)	(0.529)
Quality				
new_factor				-1.598*
				(0.952)
Constant	0.0174	0.297	-0.717**	0.473
	(0.187)	(0.350)	(0.333)	(0.656)
Pseudo R^2	0.016	0.051	0.066	0.145
chi2	9.607***	31.45***	40.66***	58.33***
AIC	613.3	601.4	602.2	378.9
BIC	625.6	634.2	655.5	445.1
Observations	445	445	445	291

Standard errors in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$