Technological Radicalness Explaining Opposition Risk For European Patents *

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Abstract

This paper brings new evidence on the determinant of opposition. The sample covers patent have been filed between 1999 to 2000, and opposed in European Patent Office (EPO). To link technological radicalness to the opposition probability, I use 431748 patents filed between 1990 to 2010 to construct a comprehensive measurement on radicalness of each patent in the opposition sample: 1) novelty - bringing new component ; 2) unique; 3) high net entry of similar patents. The econometric results suggest that patent with radical not incremental attributes imply higher probability of being opposed. In particularly, revoked and amended patent are less cited than comparable patents survived from the opposition reexamination.

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1 Introduction

This paper provides evidence on explaining the relationship between technological radicalness and opposition probability in European Patent Office(EPO). The specification of the relationship is important for the analysis both of the post grant review system and of the influence of the system design on the technology market. Opposition procedure allows competitors to challenge validity of European patents soon after grant, and effective in all EPO designated states. Previous studies reveal that opposition frequently leads to revocation or amendments on questionable claims at the early point and affordable cost(Bruno. van Pottelsberghe de la Potterie (2011) [22]; Bronwyn H. Hall and Dietmar Harhoff (2002) [35])

Interest on the post grant review is generated as the expansion of technology market. In the past decades, payments for knowledge assets, including technology transaction,licensing and related services, grew faster than GDP in most OECD countries (OECD,2015[1]). At the same time, litigation system have an "explosion" with lawsuits initiated by non practicing entities (NPE), which frequently relate to a licensing agreement (Bessen JE et al (2011)[8]). Challenging the validity of a patent is a permissible and frequent defense in an infringement action in many countries, and the judge will decides to stay or not for patentability. However, lawsuit, practically is disruptive, unpredictable and costly, so that most cases didn't go to the final trials but settlement. (Allison JR et al (2014) [4]; Cremer K et al(2013) [19]) In other words, an efficient post grant review system, can correct unclear and unpredictable patentability and reduce questionable patents on the market.

Virtually all knowledge of the opposition system derive from studies of litigation selection.The patentee may decide to negotiate or litigate the dispute. It is expected that the probability of litigation will be higher for more valuable patents (George L Priest and Benjamin Klein (1984)[49]; Michael J Meurer (1989)[47]; Jean O Lanjouw & Mark Schankerman (2001) [42]; Dietmar Harhoff et al.(2003)[38]; Federico Caviggioli et al.(2013)[12]). Proxies for value or quality of litigated patent focus on featuring economic conditions of patents and the characteristics of the parties, for example the number of different jurisdictions patent protection is sought (*Family Size*) and the portfolio of applicant. One important shortcoming in this line of research is ignoring the functional difference between opposition and litigation.

In this paper, I explore the need for post grant reviews (opposition) under the technological context. I provide empirical evidence for this claim by studying the opposition cases in EPO. The data set includes all patents having been filed between 1999 and 2000 and challenged in opposition, totally 3747 observations. Furthermore, a control group of 3747 European patents randomly drawn from the population for all patents has ensured a comparable investigation.

To construct a comprehensive measurement on technological radicalness, I adopt three measures developed by Lee Fleming (2001) [26] and Kristina B Dahlin and Dean M Behrens(2005) [21], covering both ex ante and ex post dimensions: the way to incorporate novel knowledge compared to previous technology (bringing new component or new component combination), degree of unique after comparing to filed during the same period, and impact on future technology (with high net entry of similar patents). All measures are constructed rely on patent documents in EPO.

The main findings of the paper suggest that patents with radical characters are more likely to be opposed. However, once opposed, they are relatively less likely to be revoked or amended than useless patents. Such results hold across all technology sectors and residences of applicants.

This paper contributes to advance the interpretations of the role of opposition in patent litigation system. The high incidence of opposition filing rate, compared to validity challenge mechanism in other countries, might be explained by two factors. The first factor is the lower and affordable cost (Malwina Mejer and BP de la Potterie [46], BP de la Potterie [22]). The second explanation is that opposition procedure is used to attack patent with more novelty and uniqueness. The proposed quality measures are typically only able to identify new technologies after they have succeeded commercially. This paper contributes to more measures under the technological context. Novelty is the main source for a future breakthrough, but also resents high variation with its market adaptation. Fewer patents, that make an original idea, can also catch high commercial values. Therefore, radical patent, less understandable and usable, is more possibly challenged in post grant review, but less challenged in litigation.

The remainder of the paper is structured as follows: In the second section, I briefly introduce the opposition proceeding in EPO and procedural differences between opposition and validity challenge in other litigation systems. In the third part, I review the theory on determinants of patent litigation and radicalness identification. Based on previous studies, I make new hypotheses. In the Fourth part, I describe the database and measures construction. The empirical results are reported in the Fifth part. The final section discusses implications of the results and policy implication.

2 Institutional Background

2.1 Opposition Procedure in European Patent System (EPO)

The opposition procedure and the appeals process are regulated by the European Patent Convention (EPC) via Parts V and VI, respectively. An opposition notice has to be filed within nine months of the patent being granted by the EPO (art. 99, EPC). Opposition application can be filed by any person without specifying any particular interest (Art. 99(1)EPC). The main reason for opposing a patent is that it does not meet conventional patentability criteria: novelty, inventive step and industrial applicability. Other admissible reasons for an opposition are that the disclosure of the invention is not sufficiently clear and complete to enable other people skilled in the art to perform the invention and that the scope of the patent, as granted, extends beyond that of the original application (art. 100, EPC). The opponent will have to present evidence that the above prerequisites for patentability have not been fulfilled.

The notice of opposition is examined by Opposition Division in EPO. The Opposition Division consists of three experienced examiners, one of whom may have been involved in the examination phase. Once the opposition has been filed, settlement options between the opponent and the patent holder are restricted. In fact, if the opposed parties and opponents decide to settle their case after the opposition has been filed and the opponent, for example, withdraws its opposition, the EPO still continue the case.

What makes this procedure especially attractive for opponents is that opposition decision on European patent validity is effective in all the states where the European patent is to be enforced. A decision of the EPO to revoke a European patent is supposedly final; a decision to uphold a European patent (the decision to maintain the patent as granted or in an amended form) leaves the way open for further validity challenges before national courts. Validity challenges are also possible in other national litigation systems, but they take place within the frame of regular litigation. In certain countries, for example, Germany and UK, revocation request can be brought only if no opposition proceedings are pending and the period for filing oppositions has lapsed.

2.2 National Differences in Validity Challenge Proceedings

Opposition in EPO presents procedural and functional differences with validity equivalent proceeding in other countries. Understanding the differences is the first step for discussing opposition probability. Details on characters of validity challenge mechanism in major countries are described in Table 8 in appendix.The differences can be summarizes as three aspects: Cost, Time allowed for filing notice of opposition and outcomes.

Cost The official filing fees in April 2015 were 775 €for initiating an opposition and 1860 €for requesting an appeal. Although most of the total cost of PGR will likely be lawyers' fees, not patent-office fees, opposition still takes much less cost than equivalent proceedings under judicial systems. As estimated by Malwina Meyer and BP de la Potterie (2012) [46], It is relatively affordable to file an opposition before EPO, as cost varies between €6,000 and €50,000 (including patent lawyers' fees). After opposition period expires, validity of patent only can be challenged in national jurisdictions, more complex and expensive. When validity challenge is conducted as counter-claims during an infringement suit, such as in the United States, the cost of litigation would increase with the amount at stake and with the complexity of the case. In US, massive damage ward keep increasing. For example, in 2012, three cases resulted in awards of $ billion or greater: Monsantov. DuPont, Apple v.Samsung, and Carnegie Mellon University v. Marvell (PWC2015[50]).Therefore, it is possible to make an assumption of firm homogeneity that all established firm in an industry equally have an affordability for challenging the validity of an interested patents through opposition.

Time allowed for filing notice of opposition The opposition notice must be filed within nine months after the grant decision published. I can expect that involved patents have not been realized commercial success within such a short period. Comparatively, There is no time limitation in other validity challenge proceedings and most challenge is accompanied by an infringement lawsuit, such as in Germany Patent Court, D.Harhoff et al (2014)[?] and K.Cremers et al (2013)[19].

Outcomes There are three potential outcomes of an opposition procedure. Either the patent is upheld and remains unchanged, or the patent is amended, or it is revoked. Opposed patent is reexamined by experienced patent examiners and with high rate of revoking and amending the original grant decisions: D.Harhoff et al (2003)[38] reports 14% of patents attached are revoked and D.Harhoff & Markus Reitzig(2003) [37] reports that 39% of all oppositions are revoked and about 28% of the cases the patent is amended with the European polymer patents. Comparatively, more than 80% litigation cases go the settlement in the patent litigation trials in US (MA.Lemley et al (2014)[3]; Colleen V Chien and Christian Helmers (2015)[14]), which suggest that event the patent validity was challenged in the court, most of the questionable patents still stays on the market.

3 Theory development and Hypothesis

3.1 Literature Review on Determinants of Opposition Filing

It is reasonable to analyze patent opposition under the context of litigation events, since in practice, opposition is regarded as a court of "first instance" for European patent (D.Harhoff and Markus Reitzig(2003) [37]; BH.Hall and D.Harhoff,2004 [35]). Priest and Klein (1984) [49] address a standard model on explaining the selection of patent disputes, which states that the parties will go to trial if the return net of legal cost is over the outcome of pre-trail negotiations. Subsequent models allow for different factors effecting litigants' expectations. For example, P'gn (1983)[48] discussed the firms' strategic behavior when the firm owns private information. Lanjouw and Schankerman (2001) [42] developed a model to discuss firms' activity when they regard litigation costs as asymmetric stakes.

Empirical works test these models with three broad categories: a first set of paper report casual empirical evidence, consistent with the private value of patents. The available measures include the number of different jurisdictions patent protection is sought(patent families) (D.Harhoff et al, 1999 [36]) and renewals (JO Lanjouw et al (1998) [41]),the number of patents cited by the following patents (Criscuolo and Verspagen (2008) [20]; D.Harhoff et al. (2003)[38], Lanjouw and Schankerman, 2001[42],2004[43]). The number of claim. (Lanjouw und Schankerman (2003)[42], D.Harhoff und Reitzig (2004)[37]. BH.Hall et al (2001)[33] use the citations information as ingredients to construct two more complex measures, "originality" and "generality" to predict the patent value. van Zeebroeck and van Pottelsbogh de la Potteries (2011)[56] discuss the main methodological issues in measuring and interpreting these indicators. The main conclusion of this strand of the literature is the positive impact of patent value on the probability of being attacked.

A second strand of the literature relates to strategic implications under characteristics of patent applicant. For example, patent portfolio and complementary asset affect firms' decision not only on patenting, enforcing an innovation, but also settling and litigating a patent dispute. Lanjouw and Schankerman (2001) [42] point out that larger, domestic and more established firms were more likely to initiate litigation against smaller companies because they had better information about the activities of their competitors, more resources to defend their intellectual property. These findings persistently come out in , parallel studies, D.Harhoff and BH.Hall (2002) [35], suggesting higher percentage of opposition filing takes place repeatedly between larger players.

Recently, more paper discuss the heterogeneous adoption of patenting and patent litigation system by relating it to nature of technology. Malerba and Orsenigo (1997) [45] explored innovative activities across industries and technologies, and provides significant intersectional differences in the rate of innovation, the degrees of technological entry and exist, and et al. The distinction between discrete and complex technologies is widely accepted in the literature on patenting (Cohen et al., 2000 [16], Harhoff and Hall (2002) [35]) and selection of patents disputes for litigation (Alberto Galasso &Mark Schankerman 2010 [27]). Technology field, presenting the feature of complexity and cumulativeness, such as electronic, presents increasing proliferation of patent disputes.

The generic factors above would influence the probability of both patent litigation and opposition filing. My primary hypothesis retest the impact of patent characteristics in available literature on opposition selection:

Hypothesis 1 :*Opposition probability increases as the patent scope(claims), the number of non patent literature, and patent holder's private estimation of the patent's value (family size)*

3.2 Defining Radical Invention

The proposed measures on explaining opposition are typically only able to identify new technology after they have succeeded commercially. Indeed, patented invention might be radical in a technological content without significant market adaptation. On the one side, highly innovative invention occurs frequently in an earliest period of a technology, and posing significant problems and uncertainty in practices are to some extent unavoidable (Lee Fleming (2001) [26]). On the other side, realizing economic value also asks for complementary assets, such as product development, marketing, distribution and after-sales service (Cooter and Rubinfeld(1989) [18], Josh Lerner (1995) [44]; Blind et al (2009) [9], Calderini et al (2004), [10]).

Management scholars have long history to label radical invention (Anderson and Tushman (1990), [5], Christensen and Rosenbloom (1995) [15], Cooper and Schendel (1976), [17]). Primarily, scholars define the radial invention as disrupting existing technological trajectory and driving forces of industrial and societal change, for example, breaking the power of monopolist (Giovanni Dosi (1982) [24], Manuel Trajtenberg(1990) [54]). Radical innovation is highly skewed and uncertainty. Success of an radical innovation depends upon both the technological capacity and market adaptation. Indeed, management scholars confirmed the importance of technological radical invention even it failed at the market level. Tushman and Anderson (1990) [5] claimed that market adaptability of a technology changes as the life cycle of a technology. A radical invention failed in the market at the early stage still possibly win the market later.

Another important type is incremental invention. John E Ettlie(1983) [25] documented the theoretical models to differ the radical and incremental invention:the depth and diversity of knowledge , organization's management , and dimensions of organizational structure. The following works developed the classification: incremental innovative capability is defined as the capability to generate innovations that refine and reinforce existing products and services, while radical innovative capability is the capability to generate new innovations, surpasses the old technology(Dewar and Dutton (1986) [23], Christensen and Rosenbloom(1995)[15])

Based on the above description, innovation types can be summarized as follows :

- *Successful Radical Invention*: generate new innovations and being adapted widely on the market.
- *Failed Radical Invention*: generate new innovations but poses problems in the practices or failure in the market adaptation.
- *Incremental Invention*: generate innovations that refine existing products or services, and adopted widely on the technology market.
- *Useless Invention*: can't redefine the function of existed products and services, neither make any organizational effects.

Concept of radical invention provides a complementary explanation for the patent value and litigation risk. Figure 1 describes the typical inventions and the litigation probability. The figure is intended to be illustrative and is not drawn to exact scale. As illustrated, a radical invention has the potential to start a new technology trajectory, but also variation in the market adaptation. Only patent in success radical invention may be involved in an infringement lawsuits in the future. Many scholars in the technology life cycle have observed that uncertainty peaks early and incremental invention mostly occurs in a maturity stage,less novelty and uncertainty but quick market adaptation (Anderson and Tushmen 1990 [5]). Therefore, patents in incremental invention are more possible to be challenged not in opposition proceeding, but infringement lawsuit.

3.3 Radical Patterns: Patent Based Measures and Impact on Opposition Filing

Strategic management research adopted wide kinds of models and measures to identify radical innovations. First of all, economics data are used to identify radicalness, since radical invention has been tested through production and marketing tasks and is diffused into the market place (Garcia and Calantone,2002 [28]). The most direct measurement is survey results from expert assessment (e.g. Dewar anbd Dutton, 1986 [23]; Acs and Audretsch, 1990 [2]; Chandy and Tellis, 2000 [13],Gatignon et al., 2002 [29]) . Another frequent used is hedonic price models (Henderson and Clark, 1990 [39], Jean Tirole (1988)[53]), where price is used as a dependent variable in regression models, and radicalness is defined when the inventions' characteristics significantly influence the price on the market.

Patent data provides detailed and large scale information and have been extensively used to assess the degree of innovative in knowledge domains. Although a range of different methods to measure radical invention, there are some common elements to identify the type of inventions. Such elements also generate effects on opposition probability:

Novelty Novelty with innovation is defined as no new knowledge contained in the machine or process, or an improvement over existing technology (Dewar and Dutton (1986) [23]). Using technical content, novelty is classified as creating new elements (van de Poel (2003) [55]), introducing an established element into a new setting (Hargodon and Sutton (1997) [34]) or through recombining already established elements (Fleming (2001)[26]).

Backward citation, as patent and other documents cited by the focal patent, is frequently used to assess an invention's novelty. Patentability requires patents granted show the distinction patterns compared with the citing prior art. During the patent applications, applicant need to declare the earlier documents primarily patents that have the same features as the patent applications. In EPO, patent examiners also search for the prior art and supplement the relevant documents.

However, backward patent citations, in the existed empirical works, didn't report clear correlation between the patent value and the litigation probability. For example, empirical works on US litigation data Lanjouw and Schankerman (2001) [42] and European opposition cases (Harhoff und Reitzig (2004) [37]) both reports no significant effect of backward citations per claim. The patent offices categorizes all patentable technologies into some 400 "class references". Each class is also subdivided into very fine divisions of technology or approximately 100,000 "subclasses". Each subclasses presents a piece of knowledge (Hargadon and Sutton(1997) [34]; Van de Poel (2003)[55]). The patent office typically assigns each patent into multiple subclasses within and across major classes. High degree of novelty implies patent classes of cited patents differ from those of the focal patent. Each patent office has his own construction methods.

Fleming (2001)[26] firstly tests causes of novelty: new component and new component recombination. New component indicates creating new elements while new recombination indicates recombining already established elements. Comparatively, new recombination bases more on local search and higher probability to generate incremental improvement but within established disciplines. Rosenkopf and Nerkar (2001)[51] claims that radical inventions will be more likely to cite patents from other patent classes.

Hypothesis 2 : *Opposition probability increases with the degree of novelty of a patent, especially the number of the new components in it*

Unique Literature, such as Zaltman et al. (1973) [57], present primary definition of unique invention, as "differ from preexisting alternatives to the extent that those alternatives are deemed to be insufficient substitutes". Under the technological context, unique requires the unique combinations of knowledge endowments. Even, as Van de Poel (2003) [55] claimed,unique invention goes beyond simple recombination of existed knowledge, but bring new elements. In fact, Kornish and Ulnich (2011) [40] discussed the routines of generating ideas,they found that save ideas are generated multiple times when a large number of independent efforts works together.

In the context of patentability, unique is corresponding to non-obvious to an individual who is knowledgeable in the relevant technical field. KB. Dahlin and DM. Behrens (2005) [21] measures it as no similar with other patents in the save filing years.Uniqueness positively relates to the patent value and novelty, therefore I can expect that

Hypothesis 3 : *Opposition probability increases with the degree of unique*

Net Entry of Similars Driver of technological change is the core element for identify a radical inventions. At macro level, bibliometrics studies, such as Science Citation Index, and the Newspapers for technology provide timely insight into the prospects of technological change (Zvi Griliches (1990)[31]; Bjørn L Basberg (1987) [6]) and diffusion. A new technology can open up entirely new markets and changes industries structure.

Patent data is criticized that can't catch the economic return, but widely accepted to analyze a technological change. In studies of radicalness, forward citation, the counting number of times a patent is cited by later patents, is used to evaluate the impact on future technolgies(Trajtenberg (1990) [54]; Harhoff et al.(1999) [36]).Series of empirical works correlate forward citations with measures of value such as stock market valuations, Tobin's q (Bessen (2009) [7]; Hall, Jaffe,and Trajtenber (2005) [32]) and the opposition probability in EPO or validity challenged in the infringement suits. In this paper, I construct a new indicator, net entry similar patents. The indicator develops the methods in K.B. Dahlin, D.M. Behrens (2005) [21] and can provide more precise description of technological changes before and after the patent.

Hypothesis4 : *Opposition Probability increases with the patent bringing net entry of similar patents.*

4 Description of Data and Patterns

4.1 Opposition and Control Group

I construct a dataset of patent characteristics using EPO patent applications data contained in the April 2012 version of the EPO Worldwide Patent Statistical Database (PATSTAT). Data on each patent's legal status and opposition are extrapolated from the INPADOC records of the EPO. Additional data on countries of residence of patent applicants were extracted from the OECD HAN Database. Magerman et al.(2010) provides a full description.

Construction of the main indicators base on main IPC code (International Patent Classification). During an EPO examination process, patents are assigned IPC codes of up to nine digits. Patents belonging to different technological fields and can thus be assigned several IPC codes at the same time. The IPC-Technology Concordance Table, released by the WIPO (2008, revised in 2011), which classifies IPC codes into 40 technology areas has been used.Patent level data from different sources were linked to EPO patents via their application id and publication number.

The dataset was constructed in the following manner. I firstly identify opposed patents, whose filing date were between 1999-2000, The INPADOC codes enable retrieving information on opposition and final outcomes. "EP26" retrieves the patents having been opposed, "EP27A" represents the cases, where the patent is maintained as amended, and "EP27W" represents the case in which after the reexamination of Opposition Division, challenged patents was revoked in all the contracting states. There are totally 3918 patents being challenged during the sample year. To focus on the interested patterns, I drop the patents without any backward citations. In the final sample, 3747 opposed cases are left, 1075 are revoked and 1303 amended.

For investigation of the differences between patents opposed and those not, I generate a "matched" set of patents from the population of all European granted patents. I have stratified the control group by the year of application, the residence countries of applicants and the technology classification. For each patent in the group of opposed patents, one matched patent was drawn randomly from the European patents. To ensure a one–to–one match, I excluded those patents from the investigation group, and patent without any backward citations. Finally, the reference group of non-opposed patents consists of 3747 patents as well.

We create a binary variable to distinguish between patents that were opposed from those that were not opposed. This variable reflects the endogenous outcome we want to model.

4.2 Measures of Technological Radicalness

I construct measures of technological radicalness with patent data across all technologies and residences of applicants. I propose a method for identifying inventions that although they have the potential to affect change within an industry, do not necessarily succeed in doing so. In addition, I assume that the radicalness is defined on technical content, and does not make any assumption about firm heterogeneity.

The first step to construct measure is to adopt the concept of "citation overlap" in K.B.Dahlin and D.M.Behrens 2005[21]. The search report from patent examiners provides a list of references for each patent application. The reference that the patent makes to the existing prior art is defined as *Backward Citation*. The list of referenced patents bounds the focal patent and also shows what previous ideas the invention rests upon.

I construct a dataset, denoted as J_i, where patents have at least one same backward citations with the focal patent i. Consider patent i , issued at time t_0,from the focal sample described above, and patent j issued at time t_j from set J_i. Let i_c be the set of patents cited by patent i, and let j_c be the set of patents cited by patent j: the set $i_c \cap j_c$ is the set of patents both i and j and $i_c \cap j_c \neq 0$.

To collect all the set J properly, I extract information on patents filed between 1990 - 2010 and exclude patents without any backward and same as the focal sample. I didn't exclude non-granted patents, but to control for a potential grant bias, I construct two groups of measures, calculated by total patent and calculated by only granted patents in the set j_i. The total sample contains 431748 patent applications and 311014 of patents are granted

Since one invention is usually patented through multiple offices, the basic sample described above can contain multiple equivalent patents for one invention (a so-called $patentfamily$). To remedy this issue, we opt to use the patent family according to the DOCDB definition as a unit of analysis. Since indicators and controls are calculated based on applications, we aggregate by taking the maximum value for the indicators constructed, as well as for the ones used in the literature. When using application years, we take the application year of the first patent in the family. After aggregation we are left with 259109 observations sharing at least one same backward citations as the focal sample.

Forward Citation Patent publication making references to the focal patent is defined as *Forward Citation.*Studies of innovative breakthroughs use a count of forward citations or a dummy variable indicating the breakthroughs for the top tier of cited patents) as the outcome of interest. I construct *Forward Citation* as the number of cumulative forward citations frequencies to a focal patent for eight years after its filing. This period is enough to capture the bulk of citations to a patent. I will use the *Forward Citation* as a dependent variable in negative binomial count models to test that how do radicalness explain the useless of a patent.

Novelty I distinguish the novelty as inventions that bring new component and new recombination of existing components.I proxy the element of a technology by using the IPC-class. The EPO categorizes patents into classification based on a hierarchical organization of knowledge domains. Each patent is given one or more three-digit classifications. As Fleming (2001) [26] , *New Component* is counting the number of a focal patent's subclasses and the *New Recombination* is counting the number of unique pairwise combination of focal patent's IPC classes.

For each patent, I compare existence of the IPC class and IPC class pairs in the body of similar patents j and the focal patents i. we denote i is one of the focal patent, j is the patent in the body of similar patents, which have at least one same backward citation with patent i, and $j \neq i$. IPC denote the unique IPC four digit classes for each patent and $PAIR$ denote the pairwise combination of patent's IPC class. I identify the same IPC codes between IPC_i and IPC_j and same pairwise combination between $PAIR_i$and $PAIR_j$. Similar rate is the total same IPC codes pairwise dividing the number of total IPC_i and $PAIR_i$. The $NewComponent(NC_i)$ and $NewPair(NP_i)$ is the average of non-similar rates calculated as above. If a patent has zero new IPC codes or IPC pairwise compared with total similar patents set, this two indicators amounts to zero. The function is as following:

$$NewComponent(NC_i) = \frac{1}{N}\sum_{j}^{N}(1 - \frac{Count(IPC_i \cap IPC_j)}{Count(IPC_i)})$$

$$NewRecombination(NR_i) = \frac{1}{N}\sum_{j}^{N}(1 - \frac{Count(PAIR_i \cap PAIR_j)}{Count(PAIR_i)})$$

Unique A radical patent's citation structure should be dissimilar to concurrent patents' citation structures. The measure for *Unique* compare patent i issued in t_0 to all patents j issued in the same year. The first step is to compare how citations of two patents i and j overlap. If the number of jointly cited patents $i_c \cap j_c$ is x and the number of separately cited patents $i_c \cup j_c$ is u, then : $os_{ij} = [i_c \cap j_c]/[i_c \cup j_c] = x/u$. Then os_{ij} can take values between 0 and 1, where 0 indicates "completely dissimilar" and 1 indicates "identical" citation patterns.

If we compare patent i issued in year t_0 to all patents j also issued in t_0 , and $i_c \cap j_c \neq 0$, *Unique* is one minus the summing patent i's overlap scores across all patents j, dividing n, the total number of patents j. We can denote *Unique* as $1 - \frac{\sum_j os_{ij}}{n}$, where $i \neq j$. It suggest that the radical potential patent should be unique and have high degree of *Unique*.

Net Entry of Similars The overlap score is possible to map onto the technology trajectories of the focal patent. I expect that radical patent can stands out in the normal stream of inventions and also impact on ensuing inventions. Before this patent, invention under the same technical content has low status or limited practical value. However, when a radical patent is timely and solves a technical problem, more other inventors or inventions are more likely to be elaborated upon.

The first step is to calculate i's overlap score for all patents j issued in some year t by taking the overlap score between i and each patent j issued in t.Annual overlap score of year t is defined as $\frac{\sum_j os_{tij}}{n_t} = \frac{os_{ti}}{n_t}$. Instead of counting forward citations, $\frac{os_{ti}}{n_t}$. Citation structure of a radical patent, summarized in K.B.Dahlin & D.M.Behrens(2005) [21] should be dissimilar to the citation structures of past patents and will become replicated in the future. That is $\frac{os_{ti}}{n_t}$ should be low for $t < t_0$ and should be high for $t > t_0$.

The new indicator *Change* can incorporate the entry of similar patents before and after the focal patent, which base on comparing the aggregate value of $\frac{os_{ti}}{n_t}$ when $t > t_0$ and $t < t_0$, where

$$Change_3 = \sum_{t=t_0}^{t=t_0+3} \frac{os_{ti}}{n_t} - \sum_{t=t_0-3}^{t=t_0} \frac{os_{ti}}{n_t}, t \neq t_0$$

$$Change = \sum_{t=t_0}^{t=t_0+8} \frac{os_{ti}}{n_t} - \sum_{t=t_0-8}^{t=t_0} \frac{os_{ti}}{n_t}, t \neq t_0$$

$Change_3$ capture the short term gap of annual over lap score where $Change$ capture the long-term changes before and after the filing of the focal patent i. With the same logic, two more indicators are constructed: $Similar_{before}$ captures the aggregate value of $\frac{os_{ti}}{n_t}$ when $t < t_0$, and $Similar_{after}$ captures the aggregate value of $\frac{os_{ti}}{n_t}$ when $t > t_0$.

Examples Figure 2a provides an illustration of how is patent information extracted from the patent documents and Figure 2b presents a case to explain calculations of three measures. The focal patent is denoted as i filed in year t_0. It includes the subclasses $B05B, A62C$ and two backward citations B_1, B_2. As the illustrated, there are totally five patents in the similar set $J_i : j_1, j_2, j_3, j_4, j_5$. j_1 and j_2 are filed before the filing year of the focal patent and used for the measures of $NewComponent$ and $NewRecombination$. Since the corresponding patent subclasses are $IPC_{j_1} = \{B05B, F23D\}, IPC_{j_2} = \{B05B\}$, we can calculate that $NC_i = \frac{(\frac{1}{2}+\frac{1}{2})}{2} = \frac{1}{2}$ and $NR_i = \frac{(1+1)}{2} = 1$.

Calculating the measure $Unique$ and $Changes$ requires the information of backward citations of each similar patents in the set J_i: $B_{j_1} = \{B_1\}, B_{j_2} = \{B_1, B_4, B_5\}, B_{j_3} = \{B_1, B_3\}, B_{j_4} = \{B_2\}, B_5 = \{B_2, B_6\}$. We can get $os_{0j} = 0, os_{1j} = \frac{1}{2}, os_{7j} = \frac{(1+\frac{1}{2})}{2} = \frac{3}{4}, os_{1j} = \frac{1}{3}, os_{6j} = 1$. then $Unique = 1 - os_{oj} = 1, Change_3 = \frac{1}{2} - \frac{1}{3} = \frac{1}{6}, Change = (\frac{1}{2} + \frac{3}{4}) - (\frac{1}{3} + 1) = -\frac{1}{12}$

4.3 Control Variables

We control for a variety of measures that have been used as proxies of economic value of patent in available literature.

- *Family Size* computed as the number of jurisdictions in which patent protection was sought for the same invention. Many authors Harhoff et al.(2002) [35]; Lanjouw and Schankerman (2001) [42] have found that large international patent families have been found to be particularly valuable. Firms only enforce valuable patents in multiple countries, since the expected value of the patented technology must be over than the costs required to file and enforce the patents.

- *Number of Claims* A patent comprises a set of claims that define the scope of the property rights. Lanjouw and Schankerman (2001)[42]; (2004) [43] confirm the positive correlation between the number of claims and patent value. Related to the litigation selection, since one of the opposed reason is the claims is too broad in the application, we can expect the number of claims provide positive impact on the opposition probability.

- *References to the non-patent literature* Patents may be based in part or fully on new scientific knowledge. Non-patent literature consists of peer-reviewed scientific papers, conference proceedings, databases (e.g. DNA structures, gene sequences, chemical compounds, etc.) and other relevant literature. Scholars find that patents citing NPL are of significantly higher quality than patents that do not cite scientific literature, and also suggests more complex knowledge and this in turn may influence the uncertainty and risk of being opposed.(Cassiman et al. (2008) [11]; Fleming and Sorenson (2004) [26]).

- *Residence of Patent Applicant* All the patents in the cleaned samples have a matched assignee and corresponding residence, nationality presented here is identify by the residence of patent applicant. I also construct a dummy for patents from EU15 to compare the impact differences between local and foreigner patents.

- *Technology Sectors* Technology sector is defined according to IPC-technology classification (as updated in 2010 and 2011) which relies on the International Patent Classification (IPC) codes contained in the patent documents. This taxonomy features 40 fields and classified as five main technology sectors: Electrical, Instruments, Chemistry, Mechanical and others. Making it possible to conduct within-industry comparison.

4.4 Descriptive statistics

Table A displays the distribution of opposition cases, broken down by technology sectors and nationality. European patents stand for higher percentage (51%) than patent from other regions across all major technologies. The distribution is similar with the empirical results by Lanjouw and Shankerman (2001) [42]. There are also pronounced differences in opposition counts across technology sectors, holding ownership constant. The most notable percentage is Chemistry (35%) and Mechanical Engineering (35 %).

Figure 3 describes the average overlap scores over time related to when the focal patents are filed. The solid line represent the value calculated by all the similar patents, and the dashed line represents the value calculated by only the granted similar patents. Consistent with the results in K.B.Dahlin and D.M.Behrens (2005)[21], the scores peak for the year of patent filing, confirm that patents are more similar to other patents filed at the same time.

Figure 4 contains graphs over time for selected patents which can represent the different types of the inventions: radical, incremental and failed (potentially radical). Based on the definition in K.B.Dahlin and D.M.Behrens (2005) [21], a radical patent's citation structure should be dissimilar to the citation structures of past patents. That is, os_{ti}/n_t should be low for $t < t_0$; a successful radical patent's citation structure will become replicated in the future, illustrated in Figure 4.a. That is os_{ti}/n_t should be high for $t > t_0$. The figure 4.b presents the trends of failure radical patents whole citation structure is dissimilar to the ex ante prior art but can't impact following innovation activities. The figure 4.c presents the trends of the increment inventions.

Table 3 summarizes the means and standard deviations of the sample, where the left columns are constructed by all similar patents and right columns are constructed by granted similar patents. Measures by granted patents have lower mean values than the measures by all patents. NPL ranges from 0 to 126 citations per patent; the $ForwardCitations$ within five years range from 0 to 35 per patent. On average, the applicants designates 7.6 EPC member states and 12.78 claims per patent when filing his application.

Tables4 presents the provides information in each technology group and ownership category. Measures are constructed by granted patent. Chemical patents present high means with most of the measures, especially with the measure of $NewComponent(NC$=0.425), $Non-PatentLiterature$ (NPL=2.411), $Claims$ ($Claims$=13.977) and the number of $FamilySize$ ($FamilySize$ =9.955). However,patents from EU15 do not provide higher mean value in most measures, but higher variation.

Table 5 presents a correlation matrix. Variables demonstrate low inter correlation.

5 Model Specification and Results

The econometric analysis has several objectives. First, I evaluate the technological capacity of the opposed cases. I want to know first how do the radical characters correlates to economic value. Following past studies on patent quality, I use *Forward Citation* as dependent variables. The forward citation counts takes on only whole number values (that is ,0,1,2,etc). I use Negative binomial regression to test the idea, which explicitly accommodate this over-dispersion dependent variable, where the variance (1.716) is greater than the mean (0.908). Figure 5 provides the histogram of *Forward Citation*.The form of the model equation for negative binomial regression is identified as :

$$log(ForwardCitation_i) = \alpha_i + \beta_1 NewComponent_i + \beta_2 NewRecombination_i +$$

$$\beta_3 Unique_i + \beta_4 Change_i + \beta_5 Claims_i + \beta_6 NPL_i + \beta_7 FamilySize_i + \epsilon_i$$

Econometric results are reported in Table 5. The results in left column test measures based on granted patents and results in the right column test measures based on all patents. I test the ideas with full sample and also subsample where patent has been opposed. Indicators relate to the novelty mostly present negative coefficients, such as $NewPairs$, $Unique$, NPL , suggesting that low degree of novelty related patents are more frequently cited than comparable patents with high novelty linkages. The results are consistent with our assumptions that economic value ($ForwardCitation$) : Positive relationship between $ForwardCitation$ and litigation probability can't explain whether the high novelty but market failure patent will have high opposition probability or not.

Second, I test the impact of radicalness on opposition risk by Ordinary Least Squares(OLS) analysis. Dependent variable *Opposition* is a binary variable with 0 or 1. $Opposition = 1$ if the patent has been opposed and $Opposition = 0$ if not. I firstly confirm direct effect of the control variables measuring patent quality on opposition probability: *Claims*, *Family Size*, *Non-Patent Literature* and dummies for technology sectors and residence of applicants. Then I add the measures for radical characters one by one. Table 7 presents results of Ordinary Least Squares(OLS) analysis with indicators by granted patents. For the robust check, I also report results of Probit and Logit regression in Table 6, and regression results with indicators based on total patents (Appendix Table A.2).The identification function with all independent and control variables is as follows:

$$Opposition_i = \alpha_i + \beta_1 NewComponent_i + \beta_2 NewRecombination_i +$$

$$\beta_3 Unique_i + \beta_4 Change_i + \beta_5 Claims_i + \beta_6 NPL_i + \beta_7 FamilySize_i + \epsilon_i$$

In testing Hypothesis 1, I am replicating the prior studies on patent opposition risk linking quality indicators. Though the samples of the prior studies are vastly different (in terms of numbers of observations, time periods, technological sectors), I find support for the significance of positive effect of control variables, excludes the non-patent literature. Note that, as previous studies have found, dummy of patents from EU15 presents significant positive effect. However, I didn't find the significant effect with the industry fixed effects, so no significant evidence to confirm large differences in the opposition probability across industries.

Testing Hypothesis 2, Column 2 shows that the measure of *New Component* is strongly positively associated with opposition probability, but measure of *New Recombination* is not.Column 3 confirms the positive effect of the uniqueness. In other words, holding all other variables at their means, the probability of being opposition decreases as the more other similar patents are filed during the same year. The marginal effect of uniqueness on the likelihood of being opposed is 0.78, which is substantially greater than the marginal effects of the other independent variables. To test Hypothesis 4, Column 4 use the growth gap within the three years to the filing year and Column 5 use the gap of aggregate change within the eight years. Both presents same degree of significant.

Finally, I test the impact of radicalness on revocation and amendment probability condition on the opposed cases. Here I use two different dependent variables: *Revoke* and *Revoke* + *Amend*. *Revoke* = 1 indicates that the opposed patent has been revoked after the opposition examination and *Revoke* = 0 indicates the alternative result. *Revoke* + *Amend* = 1 indicates that the opposed patent has been revoked or amended and *Revoke* + *Amend* = 0 indicates the alternative result. I report the econometric analysis by Ordinary Least Squares(OLS) analysis, Probit and Logit regression as well.

The result, reported in Table7, confirms the correct function of the opposition proceedings . Proxies for patent value, non-patent literature and claims presents significant negative effect, which suggest the more non-patent literature citing, and claims, the less probability of being totally revoked. Not all of the radical measures keep effect. Effects of the *New Component*, *New Recombination*, and *Unique* change to insignificant, and coefficient of *Change* changes to negative. Further evidence consistent with ex post impact can be found in an additional variable:$Similar_{after}$, implying the aggregate similar rate after the filing date of focal patents, shows statistically and economically significant negative.

6 Conclusion

The objective of the present paper was two folds: First, I construct a new approach to measure the technological radicalness. Three measures, novelty, unique and net entry of similar patent, are constructed based on classification and citation informations of European patents. They can be used to distinguish inventions that are introduce new ways of thinking or not. Second, I examine the radical characters in opposition cases in European Patent Office. To do this, I collect all the opposed patents during 1999-2000 in EPO and construct a matched groups of patents not involved in an opposition.

There are three main empirical findings. First, indicators for the novelty and uniqueness present negative relationships with the forward citations the focal patent received. The result suggests that it is meaningful to explore more factors than forward citations to redefine the patent quality. Second, using the full sample, the econometric suggest that three radical measures all positively effect the probability of being opposed. Finally, using the subsample based on opposition results, revoked patents lower capacity to attract net entry of similar patents, which confirm the function of opposition as amending wrong grant.

Implication for understanding determinants of opposition My approach takes seriously the idea started by Priest and Klein (1984) [49] and applied in recent studies (Lanjouw and Schankerman (2001) [42] and Harhoff et al (2003) [38]) that patent litigation selection should focus on high quality patent. After accounting for all the possible determinants of patent opposition procedures related to a patent's expected economic value, this paper presents the evidence that measures for technological radicalness still affect the likelihood of opposition, as well as the probability of the patent being revoked.

There are kinds of novel idea implicit in many studies of the identification of radicalness. In this paper, I used method in Fleming 2001 to distinguish novelty that from new components or new recombination. The contrasting results for new components and new recombination are particularly striking. they suggest that generating new elements imply high uncertainty with the patentability rather than recombining the elements in the existing patents.

Implication for litigation systems There are two potential explanations for the evidence of relative high incidence of opposition cases for patents with new components , uniqueness and net entry of similar patents. The first explanations is related to the uncertainty in the high degree of novelty and uniqueness. A second explanation is built on the mechanism design of opposition proceedings. Since opposition limits the time to file a notice within nine months of the grant decisions, it is rarely possible to enforce the patent and realize the market profit. Technological value can complement the economic value to explain the opposition filings.Firms have high incentive to transfer and license the valuable patents and file an opposition to ensuring the scope of a patent before purchasing it.

Mechanism design for reducing patent disputes is discussed more often recently(Carl Shapiro (2004) [52], Graham and Harhoff (2014) [30]).Assuming that no quality differences in the different litigation systems, I can expect that patents with high degree of uncertainty but technological value will be firstly challenged in a post grant proceedings, and fewer patents has won a market success may be challenged in an infringement suits. In fact, the recent reform of the US patent system with the "Leahy-Smith America Invents Act"(2011) has strengthen the function of post grant review procedures in USPTO. The change in the US patent system provides a natural experiment to further asses the whether does the post-grant review procedure improve the market efficiency and reduce the litigation cost.

Table 1: Composition of Opposed Patents, full sample, n=3747

By technology group	Total	%	EU15	%	US	%
Electrical	428	11%	207	48%	103	24%
Instruments	513	14%	191	37%	163	32%
Chemistry	1309	35%	593	45%	364	28%
Mechanical Engineering	1268	34%	763	60%	200	16%
Other	229	6%	171	75%	23	10%
Total	3747	100%	1925	51%	853	23%

Table 2: Descriptive Statistics, including indicators based on granted patents and total patents

	Full Sample (n=7494)				Opposed Patents (n = 3747)			
	Mean	Std	Min	Max	Mean	Std	Min	Max
FWD	1.29	2.29	0.00	58.00	1.49	2.67	0.00	58.00
BWD	5.94	4.81	1.00	121.00	6.71	5.15	1.00	121.00
$Claims$	12.78	9.46	1.00	147.00	13.56	10.07	1.00	147.00
NPL	1.09	5.57	0.00	126.00	1.33	5.62	0.00	126.00
$FamilySize$	7.65	5.39	1.00	49.00	8.37	5.87	1.00	49.00
Indicator based on granted patents								
$NewComponent$	0.39	0.30	0.00	1.00	0.40	0.30	0.00	1.00
$NewRecombination$	0.83	0.25	0.00	1.00	0.83	0.25	0.00	1.00
$Unique$	1.00	0.01	0.67	1.00	1.00	0.01	0.67	1.00
$Change_3$	0.00	0.01	-0.08	0.04	0.00	0.01	-0.08	0.03
$Change$	-0.01	0.02	-0.23	0.09	-0.01	0.02	-0.14	0.09
Indicator based on total patents								
$NewComponent$	0.39	0.31	0.00	1.00	0.40	0.31	0.00	1.00
$NewRecombination$	0.89	0.21	0.00	1.00	0.89	0.21	0.00	1.00
$Unique$	0.99	0.01	0.88	1.00	0.99	0.01	0.88	1.00
$Change_3$	0.00	0.02	-0.18	0.17	0.00	0.02	-0.12	0.17
$Change$	0.00	0.03	-0.23	0.17	0.00	0.03	-0.15	0.17

Table 3: Descriptive Statistics by Industries and Nationalities, using indicators based on granted patents. Mean & Std

	Ele. n=907	Ins. n=1034	Chem. n=2584	Mech. n=2525	EU15 n=3834	Rest n=3630
FWD	1.346	1.220	1.342	1.269	1.250	1.322
	(2.276)	(2.514)	(2.409)	(2.171)	(2.005)	(2.553)
BWD	5.164	6.384	6.082	5.870	5.531	6.373
	(5.192)	(4.050)	(5.822)	(3.570)	(4.415)	(5.162)
$Claims$	12.354	13.257	13.977	11.594	12.231	13.359
	(8.255)	(10.561)	(10.687)	(8.013)	(8.099)	(10.671)
NPL	0.560	0.748	2.411	0.218	0.706	1.498
	(1.383)	(2.482)	(9.103)	(1.010)	(3.660)	(7.019)
$FamilySize$	6.319	7.299	9.955	6.087	6.751	8.587
	(4.138)	(4.138)	(6.661)	(3.935)	(4.808)	(5.793)
$NewComponent$	0.376	0.384	0.425	0.366	0.371	0.406
	(0.286)	(0.281)	(0.293)	(0.301)	(0.303)	(0.287)
$NewRecombination$	0.848	0.864	0.754	0.877	0.841	0.820
	(0.229)	(0.225)	(0.288)	(0.219)	(0.254)	(0.249)
$Unique$	0.996	0.996	0.996	0.997	0.997	0.996
	(0.006)	(0.005)	(0.010)	(0.006)	(0.008)	(0.006)
$Change_3$	0.012	0.012	0.011	0.011	0.011	0.012
	(-0.006)	(-0.005)	(-0.004)	(-0.005)	(-0.004)	-(0.005)
$Change$	-0.010	-0.012	-0.010	-0.011	-0.010	-0.011
	(0.020)	(0.022)	(0.019)	(0.019)	(0.018)	(0.021)

Table 4: Correlation Matrix for Full Sample Patents, n=7494

	1	2	3	4	5	6	7	8	9	10
FWD	1.000									
BWD	-0.008	1.000								
$Claims$	0.025	0.103	1.000							
NPL	-0.047	0.282	0.081	1.000						
$FamilySize$	-0.024	0.155	0.206	0.213	1.000					
$NewComponent$	-0.035	0.063	0.082	0.050	0.090	1.000				
$NewRecombination$	-0.075	0.010	-0.037	-0.064	-0.164	0.247	1.000			
$Unique$	-0.028	0.032	-0.045	-0.008	-0.070	0.099	0.104	1.000		
$Change_3$	-0.003	0.013	-0.009	0.017	0.062	0.082	0.022	0.057	1.000	
$Change$	0.021	-0.020	0.007	0.009	0.048	0.051	0.005	0.058	0.712	1.000

Table 5: Comparing to direct citation counts, Dependent Variable: *ForwardCitation* within eight years from the patent filed, Full Sample

	using indicator based on granted patents				using indicator based on all patents			
	Full Sample		Opposed Patents		Full Sample		Opposed Patents	
NewComponent	-0.06	-0.07	-0.18	-0.18	-0.12	-0.13	-0.2	-0.2
	(-0.87)	(-0.94)	(-1.56)	(-1.59)	(-1.91)	(-1.92)	(-1.88)	(-1.91)
NewRecombination	-0.55***	-0.55***	-0.44**	-0.44**	-0.30**	-0.30**	-0.38*	-0.39*
	(-6.69)	(-6.69)	(-3.26)	(-3.27)	(-3.06)	(-3.11)	(-2.39)	(-2.45)
Unique	-4.73	-5.02	-3.5	-3.69	-9.29**	-8.96**	-10.73*	-10.34*
	(-1.75)	(-1.86)	(-0.87)	(-0.92)	(-3.19)	(-3.07)	(-2.36)	(-2.27)
$Change_3$	0.23		1.32		3.32*		1.640	
	(0.130)		(0.450)		(2.560)		(0.770)	
Change		2.03*		2.77		2.16**		1.490
		(2.010)		(1.660)		(2.850)		(1.160)
NPL	-0.01***	-0.01***	-0.02**	-0.02**	-0.01***	-0.01***	-0.02**	-0.02**
	(-3.58)	(-3.58)	(-2.64)	(-2.63)	(-3.55)	(-3.58)	(-2.63)	(-2.65)
Claims	0.01**	0.01**	0.01	0.01	0.01**	0.01**	0.010	0.010
	(3.060)	(3.060)	(1.890)	(1.880)	(3.060)	(3.000)	(1.830)	(1.800)
FamilySize	-0.01**	-0.01**	-0.01*	-0.01*	-0.01**	-0.01**	-0.01*	-0.01*
	(-2.84)	(-2.92)	(-2.17)	(-2.24)	(-2.65)	(-2.71)	(-2.34)	(-2.39)
Constant	6.13*	6.44*	5.010	5.230	10.49***	10.17***	12.19**	11.81**
	(2.280)	(2.400)	(1.250)	(1.300)	(3.630)	(3.510)	(2.700)	(2.610)
N	7494.000	7494	3747	3747	7494	7494	3747	3747
Log-likelihood	-9651.22	9648.80	-5138.07	- 5136.49	-9664.67	-9664.18	-5138.83	5118.84

*Notes:Negative binomial regressions, Standardized beta coefficients * p¡0.05, ** p¡0.01, *** p¡0.001*

Table 6: Regression Results,Determinants of Opposition Likelihood, using indicators based on granted patents

	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$NewComponent$		0.062**	0.054**	0.051*	0.052*	0.133*	0.205*
		(3.04)	(2.64)	(2.49)	(2.55)	(2.54)	(2.44)
$NewRecombination$		0.012	0.005	0.005	0.005	0.017	0.03
		(0.49)	(0.22)	(0.19)	(0.22)	(0.27)	(0.25)
$Unique$			3.446***	3.365***	3.352***	8.139***	16.046***
			(4.42)	(4.31)	(4.29)	(4.28)	(4.23)
$Change_3$				1.051*			
				(2.06)			
$Change$					0.626*	1.626*	2.525*
					(2.14)	(2.17)	(2.09)
NPL	0.002	0.002	0.002	0.002	0.002	0.004	0.01
	(1.59)	(1.53)	(1.48)	(1.48)	(1.49)	(1.56)	(1.52)
$Claims$	0.003***	0.003***	0.003***	0.003***	0.003***	0.008***	0.013***
	(5.03)	(4.82)	(4.99)	(5.04)	(4.99)	(4.95)	(4.90)
$FamilySize$	0.012***	0.012***	0.013***	0.013***	0.013***	0.033***	0.054***
	(10.75)	(10.60)	(10.82)	(10.68)	(10.70)	(10.58)	(10.40)
$Const$	0.375***	0.344***	-3.085***	-2.996***	-2.983***	-8.483***	-16.597***
	(13.78)	(9.88)	(-3.97)	(-3.85)	(-3.83)	(-4.47)	(-4.39)
$Technology$	No	No	No	No	No	No	No
$EU15$	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R^2	0.023	0.024	0.026	0.027	0.027	0.021	0.0213

*Notes:Dependent Variable is Patent Opposition (0/1). Standardized beta coefficients * p¡0.05, ** p¡0.01, *** p¡0.001*

Table 7: Regression Results conditional on opposition occurring. Dependent Variable: Revoke=1 or (Revoke+Amend)=1

	indicator based on granted patents			indicator based on total patents		
	Model1a revoke	Model2a revoke	Model3a revoke/amend	Model1b revoke	Model2b revoke	Model3b revoke/amend
NewComponent	-0.007	0.013	0.083**	-0.004	-0.005	0.025
	(-0.30)	(0.51)	(2.97)	(-0.18)	(-0.21)	(0.95)
NewRecombination	-0.026	-0.028	-0.061	-0.018	-0.019	-0.049
	(-0.71)	(-0.89)	(-1.79)	(-0.49)	(-0.51)	(-1.25)
Unique	-0.54	-0.848	1.867	-0.181	-0.322	5.190***
	(-0.58)	(-0.91)	(1.87)	(-0.17)	(-0.30)	(4.58)
Change	-0.004			-0.697*		
	(-0.01)			(-2.33)		
$Similar_{before}$		-0.178	-0.346		0.56	-0.2
		(-0.45)	(-0.82)		(1.65)	(-0.56)
Similar_after		-2.143*	-0.635		-0.954*	-0.869
		(-2.24)	(-0.62)		(-2.24)	(-1.92)
NPL	-0.005***	-0.005***	-0.002	-0.005***	-0.005***	-0.002
	(-3.95)	(-3.90)	(-1.58)	(-3.88)	(-3.83)	(-1.42)
Claims	-0.002**	-0.002*	0.002*	-0.002*	-0.002*	0.002*
	(-2.59)	(-2.52)	(2.28)	(-2.50)	(-2.46)	(2.36)
FamilySize	-0.002	-0.002	0.003*	-0.002	-0.002	0.004**
	(-1.67)	(-1.50)	(2.30)	(-1.41)	(-1.39)	(3.01)
Industry	No	No	No	No	No	No
EU15	No	No	Yes	No	No	Yes
Pseudo R^2	0.007	0.008	0.008	0.008	0.008	0.013

*Notes:Standardized beta coefficients * p¡0.05, ** p¡0.01, *** p¡0.001*

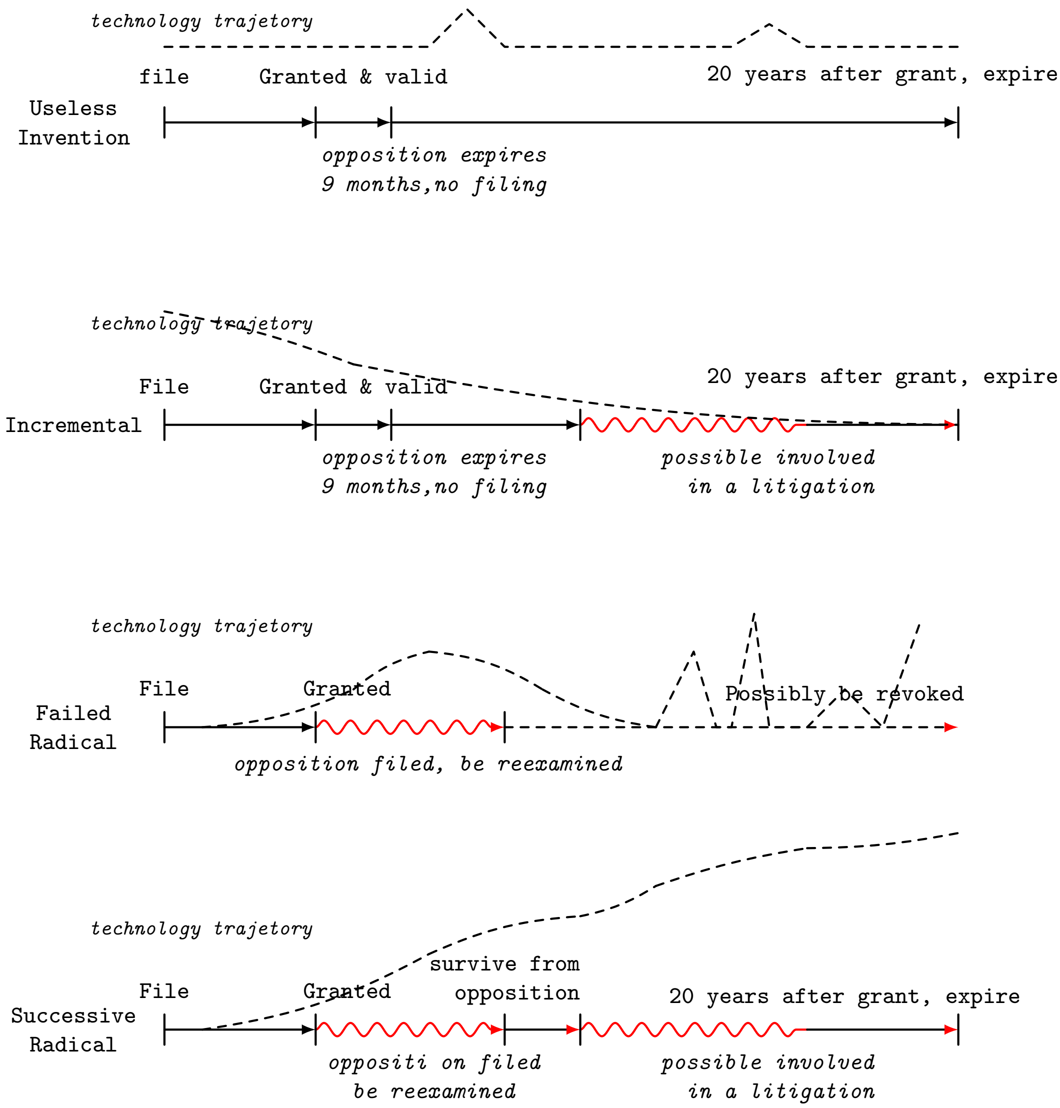


Figure 1: Inventions have different probability of being opposed and litigated

Figure 2: Example for Measures Calculation

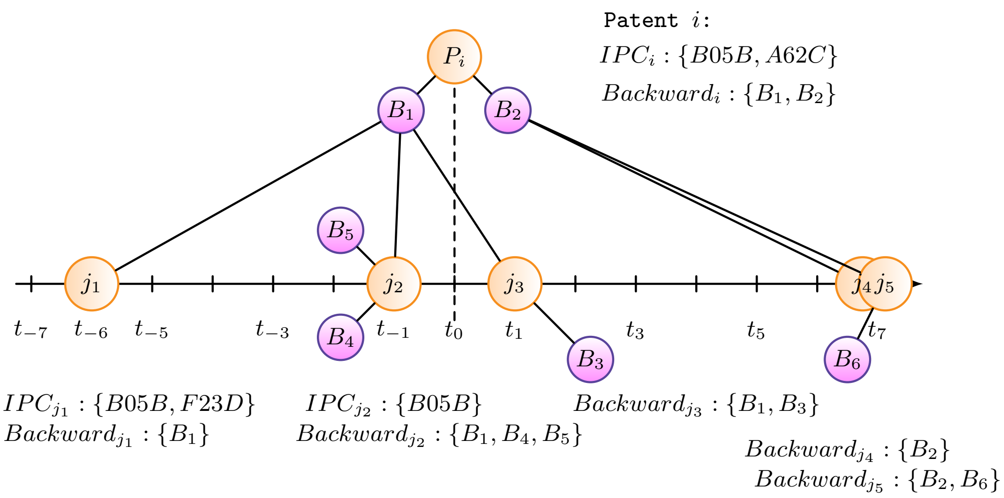


Figure 3: Distribution of overlap scores in relationship to the year a patent is filing

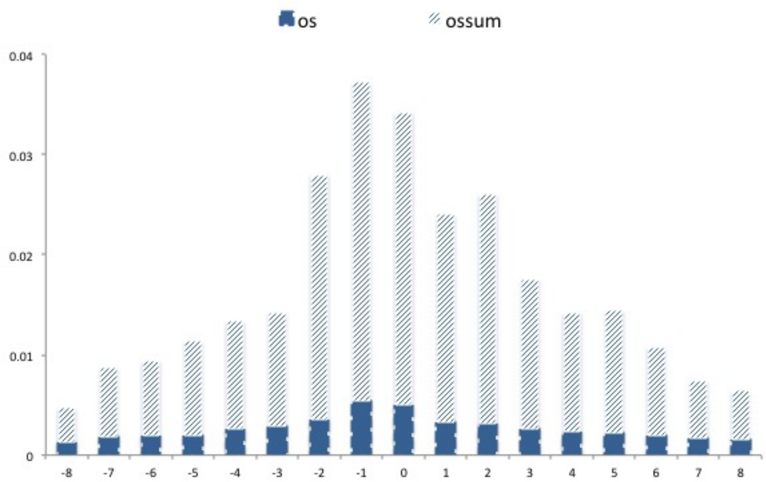
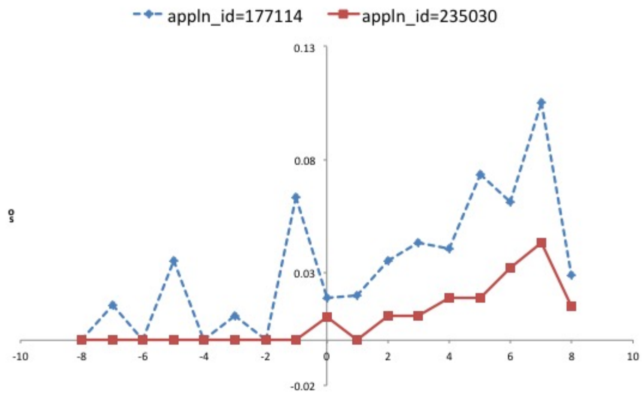
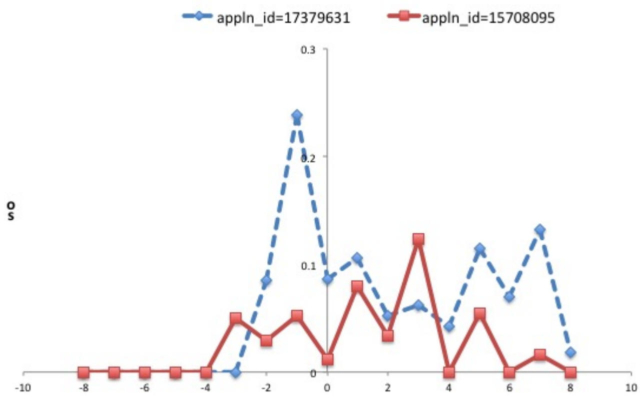


Figure 4: Selected examples to represent different types of inventions

(a) successful radical invention



(b) failed radical invention



(c) incremental invention

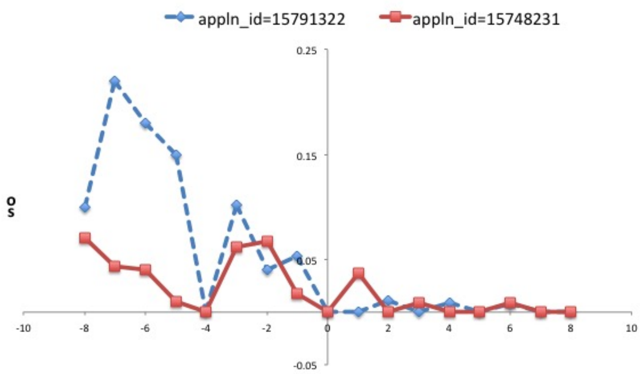
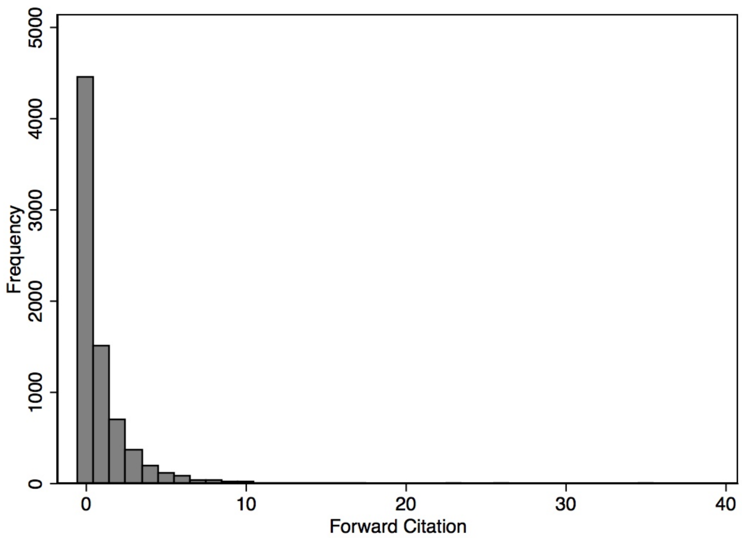


Figure 5: Distribution of Forward Citations



A Appendix

Table A.1: Validity Challenge Proceedings in Major Economics

	by Patent Office	Invalidity Counterclaims in Infringement Litigation
DE	Yes, Deutsches Patent and Markenamt (DPMA) has an opposition division to accept the request within three months from the publication of the patent specification.	Yes, After the opposition period expires, German patent or the German part of a European patent can be challenged before the Bundespatentgericht (BParG, Germany Federal Patent Court) at any time. It decides in the first instance on actions for the nullification of a registered patent, while Actions brought on account of the infringement of industrial property rights are dealt with by the civil courts of general jurisdiction.
UK	UKIPO has no opposition division.	Challenging the validity of a patent is a permissible and frequent defense in UK infringement actions.
US	Yes, "Inter reviews" and "Post-grant reviews", but it is conducted as an administrative trial before administrative patent judges of the newly-renamed Patent Trial and Appeal board.	yes,Invalidity Counterclaims is a permissible during an infringement litigation
Korea	Yes, Intellectual Property Tribunal (IPT) is established under the jurisdiction of commissioner of the Korean Intellectual Property Office to be responsible for trials and retrials for patents.	Invalidation action in IPT is conducted as an administrative trial before administrative patent judges.
Japan	Japan Patent Office has the Board of Appeals and Trials to conduct judgment on invalidation request.	After the new Patent Act in 2013, civil courts in Japan have power to declare nullity during an infringement litigation.
China	Invalidity can be tested in the Reexamination Board in SIPO.	None

Table A.2: Regression Results,Determinants of Opposition Likelihood, using indicators based on total patents

	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
NewComponent		0.052**	0.052**	0.051**	0.048*	0.123*	0.194*
		(2.77)	(2.74)	(2.70)	(2.54)	(2.53)	(2.49)
NewRecombination		0.014	0.014	0.012	0.005	0.015	0.023
		(0.50)	(0.49)	(0.43)	(0.19)	(0.21)	(0.19)
Unique			0.15	0.174	0.367	0.959	1.613
			(0.18)	(0.21)	(0.43)	(0.44)	(0.46)
$Change_3$				0.221			
				(0.59)			
Change					0.704**	1.809**	2.904**
					(3.20)	(3.21)	(3.20)
NPL	0.002	0.002	0.002	0.002	0.002	0.004	0.007
	(1.59)	(1.54)	(1.54)	(1.52)	(1.43)	(1.50)	(1.45)
Claims	0.003***	0.003***	0.003***	0.003***	0.003***	0.008***	0.013***
	(5.03)	(4.88)	(4.88)	(4.87)	(4.80)	(4.74)	(4.73)
FamilySize	0.012***	0.012***	0.012***	0.012***	0.012***	0.032***	0.052***
	(10.75)	(10.66)	(10.62)	(10.57)	(10.35)	(10.25)	(10.06)
Const	0.375***	0.345***	0.196	0.175	-0.008	-1.327	-2.213
	(13.78)	(8.96)	(0.23)	(0.21)	(-0.01)	(-0.61)	(-0.64)
Industry	No	No	No	No	No	No	No
*EU*15	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R^2	0.023	0.024	0.023	0.023	0.025	0.0194	0.0196

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