Patent Value, Uncertainty, and Standard Declaration: Implications from Patent Litigation

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ABSTRACT:

In this study, we use carefully constructed matched samples of litigated and non-litigated patents to investigate the characteristics that predict litigation. Survival time regressions allow us to demonstrate the separate impacts of value and uncertainty on litigation. In particular, standard essential patents are more likely to be litigated than non-SEPs, because they are more valuable. However, the earlier the disclosure is made, the *lower* the hazard of litigation. That is, when information is provided early to the market, uncertainty is reduced and the hazard of litigation is lower. Similarly, the total number of lifetime patent citations is positively correlated with litigation (the value effect); however, if those citations are received early in a patent's life, the informational content reduces uncertainty and consequently the litigation rate. These findings reconcile some inconsistent results in the empirical literature.

JEL: K41, L15, O34

Keywords: patents, litigation, USPTO, patent examination, uncertainty

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1. Introduction

Legal uncertainty is inevitable in a patent rights system. And since patents are fundamentally property rights, the legal environment can significantly affect the value of patent protection (Lanjouw 1994, Lemley and Shapiro 2005). Uncertainty over whether a "title" to property can be enforced will undermine its market value: the title is only as good as the ability to enforce it. Illustrative examples of the importance of property rights enforcement can be found in television portrayals of the "Old West." In 1859, a title to land in Virginia was more valuable than one in Nevada, in part because of the "underlying value of the land,"–closer to transportation and markets, more fertile, etc. However, Virginia land was also more valuable because better enforcement mechanisms were in place there. On the TV series Bonanza, the value of the Ponderosa ranch was due in part to the quality of the land for grazing cattle, and in part to the ability of the Cartwrights to enforce their title–whether through formal institutions (the local constabulary) or self-help (the number of able-bodied Cartwrights available during the episode).

Legal uncertainty is especially pervasive in emerging technology areas (or emerging patenting areas, like business methods and software patents). Where uncertainty is prevalent, the effects on appropriation and firm behavior can be dramatic. The value of property rights is also affected by other institutional and technological factors, including standard- setting and the availability of alternative mechanisms such as lead time, marketing, and trade secret. Uncertainty in any of these areas will have impacts on appropriability.

Because the purpose of a patent system is to provide incentives for research, innovation, and diffusion by creating rewards, an inability to appropriate those rewards diminishes the very incentives for which the system was designed. Different legal or institutional environments may affect the incentives for firms to license and do R&D (Reinganum 1989), to enter (Choi 1998), and to litigate (Meurer 1989). If property rights are well-defined, firms may organize transactions through arms-length negotiations. In uncertain legal environments, we expect to see more integrated transactions ranging from cross-licensing to strategic alliances to consolidation. To the extent that uncertainty affects or drives these decisions, it is of great strategic importance to firms. And, to the extent that policy-makers have some control over the amount of legal uncertainty, or legal "quality" as coined by Merges (1999), it is an important and understudied policy instrument. Simulation estimates (Lanjouw 1994, Lanjouw 1998) find that changes in patent law or the legal environment can significantly change the value of patent protection, not just for litigated patents, but for all patents even if none are ever litigated. For example, Lanjouw estimates that if the underlying probability of success for a plaintiff fell from 75% to 50%, and legal fees doubled, then the average patent value would be halved in her simulation, even if no cases were litigated.

Uncertainty is introduced into a patent system by both the administrative agency (the Patent and Trademark Office (PTO) in the US) and the legal institutions. There may also be some inherent uncertainty over patent rights due to the nature and novelty of the underlying invention. In fact, when an innovation creates something truly new, the existing technical lexicon may be insufficient for explaining it; we are left with only metaphor.[1] And, in any case, there is always linguistic uncertainty in transforming ideas into words that are subject to interpretation.

Because of the importance of enforcement on the value of intellectual property, many researchers in the US have pointed to the establishment of the Court of Appeals for the Federal Circuit (CAFC) in 1982 as a watershed in the rights of patent holders. It is claimed that the CAFC strengthened the rights of patent holders–that the court is more "pro-patent" than its district peers (Lerner 1994, Lanjouw 1994, Lanjouw and Shankerman 1997, Kortum and Lerner 1999, Henry and Turner 2006). The changes in the institutions governing patents can increase or decrease the uncertainty over the scope and validity of patents, and we must recognize that this uncertainty will have effects on firms' incentives to litigate, license, do R&D, and to patent in certain areas. Lerner (1994) finds that the "shadow" of litigation may change the patenting behavior of firms; in particular, high-litigation-cost firms may target "less crowded" technology areas in order to avoid disputes. These effects may be large, and may be an important part of the patent system. For this reason, it is important to have an understanding of the quantitative impact of uncertainty on the value of patent rights.

In this study we analyze the relationships between certain patent-related characteristics and the likelihood that a patent will be the subject of a patent infringement lawsuit. We examine several types of patent characteristics based on the stage of a patent's lifetime. In particular, we consider four stages: patent application filing, patent examination (or "prosecution"), patent issuance, and post-grant activity. *Application characteristics* are those that are observable at the time the patent application is filed at the patent office (e.g., whether the application claims the benefit of a foreign patent application). *Examination characteristics* are those that describe the examination process—or "prosecution"—of the patent application (e.g., the time in prosecution or the seniority of the examiner). *Patent characteristics* are those that are identified by the patent grant itself (e.g., the number of independent claims). Because patent examination may alter the text or characteristics of the patent, it is important to distinguish *patent characteristics* from *application characteristics.* Lastly, we consider *post-grant characteristics* which generally include time-varying features of the patent, including forward citation counts and whether the patent has been declared as a standard essential patent (SEP).[2]

Our taxonomy helps to understand the sources and consequences of uncertainty with more precision than in previous studies. As a result there are three main contributions of this study.

The first contribution is our detailed look at the prosecution history of patent applications in the context of litigation.[3] As explained above, there is some inherent uncertainty in describing an invention. But, the remaining uncertainty can be mitigated by the applicant and the examiner. Thus, by carefully investigating the initial patent application and the examination history of an application, we can better understand the ways in which uncertainty is introduced or reduced. Further, because the patent office can only actively control the examination process, this stage should be of particular interest to those policymakers interested in "patent quality" or patent examination quality.

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[1] Thanks to David Martin for this concept.
[2] It is possible for some of these characteristics to be defined prior to grant. For instance, the pre-grant publication of a patent application may be cited prior to issuance. We explain in greater detail below.
[3] See Marco and Miller (2017).

Second, by carefully constructing different matched samples we can investigate uncertainty separately from patent value. Litigation requires that a patent be valuable enough for parties to be willing to incur the overall expected costs of the dispute. However, litigation also requires an actual dispute; the parties must disagree on something.[4] The greater the uncertainty over the patent rights, the more the parties are likely to disagree (Priest and Klein, 1984).

Last, our survival time analysis enables us to investigate the timing of information disclosure to the marketplace. After issuance, the patent is subject to changes in the technological and competitive landscape that may lead to observable patent citation patterns, market transactions, and patent maintenance payments. These observable events may be correlated with either patent value or with uncertainty. In practice, it has proved difficult *a priori* to identify observable characteristics that measure value or uncertainty, but not both. For example, broader patents are likely to be more valuable, but they may also be associated with greater uncertainty over the validity of the patent.

By exploiting the timing of post-grant events using survival time regressions we are able to make inferences about the characteristics that are associated with value and those that are associated with uncertainty. Further, we are also able to reconcile some apparent inconsistencies in the previous literature. We find that the total number of citations received by a patent is associated with a higher rate of litigation; this is consistent with the interpretation of citations as a correlate of patent value. However, if those citations are received early in a patents life the rate of litigation is lower. That is, when the information about value is observed early in a patent's life, it resolves the uncertainty (to an extant) leading to fewer litigated cases. Similarly, we find that SEPs have a higher rate of litigation. However, the disclosure itself that the patent is standard essential lowers the rate of litigation. We find similar results for self-citations and for the frequency that the patent is used in a security agreement.

The next section provides an overview of the relevant literature and the patent examination process. In Section 3, we describe the data and matching methods used to create the matched samples.

Section 4 reports the results of the survival time regressions, where we estimate the hazard rate of litigation conditional on the four types of characteristics including time-varying measures of *post-grant characteristics*. We find that forward citations, forward self-citations, SEPs, and the use of patents in security agreements (as collateral) are all associated a higher rate of litigation (which we interpret to be indicate greater patent value). In each case earlier disclosure of this information leads to a lower rate of litigation, which is consistent with the information disclosure reducing uncertainty. We find that the number of ownership changes is negatively correlated with the litigation rate, which is consistent with Coasian bargaining and clear property rights. However, when those transactions occur at a high rate soon after issuance, it leads to greater uncertainty in the marketplace.

We conclude with a discussion of the policy consequences in Section 5.

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[4] It is possible that pure nuisance suits are an exception to this, where a defendant may settle a winnable case simply to avoid the court costs. See FTC (2016).

2. Background

In this section, we provide a description of the determinants of litigation as identified by legal and economic scholars and a brief review of the relevant economic and legal literature. Because we hope to add to this literature by including measures related to patent examination, we also provide a description of some of the major milestones in the examination process.

2.1 Determinants of Litigation

Theoretical models have identified several key determinants of patent litigation. First, the probability of litigation increases with the probability that a patent is infringed at all. Because the infringement has to be such that it can be observed or detected by the patent owner, we would expect patents with broader claim scope to be more likely to be litigated (Lanjouw and Schankerman, 1997).

Second, the likelihood of litigation increases if there is a greater divergence in parties' expectations about the outcome of a trial (Lanjouw and Schankerman, 1997; Priest and Klein, 1984). This divergence of expectations can be exacerbated by uncertainty regarding the scope of patent rights and the proper boundaries around the claims being allegedly infringed. The fuzzier these boundaries are, the more likely it is that potential infringers will dispute the patent or continue their potentially infringing activities when confronted by the patent owner. Such asymmetry between the parties' beliefs may also be reflected in widely different views about appropriate licensing fees.

Third, the probability of litigation increases with the value of the patent (Cooter and Rubinfeld, 1989; Lanjouw and Schankerman, 1997; Lerner 2008). Litigation is costly, so patent owners are less likely to file suit if the patent is of low value. At the same time, from a theoretical point of view, low value patents are less likely to be infringed in the first place, at any given level of vigilance on the part of the patent owner. In other words, competitors are less likely to want to adopt a product or process innovation that has little or no value.

Fourth, the probability of litigation is related to the relative cost of going to trial versus the cost of settling (Cooter and Rubinfeld, 1989; Lanjouw and Schankerman, 1997). For certain patent owners, the cost of going to trial may be overly prohibitive. The results of Lanjouw and Schankerman (2001) suggest that this might especially be the case for foreign owners.

2.2 A Brief Literature Review

In this section we consider several studies that have examined the relationships between patent, assignee, and environmental characteristics on the one hand and the likelihood that a patent will be litigated on the other hand. In their seminal work on this subject, Lanjouw and Schankerman (2001) considered a sample of 5,452 patent cases filed between 1975 and 1991 and involving 3,887 U.S. patents. From the population of all U.S. patents (both litigated and non-litigated), they generated a control group matching on the month of the patent application and the International Patent Classification (IPC) subclass assignment. Among their findings were that roughly ten infringement or validity suits are generated for every 1,000 patents applications, domestic patent holders are more likely to file suit than their foreign counterparts, litigation rates differ by technology area, and individually-owned patents are more likely to be litigated than corporate-owned ones. They also found that litigated patents have more forward citations and forward citations per claim, suggesting that more valuable patents are more likely to be asserted in litigation cases.[5] Finally they found that litigated patents generally have more claims than their non-litigated counterparts, suggesting a link between patent scope and litigation rates. However, the authors used the number of all claims (independent and dependent) as their measure of possible patent scope, whereas the number of independent claims would be a better measure.

Cockburn (2003) looked at "front page" information for 182 patents for which the U.S. Court of Appeals for the Federal Circuit (CAFC) had issued a ruling on validity between 1997 and 2000. Cockburn (2003) found that although the characteristics of patent examiners differ substantially as to experience, technological specialization, and length of time spent working on each patent application, there was no strong correlation between these characteristics and the likelihood that a patent would be invalidated by the CAFC. Cockburn (2003) also noted as a "core finding" that examiners whose patents are cited more frequently tend to have a higher probability of a CAFC invalidity ruling. Cockburn (2003) also concluded that although validity as determined by the CAFC is not related to the number of forward citations for the patent, validity is related to the proportion of citations attributable to an examiner's propensity to issue patents that receive a high level of citations. The examiner-specific citation rate could reflect a number of aspects of the patent examination process including differences across technologies, but Cockburn (2003) posited that a high degree of self-citation (the examiner's citation to patents for which she was the examiner) might be reflective of an examiner's reluctance to search beyond a narrow set of prior art with which she is already familiar.

Lanjouw and Schankerman (2004) extended their 2001 analysis by considering the effect of patent portfolio holdings on litigation activity. They obtained their data from the LitAlert database and considered 13,625 patent suits filed between 1978 and 1999. They focused on the main patent listed in each suit. A total of 9,345 such patents were included and the information included progress or resolution of suits as of the end of 1997. The method for constructing the control group was similar to the one used in Lanjouw and Schankerman (2001). The main findings of the study were that having a larger portfolio of patents reduces the probability of filing a suit on any individual patent in the portfolio and that this portfolio effect is stronger for smaller companies (measuring size by employment). For small firms, having a portfolio of patents is likely to be the key mechanism for avoiding litigation. They also found that firms operating in more concentrated technology areas (that is, where patenting is dominated by fewer companies) are much less likely to be involved in patent infringement suits. These firms are more likely to encounter the same disputants over time, so theory predicts greater incentives for settlement. Finally, they found that all sorting with respect to observed characteristics among patent disputes occurs in the decision to file suit. The key post-lawsuit outcomes do not depend on these characteristics.

In work that is most closely related to our study of the incidence of litigation, King (2003) examined the relationship between examiner hours per disposal within a particular examination group and the rate of litigation for those patents issued by the examination group.[6] His unit of analysis was the examination group itself and he focused on patents issued by each examination group in the years 1989, 1990, and 1991. He found that time spent examining was negatively related with patent litigation. In particular, his

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[5] A patent's forward citations are citations to that patent by future patents. A patent's backward citations are citations in that patent to previous patents. The number of forward citations is often used as a measure of patent value.

[6] Examination groups are the precursors of the current technology centers.

results indicated that a 1-percent increase in examiner hours per disposal is associated with a decrease in patent litigation ranging from 1.15 to 1.33 percent.

Lerner (2008) examined the litigation of all financial patents issued between 1976 and 2003.[7] He also found that there is great variation in litigation rates across technology areas as he determined that financial patents have been litigated at a rate of 27 to 39 times the rate of patents as a whole. Like Lanjouw and Schankerman, Lerner found that patents issued to individuals are much more likely to be litigated and that they appear to be more important than other financial patents in that they have more claims and more forward and backward citations. He also found that while the plaintiffs were disproportionately individual owners, defendants are usually larger firms.

In keeping with the findings of Lanjouw and Schankerman (2001), Allison (2009) also found that the characteristics that distinguish the most-litigated patents from other patents are also the ones that researchers have long used to identify the most-valuable patents: more claims, more prior art citations, more forward citations, a higher likelihood of assignment between issue and litigation, and larger numbers of continuation applications. In addition, the most-litigated patents were more likely to be software and telecommunications patents, and were disproportionately owned by non-practicing entities. These highly litigated patents also had the most continuations, and greater than 50% more claims than the control set.

Chien (2011) studied what she termed "acquired" or post-issuance characteristics of a patent, including changes in ownership, continued investment by way of reexamination and maintenance fees, collateralization, and forward citations, as predictors of litigation. She found that litigated patents were more likely to have changed ownership, and especially likely to have undergone a change in ownership size. They were more likely to have been reexamined, and more likely to have had their maintenance fees paid. They were also collateralized and cited more often than unlitigated patents. Petherbridge (2012) and Kesan (2012) generally confirmed the findings of Chien (2011).

Miller (2013) argued that high quality patents possess stronger property rights *ex ante* and are thus more likely to be found valid and infringed. In his view, patents asserted in more lawsuits should have greater litigation success because: (1) repeat patent plaintiffs choose to incur more litigation expenses and so should expect a higher return from litigation; (2) repeat patent plaintiffs tend to assert higher quality patents; and (3) divergent owner and alleged infringer beliefs about patent quality should favor the repeat patent plaintiff. Miller (2013) found that patents asserted in more cases generally do win more validity and infringement decisions, suggesting that the higher litigation costs borne by repeat patent plaintiffs are at least somewhat compensated by the fact they assert higher quality patents.

2.3 The Patent Examination Process

Because our study involves the relationship between the patent examination process and subsequent litigation, we provide a very basic description of patent examination and describe some of its milestones. The process begins with the filing of a patent application. When the application is received by USPTO, it goes through an extensive pre-examination review to make certain that all necessary forms have been

[7] Lerner uses the term "financial patent" to refer to a patent that is classified in any of Class 705 subclasses 4 or 35 through 45 or Class 902 subclasses 1 through 41.

filed, all relevant fees have been paid, and that the application is complete. A complete application requires a written description of the invention, at least one claim, and any necessary drawings.[8] As part of this review, the application is classified according to its subject matter and forwarded to the relevant *Technology Center* (TC) for examination. Within the TC, the application is then assigned to an examiner in one of the group art units (GAUs).[9] It can take several months (even over a year) for an application to be placed on an examiner's docket.

Examiners generally work on applications in filing date order although they have some discretion in this matter. Therefore, even after the application has reached the examiner's docket, it may remain unexamined for some time while the examiner works on other applications. When the examiner considers the application, she may issue a *restriction requirement* if multiple inventions appear in the claims. The applicant would then be required to choose claims drawn to a single invention.[10] Once an initial claim set for examination has been selected, the examiner evaluates those claims for compliance with the applicable statutes and regulations. She checks to make certain that the claims are directed to patent-eligible subject matter, that the written description is adequate to describe and enable the claimed invention, and that the claims clearly define the invention. She also conducts a prior art search to determine whether the claimed invention is new and nonobvious. She looks for previous patents (US or foreign) or non-patent literature to determine whether the invention is anticipated by a single reference, or rendered obvious either by a single reference or by a combination of references. Based on this examination, the examiner may issue an Allowance that allows all claims that have been examined, or may issue a Non-Final Rejection that rejects or objects to one or more of the claims.[11] It is also possible for the examiner to issue an office action indicating that although the subject matter of the examined claims appears to be allowable, certain formal requirements still remain and must be addressed. At first-action, between 85 and 90 percent of all applications receive a Non-Final Rejection.[12]

The applicant is generally given three months to respond to a non-final office action, but may take up to three additional months in exchange for additional fees. The applicant typically responds with some combination of arguments and amendments to the claims to clarify them or to narrow their scope to avoid the prior art. While claims may be amended, the written description and drawings may not be altered during prosecution, with rare exceptions. Thus, there is a greater incentive for the applicant to invest time in the written description and drawings at the time of filing. Further, there is less opportunity for strategic behaviour related to claims drafting. For instance, an applicant will typically draft very broad claims knowing that these will be narrowed during prosecution.

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[8] See the Manual for Patent Examination Procedure (MPEP) 601.01. A filing date is assigned when the application is complete.
[9] Technology Centers are comprised of work groups which are further comprised of group art units.
[10] If the applicant wishes to pursue patent protection on the additional inventions that are not chosen, one or more divisional applications may be filed. Such divisional applications retain the benefit of the filing date of the original application, and therefore have a longer pendency from filing of the original application to issue, even though the prosecution of the divisional application itself may not have been particularly lengthy.
[11] If the examiner decides to allow all claims at this stage, the communication sent to the applicant is referred to as a first-action allowance.
[12] See Mitra-Kahn et al. (2013).

The applicant may also file information disclosure statements, which are used to comply with the applicant's duty to disclose any information material to patentability. The information typically includes potential prior art, particularly when revealed to the applicant during the examination of a related foreign or domestic application. The applicant may also ask for a telephonic or in-person interview with the examiner. After the examiner receives the applicant's response, she reevaluates the claims to determine whether the rejections or objections have been overcome. If no issues remain, the applicant is informed that the claims are allowable. Otherwise, the examiner will typically issue a Final Rejection, thus formally closing the examination process—at least temporarily.

After receiving a Final Rejection, the applicant has several options. First, the applicant may choose not to continue to seek patent protection for the invention by abandoning the application, either by express request or simply by failing to respond within the specified period.[13] Second, the applicant may continue to seek patent protection before the examiner. This may be done either by filing a new continuation application (CON) which is entitled to benefit of the filing date of the original application,[14] or by filing a Request for Continued Examination (RCE).[15] Finally, the applicant may file an appeal with the USPTO's PTAB[16] arguing that the PTAB should reverse the examiner's rejections.

If examination continues before the examiner, the applicant has further opportunities to amend claims and make further changes. Again, the examiner may or may not allow the claims and could ultimately issue further Non-Final Rejections and Final Rejections. The applicant can again respond and re-open prosecution, and this process can go through several rounds. On average, each round of examination tends to lead to changes in the application's claims. Also, it is important to note that examination ends in either a grant or an abandonment. There is no such thing as a terminal rejection. For the applications that we will be considering in our empirical section, at least some of the claims were allowed and the patent was issued.

3. Data

Following Lanjouw and Schankerman (2001, 2004) we create matched samples of litigated and non-litigated patents. In order for a patent to be included in our sample of litigated patents, it had to meet the following two criteria. First, it had to have been involved in a litigation filing between 2005 and September 2015. Second, the patent had to have been issued between 2005 and 2011. We restrict our analysis to those granted after 2004 in order to avoid left censoring for the matched patents; we do not observe litigation prior to 2005, thus we cannot ensure that a matched control was not previously litigated.

Below, we describe our samples of litigated patents and the patent-related data that we joined to these samples. We then describe the methods that we use to create matched control groups of non-litigated patents. We close this section by describing the explanatory variables used in the statistical analysis.

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[13] This is not an applicant's only opportunity to abandon an application as applications may be abandoned at any time.

[14] CONs may be pursued at any time.

[15] Prior to the introduction of the RCE, applicants could file Continued Prosecution Applications (CPAs). In both cases, the continuations maintain the same serial number.

[16] Prior to the AIA, the PTAB was known as the Board of Patent Appeals and Interferences, or BPAI.

3.1 Sources

3.1.1 Litigated Patents

Litigation data were provided by RPX.[17] The sample includes information on all patent litigation cases filed in US district courts between January 1, 2005 and September 1, 2015. For each case, we observe the filing date, the district court in which the suit was filed, the docket number for the case, and the patent numbers for the patents involved in the litigation (the patents-in-suit). Using these data, we created a list of all patents that had been involved in at least one patent litigation filing since 2005. We restrict our analysis to those patents granted in 2005 or after, to ensure that we observe the full litigation history of each patent. Our sample of litigated patents consists of 11,236 patents that were granted between 2005 and 2013 and were named in litigation proceedings between January 1, 2005 and September 1, 2015.

3.1.2 Examination Data

The source of our examination data come from the Patent Examination Research Dataset (PatEx) described in Graham et al (2015). The PatEx data contains the examination history of each published application, including metadata for each transaction in the course of patent prosecution. It contains a list of all communications either sent or received by the USPTO in connection with prosecution of a particular patent application. It also includes additional information concerning the internal processing of the application. For instance, the file includes information about when each application was filed, and when it was placed on an examiner's docket. PatEx data indicate whether the application is for a utility, design, or plant patent, and the group art unit (the examination group) to which the application is assigned. The database also includes the nature and date of each of the examiner's rejections and allowances, and each of the applicant's responses. The applicant's submissions can include arguments, amendments, information disclosure statements (IDS, containing prior art references submitted by the applicant), notices of appeal, and requests for continued examination (RCE). PatEx also includes information about related filings when the application is the national stage of an international application, or when it claims the benefit of foreign priority. Information about the applicant is included, such as name, address, citizenship, representation by counsel, and whether the applicant qualifies for small entity status. Finally, information about issuance of a patent or other final disposition of an application may also be found in PatEx.

3.1.3 Other USPTO Data Sources

Although PatEx is our primary source of data on patent characteristics, certain metrics that we include are from other sources. Information on forward and backward citations comes from PatentsView bulk downloads, maintained by the Office of the Chief Economist at USPTO.[18] PatentsView is also the source for the government interest statement. Several of our explanatory variables are derived from the text of the patent claims, such as the number of independent claims and the number of words per independent claim. We obtain the claims information from the Marco et al (2016).

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[17] www.rpx.com. RPX is a defensive patent aggregator. As part of its market intelligence service, RPX compiles data on patent litigation in US district courts. These data were provided for research purposes to the Office of the Chief Economist at the USPTO.

[18] www.PatentsView.org.

Information on the reassignment of patents and on the use of patents for as a security interest comes from the Patent Assignment Research Dataset as described in Marco et al (2015). The dataset contains detailed information on 6.8 million patent assignments and other transactions recorded at the USPTO since 1970 and involving roughly 11.1 million patents and patent applications. We used internal USPTO human resources data on promotions to determine the pay grade of the examiner to whom the case was docketed at the date of patent allowance. Internal sources were also used to determine the entity status (small or large) based on the fees paid at the time of filing.[19]

3.1.4 Other Data Sources

The information on related patent filings in foreign jurisdictions (family size) comes from the European Patent Office's (EPO) PATSAT dataset.[20] PATSTAT contains data extracted from EPO's internal databases and includes bibliographical and patent status data from the leading patent offices around the world. We use data from the Searle Center Database on technology standards and standard setting organizations[21] (see Baron, Ménière, and Pohlmann, 2014, and Baron and Pohlmann, 2015) and the Disclosed Standard Essential Patents Database[22] (Bekkers, Catalini, Martinelli, and Simcoe 2012) to identify patents that have been disclosed to major standard setting organizations (SSOs) and the dates of these disclosures.

In general, most of the data are merged by patent number. The merging for examiner pay grade data is more complex. PatEx includes information on the various examiners who worked on each patent application, and the dates over which each examiner was assigned to it. From this information, one can determine which examiner was assigned a patent application on the day that it was allowed.[23] The human resources data include each examiner's GS-level and the date range over which the examiner was at the GS-level. Using this information, we merge on the examiner identification number and the allowance date to determine the GS-level of the examiner at the time of allowance.

3.2 Matched Samples

Our research goal is to determine whether litigated patents differ from non-litigated patents in any systematic way, and whether those difference correspond with patent value or uncertainty. In order to do that, we construct several one-to-one matched case-control samples. For each subject patent, we select one control patent that is similar to the subject patent, but for which we do not observe litigation. The extent of the similarity depends upon the particular matching method that is used. In this analysis we use four different methods, and compare the results.

Below, we describe the details for generating the matched sample with regard to the incidence of litigation. It is important to note that any characteristic used for matching cannot be used in the statistical

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[19] Small entities receive a 50% discount on most fees. The America Invents Act (implemented in 2013) created a new category of "micro entity." The patents in our sample pre-date the implementation of the AIA.
[20] Information on PATSTAT can be found at https://www.epo.org/searching-for-patents/business/patstat.html#tab1.
[21] The Searle data can be found at https://www.law.northwestern.edu/research-faculty/clbe/innovationeconomics/data/technologystandards/
[22] The dSEP can be found at http://www.ssopatents.org
[23] Note that the examiner is the one to whom the application was docketed at the time that the Notice of Allowance was mailed. This may be an examiner who does not have the independent authority to allow claims, and whose work is therefore overseen by a supervisor or primary examiner with signatory authority.

analysis. For instance, we require a matched patent to have been issued by the same group art unit as its litigated partner. Thus, there will be no variance in the mix of group art units across the litigated group and the control group. Each study design must determine at the outset the set of variables that are used to determine a good match, in order to isolate the variables of interest in the study.

1. **Define the set of all potential matches based on art unit and grant year.**
   We create a comparison group of non-litigated patents that are identical to the litigated patents across two dimensions: the year of the patent grant and the group art unit to which the patent was assigned on the date of allowance. This results in multiple, often thousands of, patents that could be matched to each of the individual litigated patents – the potential matches.

2. **Given the potential matches based on art unit and grant year, choose matching patent for each litigated patent as defined by the particular matching algorithm.**
   a. *Random match.* Randomly choose one control patent from the group of each litigated patent's potential matches
   b. *Application match.* Use propensity score matching based on the **filing characteristics** of the litigated patent. Choose the nearest neighbour with respect to the propensity score.
   c. *Value match.* Use propensity score matching based on the **value characteristics** of the litigated patent. Choose the nearest neighbour with respect to the propensity score.
   d. *Full match.* Use propensity score matching based on both the **filing and value characteristics** of the litigated patent. Choose the nearest neighbour with respect to the propensity score.

Table 3-1 summarizes the construction of our control groups. The *random match* provides a baseline against which to compare our other control groups. Note, though, that the *random match* chooses a random patent *from within* the potential matches. So, the random control patent is chosen from the set of patents from the same grant year and art unit as the litigated patent. That is, the *random match* represents an exact match on grant year and art unit, and a random match for all other characteristics.

In propensity score matching, [24] the litigated patents and their potential matches are first combined into one data set. Next, a classification model – in our case a logistic model – is estimated using particular patent characteristics as potential predictors of litigation (those characteristics upon which the researcher desires to match). After the model is estimated, it is used to predict the probability that any patent in the entire data set would have been a member of the litigated set and this probability is converted into a propensity score. The last step is to match each litigated patent to that member of its potential matches that is the nearest neighbor to the litigated patent with respect to the propensity score.

In our analysis, the predictors used for propensity score matching include *application characteristics* or *value characteristics* or both (described in more detail below). Our results show that *application characteristics* are the strongest predictors of litigation. Matching these characteristics allows us to focus more precisely on the *examination characteristics.* They are of special interest because they represent the

[24] See Rosenbaum and Rubin (1983) for a discussion of propensity score matching.

factors that the patent office can most easily influence. Further, by matching on *value characteristics* (to the extent possible), we attempt to isolate the impact of *examination characteristics* on uncertainty.

In Table 3-2, we present the distributions of the propensity scores for the litigated and un-litigated patents in our matched sample. The group of un-litigated patents closely matches the group of litigated patents on this measure. The average difference in the score between the two groups (0.0009) is quite small compared to the average score of 0.0172.

3.3 Explanatory Variables

After generating the matched samples we estimate models meant to predict the likelihood that the patent will be litigated. The explanatory (and matching) variables can be broken out into four main categories. In addition, some of the characteristics are also designated as standard correlates of patent value.

- Application characteristics (known at the time of the patent application filing)
- Examination characteristics
- Patent characteristics (defined at the time of the patent grant, but influenced by the initial application and the examination process)
- Post-grant characteristics (defined by events that occur after the patent is granted)

Value characteristics are indicated by a "[V]", below.

3.3.1 Application Characteristics

The first set of variables includes characteristics of the application which are known at or near the time of filing.

Small entity. This indicator variable is equal to one in cases where the applicant was granted small entity status (based on filing fees) and set to zero otherwise. Lanjouw and Schankerman (2001) have found that individually owned patents are more likely to be litigated than corporate owned ones, despite that fact that individuals likely face steeper litigation costs. They suggested that this would most likely be due to corporate owners' advantages in reaching settlement agreements before having to file suit. We use the small entity indicator to control for any possible differences in litigation rates.

US parents. In some cases an application claims the domestic benefit of an earlier-filed U.S. application.[25] Applications earlier in the continuity chain are usually called parent applications. Thus, this variable is a count of the number of regular U.S. parent applications (i.e., non-foreign, non-provisional applications) in the chain of continuations from the progenitor application to the subject patent. Parent applications may or may not have issued as separate patents.

Docket pendency. This variable also relates to the continuation history of the patent. In this case we measure pendency (in years) from the application date of the earliest US parent application (the progenitor application) to the docketing date of the issued application. For an application with no parents, this variable is equal to the pendency from the application date to docketing.

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[25] If a later application is a continuation or divisional of an earlier application, the actual filing date of the earlier application becomes the effective filing date of the later application.

Foreign priority. The application claims priority to a foreign application under 35 U.S.C. § 119. Previous studies, including those of Lanjouw and Schankerman (2001), found that U.S. patents granted to foreign applicants are less likely to be litigated.

PCT. The application (or its parent) is a U.S. national stage filing of a Patent Cooperation Treaty (PCT) application under 35 U.S.C. § 371. This is an alternative definition for foreign priority, depending on what mechanism the applicant chose for filing the domestic application.

Government interest. The Statement of Government Interest on the face of the patent indicates whether the US government has any interest or right pertaining to the patented invention. Such an interest generally arises if the inventor is a government employee or member of the armed services, or if the invention was the result of government-funded research under the Bayh-Dole Act (1980).

3.3.2 Examination Characteristics

As far as examination history-related variables are concerned, we consider several different metrics that are related to the intensity of activity in an application.

IDS filings. This variable is a simple count of the number of instances in which an Information Disclosure Statement is recorded in PALM. More IDS filings may indicate greater "effort" by the applicant. Note that this is a count of the number of IDS forms submitted, and not a count of how many document are cited on those IDS forms.

Interviews. This variable is a simple count of the number of instances in which an interview is recorded in PALM.[26] Like IDS filings, interviews may be correlated with applicant effort or investment.

First-action allowance. This is an indicator variable set equal to one for cases in which the application is allowed on the first action. In these cases, the examiner, finding no grounds for rejection or objection, allows the claims without ever having issued a rejection. This does not indicate that the claims at grant are identical to the claims at filing; however, it is unlikely that there are substantial changes.

RCEs. This is a simple count of the number of Requests for Continued Examination (RCEs or RCE-type continuation) filed during the course of examination. RCEs are most often utilized by applicants as a means for re-opening the examination of a patent application that has received a Final Rejection. There is no formal limit to the number of RCEs that an applicant can file in a particular application, although there is a fee involved.[27] RCEs are the primary reason why there is no terminal rejection decision in the US. They may represent a complex case, or they may be correlated with value because applicants are less likely to abandon an application on an invention with high perceived value. Some practitioners may use RCEs to slowly whittle down claim breadth (rather than to make significant changes) so as to preserve the broadest possible claims at allowance.

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[26] Sometimes examiner interviews are not separately indexed in PALM because they are appended to other documents. Thus, our reliance on PALM data undercounts the number of examiner interviews.

[27] Currently the fee is $1200 for the first RCE in an application, and $1700 for the second and subsequent.

Appeal. Another measure that we consider is the use of appeals to the Board of Patent Appeals and Interferences (BPAI) at the USPTO.[28] In order to account for this, we include an indicator equal to one for cases where there was at least one appeal that ended with a decision. This choice was made to distinguish those cases that went all the way through the appeal process from those where the appeal is filed, but later withdrawn. In the latter case, the appeal may be used as a delay tactic.

Examination pendency. We include a measure of each application's examination pendency, defined as the time (in years) between docketing and allowance. We would expect that, on average, an application with longer examination pendency would have gone through more rounds of negotiation between the applicant and the examiner.[29] The next three variables are all related to the idea of repeated negotiation.[30]

Examiner seniority. To account for examiner characteristics, we define a set of indicator variables related to the signatory authority of the examiner who allowed the patent.

> **Junior.** The first category consists of examiners having a pay grade of GS-12 or below and those having a pay-grade of GS-13, but who have not been granted any signatory authority. These non-signatory examiners cannot represent the USPTO or independently sign any of their own work, so a supervisor or another examiner with full signatory authority must review the work and sign it.
>
> **Partial sig.** The second category consists of examiners at the GS-13 level who had been granted partial signatory authority, and therefore can sign at least some of their own work. They tend to have more responsibility and are supervised less closely than examiners at lower GS-levels.
>
> **Full sig.** The third category consists of full signatory examiners with pay grades at GS-14 or above. Although supervisors still provide oversight, these examiners generally work independently.[31] As examiners progress through the GS-levels they gain experience. Therefore, as the GS-level increases, not only do they gain signatory authority but the time allotted for an examiner to complete her review of an application decreases. Thus, those examiners with signatory authority will generally have more experience, but less time to devote to examining a given patent application. Information about the examiner's pay grade and signatory authority was missing for roughly 2 percent of the patents in our sample.

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[28] The BPAI was replaced with the Patent Trial and Appeal Board with the implementation of the America Invents Act of 2011.

[29] It is important to note that here we are measuring the examination pendency of the application that was ultimately issued as a patent. The application may have been a continuation of a previous application. Any examination pendency inherent in the parent applications would be captured in the measure of pendency from the application date of the earliest parent application to the docketing date of the issued application.

[30] Claims are usually amended with each round of repeated negotiation.

[31] Signatory authority is granted in stages, and includes two evaluation periods called the partial signatory authority program and the full signatory authority program. A newly-promoted GS-13 examiner, before beginning the partial signatory program, has no signatory authority. When the examiner begins the partial signatory authority program, she is granted temporary partial signatory authority. Upon successful completion, the partial signatory authority becomes permanent. When the examiner begins the full signatory authority program, she is granted temporary full signatory authority. Upon successful completion, the examiner is promoted to GS-14, and full signatory authority becomes permanent. However, a GS-13 examiner with permanent partial signatory authority may also be promoted to GS-14 by establishing Master's level competence in the technology of her assigned docket. Thus, not all GS-14 examiners have full signatory authority.

3.3.3 Patent Characteristics

Patent characteristics represent the characteristics of the issued patent, typically from the "face" of the patent. These characteristics are officially defined at the time of issuance (or allowance), but they are obviously influenced by the incoming application as well as the examination process. For instance, the number of independent claims will be the result of a bargaining process between the applicant and the examiner.

IC count. The first variable is a count of allowed independent claims. We expect this variable to be positively correlated with litigation, because generally we expect that a patent with more independent claims (controlling for technology area) would be of broader scope and thus more likely to be infringed. We believe that the number of independent claims is a better measure of scope than the number of total claims as used in Lanjouw and Schankerman (2001, 2004). Dependent claims typically do not broaden the scope because they are subordinate to the breadth of their independent claims.

IC length. The second variable is the word count for the shortest independent claim. We expect that as this word count increases, the boundary of the property right would be better defined. Thus it is our hypothesis that this variable is negatively correlated with litigation. Better-defined boundaries would lead to fewer disagreements regarding whether a party's actions amounted to infringement. We choose this measure rather than the average number of words per independent claim, because we believe patent holders will likely seek infringement relief by asserting their least-well-defined (shortest) independent claims.

Functional claim. We also include an indicator for whether any of the claims have a functional limitation. A functional claim limitation is commonly introduced by the phrase "means for" or "step for."[32] Importantly, a functional claim covers all devices that perform the stated function. Therefore, claims that contain functional limitations are generally considered to be broader and less clear than claims that do not. Several recent Federal Circuit decisions take up the issue of functional claiming, including *In re Katz* (Fed. Cir. 2011)

CPCs. We include the number of Cooperative Patent Classification (CPC) subclasses (the four-digit level). We include the number of CPC classes (or equivalents) listed on the front of the patent as a measure of patent scope (Lerner 1994).

Prior art references. We include three different types of cited prior art references (aka backward citations). Applicants or examiners can cite domestic (U.S.) patents and applications, patents issued by foreign jurisdictions, as well as what is known as non-patent literature. The non-patent literature often includes scholarly journal articles, but may include technical manuals, online forums, or Star Trek episodes.[33] The number of backward citations has been argued to be a proxy for patent value and previous

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[32] It is possible that a functional claim limitation may lack one of these phrases, or (less likely) that a non-functional claim limitation may include them. However, experts at the USPTO indicated that the definition is more likely to be under-inclusive rather than over-inclusive. Thus, for the purpose of this study we adopt a conservative definition. Other functional language includes terms like "configured for," "permitting," "so that," etc. See 35 USC 112(f) and MPEP 2081(l).

[33] In fact, Star Trek is cited by several granted patents and also by examiners in rejections. See, for example, patent 9,494,807 "Wearable high resolution audio visual interface," citing (by examiner) Star Trek Deep Space Nine, "A

studies have found a positive relationship between the number of such citations and the likelihood of litigation.[34] However, others have found that backwards citations are most meaningful on applications without an excessive number of prior art references (Kuhn et al 2017). Our specific prior art variables are:

US references. Prior art references to US Patents or pre-grant publications.

Foreign references. Prior art references to foreign patents or pre-grant publications.

NPL references. Prior art references to non-patent literature.

Family size [V]. Family size represents the number of jurisdictions within which the applicant has sought patent protection. It is typically used as a measure of value, because applicants will only apply for patents in multiple jurisdictions if they expect to be able to use the invention in those areas.

3.3.4 Post-grant events

Events occurring after patent grant may affect the likelihood of litigation, or they may signify something about the patent that is later revealed or that influences later events.

Forward citations [V]. This represents the number of times the patent was cited as a prior art reference in another patent (excluding self-citations). We include the three year count in the static (logistic) models. The survival time models use a time-varying running total.

Self-citations. The number of times the patent was cited as a prior art reference in a patent owned by the same assignee. Like forward citations, we include a three-year count in the static (logistic) models. The survival time models use a time-varying running total.

Maintenance payments [V]. Maintenance fee payments are due at 3.5, 7.5, and 11.5 years after issuance for US patents. Because some of our sample patents are very young, they have not had the opportunity to pay all three maintenance payments. However, because we match on grant year, the same will be true for their matched control patents. The variable is defined as the number of maintenance payments (0-3) paid as of September 1, 2015.

SEP [V]. We obtained a list of patents that have been declared "standard essential" with particular standard setting organizations (SSOs). The data also include the date at which the patent holder declared the patent as an SEP. Where there are multiple declarations, we use the first declaration date. Different SSOs handle declarations in different ways. In some SSOs, patents may be newly declared in each version or sub-standard. In others there may only be one declaration. Thus, we define this variable is an indicator not a count: we indicate only whether the patent is ever declared an SEP.

Re-assignments. The total number of assignment changes (after grant) that represent changes in ownership. See Marco, et al (2015) for more details.

Time to Stand," Sep. 29, 1997. Patent 8,128,500 cites Futurama and Watchmen (also cited by examiner). We thank Paul D'Agostino for sharing his experience in this area.

[34] See Lanjouw and Schankerman (2001, 2004), Lerner (2008), and Allison (2009), among others.

Security interests. The total number of times the patent has been assigned in a security agreement. Typically, the assignment is to the lender when a patent is used as collateral for a loan. See Marco, et al (2015) for more details.

3.3.5 Proxies for Patent Value

We include several standard proxies for patent value based on the explanatory variables above: *forward citations*, *maintenance payments*, *family size*, and *SEP*. Each of these measures is expected to have a positive relationship with the likelihood of litigation, based on the relationship between value and litigation.

Of course, it is impossible to perfectly control for patent value; there is significant heterogeneity among patents in this regard. However, our choice of value proxies is intended to represent those characteristics that are most directly correlated with the private value of the patent holder, especially *maintenance payments* and *family size*. Standard essential patents are also the subject of a debate in the economics literature with respect to whether they provide an opportunity for "patent holdup" (Lemley and Shapiro 2006). Whether or not SEPs are associated with holdup, they provide a greater opportunity to generate licensing revenue.

Other characteristics, like patent breadth (measured by *IC count* or *CPCs*) may be associated with higher value. However, the higher value should show up in more direct measures, like maintenance payments and family size. Further, breadth may also be correlated with uncertainty because broader patents—if over-broad—are less likely to survive a validity challenge.

4. Estimation

In this section, we present the results estimating the relationship between patent- and examination-related variables and the hazard rate of litigation (by September 1, 2015) for patents issued between 2005 and 2013. We provide some basic comparisons between the litigated patents and their matched control groups, and the results of the relevant econometric models. Our matching algorithm generated 12,674 matched pairs that can be included in the analysis. Our full set of explanatory variables is available for 9,688 matched pairs.

Descriptive statistics for the explanatory variables are presented in Table 4-1. The first two columns provide the means and standard errors for each explanatory variable for the litigated patents. The next two columns provide these statistics for the randomly matched control group and the final two columns provide the statistics for the propensity score matched control group.

We estimate the hazard of litigation with respect to application, examination, and patent characteristics. The duration models use the characteristics described in Section 3.3 to model the time that elapses between patent issuance and the filing of a patent litigation lawsuit. More precisely, we estimate a multiple-failure survival time regression, assuming the Weibull distribution with shared-frailty for each subject. The subjects are the individual patents, and a failure represents the filing of patent litigation lawsuit. Multiple filings within the same month (e.g., the same patent asserted against multiple defendants within the same month) are ignored.

The explanatory variables include time-varying covariates (TVCs) as well as non-time-varying covariates (NTVCs). The TVCs comprise the post-grant events, because those variables change during the time in which we observe litigation. In fact, this is one of the primary reasons to use survival time modeling rather than static models such as logit or probit. Since the model allows for multiple instances of litigation, we include the number of previous litigation events as a time-varying covariate. Each subject patent accounts for multiple observations; new observations are generated for each change in the time-varying covariates at that calendar date. Thus, the data used in the estimation comprise 19,376 subjects, half of which are litigated at least once. We observe 28,653 total failures for the litigated subjects. The subjects account for 247,314 total observations, due to multiple observations of the TVCs during the observation period.

To control for any unobserved heterogeneity among the patents in our samples, we include patent-level random effects. Duration models with random effects are referred to as shared-frailty models in the literature. A frailty is defined as a latent multiplicative effect on the hazard function and is assumed to have a mean equal to one and a variance parameter that is estimated along with the other parameters in the model. In shared frailty models, the frailty is assumed to be common among groups of observations – in our case, observations on an individual patent – but randomly distributed across the groups.

The results of the duration models can be found in Tables 4-2 and 4-3. Table 4-2 presents estimates for each different matching algorithm. The coefficients are given as hazard ratios; the effect on the hazard rate is multiplicative. A hazard ratio of 1.1 indicates that a one unit increase in the independent variable increases the hazard rate of litigation by a factor of 1.1 (10%). The hazard ratios are very similar across samples. In particular, for the NTVCs, the results are consistent with Marco and Miller (2017).

Among the TVCs, there are several implications. First, we find that prior litigation increases the hazard of future litigation (i.e., there is positive incidence-dependence). More surprisingly, we find that several value proxies are associated with a lower litigation hazard rate. This is surprising because—as discussed in Section 2.1—patent holders will be more likely to incur the cost of litigation if the patent is more valuable. However, it is important to remember that a sufficiently high expected reward is a necessary, but not sufficient, condition for litigation.

The results indicate that as a patent accumulates both external citations and self-citations, the hazard of litigation falls. The same is true for the use of patents in security interest agreements and disclosures to SSOs. Each of these explanatory variables may be correlated with value.

This result regarding forward citations contrasts with most of the previous literature using static models (e.g., probit or logit models), which finds that the number of forward citations is positively related to the probability of litigation (e.g., Lanjouw and Schankerman 2001). However, our duration results are consistent with those of Marco (2005), who also uses duration modeling on litigation. The different results from the different estimation strategies raise questions regarding the mechanism through which forward citations and the likelihood of litigation are related, which we explore below.

One problem in using time-varying covariates is that they conflate two effects. For instance, a patent that is standard essential may, indeed, be more valuable. However, the fact that it is *declared* to be standard essential also means that this information is available to the marketplace. Similarly, a highly cited patent is generally thought to be valuable. But, when does the market determine its value? It may be known immediately and the subsequent citations merely reflect this value. Or, the observation of the accumulation of citations may inform observers of its value. In the latter case, forward citations are providing information about value and decreasing uncertainty. Decreasing uncertainty should *reduce* litigation by reducing the risk of disputes, as discussed in Section 2.1.

To distinguish between the two possible effects, we estimate models where we include the *prospective* values of the time-varying covariates along with the contemporaneously *observed* time-varying covariates. The prospective versions represent the total observed value for each variable at the end of the observation period (September 1, 2015). The prospective counts should be correlated with the ultimate patent value. The time-varying count represents when the information is observed by the marketplace. Thus, including both values enables us to make inferences about the relative importance between value and the resolution of uncertainty about that value.

We estimate these models only on the "random match" sample in Table 4-3. Column 1 incorporates both the running totals of the TVCs as well as the prospective counts for the TVCs. Column 2 replicates the model from Table 4-2 for reference. For each TVC, the hazard ratios are very similar—in terms of sign—between the two models. However, adding the prospective counts changes the magnitude of some of the hazard ratios, and also enables us to make inferences about the relative effects of patent value and the resolution of uncertainty.

For example, in the cases of *Forward Citations, Self-citations, Security Interest* and *SEP*, the hazard ratios for the prospective counts are greater than one, indicating a positive correlation with the hazard of litigation. This is in stark contrast to the *negative* correlation associated with the time-varying running totals. Figure 4-2 helps to interpret these results, showing the marginal effects of a one-standard deviation increase in the prospective counts and the time-varying counts, as well as the combined effect.[35]

For SEPs, the fact that a patent will ever be declared as standard essential increases the hazard of litigation by 55% (hazard ratio of 1.55). This is consistent with the interpretation of SEPs being more valuable and thus more likely to be litigated. However, when the patent is actually declared to be standard essential, the hazard of litigation falls by 65% (hazard ratio of 0.35). The net effect of being an SEP and being declared as an SEP is that the hazard of litigation falls by 46% (the joint hazard ratio is 1.55*0.35=0.54). Not coincidentally, this is very close the hazard rate of 0.51 found in the original specification, because the two effects are not separable in that specification.

Similarly, prospective forward citations have a hazard ratio of 1.005. For a one-standard deviation increase (28 citations), the hazard ratio is 1.14 (1.005^28). In contrast, the corresponding hazard ratio for 28 observed citations is 0.73 (0.988^28). The net effect is a hazard ratio of 0.84. This means that for a patent that will ultimately receive 28 citations, the hazard of litigation is 14% higher than average if none of them are observed. However, if all of the citations are observed the hazard is 16% *lower* than average. That is, the resolution of uncertainty associated with observing forward citations more than makes up for litigation impact of the citations themselves.

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[35] Because it is an indicator variable, SEP is calculated as a one unit change.

We see similar effects with *Security Interests* and *Self-citations*. In each case, the prospective counts increase litigation because they are associated with value. But, the disclosure of that information reduces uncertainty so that the net effect is a decrease in the hazard of litigation. Those effects are further demonstrated in Figures 4-3 to 4-4. They show that net effect on litigation is zero when 40% of forward citations are disclosed or 10% of self-citations are disclosed.

5. Discussion

In this paper we analyzed the relationships between certain patent-related characteristics and the likelihood that a patent will be the subject of a patent infringement lawsuit. Our empirical strategy of using matched samples enables us to focus on the dynamics of litigation based on changes in post-grant variables. We match based on for several types of patent characteristics based on the stage of a patent's lifetime: application characteristics, examination characteristics, and patent characteristics. This allows us to focus exclusively on post-grant time-varying characteristics. The survival time regressions enable us to estimate the impact of information disclosure as it relates to reduced uncertainty relative to patent value.

The survival time results indicate that as a patent accumulates both external and self-citations, the likelihood that the immediate hazard of litigation falls. This result contrasts with results from discrete independent variable models such as Lanjouw and Schankerman (2001) and Marco and Miller (2017). Yet, the duration results are consistent with those in Marco (2005). We see similar patterns with SEPs and the number of re-assignments, both of which should be correlated with value. We reconcile the contradiction by including both prospective counts and time-varying running totals in the estimation.

The prospective counts of forward citations and self-citations are correlated with higher litigation rates. This is consistent with the prior literature, and also consistent with the interpretation of forward citations and self-citations as a proxy of value. Importantly, by measuring the running totals, we find that when information is revealed to the marketplace, it reduces uncertainty and lowers the hazard of litigation. The same is true for standard essential patents and security interests.

The change of ownership of patents illustrates Coasian bargaining. High numbers of transactions for a patent (or any property) do not necessarily indicate value. Sales volumes are high for stocks on their way up or on their way down. However, easily tradeable property is the result of well-defined property rights and low transactions costs. Thus, the fact that *re-assignments* are correlated with lower litigation rates is evidence that *re-assignments* reflect less uncertainty in the patent right. That is, lower uncertainty facilitates Coasian bargaining.

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7. Tables and Figures

Table 3-1: Description of matched samples

		Propensity Score Match		
	Random Match	Application	Value	Full
Examination art unit	Exact	Exact	Exact	Exact
Grant year	Exact	Exact	Exact	Exact
Application characteristics	Random	Propensity	Random	Propensity
Value characteristics	Random	Random	Propensity	Propensity

Table 3-2: Distributions of Matching Factors for the Litigated and Non-litigated Patents

	Propensity Score	
Percentile	Litigated	Non-litigated Patents
Smallest	0.0004	0.0004
1%	0.0012	0.0012
5%	0.0024	0.0024
10%	0.0038	0.0038
25%	0.0068	0.0068
50%	0.0122	0.0122
75%	0.0222	0.0222
90%	0.0348	0.0345
95%	0.0474	0.0458
99%	0.0829	0.0737
Largest	0.998	0.6741
Mean	0.0175	0.0169
Std. Deviation	0.0227	0.0172

Table 4-1: Descriptive Statistics for the Explanatory Variables

	Litigated Patents		Random Match Control Group		Propensity Match Control Group	
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
Proxies for Value						
Forward citations (3-yr)	7.073	0.139	3.722**	0.088		
Maintenance payments	1.298	0.006	1.125**	0.007		
Family size	5.448	0.057	4.046**	0.041		
SEP	0.006	0.001	0.002**	0.000		
Application Characteristics						
Small entity	0.371	0.005	0.246**	0.004		
US parents	2.152	0.035	0.877**	0.015		
Docket pendency	2.062	0.018	1.379**	0.014		
PCT	0.037	0.002	0.099**	0.003		
Foreign priority	0.121	0.003	0.346**	0.004		
Government interest	0.019	0.001	0.022	0.001		
Examination Characteristics						
IDS filings	5.619	0.076	3.499**	0.040	4.035**	0.055
Interviews	0.481	0.009	0.325**	0.007	0.329**	0.007
First-action allowance	0.109	0.003	0.136**	0.003	0.133**	0.003
RCEs	0.493	0.008	0.386**	0.007	0.398**	0.007
Appeal	0.022	0.001	0.014**	0.001	0.016**	0.001
Examination pendency	2.648	0.018	2.664	0.015	2.524**	0.015
Examiner seniority						
Junior	0.263	0.004	0.327**	0.004	0.299**	0.004
Partial sig	0.056	0.002	0.058	0.002	0.062	0.002
Full sig	0.681	0.004	0.616**	0.005	0.640**	0.005

	Litigated Patents		Random Match Control Group		Propensity Score Control Group	
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
Patent Characteristics						
IC count	3.632	0.032	2.866**	0.022	3.016**	0.023
IC length	143	0.938	158**	0.990	153**	0.958
Functional claim	0.152	0.003	0.157	0.003	0.162*	0.003
CPCs	2.21	0.014	1.81**	0.011	1.93**	0.012
US references	57.0	0.969	24.7**	0.521	36.7**	0.695
Foreign references	9.17	0.227	4.76**	0.151	5.46**	0.157
NPL references	29.2	0.943	7.42**	0.272	12.3**	0.415
Changes in Patent Assignment						
Re-assignments	0.938	0.012	0.426**	0.008	0.525**	0.009
Security interests	0.424	0.010	0.216**	0.008	0.290**	0.009

**Significantly different from the mean for litigated patents at the 1-percent level.
* Significantly different from the mean for litigated patents at the 5-percent level.

Table 4.2: Duration Model Results With Time-Varying Covariates (z-statistics in parentheses)

	Random Match	Propensity Score Matches Full	Value	Appl Chars
Time Varying Covariates				
Forward citations (running total)	0.991***	0.990***	0.990***	0.991***
	(-11.39)	(-12.83)	(-12.39)	(-12.12)
Self-citations (running total)	0.949***	0.946***	0.946***	0.946***
	(-13.52)	(-14.45)	(-14.51)	(-14.40)
Prior litigation (running total)	1.008***	1.009***	1.009***	1.009***
	(29.69)	(31.49)	(30.40)	(30.95)
Re-assignments (running total)	1.749***	1.761***	1.751***	1.758***
	(50.83)	(50.50)	(50.48)	(50.67)
Security Interest (first instance)	0.712***	0.692***	0.722***	0.695***
	(-19.88)	(-21.22)	(-18.86)	(-21.12)
SEP (first instance)	0.511**	0.399***	0.347***	0.500**
	(-2.78)	(-3.99)	(-4.80)	(-2.81)
Application Characteristics				
Small entity	1.482***		1.470***	
	(15.73)		(15.26)	
US parents	1.051***		1.041***	
	(9.42)		(8.26)	
Docket pendency	1.104***		1.107***	
	(15.05)		(15.18)	
PCT	0.804***		0.775***	
	(-3.89)		(-4.59)	
Foreign priority	0.647***		0.742***	
	(-13.18)		(-9.09)	
Government interest	0.768**		0.699***	
	(-3.25)		(-4.40)	
Proxies for Patent Value				
Maintenance payments	1.303***			1.242***
	(10.29)			(8.49)
Family size	1.031***			1.025***
	(13.20)			(11.12)
Examination Characteristics				
IDS filings	1.002	1.000	1.001	0.999
	(0.91)	(0.00)	(0.58)	(-0.57)
Interviews	1.087***	1.104***	1.106***	1.093***
	(6.68)	(7.67)	(7.87)	(6.91)
First-action allowance	0.972	0.951	0.968	0.968
	(-0.79)	(-1.37)	(-0.89)	(-0.90)
RCEs	1.058***	1.037*	1.054***	1.046**
	(3.79)	(2.44)	(3.51)	(2.97)
Appeal	1.313**	1.290**	1.196*	1.314**
	(3.25)	(2.93)	(2.16)	(3.14)
Examination pendency	0.990	0.977**	0.985	0.986
	(-1.35)	(-2.90)	(-1.86)	(-1.78)

	Random Match	Propensity Score Matches Full	Value	Appl Chars
Examiner seniority (base: Full sig)				
Junior examiner	0.832***	0.819***	0.817***	0.815***
	(-7.32)	(-7.70)	(-7.90)	(-7.96)
Partial sig	0.893*	0.861**	0.928	0.871**
	(-2.34)	(-3.04)	(-1.52)	(-2.79)
Patent Characteristics				
IC count	1.029***	1.032***	1.034***	1.034***
	(7.56)	(8.04)	(8.51)	(8.50)
IC length	0.999***	0.999***	0.999***	0.999***
	(-6.50)	(-6.60)	(-7.84)	(-5.50)
Functional claim	1.047	1.050	1.048	1.081*
	(1.54)	(1.58)	(1.53)	(2.54)
CPCs	1.031***	1.057***	1.033***	1.048***
	(3.80)	(6.98)	(4.02)	(5.87)
US references	1.001**	1.000**	1.000*	1.000**
	(3.14)	(2.78)	(2.03)	(2.79)
Foreign references	0.997***	0.999	0.999	0.997***
	(-3.96)	(-1.69)	(-1.93)	(-3.99)
NPL references	1.001***	1.001***	1.001***	1.001***
	(5.34)	(7.39)	(5.85)	(7.84)
Issue Year Fixed Effects	Yes	Yes	Yes	Yes
Technology Center Fixed Effects	Yes	Yes	Yes	Yes
subjects	12,674	12,674	12,674	12,674
observations	247,313	274,826	277,115	257,986

Table 4-3: Duration Model Results for "Random Match" Sample (z-statistics in parentheses)

	Including Static Variables	Not Including Static Variables
Time Varying Covariates		
Forward citations (running total)	0.988***	0.991***
	(-14.99)	(-11.45)
Self-citations (running total)	0.944***	0.949***
	(-13.83)	(-13.59)
Prior litigation (running total)	1.009***	1.008***
	(30.29)	(29.77)
Re-assignments (running total)	2.150***	1.751***
	(47.89)	(50.88)
Security Interest (first instance)	0.611***	0.712***
	(-20.88)	(-19.85)
SEP (first instance)	0.348***	0.512**
	(-3.77)	(-2.77)
Non-Time Varying		
Forward citations (total)	1.005***	
	(11.31)	
Self-citations (total)	1.006**	
	(3.19)	
Re-assignments (total)	0.741***	
	(-18.26)	
Security interest (ever)	1.195***	
	(10.23)	
SEP (ever)	1.540*	
	(2.39)	
Application Characteristics		
Small entity	1.486***	1.481***
	(15.94)	(15.72)
US parents	1.051***	1.051***
	(9.61)	(9.39)
Docket pendency	1.110***	1.105***
	(15.94)	(15.05)
PCT	0.830***	0.803***
	(-3.36)	(-3.91)
Foreign priority	0.673***	0.648***
	(-12.02)	(-13.10)
Government interest	0.727***	0.767**
	(-3.96)	(-3.26)
Proxies for Patent Value		
Maintenance payments	1.288***	1.302***
	(9.92)	(10.28)
Family size	1.027***	1.031***
	(11.54)	(13.14)

	Including Static Variables	Not Including Static Variables
Examination Characteristics		
IDS filings	1.000	1.002
	(0.02)	(0.91)
Interviews	1.073***	1.087***
	(5.71)	(6.63)
First-action allowance	0.966	0.971
	(-0.99)	(-0.83)
RCEs	1.066***	1.057***
	(4.35)	(3.76)
Appeal	1.310**	1.310**
	(3.28)	(3.23)
Examination pendency	0.989	0.990
	(-1.38)	(-1.32)
Examiner seniority (base: Full sig)		
Junior examiner	0.830***	0.832***
	(-7.47)	(-7.29)
Partial sig	0.884*	0.892*
	(-2.57)	(-2.35)
Patent Characteristics		
IC count	1.025***	1.029***
	(6.70)	(7.58)
IC length	0.999***	0.999***
	(-7.46)	(-6.52)
Functional claim	1.056	1.049
	(1.84)	(1.59)
CPCs	1.027***	1.032***
	(3.29)	(3.82)
US references	1.000*	1.001**
	(2.02)	(3.15)
Foreign references	0.998***	0.997***
	(-3.69)	(-3.92)
NPL references	1.001***	1.001***
	(5.74)	(5.28)
Issue Year Fixed Effects	Yes	Yes
Technology Center Fixed Effects	Yes	Yes
observations	247,306	247,306
subjects: litigated	9,688	9,688
subjects: matched	9,688	9,688
failures	28,653	28,653

Figure 1-1: Observation of patent information

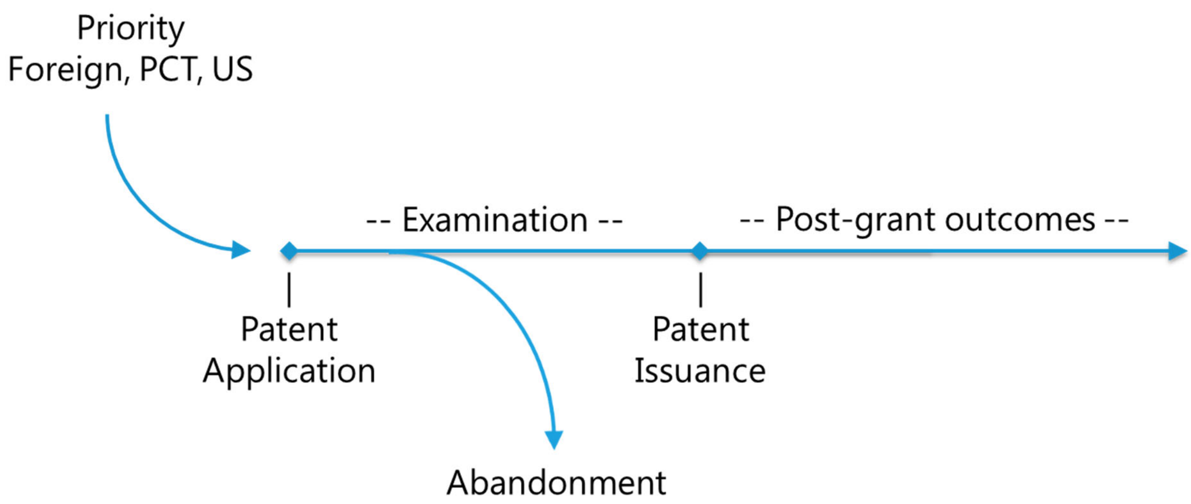


Figure 4-1: Marginal effects for the survival time regression (non-time-varying covariates)

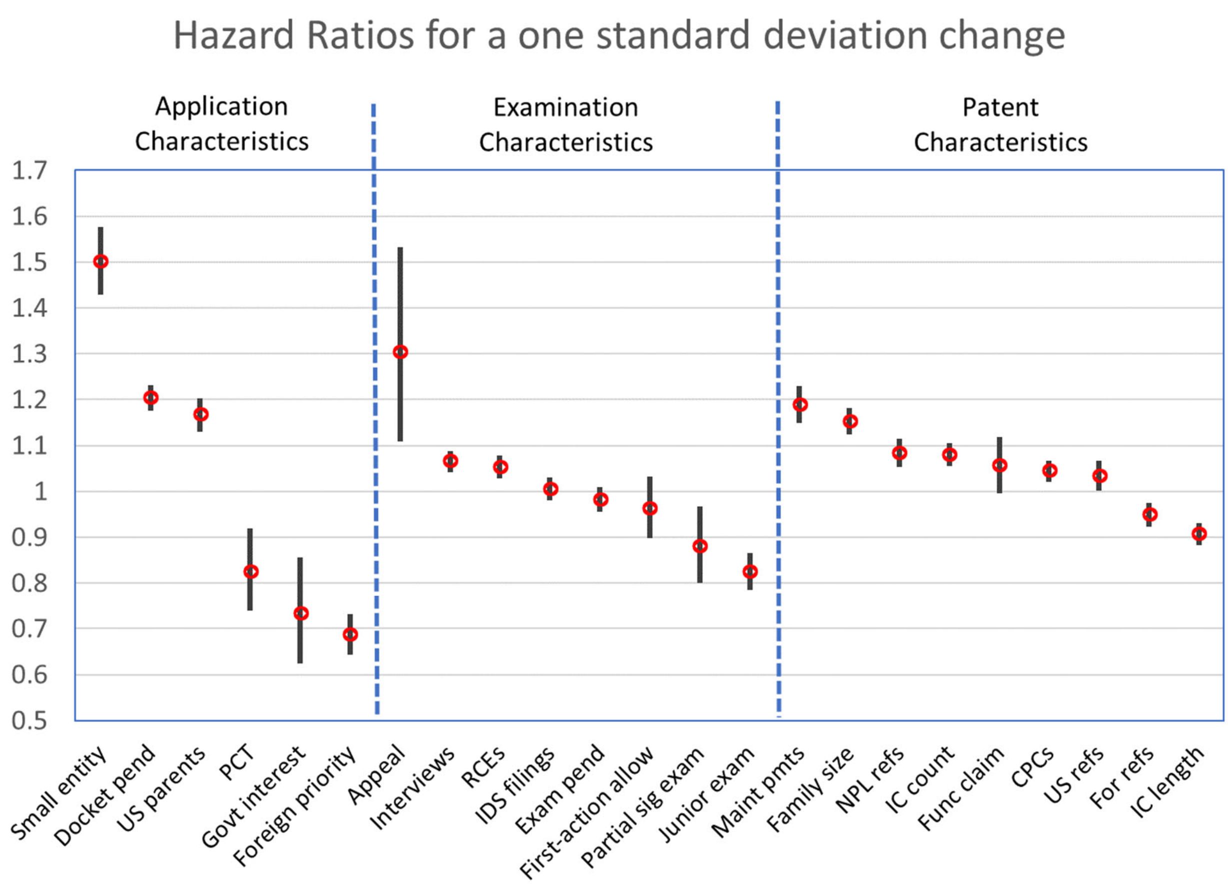
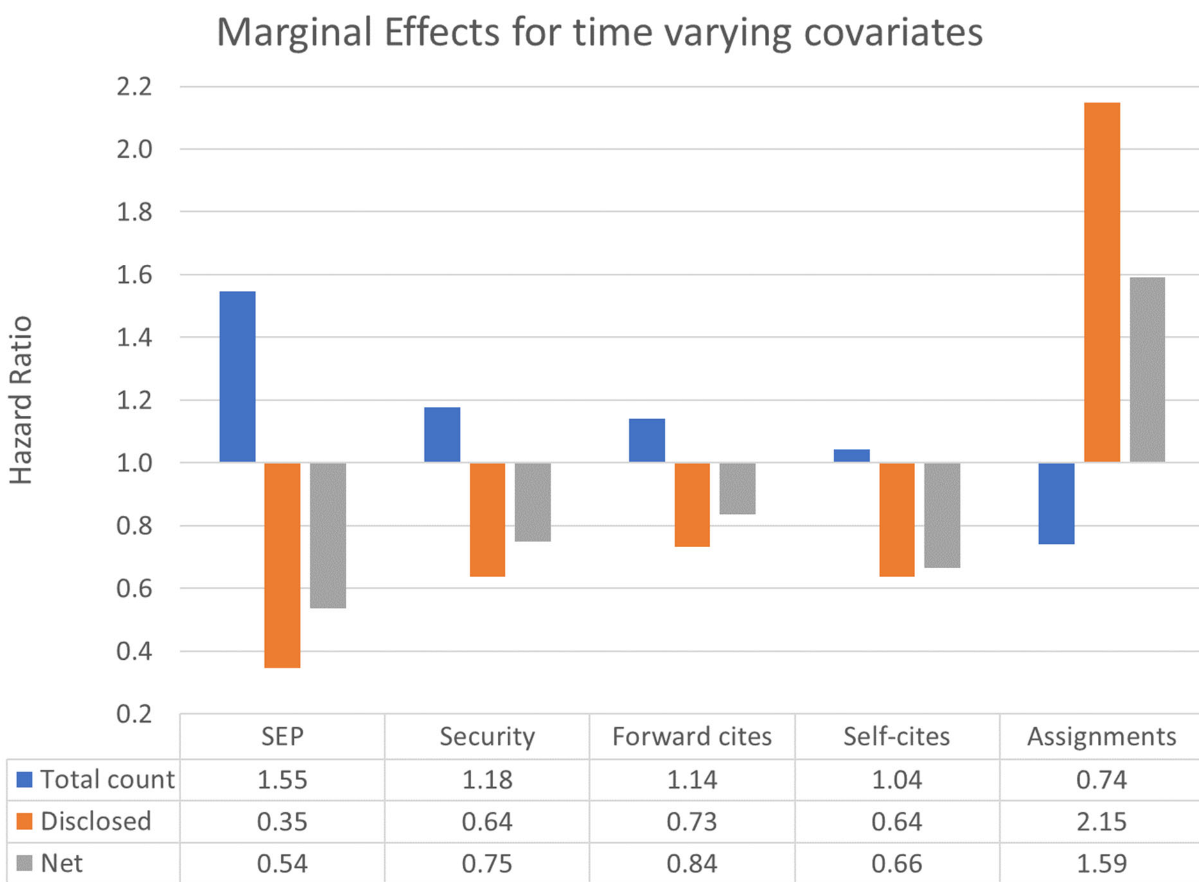


Figure 4-2: Marginal effects for the survival time regression (time-varying covariates)



	SEP	Security	Forward cites	Self-cites	Assignments
Total count	1.55	1.18	1.14	1.04	0.74
Disclosed	0.35	0.64	0.73	0.64	2.15
Net	0.54	0.75	0.84	0.66	1.59

Note: *Total Count* represents the prospective count observed over the lifetime of the patent, with the exception of SEP which is defined as an indicator variable (indicating whether the patent was ever disclosed as standard essential). *Disclosed* identifies the observed count at a given analysis time (time since grant); *Disclosed SEP* is an indicator identifying whether the patent was disclosed as standard essential at any point before a given analysis time. In all cases except for assignments, the prospective count raises the hazard of litigation and disclosure lowers the hazard of litigation, with the net effect reducing litigation.

Figure 4-3: Dynamic effects of time-varying covariates: Forward citations

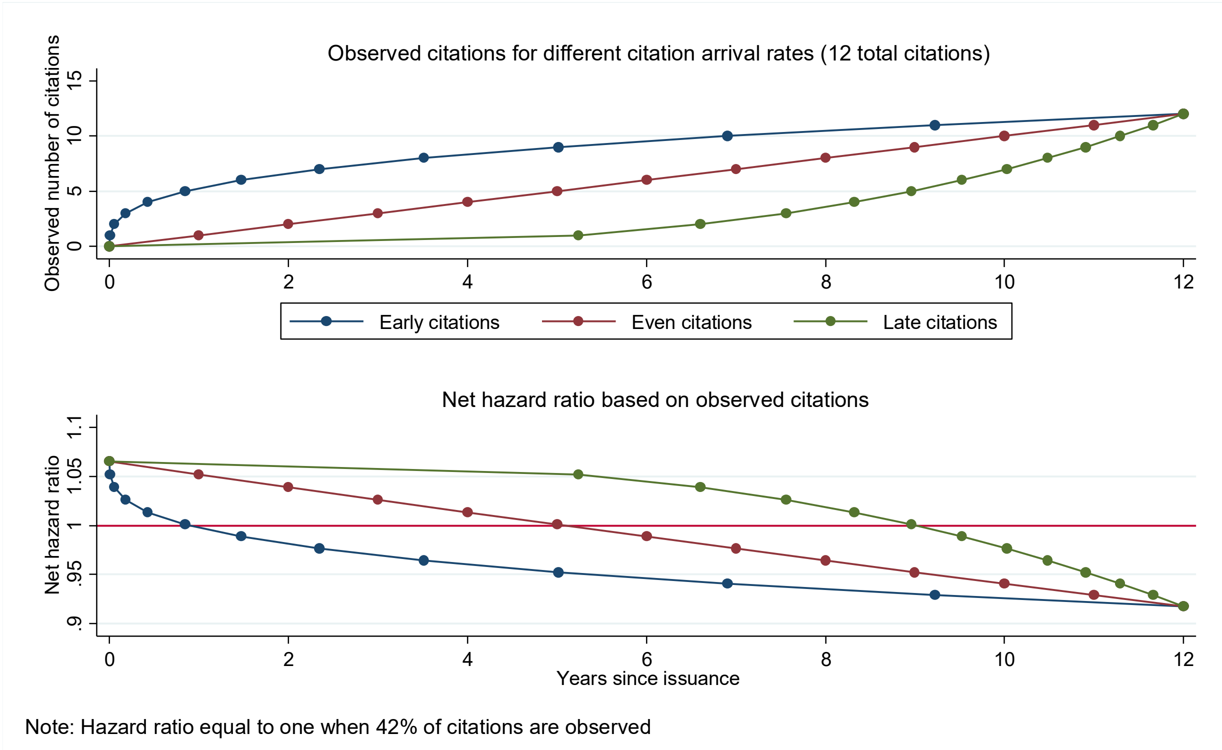


Figure 4-4:

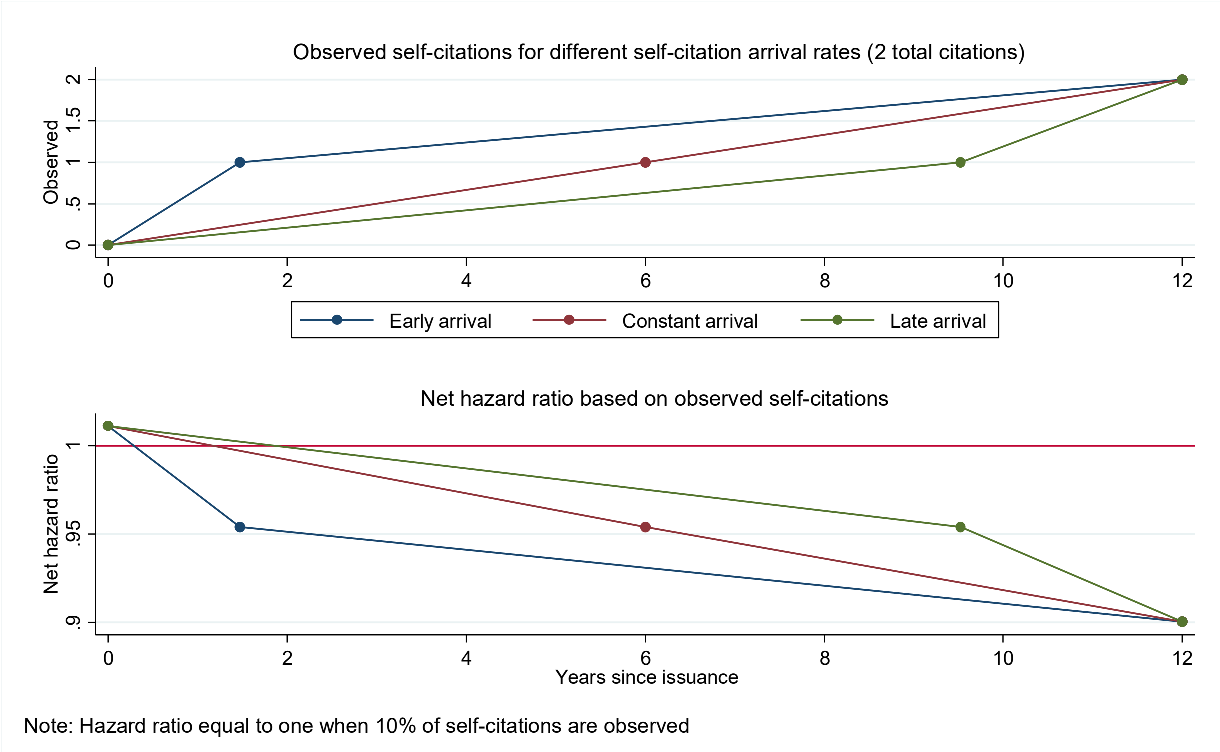


Figure 4-5: Individual-level litigation hazard

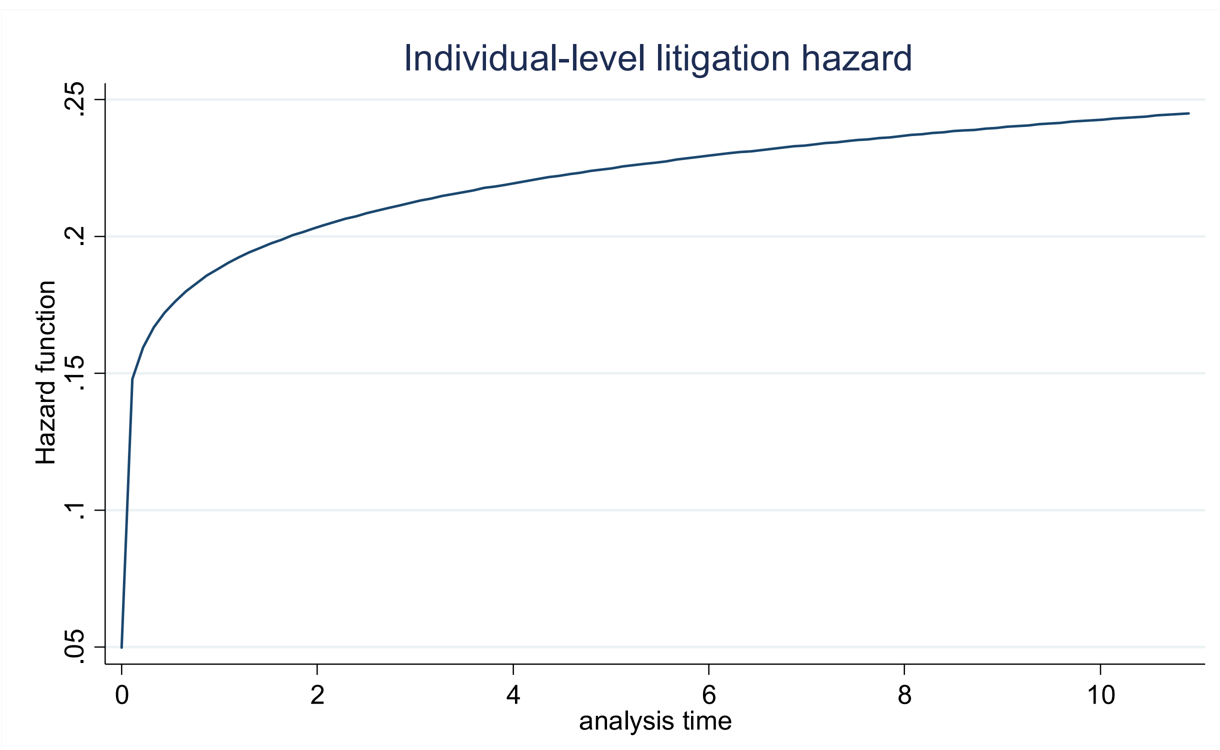


Figure 4-6: Population litigation hazard