Disclosure Rules and Declared Essential Patents*

Rudi Bekkers[1], Christian Catalini[2], Arianna Martinelli[3], Cesare Righi[4], and Timothy Simcoe[5]

[1]Eindhoven University of Technology
[2]MIT Sloan School of Management
[3]Scuola Superiore Sant'Anna, Pisa
[4]Boston University, Questrom School of Business
[5]Boston University, Questrom School of Business and NBER

July 18, 2017

Abstract

Many standard setting organizations (SSOs) require participants to disclose patents that might be infringed by implementing a proposed standard, and commit to license their "essential" patents on terms that are at least fair, reasonable and non-discriminatory (FRAND). Data from these SSO intellectual property disclosures have been used in academic studies to provide a window into the standard setting process, and in legal proceedings to assess parties' relative contributions to a standard. We develop a simple model of the disclosure process to illustrate the link between SSO rules and patent-holder incentives, and examine some of the model's predictions using a novel dataset constructed from the disclosure archives of thirteen major SSOs. The central message of the paper is that subtle differences in the rules used by different SSOs can influence which patents are disclosed, the terms of licensing commitments, and ultimately long-run citation and litigation rates for the underlying patents.

Keywords: Standards, compatibility, patents, licensing, FRAND.

JEL Codes: L15, O31, O34, K41.

* Support for this research was provided by the Hoover IP2 initiative. All opinions and any errors are attributable to the authors. Address for correspondence: tsimcoe@bu.edu.

1 Introduction

Voluntary consensus standardization is an important activity in the Information and Communications Technology (ICT) sector, where compatibility standards can help launch markets or promote major upgrades to existing platforms. However, new standards may fail to produce these catalytic effects if users fear they are built on proprietary technology, and therefore carry substantial legal or financial risks. Standard Setting Organizations (SSOs) address this concern by requiring members to disclose relevant patents during negotiations over the design of new standards, and by seeking a commitment that any essential intellectual property (IP) will be licensed on liberal terms. Patents disclosed as part of this process are often called "declared essential" patents (dSEPs).[1]

Data from declared essential patents have been used in academic studies to provide a window into the standard setting process, and in legal proceedings to assess parties' relative contributions to a standard.[2] In this paper, we analyze how SSO rules governing disclosure influence the selection of patents to disclose, the terms of licensing commitments for those patents, and their subsequent citation and litigation rates.

We begin by describing differences in SSOs' disclosure policies, and developing a simple model of the disclosure process. The model emphasizes two choices made by the owner of a possibly essential patent: whether to make a specific or "blanket" patent disclosure, and whether to offer a royalty-free or a fair reasonable and non-discriminatory (FRAND) licensing commitment. Blanket disclosures do not list specific patents, and in the equilibrium of our model, firms use blanket disclosures to increase the odds that relatively weak patents are nevertheless infringed by the standard. Royalty-free licensing commitments occur when there is *ex ante* competition between technologies for inclusion in the standard, and the benefits of implementing familiar technology outweigh the costs of forgone FRAND royalties.

The second half of the paper uses data from the publicly available disclosure records of thirteen

[1] Although many authors call any patent disclosed to an SSO a Standards Essential Patent (SEP), we use the acronym dSEP to emphasize the distinction between disclosure and essentiality, which will be important below.

[2] Academic studies include Rysman and Simcoe (2008), Kang and Bekkers (2015), Baron, Pohlmann, and Blind (2016), Kuhn, Roin, and Thompson (2016) and a number of others cited below. For an example of a court that used declared essential patent counts to apportion royalties, see *In re Innovatio IP Ventures, LLC*, No. 11 C 9308, slip op. at 82–84 (N.D. Ill. Sept. 27, 2013)

SSOs to study the operation and impact of different IPR policies, and to explore the unique characteristics of declared essential patents.[3] An initial look at the disclosure data reveals that two SSOs – the European Telecommunications Standards Institute (ETSI), and the Internet Engineering Task Force (IETF) – stand out in ways that can be linked back to our theoretical model of disclosure. ETSI does not allow blanket disclosure, and therefore accounts for almost half of the patents in our sample. In our model, prohibiting blanket disclosure leads to specific disclosure of weaker patents, and therefore a greater probability that disclosed patents will not actually be essential. In the data, we find that the marginal impact of disclosure on patent citations is negative for ETSI, and positive for all other SSOs. The IETF's disclosure rules encourage *ex ante* competition by promoting early disclosure, and discouraging blanket disclosure *unless* a patent-holder is willing to offer a royalty-free licensing commitment. In the model, *ex ante* competition is a necessary condition for royalty-free licensing commitments, and we find that they are far more likely at the IETF than other SSOs. Our empirical analysis also reveals that firms are more likely to offer royalty-free licensing commitments if they have a "downstream" business model that derives relatively more profit from implementation than technology licensing.

After studying the link between IPR policies and disclosure, we turn to an analysis of declared essential patents. We begin by constructing a pair of matched control samples, and showing that dSEPs differ from these controls along a number of observable dimensions that suggest technical importance and economic value. In particular, after matching on vintage, technology-class, patent type and the number of claims, declared essential patents receive sixty to seventy percent more forward citations, are two to three times more likely to be asserted in litigation, and come from significantly larger patent families (indicating that protection was sought in a larger number of countries). We use regression to explore heterogeneity in these differences between SSO and control patents. While the gap in forward citations does not vary significantly with the terms of the licensing commitment, we find that the probability of litigation is lower for royalty-free than FRAND commitments, and significantly higher when there is no ex-ante licensing commitment. Citation and litigation rates also vary significantly across SSOs.

[3]The authors are placing these data into the public domain to promote research on standards and intellectual property. They are available for download at www.ssopatents.org.

The final section of the paper exploits the panel structure of the patent data to move towards causal estimates of the impact of standardization on patent value and litigation. We begin by constructing a control sample that is matched to the dSEPs based on pre-disclosure citation patterns. Event studies and difference-in-differences regressions show that citations to dSEPs increase by 6 to 20 percent following disclosure, suggesting that inclusion in a standard increases the value of the patent. As noted above, we find that this effect is negative for ETSI, where mandatory specific disclosure rules may reduce the odds of essentiality conditional on disclosure. Finally, we show that litigation rates increase after disclosure, and that dSEPs are more likely to be litigated following a change in ownership than their citation-matched controls.

This study makes several contributions to the literature on standard setting and intellectual property. First, we provide a theory that links SSO rules to variation in disclosure terms and dSEP outcomes. To our knowledge, the only other model of the disclosure process is found in Lerner, Tabakovic, and Tirole (2016), and we emphasize a different set of mechanisms and strategies. Second, we extend the empirical analyses of citation and litigation rates in Rysman and Simcoe (2008) and Simcoe, Graham, and Feldman (2009) by using additional data and new methods, and by using our theory to help interpret heterogeneity in the impact of disclosure across SSOs. Our findings reinforce the idea that SSOs both select important technologies, and contribute to their value. However, they also show that SSO policies have a substantial impact on the patents that get disclosed and the terms of the associated licensing commitment. It is important to account for these differences in studies that rely on dSEP data.

A third contribution of our work is to provide the first empirical evidence linking the terms of licensing commitments to SSO policies and patent-level outcomes. Not surprisingly, patents disclosed on royalty-free terms are less likely to be litigated. Perhaps more interestingly, the IETF's disclosure policy yields a much higher share of royalty-free commitments than at other SSOs. Finally, our paper provides some preliminary evidence on the link between business models (which we operationalize as a firm's location in the ICT value chain) and the terms of SSO licensing commitments. Licensors and component suppliers are less likely to make royalty-free commitments and more likely to litigate their dSEPs, consistent with the idea that those firms are more reliant on intellectual property to appropriate the returns to innovation.

Our findings have implications for the academic literature that uses data from dSEPs, for courts that rely on dSEP counts in damage calculations, and for SSOs (or antitrust agencies) evaluating alternative disclosure rules. In particular, several of our results illustrate the trade-offs that SSOs face in crafting an effective intellectual property policy. For example, we find that allowing blanket disclosures can have a substantial impact on the amount of IP declared. This is not surprising, since it will typically be cheaper and less risky for firms to make a blanket licensing commitment, even if that leads to an incomplete picture of the overall patent landscape. At the same time, mandatory specific disclosure rules may increase the likelihood that disclosed patents are not actually essential.[4] Similarly, we find that a substantial amount of disclosure occurs before patents issue, when there can still be considerable uncertainty about the scope of their claims. Later disclosure might therefore reduce uncertainty, but could also increase the risk of hold-up.[5] We view these timing and specificity problems, combined with the economic importance of dSEPs and the difficulty of determining a FRAND price after standard are widely deployed, as jointly causing the high dSEP litigation rate. At a more general level, our results show that seemingly small changes in disclosure rules may have large impacts. This broad lesson parallels the findings of other studies that examine disclosure as a policy instrument outside the private political domain of industrial standardization (e.g., Fung, Graham, and Weil, 2007; Dranove and Jin, 2010)

The balance of the paper proceeds as follows: Section 2 describes SSO policies, and presents our model of the disclosure process. Section 3 analyzes disclosure characteristics. Section 4 analyzes dSEP characteristics. Section 5 uses matched-sample difference-in-differences regression to estimate the effect of disclosure on citation and litigation rates. Section 6 concludes.

---

[4] As discussed below, firms often make an informal announcement about potentially essential IPR to a technical committee, and these announcements may precede the formal blanket declaration. We have no data to indicate whether these informal declarations provide more details about specific patents, and might therefore be useful to a technical committee hoping to evaluate potential trade-offs between technical quality and implementation costs.

[5] Hold-up occurs when an essential patent-owner charges royalties that exceed the *ex ante* competitive price for their technology, and therefore appropriates (part of) the economic returns to implementers' sunk investments in a standard. See Farrell, Hayes, Shapiro, and Sullivan (2007) for an overview of the extensive literature on this topic.

2 Intellectual Property Policies and Disclosure Outcomes

In one of the first systematic studies of SSO intellectual property policies, Lemley (2002) suggests that they typically have three components: search, disclosure and licensing rules. Because none of the thirteen organizations that we examine below have a mandatory search rule, our discussion will focus on policies governing disclosure and licensing. Disclosure rules specify how and when firms must notify other participants in an SSO that they own IP that may be infringed by implementing a standard. Licensing rules specify the commitments that patent holders are requested to make regarding future licensing, the conditions that can be attached to those commitments, and the methods of enforcement. Table 1 provides an overview of the IPR policies for the SSOs in our data set, and Appendix A goes into greater detail.[6]

2.1 Disclosure rules

SSOs take different approaches to disclosure specificity. All of the organizations in the data that we use below allow for specific disclosure statements that list one or more patents (or pending applications) that may be infringed by a standard. Two of the SSOs in our sample (ETSI and the Open Mobile Alliance (OMA)) require specific disclosures, and the IETF requires specificity unless the disclosure is accompanied by a royalty-free licensing commitment. The ten remaining SSOs also allow general patent disclosure statements, or "blankets." A blanket disclosure indicates that a participant believes it owns relevant IP, without revealing any information about specific patents or patent applications.[7]

Blanket disclosure is clearly less costly for patent holders, since they do not have to search through their patent portfolios to identify relevant IP as the standardization process unfolds. Thus, allowing blanket disclosure can be efficient if the main purpose of a disclosure policy is to reassure prospective implementers that a license will be available. On the other hand, blanket disclosure

[6]See Bekkers and Updegrove (2012) for additional information on policies governing disclosure and licensing commitments. It is important to note that these policies may change over time, and our data on SSO policies were collected between 2012 and 2014.

[7]In the dSEP database, we distinguish between a blanket disclosure (which does not list any patents or pending applications) and a blanket licensing commitment (which extends to all disclosed and undisclosed essential patents). Many declarations combine specific disclosure and blanket commitments, but in some cases the scope of the licensing commitment is limited to only the disclosed IP.

shifts search costs from the patent holder (who presumably has a comparative advantage at finding its own essential patents) onto other interested parties, such as prospective licensees who wish to evaluate the scope and value of a firm's dSEPs; other SSO participants seeking to make explicit cost-benefit comparisons of alternative technologies before committing to a standard; and regulators or courts that might use information about relevant dSEPs to determine reasonable royalties.

Most SSOs encourage early disclosure. For example, ETSI seeks disclosures "in a timely fashion" and the ANSI IPR Policy Guidelines (ANSI, 2006) encourage "early disclosure." However, few SSOs provide explicit deadlines or milestones. In practice, disclosure often has two stages: an initial Call for Patents and the subsequent filing of a formal notice or declaration. At most SSOs, the call for patents occurs at the beginning of each technical committee meeting. Participants are expected to mention any IPR related to their own proposals (which may or may not become part of the standard), and may also draw attention to patents owned by others. We know of no systematic information that indicates when, or with what degree of specificity, the first stage call for patents is answered at any particular SSO. The second stage of the disclosure process occurs when a firm formally notifies an SSO in writing of dSEPs for a specific standard or draft. Our data come from these letters, which we henceforth refer to as *declarations*.

Policies that encourage or require specific disclosure typically apply to any patent or patent application that an SSO member believes might be technically essential, meaning that infringement would be necessary to produce a compliant implementation of the standard. However, SSO participants are not necessarily required to disclose commercially essential patents, which cover methods of implementation that deliver dramatic cost reductions or quality improvements. In economic terms, a technically essential patent has no substitutes, while a commercially essential patent has at least one (possibly unattractive) alternative. Patents covering both mandatory and optional features of a standard are normally considered essential, as are patents required to implement only a certain category of products.[8] However, patent owners are not typically required to indicate whether their dSEPs apply to optional features, or to certain product categories.

SSOs do not adjudicate essentiality, and many dSEPs are not in fact essential. Over-disclosure

[8] For example, in the Compact Disc standard, some patents are infringed by the disc, others are infringed by the player, and some cover both components or a combination thereof. All of these patents are considered essential.

is often caused by changes in a draft standard or the claims of a patent application during the standardization process. Mandatory specific disclosure policies also create incentives to err on the side of inclusivity by making undisclosed essential patents unenforcible, while providing no penalty for disclosure of patents that are only vaguely related to a standard. Because courts ultimately determine essentiality, it is hard to estimate the share of dSEPs that are truly essential. Although studies by Goodman and Myers (2005) and Van Audenrode, Royer, Stitzing, and Saaskilahti (2017) suggest that 20 to 40 percent of the patents disclosed to ETSI are essential, we expect that these figures vary across SSOs and over time.

Figure 1 illustrates the complex relationship between key events in the patenting, standard setting and IP disclosure process using two possible scenarios. In the first scenario (top panel), a patent issues before the patented invention is proposed for inclusion in a standard. When an invention is first proposed to the SSO, the owner is usually required to respond to the call for patents at the meeting where this proposal is discussed. Any response to a call for patents would be visible to other meeting participants, but does not leave a public paper trail. The patent holder typically follows up with a formal declaration (which we do observe) sometime after the publication of a draft standard, and preferably before the final specification is approved, though in practice some disclosures occur much later (see, for example, Layne-Farrar, 2014). In the second scenario (bottom panel), all of the key standardization decisions and disclosure events occur while the patent application is being reviewed by the patent office.[9] Thus, while formal IPR declarations may provide a great deal of information, it is important to recognize that SSOs may receive them well-after the date when the IPR was first disclosed to a technical committee, or when the key technical decisions that determine a patent's essentiality were made.[10]

[9]Figures B-2 and B-3 in the appendix show that a substantial share of the patents in our data are disclosed to an SSO before they are issued by the USPTO.

[10]In principle, since most declarations do indicate the relevant standard, one could identify the dates of key technical decisions. However, that information can be hard to find, and the links are often messy, and standards often see improved, updated releases, so we have not taken that step.

2.2 Licensing Commitments

All declarations, regardless of the type or timing of the disclosure, offer some guidance about the licensing terms that an IP owner will offer to prospective standards implementers for essential IP. We refer to this part of the declaration as a licensing commitment.

The most common form of licensing commitment is a promise to license on Reasonable and Non-Discriminatory (RAND) or Fair, Reasonable and Non-Discriminatory (FRAND) terms.[11] There is a substantial legal and economic literature, reviewed by Farrell, Hayes, Shapiro, and Sullivan (2007), and a considerable amount of controversy over the precise meaning of FRAND. At a minimum, it implies that an IP owner is required to enter good faith negotiations and grant a license to any firm wishing to implement the standard. There is also a broad consensus – at least among economists – that FRAND commitments are intended to prevent hold-up by constraining prices to an *ex ante* competitive rate that reflects the value of essential patents relative to alternatives available at the time of standardization (e.g. Swanson and Baumol, 2005).[12]

Most of the SSOs in our data allow, but do not require, more stringent types of licensing commitments than FRAND. For example, many firms promise to grant a royalty-free license to any standards implementer, or provide a covenant not to assert their essential patents. Many firms add conditions to their licensing commitments, though SSOs vary in their willingness to allow free-form declarations.[13]

SSO intellectual property policies typically specify a set of procedures for dealing with the rare event that a firm is unwilling to offer a licensing commitment for essential IPR. In most cases, the SSO will halt work on the standard in question, and investigate opportunities to invent-around the essential patents. If these efforts fail, the SSO might stop working on the standard altogether, or withdraw a specification that was already issued.

[11] Like most observers, we view the terms RAND and FRAND as equivalent for all practical purposes.

[12] Recently, courts have also issued a number of rulings that clarify several aspects of FRAND, including the remedies available to the owner of a valid and infringed FRAND-encumbered patent.

[13] Common conditions include defensive suspension provisions (which terminate the FRAND commitment if an implementer sues the essential patent holder for infringement) and reciprocity requirements (which make a FRAND commitment conditional on receiving similar terms from any implementer who also holds essential patents). Licensing commitments can also vary in scope. Some commitments only apply to specifically disclosed patents, while others apply to a particular standard (document), all work by a particular technical committee (Working Group), or even to the entire SSO. One very common type of declaration combines a specific disclosure with a blanket FRAND licensing commitment that covers all work on a particular standard.

The data we examine come from public IP disclosure records, and most SSOs provide a set of standard disclaimers with their disclosure data.[14] Beyond common disclaimers, SSOs differ in what they require, what they (explicitly) allow, and what they seem to tolerate in practice.[15]

2.3 A Model of Disclosure

This subsection develops an economic model of the disclosure process. The model's purpose is twofold: to illustrate some basic trade-offs for SSO participants, and to explain how variation in SSO policies can generate patterns that we observe in the dSEP data.

For simplicity, we assume two players: a firm and an SSO. The SSO wishes to incorporate a new feature into its standard, and the firm holds patents on a technology that may be used to implement that feature.[16] Standardizing the firm's patented technology will produce an expected surplus of v_1 per implementation, and the best alternative technology (should one exist) yields an expected surplus of v_2. The firm's payoff can be written as:

$$\pi = \underbrace{\sigma(V + wb)}_{\text{Implementation}} + \underbrace{(1-\sigma)r}_{\text{Licensing}}$$

where $\sigma \in [0,1]$ represents the firm's share of the downstream market; $V \in \{v_1, v_2\}$ is the surplus produced by the standard; $w \in \{0,1\}$ is an indicator that equals one if and only if the SSO standardizes the firms' patented technology; $b \geq 0$ captures the benefits of implementing familiar technology; and r denotes expected royalties from patent licensing. The familiarity benefits b reflect a combination of time-to-market advantages, avoidance of redesign costs, greater compatibility with proprietary complements, and backwards compatibility with the firm's installed base. By assumption, a pure licensor ($\sigma = 0$) receives no benefit from implementing a superior technology

[14] These include: (1) The statements are self-declarations and the SSO takes no responsibility that the list is complete and correct, (2) members agree to reasonable endeavors to identify their own essential IPR, yet do not have an obligation to perform patent searches, (3) it is up to the patent owner and the prospective licensees themselves to negotiate licensing agreements, and (4) the SSO does not handle disputes; in such cases, parties should go to court.

[15] The formal requirements may be part of the IPR policy itself (usually these are binding rules, such as statutes, by-laws, or undertakings), but may also become clear from the administrative procedures, such as templates that firms should use for their declarations, or from the actual declarations that are made public.

[16] We use the term feature because patents typically cover a small part of the relevant standard. For our purposes, it does not matter whether the firm proposed the new feature because it wishes to insert its patent into the standard, or just happens to hold patents for technology that can be used to implement a desirable feature.

(or a more familiar one), whereas firms with a larger share of the implementation market place more weight on those factors. We also assume that the alternative technology (if discovered) is freely available, so there is no licensing cost if the firm's technology is not chosen.[17]

The SSOs' payoff is $V - r + \varepsilon$, where ε is a mean zero random variable that reflects uncertainty (from the firm's perspective) about the objectives of other SSO members.[18] This payoff could represent either the objectives of SSO management, or a reduced-form expression for the collective preference of other participants in the standardization process.[19] Thus, higher V reflects the direct benefits of increased implementation and performance, and perhaps also reputational benefits to the SSO from creating a high quality standard. Similarly, the distaste for royalties could reflect either the political influence of implementers within the SSO, or an SSO's belief that higher royalties reduce the likelihood of widespread implementation.

The game has three (discrete) time periods:

- At $t = 0$ the SSO begins developing the new feature, and the firm decides how to disclose. Disclosure consists of an announcement that can be either Blanket or Specific and a licensing commitment that can be either FRAND or Royalty-free.[20] At this stage of the standardization process, there is uncertainty about the existence of an alternative technology.

- At $t = 1$, uncertainty about *ex ante* substitutes is resolved, the firm has another opportunity to disclose, and the SSO selects a technology to use for the new feature.

- At $t = 2$, *ex post* substitutes are revealed and the SSO decides whether to incorporate them into the standard, licenses are negotiated and payoffs are realized.

A royalty-free commitment implies that $r = 0$, and we interpret FRAND as a commitment to the *ex ante* competitive price. The competitive price is established through Nash bargaining

[17] We can derive similar results under the assumption of Bertrand competition between two patented technologies, but the exposition is simpler for the case of a free and open substitute.

[18] The Condorcet (1785) jury model could be invoked to provide micro-foundations for the random component of SSO utility, and we consider the case where the variance of ε shrinks to zero below.

[19] Lerner and Tirole (2006) model an SSO's preferences in terms of a parameter that reflects the relative weight attached to the interests of technology sponsors versus users.

[20] Assuming that licensing commitments can be of two types – FRAND or royalty-free – simplifies the analysis. In reality, firms might also commit to a price cap. While many economists have suggested that price commitments are desirable (e.g., Lerner and Tirole, 2015), they remain quite rare in practice.

that evenly divides any surplus between the patent holder and prospective implementers. The amount of surplus depends on the quality and availability of substitute technologies, whether those substitutes are discovered *ex ante* ($t = 1$) or *ex post* ($t = 2$), and whether they infringe the firm's patent. Specifically, we assume that at the start of each period ($t = 1, 2$), if no substitute has emerged the SSO identifies an alternate technology with probability ρ, having expected surplus v_2 drawn from the cumulative distribution $F(x)$.

Standardizing an alternative technology that is discovered *ex post* incurs a switching cost c that reflects technology-specific sunk costs of implementation, as well as the direct cost of standardization. These switching and coordination costs create a hold-up problem that many observers take as the primary rationale for SSO intellectual property policies.

We call a firm's patent technically essential ($e = 1$) if it is infringed by all available technologies, and commercially essential ($e = 0$) if there exists a non-infringing alternative.[21] Following Lerner, Tabakovic, and Tirole (2016), we model the choice between blanket and specific disclosure as a trade-off between obfuscation – which increases the probability of technical essentiality – and enforcement risk. Let δ be an index of patent scope, such that when $\delta = 0$ the patent is inevitably technically essential: it is impossible to implement the desired feature without infringing. When $\delta = 1$, the patent is so narrow that it is trivial to avoid infringement by using a different technology. We assume that the firm can use generic disclosure to obscure the details of its patent, and increase its probability of essentiality. In particular, a standard based on a substitute technology will infringe the firm's patent with probability $1 - \delta$ under specific disclosure and $1 - \delta\theta$ (where $\theta < 1$) under blanket disclosure.

Although specific disclosure reduces the likelihood of technical essentiality, it can strengthen a patent in the eyes of licensors and courts. We capture this idea by assuming that blanket disclosure lowers expected royalties from r to $(1 - \gamma)r$. For example, Lim (2014) suggests that firms favor specific disclosure because antitrust concerns can arise if they sue based on patents that were not disclosed, and because they believe that by declaring a large number of patents they can obtain

[21] When discussing our model, we use the terms technically and commercially essential differently from most SSOs. In particular, we allow a patent to be either technically or commercially essential *ex ante* (i.e. before the standard is finalized), whereas most SSOs only view a patent as essential after that decision has been made.

better leverage in negotiations. The latter belief may be justified if declared essential patent counts are used to apportion royalties in an arbitration or damages in a patent lawsuit.

2.3.1 Equilibrium Disclosure

We characterize the subgame-perfect Nash equilibrium of this disclosure model by solving it backwards. There are two outcomes to consider in the final period: royalties and the decision to switch technologies. The SSO will standardize an alternative technology discovered in period 2 if and only if $v_2 - c > v_1$. Royalties from Nash bargaining under a FRAND commitment are therefore:

$$r(v_1, v_2, e) = \begin{cases} \frac{1}{2}v_1 & \text{if } v_2 = 0 \\ \frac{1}{2}\max\{v_1, v_2 - c\} & \text{if } v_2 > 0 \text{ and } e = 1 \\ \frac{1}{2}(v_1 - \max\{0, v_2 - c\}) & \text{if } v_2 > 0 \text{ and } e = 0 \end{cases}$$

The latter two cases show that when a substitute is found, the firm can benefit if its patent remains technically essential, and may lose bargaining leverage if the patent becomes commercially essential (though both effects are dampened by switching costs).

We are now ready to move backwards to $t = 1$ and consider the firm's disclosure decision. There are two cases to consider:

Case 1: No Competition: If there are no *ex ante* substitutes, the firm's technology will be standardized. The firm will offer a FRAND commitment, because that leaves open the possibility of monetizing its patents. The choice between specific and blanket disclosure will not affect the implementation part of the firm's payoff, and therefore depends only on expected royalties. In the appendix, we show that the firm will make a specific disclosure if and only if

$$\gamma\left\{(1-\rho)\frac{v_1}{2} + \rho E[r(v_1, 1)]\right\} \geq \rho\delta(1 - \theta(1-\gamma))E[r(v_1, 1) - r(v_1, 0)] \tag{1}$$

where the expectation is taken with respect to v_2. On the left side of this inequality are the marginal royalties from specific rather than blanket disclosure of an *ex post* technically essential patent. The right side of the expression measures the marginal cost of specific rather than blanket disclosure because of *ex post* competition from alternative technologies.

Several results follow immediately. A firm with an "ironclad" patent ($\delta = 0$) will always make a specific disclosure. The probability of specific disclosure increases when obfuscation is less effective ($\theta \to 1$), enforcement risk under blanket disclosure increases ($\gamma \to 1$), or *ex post* competition becomes less likely ($\rho \to 0$). In the appendix, we show that specific disclosure also increases with the value of the firm's technology (v_1).[22] All of these observations can be collected as:

Prediction 1. *When there is no ex ante competition, the firm makes a specific FRAND disclosure if and only if (1) is satisfied, and a blanket FRAND disclosure otherwise. Specific disclosure increases with patent scope $1 - \delta$, patent value v_1, and enforcement risk γ; and declines with the probability of ex post competition ρ, and the impact of obfuscation $1 - \theta$.*

Case 2: Competition: When a substitute is discovered *ex ante* the firm makes a specific disclosure, because there is no longer any benefit from obfuscation. If its patent is technically essential, the firm will make a FRAND commitment. But if the patent is commercially essential, the firm may opt for a royalty-free licensing commitment to influence the SSO's decision.

The SSO will standardize the firm's patented technology whenever $v_1 - r + \varepsilon_1 > v_2 + \varepsilon_2$. A risk-neutral firm would be willing to commit to a FRAND price $r^F \leq v_1 - v_2$ to try and induce a favorable choice. But if the firm cannot commit, the threat of hold-up might lead the SSO to standardize a competing technology.[23]

Given our assumption that the firm can only commit to royalty-free licensing, let $\underline{G}$ and $\overline{G}$ denote the probability that the SSO picks the firm's technology under a FRAND or royalty-free commitment respectively.[24] In the appendix, we show that the firm will offer a royalty-free licensing commitment if and only if

$$r(v_1, v_2, 0) \leq \frac{\sigma}{1-\sigma} \frac{\overline{G} - \underline{G}}{\underline{G}} (v_1 - v_2 + b) \tag{2}$$

[22] The firm's downstream activities do not influence the trade-off, except by making it more "salient" in the sense of these costs and benefits representing a larger share of the firm's total payoff.

[23] In principle, the SSO could rely on courts to enforce a FRAND commitment by capping reasonable royalties at $r^F = v_1 - v_2$. But in practice, courts find it difficult to measure v_1 and (especially) v_2 *ex post*, and to decide how the *ex ante* surplus should be divided. SSO policies often discourage explicit discussion of pricing, and as noted above, *ex ante* commitments to a specific price remain quite rare.

[24] Formally, $\underline{G} = Pr(v_1 - v_2 - r(v_1, v_2, 0) > \varepsilon_2 - \varepsilon_1)$ and $\overline{G} = Pr(v_1 - v_2 > \varepsilon_2 - \varepsilon_1)$

It follows immediately that implementers with a larger share of the downstream market (higher σ), or who derive more benefits from standardizing a familiar technology (higher b) are more likely to offer a royalty-free commitment.[25] Holding v_2 fixed, the risk that SSO will choose a substitute technology disappears as v_1 grows large, leading the firm to make a FRAND commitment. Gathering these observations together, we have:

Prediction 2. *When there is ex ante competition, the firm makes a specific disclosure. It will make a royalty-free licensing commitment if and only if (2) is satisfied. Royalty-free commitments increase with downstream market share σ, increase with the benefits of implementing familiar technology b, and decrease as the quality of a firm's technology v_1 grow large.*

The relationship between switching costs and licensing commitments under *ex ante* competition depend on a firm's business model. Because *ex post* royalties are weakly increasing in c, licensors will favor FRAND commitments. At the same time, increased royalties imply a greater chance that the SSO will select a substitute technology, leading implementers to favor royalty-free commitments. In the appendix, we formalize this intuition by showing that there is a critical value $\widehat{\sigma}(v_1, b)$ such that the probability of a FRAND commitment is increasing in c for all $\sigma < \widehat{\sigma}$ and decreasing in c for all $\sigma > \widehat{\sigma}$.

Finally, consider the disclosure choice at $t = 0$, before any competition has emerged. At that time, blanket FRAND disclosure is a dominant strategy for the firm. Blanket disclosure reduces the likelihood of *ex ante* competition, and FRAND preserves the option to monetize the patent.

2.3.2 Implications and Extensions

Table 2 summarizes equilibrium disclosure in our model. At the start of the standardization process, when there is no competition, firms naturally prefer blanket FRAND disclosure. However, as the SSO's decision approaches, they could face several scenarios. When there is competition from substitute technologies, firms will make a specific FRAND disclosure if they have a "strong"

[25] In the appendix, we show that in the limiting case where there is no uncertainty ($\varepsilon_1 = \varepsilon_2 = 0$), the firm will make a royalty-free commitment if and only if the SSO would choose the competing technology under FRAND. In that case, the terms of the licensing commitment do not vary with σ or b.

patent, and a specific royalty-free disclosure if the patent is "weak" or the benefits of using familiar technology are large (where "strong" implies either technical essentiality or $v_1 \gg v_2$, and "weak" implies commercial essentiality and $v_1 \approx v_2$). All else equal, firms with a larger share of the implementation market are more likely to make a royalty-free commitment. When there is no *ex ante* competition, firms will make a specific FRAND disclosure for "strong" patents, and a blanket FRAND disclosure for "weak" patents (where strong implies low δ or $v_1 \gg E[v_2]$ and weak implies the converse).

Disclosure policies and patent outcomes: Our model sheds some light on debates about the blanket disclosure option. In particular, allowing blanket disclosure can lead to more weak patents actually becoming essential. On the other hand, prohibiting blankets will produce a list of dSEPs containing more non-essential patents.

In the empirical analysis below, we focus on two long-run patent-level outcomes: citation and litigation. Although our model of disclosure emphasizes the *selection* process behind the dSEP data, it can easily be linked to these two outcomes. In particular, we expect more valuable patents (higher v_1 and lower δ) to experience a larger increase in citations following disclosure, because they are more likely to become and remain technically essential. We also expect more valuable patents to have a higher litigation rate, unless they are offered on royalty-free terms.[26]

In our model, we can analyze a mandatory specific disclosure policy by setting $\gamma = 1$, which implies that firms cannot collect royalties for essential patents declared in a blanket disclosure. It should be obvious (and equation (1 confirms) that every relevant patent is specifically disclosed under such a policy. If disclosure occurs at $t = 0$, we should see more *ex ante* competition in $t = 1$, leading to both a lower rate of dSEP *ex post* technical essentiality, and a higher rate of royalty-free licensing commitments. And regardless of disclosure timing, patents disclosed under a less strict policy where $\gamma < 1$ should have a (weakly) higher expected values of v_1 and lower values of δ. Thus, we should expect SSOs with mandatory specific disclosure rules to exhibit lower dSEP citation and litigation rates.

Consistent with these predictions, we find below that the impact of disclosure on citations and

[26]This prediction can be derived, for example, within the Priest and Klein (1984) model of litigation.

litigation is lower at ETSI and IETF, the two SSOs in our data that mandate specific disclosure.[27] The difference is particularly striking for ETSI, where the marginal impact of disclosure on citations is negative. Early specific disclosure also encourages *ex ante* competition, which should lead to more royalty-free licensing commitments. Although ETSI does not provide a royalty-free option, we find that royalty-free commitments are much more common at IETF than other SSOs.

Extensions: One natural extension of our model is to assume that firms must determine whether they own potential SEPs. Many observers (e.g., Biddle, 2015) suggest that search costs are in fact substantial, and provide an important rationale for the blanket disclosure option. In our model, these costs can enter through γ, making blanket disclosure more attractive relative to specific.

Another extension would be to allow for the creation of a "profile" that incorporates both technologies (v_1 and v_2), leaving the final decision to implementers. If the profile creates no loss in overall compatibility, this option should reduce the incentive to offer royalty-free licensing commitments, because a firm can always implement the more familiar technology in cases where $v_1 < v_2 < v_1 + b$. However, a more realistic model might incorporate some risk of coordination failure, so that V declines in expectation when the SSO fails to make a clear choice between competing options.

3 Disclosure Characteristics

This section uses our novel database of intellectual property declarations to document a number of stylized facts about the standardization process at thirteen major SSOs. The data contain 45,349 disclosures (general or specific licensing statements) that can be grouped into 4,910 declarations (statements submitted to a single SSO by a single firm on a given date).[28] Appendix A provides additional information about the dataset.

Figure 2 graphs the total number of declarations in our data, starting in 1985. The figure exhibits two striking features: the number of declarations (and amount of disclosed IP) has grown

[27] While the IETF policy is not technically a mandate, many IETF Working Groups have a *de facto* prohibition on blanket FRAND disclosures, as described in Contreras (2016).

[28] Tables C-1 and C-2 show the most active firms in our data, in aggregate and by SSO. The ten most active firms account for 33% of the declarations (and an even larger share of dSEPs), but we observe a total of 926 unique organizations that make one or more disclosures, and the "long tail" of small organizations is collectively substantial.

dramatically over time, and there was a sharp increase in disclosure size around 2000. The increase in disclosure size is linked to a relatively small number of declarations that list very large numbers of patents, particularly at ETSI. But the overall pattern is one of a rapidly increasing number of disclosures, and a rapidly expanding base of declared essential patents.

Simcoe (2007) discusses four possible explanations for this trend. First, in the mid-1990s expectations about the enforcement of these policies may have changed due to a pair of court cases filed by the U.S. Federal Trade Commission.[29] In particular, the outcome of *Dell Computer* suggested that firms that failed to disclose essential IP could lose the right to assert their patents, and this naturally increased the incentive to comply with disclosure policies. Second, the trend may reflect the increasing importance of several shared technology platforms governed by SSOs in our sample, notably the Internet (associated with IETF), cellular telephony (ETSI) and wireless networking (IEEE). As these groups develop more standards, this naturally leads to more IP disclosure. The increase in patenting, especially within the US, offers a third potential explanation for the disclosure boom, though we observe that the number of dSEPs is growing even faster than the number of information and communications technology patents. Finally, the trend in disclosure may reflect a trend towards vertical dis-integration in the ICT sector that is closely linked to the rise of shared platform technologies such as the Internet. Upstream technology developers naturally rely more on patents, and the notable success of some licensing-oriented business models may have spawned a certain amount of imitation.

Table 3 examines disclosure characteristics by SSO. The first column in this table shows that the distribution of declarations across SSOs is very uneven. While several SSOs have 500 or more declarations, others have only a handful. For this reason, we pool the organizations in some of the analyses below. The last column in Table 3 shows this grouping. Our first group are the three "Big I" international Standards Developing Organizations, IEC, ISO and ITU. Our second group contains the regional umbrella organizations CEN/CENELEC for Europe and ANSI for the US, along with the Broadband Forum. IEEE, ETSI and IETF each constitute their own group. The final group consists of several smaller forums that develop mobile telecommunications standards.

[29] *In Re Dell Computer* and FTC vs. Rambus.

The second column in Table 3 shows variation in the share of blanket declarations that list no specific patent or application numbers. Overall, roughly half of all declarations are blankets. The SSO with the lowest share is ETSI, which has a policy of mandatory specific disclosure. The average disclosure size at ETSI is almost 40 patents, which is four times larger than the next largest SSO, and the total amount of IP disclosed at ETSI is over half our sample of dSEPs. Other differences in the size and frequency of disclosure across SSO may reflect the scope of the work carried out within the SSO, the different IP policies summarized in Table 1, and differences in the patenting propensity of participating firms.

The next set of columns in Table 3 focus on the terms of licensing commitments. As noted above, the overwhelming majority (89%) of disclosures offer a FRAND commitment (in some cases because that is the only option allowed by an SSO). Overall, 9 percent of licensing commitments are royalty free, and we observe only a handful that either withhold a commitment or provide specific licensing terms and conditions. When looking across SSOs at the distribution of licensing commitments, the clear outlier is the IETF, where more than one third of the declarations provide a royalty-free commitment. Many IETF Working Groups have a stated preference for royalty free standards, though others will consider royalty-bearing technology if justified on technical merits. Our model suggests that royalty-free disclosures emerge only if there is *ex ante* competition for inclusion in the standard, which requires knowledge of relevant IP relatively early in the standardization process, before design decisions have become entrenched. Thus, it is interesting to note that the last two columns show that patents are generally disclosed earlier at the IETF – on average six months before they even issue.

Figure 3 illustrates the distribution of elapsed time between patent application (or issuance) and disclosure to an SSO in our sample. Overall there is considerable dispersion. On the one hand, many patents are disclosed 5 or more years after they issue, suggesting that invention preceded standardization by a considerable period of time. On the other hand, we can see that almost half of the disclosed patents applied for after 2000 (when US patent applications first began to be published) are disclosed *before* the patent issues. The disclosure of potential dSEPs to an SSO before the patent issues illustrates one reason that some SSOs have given for their resistance to explicit pricing commitments during the standardization process: it is not yet clear what the claims of the issued patent will say.

In order to examine the predictions from our theoretical model within a regression framework, we created a variable that captures whether a firm is primarily a "downstream" standards implementer, as opposed to an "upstream" licensor or component vendor. While any such distinction is inherently somewhat arbitrary, we found it relatively easy to classify the most active firms in our data into a handful of business model categories, as illustrated in Table 4, and have made the data public so that interested readers can experiment with alternative classification schemes. We classified all entities that made five or more declarations, and believe that most of the remaining unclassified observations would fall into the "upstream" category, based on inspecting the data and because scale economies in implementation lead most downstream firms to be familiar brands.[30]

Table 5 presents coefficients from linear probability (OLS) models of the two choice variables in our theoretical model: specific versus blanket disclosure, and royalty-free versus FRAND commitments. Because all of the explanatory variables are dummies, each coefficient can be interpreted as a percentage-point change in the probability of the outcome variable.[31] The estimates in column (1) show that upstream firms are less likely to offer a royalty-free licensing commitment, as predicted by our model. Unclassified firms are indistinguishable from downstream firms who are closer to the implementation market. Column (2) adds SSO dummies, and we see that this correlation declines in magnitude, but remains statistically significant. Not surprisingly, there is also a large and statistically significant coefficient on the IETF dummy.

Columns (3) and (4) in Table 5 show that upstream licensors are also more likely to offer blanket disclosures, and that blanket disclosure is less prevalent at ETSI and IEEE.[32] Interestingly, blanket disclosure is used at IETF as much as ANSI, even though blanket disclosure creates a strong preference for royalty-free licensing at the former SSO.

[30] Unclassified observations comprise 63 percent of all claimants, but only 16 percent of disclosures and 4 percent of the declared essential patents in the data set.

[31] Table C-3 shows that we obtain nearly identical estimates of the marginal effects from a logit specification.

[32] The coefficient for ETSI in the blanket regression is identified because there are a very small number of SSO-wide blanket FRAND commitments included in our data set, even though firm's still must specifically declare to ETSI any patent they intend to enforce.

4 Declared Standard Essential Patents (dSEPs)

This section examines the declared essential patents contained in our data. While the declarations list patents from many countries, we limit our patent-level analyses to a group of 6,723 granted US patents that were either declared essential, or share a common priority application with a European declared essential patent.[33] The United States is the most common issuing country in our overall dataset, and limiting the analysis to US patents keeps the presentation and interpretation of statistics relatively simple. Henceforth, we refer to this sample as dSEPs.

As a point of comparison, we also created two "control" samples. The first group of comparison patents was selected by randomly choosing an undeclared US patent with the same primary (3 digit) technology class, grant year, patent type (i.e. regular utility or reissue utility patent) and with roughly the same number of claims as each of the dSEPs.[34] This one-to-one matching procedure ensures that the joint distribution of technology classes, grant years, patent type and claims is balanced in the two samples. We refer to these patents as Random Matches. For the second comparison group, we also matched on a count of patents in the same DOCDB patent family within one year of the earliest priority date associated with the focal patent. Our goal in creating this second comparison set was to use family size as a proxy for the perceived value of the patent to the applicant – since it is more expensive to file for protection in more countries – without providing too much time for family size to grow, so it does not become a function of essentiality.

To be clear, neither set of "control" patents is meant to provide an estimate of the true counterfactual outcome for dSEPs had they not been declared essential. Rather, these comparison groups yield an estimate of the "average outcome" in a set of patents with similar ages, technical characteristics and perceived importance around the time of application. Rysman and Simcoe (2008) discuss this type of matching in detail, and note that a difference-in-differences comparison of these two groups before and after disclosure can measure both selection effects (differences that would

[33]The algorithm to identify US patents that share a common priority application with a declared essential patent had four steps: (1) Take the appln_id of all DOCDB family members for each dSEP, (2) for applications identified in step 1, find the appln_id for the parent application of any continuations, (3) for applications identified in step 1 and 2, find the appln_id for the earliest parent application associated with each focal application, (4) identify any issued US patent originating from an application identified in steps 1 through 3.

[34]For matching on claims, we chose a control patent from the same decile of the cumulative distribution of total claims as the focal dSEP patent.

exist regardless of standardization) and marginal effects (differences caused by disclosure and/or standardization).

Because the IP declarations are not an ideal data source in all respects, it is worth reiterating several caveats before presenting our initial patent-level analyses. First, these data do not contain all essential patents, since many SSOs allow blanket disclosure. We know of no easy way to identify undeclared essential patents, including those in blanket disclosures. Second, any sample of dSEPs will contain some patents that are not technically essential. As described above, both standards and patent applications change over time, so a patent or pending application that was essential to a particular draft may no longer be infringed by the time an SSO settles on the final specification. Firms may also "overdeclare" out of caution (since non-disclosure could render their IP unenforceable) or because they have a strategic motive to inflate their dSEP counts, possibly with an eye towards future negotiations. Finally, when we examine disclosure timing, it is important to recall that declaration dates are only loosely connected to the underlying standard development process. Depending on the rules of a particular SSO, formal declarations can predate the key technical decisions, occur at roughly the same time, or appear long after a standard is published and diffused.[35]

All of our patent-level outcomes data come from the USPTO, with the exception of the data on patent litigation, which was obtained from the Thomson Innovation database in April 2016.[36]

4.1 The Significance of dSEPs

Table 6 provides an initial comparison of dSEPs and control patents. Note that all of the dSEPs have a random match, whereas matching on family size (at 1 year) produces a material reduction in sample size. Nevertheless, the results are similar for both comparison groups, and the main message of the table is that dSEPs score higher than controls on a variety of metrics used to proxy

[35] Our database provides details on the underlying technical committee and document wherever possible, and we encourage enterprising researchers to supplement these declarations data with more precise dates of key technical decisions as part of future research.

[36] We combine data from various sources, including PATSTAT, PatentsView (`http://www.patentsview.org`), the USPTO Patent Assignment Dataset (Marco, Myers, Graham, D'Agostino, and Kucab, 2015), the Harvard Patent Dataverse and the Fung Institute GitHub website (Li, Lai, D'Amour, Doolin, Sun, Torvik, Amy, and Fleming, 2014). Details are available upon request.

for value and technological significance.

The first two rows in Table 6 examine "long run" differences between SSO and Control patents. The first row shows that the probability of litigation in the sample of SSO Patents is four times higher than the random matches (7.27 percent versus 1.76 percent), and more than three times higher than in the family matches.[37] The second row shows that SSO Patents are cited as prior art by other US patents 70% more than the random matches and 60% more than the family matches. It is important to note that dSEPs and control patents have the same distribution of grant years (and as the table shows, application year), so these differences in long-run outcomes are not caused by any difference in exposure to the risk of a citation or a lawsuit. While it is hard to place a value on a forward citation, or understand the precise significance of a particular lawsuit, these measures are widely used by innovation researchers and rarely show differences of the size and statistical significance observed in our analysis.

The third row in Table 6 examines the rate of reassignment (i.e. transfer of patent ownership) and finds differences that are statistically significant, but rather small, between dSEPs and control samples. In the fourth row, we see a very large difference in the family size of the dSEPs and the random match comparison group. This suggests that applicants are aware of the value of declared essential patents from a relatively early date, and motivated our construction of the additional family matched control group. Interestingly, even after matching on the size of the international patent family within one year from the priority date, we see a significant difference in the overall family size for dSEPs and family matched controls.

Finally, Table 6 shows that dSEPs have more listed inventors, and make more references to both patent and non-patent prior art. These findings suggest that they are "broader" than the controls, and that applicants were more careful in delineating the underlying innovation (relative to prior patents) in their application. Large differences between dSEPs and control patents at the time of filing suggest a selection effect, whereby SSOs attract and select high-value technologies. However, Bekkers, Bongard, and Nuvolari (2011) show that firms often file for patents and submit the underlying technology to an SSO almost simultaneously, so even *ex ante* value metrics may

[37] We measure litigation at the level of the individual patent, so a suit that incorporates two or more declared essential patents may be counted more than once.

reflect an SSO's influence.[38]

4.2 Cross-sectional Comparison Between dSEPs and Control Patents

Our next set of patent-level analyses examine how differences in long-run outcomes (i.e. citations and litigation) vary with the "visibility" of disclosures, the business model of the claimant, the SSO, and the type of licensing commitment. We continue to use the randomly matched control sample as a way to adjust for differences in technology class, age, patent type and the total number of patent claims. However, we now adopt the following regression framework:

$$Y_{ij} = Declared_i \beta_j + \alpha_j + \lambda_g + \gamma_c + X_i \theta + \varepsilon_i \quad (3)$$

where Y_{ij} is either a citation count or a litigation indicator for patent i in group j, $Declared_i$ is an indicator variable that equals one if patent i was declared essential to an SSO, and X_i is a vector of control variables that includes the number of claims, patent references and non-patent prior art references made by the patent. We focus on four groups (indexed by j): dSEPs (versus undeclared family members), business models (Upstream, Downstream or Unclassified), Licensing Commitments, and SSOs.[39] The coefficients λ_g and γ_c are a set of issue-year and technology class fixed-effects, while the coefficients α_j measure differences in control patent outcomes across groups. We are interested in the vector of coefficients β_j that measures a group-specific difference between the SSO and matched control patents.

Table 7 reports estimates of β_j, using both citations and litigation as outcomes.[40] For the citation models, we estimate equation (3) as a Poisson regression with robust standard errors.[41] For the litigation outcome, we use a linear probability model.

[38] To see whether "simultaneous" application and disclosure had a large impact on our results, we re-ran the analysis in Table 6 on the sub-sample of dSEPs (and matched controls) in the upper quartile of the application-to-disclosure lag distribution, which were declared 7.7 or more years after their application date. The results of this unreported analysis are quite similar to those reported in Table 6, suggesting that there is a substantial element of selection on observed (to the patent-holder) quality in our sample of dSEPs.

[39] When a patent is declared essential to more than one SSO, we assign it to the one where it was first declared.

[40] Table 7 focuses on the full sample of SSO Patents and Random Matches, while Table C-4 shows for robustness that we get similar results when focusing on the Family Matched comparison group.

[41] The is sometimes called the Poisson quasi-likelihood estimator, and using the robust standard errors corrects for any overdispersion in the outcome.

Columns (1) and (5) in Table 7 compare the "disclosure effect" for patents that were actually listed as dSEPs to the effect for family members that were not specifically declared. We find a statistically significant increase in citations and litigation for both groups, though the effect is much larger for the dSEPs. A coefficient of 0.55 in column (1) indicates that dSEPs receive about 73% more forward citations than the random match controls, compared to around 14% for their family members.[42] The coefficient of 5.56 in column (5) indicates that the difference in probability of a lawsuit is 5.6 percentage points.

Columns (2) and (6) in Table 7 examine the relationship between the patent holder's business model and dSEP citation and litigation rates. We created a separate business-model category for the control patents, whose owners we did not attempt to code, and use that as the omitted category in these regressions. In column (2), we see that patents disclosed by pure-licensors, universities and component producers receive more citations than those disclosed by downstream implementers. Column (6) shows that firms with upstream business models are also more likely to assert their dSEPs in litigation. These findings are consistent with the idea that upstream technology developers are more reliant on patent monetization as part of their overall business model. Interestingly, we find similar results of even larger magnitude for the group of unclassified patent-holders. One interpretation of the latter finding is that the unclassified firms are relatively small, and consequently face similar incentives to monetize their patents instead of relying on complementary assets for capturing value.

Columns (3) and (7) in Table 7 examine how the citation and litigation of dSEPs vary according to the terms of the licensing commitment. We consider four types of commitment: FRAND; Free (which includes both a royalty-free license and a non-assertion covenant); Terms (for a specific set of conditions, including price) and None. Column (3) shows that the difference in forward citations between dSEPs and randomly matched control patents is largest for commitments to license the patents free of charge. However, the standard errors associated with non-FRAND commitments are all relatively large due to small sample sizes. Column (7) shows how the probability of litigation varies with the terms of the licensing commitment. For patents under a Free licensing commitment,

[42] Poisson coefficients can be translated into a percentage change by exponentiating and subtracting one, i.e. $e^{0.55} - 1 = 0.73$.

there is no difference in the probability of litigation between the dSEPs and matched control patents. However, the FRAND patents have a 5.1 percentage point increase in litigation probability (roughly 300% compared to the baseline litigation rate for the controls), and the patents with no licensing commitment are 9.6 percentage points more likely to be litigated than their associated control patents.

The fact that royalty free patents are less likely to be litigated may not be surprising: there is little incentive to sue if a patent can be freely infringed (though defensive suspension provisions and applications of the patented technology outside of the scope of the standard may explain why these patents are still litigated in some cases).[43] However, the larger citation increase for royalty free dSEPs suggests a greater willingness to "build on" royalty free technology (as long as one is prepared to accept that relatively common interpretation of patent citations). These results also suggest that FRAND offers some additional degree of certainty relative to patents where no licensing commitment was provided.

Columns (4) and (8) in Table 7 examine differences across the "SSO Groups" defined in Table 3 and discussed above. Column (4) shows that dSEPs receive more citations than their matched controls at every SSO, though the magnitude of the difference varies considerably. The citation gap between declared essential and "average" patents is greatest for the "Other" group containing Open Mobile Alliance, TIA and ATIS, and also at the IETF. The citations gap is notably smaller for ETSI, ANSI, and the Big-I international organizations. This variation in the citation gap may reflect differences in either the selectivity or the "treatment effect" of different SSOs, or more likely a combination of both effects. However, the use of control patents, along with the technology-class and issue-year fixed effects, should capture any broad differences in citing patterns across technologies and time (i.e. the part of the selection effect that is linked to these observables).

Column (8) examines heterogeneity in litigation rates between dSEPs and control patents. Once again, we see considerable variation across SSOs. The difference in litigation probabilities between Control and SSO Patents is largest at ANSI, where there is a 12.9 percentage point increase in

[43] Note that even though a patent may be offered royalty-free when implemented in the context of a specific standard, the owner my ask monetary compensation for that same patent if used in a different context. If that latter scenario results in litigation, it would be recorded in our database.

litigation. The gap is smaller at IETF, where one third of the commitments are royalty-free, and at ETSI, where a mandatory specific disclosure may lead to weaker patents and a lower rate of *ex post* technical essentiality.

While one might have expected the estimated citations and litigation coefficients to co-vary positively across SSOs, Table 7 does not show any obvious relationship. For example, ANSI has the largest litigation gap and the second-lowest gap in citations, while the patents declared to IETF are cited at a very high rate relative to their controls, and have one of the smaller litigation gaps. This may say something about the relative efficacy of alternative disclosure policies. However, we remain cautious about placing a causal interpretation on any of these comparisons. In particular, all of the measured "effects" could be explained by unobserved differences in technology or the types of firm participating in different SSOs. Moreover, we have no way of knowing the citation or litigation rates for patents declared under a blanket disclosure.

5 Disclosure Effects

Up to this point, we have emphasized that disclosure timing is not tightly linked to the adoption of a standard. Some patents are disclosed long after a standard has emerged, and in other cases, SSO participants may be aware that sponsors of a proposal own related IP well before a formal declaration is made. Nevertheless, most of the SSOs in our data encourage early disclosure, and the "patent ambush" cases against Dell and Rambus discussed above provide incentives for timely disclosure. If one is willing to assume that disclosure is a reasonable proxy for the timing of standards development (at least over a fairly long time-series), then we can use panel data to further explore the idea that standardization has a causal impact on the long-term outcomes of declared essential patents. This section provides evidence of a "Disclosure Effect" on citations and litigation using difference-in-differences regressions.

5.1 Citation Effects

To explore the relationship between disclosure and citations, we created a panel data set that contains one observation per year for each dSEP and Control patent with an age between -5 and

20 (where age is defined as calendar-year minus issue-year). Our outcome variable is a count of references from all issued patent applications filed in year t to each dSEP or control patent i.

Figure 4 graphs the average annual citation rate by age for dSEP and random match control patents in the raw data. The first panel in this figure shows that dSEPs receive roughly 20% more citations than control patents by the time they issue. This gap widens for about 10 years, as the dSEPs' average annual citation rate climbs from 5 to 6, and the control patent rate stays constant at about 4. The second panel in Figure 4 provides a separate annual citation rate for each SSO, and shows that much of the "bump" in the first panel is linked to two groups: IETF, and the "telecom" group consisting of ATIS, TIA and OMA.

Overall, these graphs suggest that there is *both* a substantial selection effect, whereby dSEPs receive a higher baseline citation rate prior to standardization, and a smaller standardization effect (perhaps concentrated in particular SSOs) whereby citations increase after a patent is declared essential. To further explore the standardization effect, we created an additional set of *citation matched* control patents that have the same average level and trend in forward citations as the dSEPs. We constructed the citation matched controls by drawing a single patent from the same technology class as each dSEP and having the same number of cumulative cites k years before disclosure (where $k = 2, 4, 6 \ldots$ depending on the age of the dSEP at disclosure). Because these patents are constructed to have the same pre-disclosure citation trends, it is more plausible to assume that the citation matched controls provide a valid estimate of the counterfactual post-Disclosure outcomes for the declared essential patents.

Figure 5 plots the coefficients and standards errors from a pair of event study regressions using the dSEPs and their citation matched controls. The underlying regression specification is

$$Cites_{it} = DeclaredEssential_i \beta_k + \alpha_i + \gamma_{ay} + \varepsilon_{it} \tag{4}$$

where $DeclaredEssential_i$ is an indicator for a dSEP; α_i is a patent-level fixed effect; and γ_{ay} is a full set of age-by-year effects that should absorb both secular trends in the overall citation rate and the underlying shape of the citation-age distribution. We plot the coefficients β_k, where k indexes years-to-disclosure (i.e. calendar year minus the year when a patent is declared essential), normalizing $\beta_{-2} = 0$. We chose this normalization because both the data and our discussions with standards practitioners suggest that committee members obtain information about potentially essential patents during the year before disclosure, although normalizing $\beta_{-1} = 0$ produces similar results.

The first panel in Figure 5 is based on the complete sample of dSEPs and citation matched controls, using a regression that omits the patent fixed effects (α_i). There are three important features of this graph. First, even without providing a patent-specific intercept, it is apparent that our citation-matching procedure produces a good match in the pre-disclosure levels and trends of citations between the dSEPs and the control group. In particular, none of the β_k for $k < -2$ is statistically significantly different from zero. Second, we see a sharp increase in cites starting the year before formal disclosure. And third, following disclosure we observe a long-term persistent difference in the citation rate of the dSEPs and citation-matched controls. That is, the coefficients β_k are all statistically different from zero for $k = -1$ to 10. We interpret this pattern as indicating that the standardization process has a causal impact on the economic and technical importance of declared essential patents.

The second panel in Figure 5 changes the regression specification by adding patent fixed-effects, and more importantly drops the patents declared essential at ETSI and their associated controls.[44] We have plotted the two figures on the same scale to show that dropping ETSI from the estimation sample roughly doubles the size of the "disclosure bump" that is apparent around the time of standardization, and leads to a long-term impact that is substantially higher, at just over half a citation per year.

Table 8 illustrates similar results to Figure 5, only using a more parsimonious regression model, building on the approach developed in Rysman and Simcoe (2008). Our specification is

$$Cites_{it} = PostDisclosure_{it}\beta_j + SSO_i\alpha + \gamma_{ay} + \varepsilon_{it} \tag{5}$$

where $PostDisclosure_{it}$ is an indicator for a patent that has been declared essential to an SSO.

[44] Recall that ETSI has a mandatory specific disclosure policy that our theory suggests will lead to disclosure of patents that are less likely to be *ex post* technically essential than at SSOs permitting blankets.

Columns (1) and (2) show how pre-disclosure citation-matching helps address the strong selection issue in these data. If we use the randomly matched control sample, the regression suggests a very strong selection effect of 1.3 citations per year (on a baseline of 2.3 cites per year), but no post-disclosure increase in citations. However, when we switch to the citation matched controls, there is no pre-disclosure difference in cites by construction, and we estimate a 12 percent increase in citations following disclosure to the SSO. In column (3) we add patent fixed effects, and the estimated disclosure effect falls to 0.17 citations per year (around 5 percent).[45] However, dropping ETSI from the estimation sample in column (4) leads to a four-fold increase in the estimated disclosure effect.

The results in Table 8 are broadly consistent with the findings in Rysman and Simcoe (2008), and indicate that SSOs produce both a strong selection effect, by choosing patented technologies that are *ex ante* more valuable, as well as a disclosure effect by encouraging coordinated adoption of those technologies. The two contributions we make relative to that study are the construction of a citation-matched control sample, and the observation that the disclosure effect is dramatically reduced by including ETSI in the estimation sample. We argue that ETSI's mandatory specific disclosure policy is driving this heterogeneity. If this argument is correct, it may be appropriate to view even the result in column (4) as a lower bound on the true disclosure effect, given that all of our SSOs include a share of disclosed patents that are not truly essential.

Our novel data on multiple SSOs and licensing terms also allow us to explore heterogeneous disclosure effects by letting β_j in equation (5) vary with the SSO or the terms of the licensing commitment. Table 9 illustrates the results of this approach. In columns (1) and (2) we can see that the citation effects of disclosure are concentrated among dSEPs, with no statistically significant impact for undeclared family members of the dSEPs. This suggests either a selection effect, whereby the disclosed patents are more important, or that the visibility afforded by disclosure matters for attracting citations.

Columns (3) and (4) in Table 9 examine heterogeneity across different types of licensing com-

[45] Chabé-Ferret (2016) shows that it is not obvious *a priori* whether we should prefer the specification in column (2) or (3). Because the latter specification includes two high-dimensional vectors of unobserved effects, for both patents (α_i), and age-years (γ_{ay}), we estimate (5) via OLS using a Stata package and estimator described in Guimaraes and Portugal (2010).

mitment. Not surprisingly, we find results similar to Table 8 for the FRAND patents that comprise 90% of the estimation sample. Estimates for the FREE, Specific and No Commitment groups are all positive but imprecisely estimated. Table C-5 reports estimates from the same set of regressions using Self Citations (i.e. cites from patents owned by the same firm) as the outcome variable. There, we find the largest effect for patents disclosed under a Royalty Free licensing commitment. While the terms of the commitment are clearly endogenously selected by the patent holder, one interesting interpretation of this finding is that companies may be more likely to offer free commitments when they also hold a number of proprietary complements (i.e. the citing patents).

Finally, in Column (5) we allow the disclosure effect to vary by SSO. The most notable finding here is the *negative* disclosure effect for patents declared essential to ETSI. It is also interesting that the disclosure effect at IETF is not statistically significant, even though Figure 4 suggest that patents disclosed to IETF are among the most highly cited. This finding that the two SSOs with specific disclosure rules have the smallest disclosure effect on citation rates is broadly consistent with our theoretical model, as discussed above. Setting aside ETSI and IETF, we find larger effects at ANSI and the mobile consortia (ATIS, TIA, OMA), a somewhat smaller and less precisely estimated effects at the Big-I organizations and IEEE.

Overall, if one is willing to maintain the assumptions that citations reflect value and that disclosure is a reasonable proxy for essentiality, these results suggest that SSOs are *both* selecting high quality patents and contributing to their long-term importance. In the next sub-section, we will see that SSOs are performing less well at the related task of mitigating conflict over declared essential IP.

5.2 Litigation Effects

Our final set of analyses will examine the relationship between disclosure and litigation. The data consist of a patent-year panel that retains all never-litigated patents, and all litigated patents only up to the year of their first lawsuit. Dropping patent-year observations that post-date the initial suit for a given patent simplifies the setup of our hazard models, and allows us to ignore the complexities that emerge when considering how outcomes of one suit impact future litigation propensity for the same patent.

Figure 6 shows the 20-year cumulative hazard of litigation for declared essential and the citation-matched control patents. The dramatic divergence over time illustrates the same gap in litigation probabilities that we saw with the cross-sectional results in Section 4. However, where the cross-sectional models report a difference in litigation rates averaged over patents at different ages, this Figure shows that the difference in the propensity to litigate dSEPs versus controls grows larger over time. By age 20, the cumulative difference in litigation probabilities is considerably larger than the 5 to 7 percentage point difference reported in Section 4, reflecting the fact that litigation probabilities increase over time for declared essential patents, and that we have more "young" patents in the entire sample.

We now examine the relationship between disclosure-timing and litigation. A patent that is litigated prior to its disclosure suggests that patent characteristics are causing selection into the dSEP group, whereas an increase in litigation following disclosure is more consistent with the idea that SSOs help boost patent value, and therefore the probability of assertion and subsequent disputes.

To measure the link between disclosure and litigation, we estimate linear probability models that include a complete set of patent-age and calendar-year effects to control for the baseline hazard and any time-trends in the overall patent litigation environment. The basic specification is:

$$Litigation_{it} = PostDisclosure_{it}\beta_j + \gamma_a + \lambda_y + X_{it}\theta + \varepsilon_{it} \quad (6)$$

where $Litigation_{it}$ equals 100 in any year where a patent is first litigated, so coefficients represent a percentage-point increase in the hazard rate. The parameters γ_a measure age effects (or equivalently the baseline hazard), starting in the grant-year when a patent is first eligible for assertion. The parameters λ_y are calendar year effects, and the vector of controls X_{it} includes Claims, Patent References and Non-Patent References (which are all fixed at patent grant), as well as lagged citations and a dummy for Reassignment, which indicates a change in patent ownership. Table 10 presents our initial results.

We begin by focusing on the full sample of dSEPs, omitting all controls. The coefficient in column (1) shows that the probability of first-lawsuit for a dSEP increases by 0.33 percentage points following disclosure, controlling for age, and calendar-year time trends. In column (2) we add time-invariant controls and find little change in the estimated impact of disclosure on litigation. Column (3) adds time-varying controls for lagged cites and reassignment. Although these controls may introduce an endogeneity problem if disclosure influences citations and reassignment, the coefficient on $PostDisclosure_{it}$ does not change. The very large coefficient on reassignment is of independent interest, because it indicates a 1.2 percentage point increase in the annual litigation rate following a change in ownership. This might be either a selection effect, whereby more important patents are bought and sold, or evidence that the market for dSEPs is leading to increased litigation.

Columns (4) and (5) in Table 10 re-introduce the citation-matched control sample, and use a difference-in-differences specification to examine the litigation rate of dSEPs before and after disclosure relative to the controls. In column (4) we see that dSEPs are 0.24 percentage points more likely to be litigated than the controls *before* disclosure, and that this rate increases by 0.21 percentage points following disclosure. Column (5) shows that the correlation between reassignment and litigation is stronger for dSEPs than citation-matched controls, and increases substantially following disclosure. Overall, the results in Table 10 provide further evidence that SSO's are *both* selecting patents that have a high propensity for assertion, and influencing the likelihood of a lawsuit.

Our final set of empirical results examines the role of licensing commitments in potentially mitigating the effect of disclosure on litigation, and they are presented in Table 11. Columns (1) through (3) focus on the full sample of dSEPs, with no additional controls. In column (1), we see that the marginal impact of disclosure on litigation is larger for firms that focus on licensing, as opposed to downstream implementation, and is particularly large for the the small firms that are difficult to classify. The second column presents some evidence in-line with priors regarding the role of licensing commitments. For patents disclosed under a royalty-free licensing commitment, there is no change in litigation rates. Indeed, the point estimate is negative. Patents disclosed under FRAND terms see a 0.24 percentage point increase in the litigation hazard. This is similar to the estimate for patents disclosed with specific licensing terms and conditions, although the small sample of specific patents leads to imprecise estimates. The most interesting result in column (2) is the large coefficient for patents that are disclosed with no licensing commitment. These patents experience a 1 percentage point increase in the annual probability of litigation.

Column (3) examines heterogeneity in the link between disclosure and litigation across SSO groups. We find a large statistically significant correlation for ANSI, the Big-I organizations, and IEEE. There is no evidence of a correlation between disclosure and litigation for ETSI and IETF. The latter result is interesting because it suggests at least two different intervening mechanisms. At ETSI, the absence of a relationship may be due to the specific disclosure policy encouraging many "false positives" (i.e. disclosure of marginal patents), and efforts targeted at designing around. The IETF, on the other hand, has a strong culture of favoring standards that are not IP-encumbered, as evidenced by its large share of royalty-free licensing commitments.

Columns (4) through (6) in Table 11 add the citation matched control sample, and include a dummy for patents in the dSEP sample. As above, we continue to see a 0.2 percentage point selection effect, indicating that dSEPs are more likely to be litigated than citation-matched controls prior to disclosure. The general pattern of results for business model, licensing commitments and SSO-level heterogeneity is otherwise similar to the results in columns (1) through (3).

The general finding that disclosure is correlated with litigation naturally raises the question of whether this is evidence of actual or attempted patent holdup. If one is willing to assume that disclosure is a reasonable proxy for the timing of standardization, an increase in litigation rates is certainly consistent with the idea that declared essential patent holders are *trying* to capture some of the value created by widespread implementation of a standard. However, we cannot observe whether plaintiffs are seeking royalties that exceed the *ex ante* value of the patented technology, or whether the settlements and remedies that emerge from these cases systematically exceed the appropriate benchmark. Moreover, the large selection effects that we find in our cross-sectional and difference-in-differences models suggest that many dSEPs would have a relatively high litigation rate even if they were not incorporated into a standard, and we cannot disprove the claim that time-varying unobserved factors may be driving both disclosures and litigation. Nevertheless, if one considers SSO intellectual property policies through a contractual lens, our belief is that both the high overall dispute rate and the positive correlation between disclosure and litigation tend to undermine any presumption that these contracts are "optimally incomplete" as some observers have suggested (e.g., Tsai and Wright, 2015).

6 Conclusion

SSOs adopt IP disclosure and licensing policies to promote widespread diffusion of standards that may incorporate intellectual property rights. In the first part of our paper, we provide an overview of disclosure policies, develop a formal model of the disclosure process, describe a novel database containing information on declared essential patents, and illustrate some of the ways that these data can be used. The number of IP declarations in our sample of 13 major SSOs has been steadily increasing for the last two decades, perhaps reflecting the increasing importance of standards and open technology platforms to the ICT sector: In our data, the 6,723 declared essential US patents score much higher than a set of "average" patents with similar age and technology profiles on a variety of indicators of patent value and technical significance. We also show that the difference between declared essential patents and their matched controls varies across SSOs, licensing commitments and disclosure timing.

In the second part of our paper, using a set of control patents that is matched to the dSEPs based on their pre-disclosure citation patterns, we find evidence that disclosure and incorporation into a standard increase both citations rates and the probability that a patent is asserted in litigation in US courts. Exploring heterogeneity in these results uncovers a number of novel patterns. The citation and litigation effects are smaller for two SSOs – ETSI and the IETF – and we argue that this reflects the significant differences in their policies captured by our formal model. ETSI has a mandatory specific disclosure policy that leads to specific disclosure of more patents that individually have a lower probability of remaining technically essential. This leads to smaller estimated disclosure effects. At the IETF, we see earlier disclosures, and a much higher number of royalty-free licensing commitments, and argue that this reflects a culture of encouraging *ex ante* competition among alternative technologies during the standardization process, leading to fewer cites when a disclosed patent is circumvented, and lower litigation rates when it is available for free.

The data also allow us to describe how changes in citation and litigation rates vary with the terms of licensing commitments. Consistent with the prior theoretical literature on the topic, after disclosure, litigation increases more for patents disclosed under FRAND terms than royalty free terms, and more for patents that have no licensing commitment than for FRAND encumbered IP. Interestingly, we see a large increase in self-citation to patents declared under royalty-free terms, and future research might explore the idea that this reflects a strategic decision to offer essential IP for free when a firm owns a large stock of proprietary complements.

Our findings suggest several novel hypotheses and avenues for future research. First, we document a substantial increase in dSEPs in recent years. Future research might examine the relative contribution of various factors to this recent growth pattern. A second stylized fact that clearly emerges from our analysis is the key role played by dSEPs in these industries. Consistent with Rysman and Simcoe (2008), compared to an average patent with similar observable characteristics, these patents score considerably higher on a range of metrics that are correlated with value or importance. A key question for evaluating the relative role of different institutional rules in supporting standardization, and the potential for patent hold-up is whether these differences were caused by inclusion in a standard, or reflect a selection effect whereby SSOs and firms identify technologies that were already on their way to prominence (e.g. patents with a high technical merit). By introducing data on licensing terms and improving on the matching methods used in prior studies, our paper is a first step in this direction: Subtle differences in the polices different SSOs rely on to elicit contributions and support collaboration can have a large influence on the types of patents that are ultimately disclosed, on the terms they are disclosed at, and on key economic outcomes.

Our hope is that by making our data public we will encourage researchers in this space to further explore questions related to the economics of standard setting and intellectual property strategy.

References

ANSI (2006): "ANSI Essential Requirements: Due process requirements for American National Standards," http://www.ansi.org (accessed January 2009).

Baron, J., T. Pohlmann, and K. Blind (2016): "Essential Patents and Standard Dynamics," *Research Policy*, 45(9), 1762–1773.

Bekkers, R., R. Bongard, and A. Nuvolari (2011): "An empirical study on the determinants of essential patent claims in compatibility standards," *Research Policy*, 40(7), 1001–1015.

Bekkers, R., and A. Updegrove (2012): *A study of IPR policies and practices of a representative group of Standards Setting Organizations worldwide*. National Academies of Science, Washington, D.C.

Biddle, B. (2015): "Five Reasons Why Patent Disclosure in Standards-Setting Organizatiaons Doesn't Work (and What To Do Instead)," *Working Paper*, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2669893.

Chabé-Ferret, S. (2016): "Bias of Causal Effect Estimators Using Pre-Policy Outcomes," *Working Paper*.

Condorcet, M. (1785): *Essai sur l'application de l'analyse à la probabilité des décisions rendues à la pluralité des voix*. Imprimerie Royale.

Contreras, J. (2016): "A Tale of Two Layers: Patents, Standardization, and the Internet," *Denver University Law Review*, 93(4).

Dranove, D., and G. Jin (2010): "Quality Disclosure and Certification: Theory and Practice," *Journal of Economic Literature*, 48(4), 935–963.

Farrell, J., J. Hayes, C. Shapiro, and T. Sullivan (2007): "Standard Setting, Patents and Hold-Up," *Antitrust Law Journal*, 74, 603–670.

Fung, A., M. Graham, and D. Weil (2007): *Full Disclosure*. Cambridge University Press.

Goodman, D., and R. Myers (2005): "3G Cellular Standards and Patents," in *2005 International Conference on Wireless Networks, Communications and Mobile Computing*, ed. by IEEE, pp. 415–420.

Guimaraes, P., and P. Portugal (2010): "A Simple Feasible Alternative Procedure to Estimate Models with High-Dimensional Fixed Effects," *Stata Journal*, 10(4), 628–649.

Kang, B., and R. Bekkers (2015): "Just-in-time patents and the development of standards," *Research Policy*, 44(10), 1948–1961.

Kuhn, J. M., B. N. Roin, and N. C. Thompson (2016): "Causal Inference on Patent Protection," *Working Paper*.

Layne-Farrar, A. (2014): "Assessing IPR Disclosure Within Standard Setting: An ICT Case Study," in *Modern Trends Surrounding Information Technology Standards and Standardization Within Organizations*, ed. by K. Jacobs. IGI Global.

Lemley, M. (2002): "Intellectual Property Rights and Standard Setting Organizations," *California Law Review*, 90, 1889–1981.

Lerner, J., H. Tabakovic, and J. Tirole (2016): "Patent Disclosures and Standard-Setting," *NBER Working Paper No. 22768*.

Lerner, J., and J. Tirole (2006): "A Model of Forum Shopping," *American Economic Review*, 96(4), 1091–1113.

——— (2015): "Standard-Essential Patents," *Journal of Political Economy*, 123(3), 547–586.

Li, G.-C., R. Lai, A. D'Amour, D. M. Doolin, Y. Sun, V. I. Torvik, Z. Y. Amy, and L. Fleming (2014): "Disambiguation and co-authorship networks of the US patent inventor database (1975–2010)," *Research Policy*, 43(6), 941–955.

Lim, D. (2014): "Standard Essential Patents, Trolls and the Smartphone Wars: Triangulating the End Gmae," *Penn State Law Review*, 119.

Marco, A. C., A. F. Myers, S. Graham, P. D'Agostino, and J. Kucab (2015): "The USPTO Patent Assignment Dataset: Descriptions, Lessons, and Insights," *Working Paper*.

Priest, G. L., and B. H. Klein (1984): "The Selection of Disputes for Litigation," *Journal of Legal Studies*, 13, 1–55.

Rysman, M., and T. Simcoe (2008): "Patents and the Performance of Voluntary Standard Setting Organizations," *Management Science*, 54(11), 1920–1934.

Simcoe, T. (2007): "Explaining the Increase in Intellectual Property Disclosure," in *Standards Edge: The Golden Mean*, ed. by B. Group, pp. 260–295.

Simcoe, T., S. Graham, and M. Feldman (2009): "Competing on Standards? Entrepreneurship, Intellectual Property and Platform Technologies," *Journal of Economics and Management Strategy*, 18, 775–816.

Swanson, D., and W. Baumol (2005): "Reasonable and Nondiscriminatory (RAND) Royalties, Standards Selection, and Control of Market Power," *Antitrust Law Journal*, 73(1), 1–58.

Tsai, J., and J. Wright (2015): "Standard Setting, Intellectual Property Rights, and the Role of Antitrust in Regulating Incomplete Contracts," *Antitrust Law Journal*, 80(1), 157–183.

Van Audenrode, M., J. Royer, R. Stitzing, and P. Saaskilahti (2017): "Over-Declaration of Standard Essential Patents and Determinants of Essentiality," *Working Paper*.

Tables and Figures

Table 1: SSO Intellectual Property Policies

SSO	*General patent disclosure statement ('blanket')*	*Allowed licensing commitments*	*Explicitly allowed licensing commitment options*	*Scope of the licensing commitment*
ANSI	Not specified (8)	RF; FRAND; non-assertion	Not specified	Not specified
ATIS	Allowed	RF; FRAND	- Reciprocity - RF-reciprocity (3)	A specified ATIS Forum, an ATIS Committee, an ATIS Document OR only the disclosed patents (at the choice of the declarant)
Broadband Forum	Allowed (although specific patent disclosure is 'desired')	Reciprocal RF Reciprocal FRAND		A BF Technical Report (TR) A BF Working Text (WT)
CEN	Allowed (5)	RF; FRAND	- Reciprocity - RF-reciprocity (3)	A CEN Deliverable
CENELEC	Allowed (5)	RF; FRAND	- Reciprocity - RF-reciprocity (3)	A CENELEC Deliverable
ETSI	Not allowed (though there is a general licensing statement since 2009) (4)	FRAND	- Reciprocity - For own contributions only (in case of general licensing statement.) (2)	Specific statement: Disclosed patents, with some exceptions. General licensing statement: A specified deliverable or a specified 'ETSI Project' or any 'ETSI Project'
IEC (1)	Allowed (5)	RF; FRAND	- Reciprocity - RC-reciprocity (3)	An IEC deliverable
IEEE	Allowed	RF; FRAND; non-assertion	- Licensing fees (ex-ante) - Sample of licensing contract	A specified IEEE 'Standard' or a IEEE 'Project' OR only the disclosed patents (at the choice of the declarant)
IETF	Not allowed (unless when accompanied by an RF commitment)	RF; FRAND; non-assertion	- Reciprocity - Any licensing information	The disclosed patents, or, in case of a RF blanket statement, a specific of any IETF contribution (7)
ISO (1)	Allowed (5)	RF; FRAND	- Reciprocity - RF-reciprocity (3)	An ISO Deliverable
ITU	Allowed (not allowed when unwilling to license)	RF; FRAND	- Reciprocity - RF-reciprocity (3)	An ITU Recommendation
OMA	Not allowed	Reciprocal FRAND		An (Draft) Technical Specification
TIA	Allowed	RF; FRAND	- Reciprocity	*With a general patent disclosure statement*: A 'Designated Document Number' or 'Designated Committee Documents' or 'All TIA Documents'. With a *specific patent disclosure statement*: only the disclosed patents (6) OR the same categories in the general statement (at the choice of the declarant)

(1) Includes JTC-1 activities. (2) For General IPR Licensing Declarations, ETSI allows the declarant to restrict its commitment only to IPRs contained in its own technical contributions. (3) These SSOs provide the option to make an explicit RF commitment, and the option to make a less restrictive FRAND commitment. (4) ETSI's general licensing statement (known as "GL") allows participants to commit to license any essential patents at FRAND terms, but does not indicate any belief that a participant actually owns essential patents, and does not replace the obligatory disclosure of specific patents. (5) If the patentee submits a refusal to license, a specific patent statement is "strongly desired" by ISO, IEC, CEN and CENELEC. (6) There is a requirement that the list of disclosed patents must include all essential patents for that standard. (7) There is an option to limit to standards-track IETF documents. (8) In the ANSI baseline policies, disclosures are not obligatory, but ANSI-accredited SSOs may include them in their procedures.

Table 2: Disclosure Model Predictions

	Competition	No Competition
Initial Submission ($t = 0$)	Blanket FRAND	
Ex Ante ($t = 1$)	Specific Free (weak patent, implementer) FRAND (strong patent, licensor)	FRAND Blanket (weak patent) Specific (strong patent)

Table 3: Disclosure Summary Statistics

SSO	Total Declarations	Percent Blanket	Mean Size	Unique IPR	Commitment Terms (Percent) FRAND	Free	Specific	None	Disclosure Lag (Years) App-Disc	Grant-Disc	SSO Group
ANSI	346	57	1.3	273	83	8	5	4	3.0	0.4	2
ATIS	99	66	5.1	217	84	8	1	7	3.4	-0.1	6
BBF	23	26	5.6	44	87	9	0	4	2.6	-1.8	2
CEN	5	0	4.2	5	100	0	0	0	5.3	1.2	2
CENELEC	11	73	0.4	4	100	0	0	0	5.3	3.0	2
ETSI	699	10	39.2	3,839	100	0	0	0	5.5	2.0	3
IEC	362	55	3.9	402	98	2	0	0	5.9	2.6	1
IEEE	716	46	2.6	712	95	2	1	2	4.2	1.0	4
IETF	821	57	2.7	694	57	37	0	6	3.5	-0.5	5
ISO	519	64	2.3	341	96	3	0	1	7.5	4.4	1
ITU	927	68	1.9	586	94	6	0	0	5.0	2.0	1
OMA	100	0	9.2	295	100	0	0	0	5.4	2.0	6
TIA	282	91	1.4	94	96	1	0	3	8.6	6.1	6
Total	4,910	52	7.8	6,723	89	9	1	2	5.0	1.6	

Blanket declarations list no specific IPR (defined as a US or EPO patent or patent application number). Mean Size is the average number of specific IPR per non-blanket disclosure. “Free” licensing commitments include both royalty-free pledges and non-assertion covenants. Disclosure lag measure elapsed time between application/grant and formal declaration. SSO Group defines a set of related SSOs whose disclosed IPR is pooled in later regressions.

Table 4: Business Model Categories

Business Model	Examples	Category	Claimants (Percent)	Declarations (Percent)	Patents (Percent)
Pure upstream R&D, patent holding	Dolby, DTS, InterDigital	U	2.7	3.0	9.8
Universities, public research institutes	Columbia Univ., Fraunhofer Inst.	U	2.6	2.8	0.5
Components (incl. semiconductors)	Qualcomm, Intel Harting	U	6.6	11.5	18.2
Individual Patent owner		U	0.7	0.3	0.1
Software and s/w-based services	Microsoft, Sun, Oracle	D	3.1	5.4	4.9
Product & equipment, suppliers, integrators	Ericsson, Nokia, Dell, HP	D	15.1	50.2	55.9
Service providers (telecom, radio, etc.)	Vodafone, BBC, Comcast	D	3.0	8.5	5.4
SSO, consortia, technology promoters	Konnex Assoc., ETSI	D	0.3	0.2	0.1
Instruments, testing and Measurement	Tektronix, Rhode & Schwarz	D	2.0	1.8	0.8
Too small or diverse to classify		O	63.8	16.3	4.4

Business model categories: U = Upstream; D = Downstream; O = Other/unclassified.

Table 5: Disclosure Models

Outcome Specification	Royalty Free (%) OLS		Blanket (%) OLS	
	(1)	(2)	(3)	(4)
Unclassified	-0.3 [1.2]	1.2 [1.1]	-0.8 [2.1]	-4.0 [2.1]
Upstream	-6.3 [1.0]**	-2.3 [0.9]**	7.6 [2.0]**	6.1 [1.8]**
BIG-I		-2.6 [1.5]		7.0 [2.9]*
ETSI		-6.7 [1.4]**		-46.1 [3.0]**
IEEE		-4.6 [1.5]**		-9.6 [3.2]**
IETF		30.0 [2.2]**		1.6 [3.2]
OTHTEL		-4.0 [1.5]**		10.9 [3.4]**
Disc. Year Effects	Yes	Yes	Yes	Yes
Observations	4,731	4,731	4,731	4,731
R-squared	0.02	0.21	0.01	0.14

Robust standard errors in brackets. *Significant at 5%; **significant at 1%. The omitted business model is "Downstream" and the omitted SSO is ANSI.

Table 6: dSEPs vs. Matched Control Patents

	Random Matches				Family Matches			
	Control	dSEP	T-stat	Norm Diff	Control	dSEP	T-stat	Norm Diff
Percent litigated	1.76	7.20	15.40	0.27	2.11	6.78	12.35	0.23
Forward citations	39.29	67.77	16.40	0.28	40.38	64.08	13.06	0.24
Reassigned Dummy	0.28	0.30	3.13	0.05	0.26	0.31	6.50	0.12
Family Size	4.47	13.09	33.98	0.59	8.76	10.72	6.35	0.12
Family Size (1 year)					7.34	7.50	0.74	0.01
Inventors (count)	2.44	2.76	10.93	0.19	2.53	2.76	7.06	0.13
Patent References	21.05	29.32	8.88	0.15	24.50	29.38	4.67	0.09
Non-patent References	4.63	9.30	11.80	0.20	6.06	9.28	7.04	0.13
Claims	22.70	23.23	1.68	0.03	22.64	23.00	1.09	0.02
Application year	1999	2000	0.57	0.01	2000	2000	0.27	0.00
Issue year	2003	2003	0.00	0.00	2003	2003	0.00	0.00
Observations	6,723	6,723			5,872	5,872		

Random Matches are a 1-1 match to dSEPs based on patent type (regular utility or reissue utility), grant year, 3-digit US primary technology class, and number of claims. Family Matches additionally match on the number of applications in the patent's DOCDB patent family within one year of its priority date. The normalized difference of sample means $\overline{X_1}$ and $\overline{X_2}$ is defined as $(\overline{X_1} - \overline{X_2})/[\frac{1}{2}(\sigma^2_{X_1} + \sigma^2_{X_2})]^{\frac{1}{2}}$.

Table 7: Cross Sectional Citation and Litigation Regressions

Outcome Specification	Forward Citations Poisson				Percent Litigated OLS			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SEP Family	0.13 [0.04]**				3.42 [0.52]**			
Declared SEP	0.55 [0.03]**				5.56 [0.43]**			
Upstream		0.60 [0.05]**				6.54 [0.66]**		
Unclassified		0.77 [0.08]**				15.60 [2.28]**		
Downstream		0.41 [0.03]**				3.59 [0.40]**		
Declared SEP * FRAND			0.47 [0.03]**				5.10 [0.38]**	
Declared SEP * Free			0.67 [0.09]**				-0.54 [0.67]	
Declared SEP * Terms			0.56 [0.14]**				6.89 [4.44]	
Declared SEP * None			0.47 [0.17]**				9.60 [3.05]**	
Declared SEP * ANSI				0.25 [0.11]*				12.06 [2.22]**
Declared SEP * Big-I				0.22 [0.10]*				6.39 [1.38]**
Declared SEP * ETSI				0.27 [0.10]**				3.83 [1.09]**
Declared SEP * IEEE				0.41 [0.10]**				7.46 [1.41]**
Declared SEP * IETF				0.61 [0.11]**				2.58 [1.28]*
Declared SEP * Other				0.93 [0.11]**				8.61 [1.76]**
Grant Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Patent Class Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,446	13,446	13,446	13,446	13,446	13,446	13,446	13,446
(Pseudo) R-squared	0.45	0.45	0.44	0.46	0.06	0.07	0.06	0.06

Robust standard errors in brackets. *Significant at 5%; **significant at 1%. Omitted business model category is "Downstream." Additional Controls are log of 1 plus the number claims, patent references and non-patent references.

Table 8: Citation Diff-in-Diffs

Outcome	Citations_{it}			
Specification	OLS			
Estimation Sample	Random Match	Cite Matched	Cite Matched	Drop ETSI
	(1)	(2)	(3)	(4)
PostDisclosure	-0.13	0.34	0.17	0.65
	[0.08]	[0.09]***	[0.06]**	[0.10]**
Declared Essential	1.33	0.07		
	[0.09]***	[0.10]		
Patent Fixed Effects	No	No	Yes	Yes
Age-Year Effects	Yes	Yes	Yes	Yes
$E[\text{Citations}_{it}]$	2.34	2.81	2.81	3.03
Observations	167,461	160,279	160,279	74,728
Patents	13,384	12,200	12,200	5,604
R-squared	0.08	0.06	0.60	0.60

Robust standard errors (clustered on patent) in brackets. *Significant at 5%; **significant at 1%.

Table 9: Citation Diff-in-Diffs: Heterogeneous Effects

Outcome			Citations_{it}		
Specification			OLS		
Estimation Sample	Cite Matched	Drop ETSI	Cite Matched	Drop ETSI	Cite Matched
	(1)	(2)	(3)	(4)	(5)
PostDisclosure * Family	-0.01	0.08			
	[0.09]	[0.19]			
PostDisclosure * dSEP	0.22	0.76			
	[0.07]**	[0.11]**			
PostDisclosure * FRAND			0.17	0.70	
			[0.06]**	[0.11]**	
PostDisclosure * FREE			0.20	0.20	
			[0.18]	[0.19]	
PostDisclosure * TERMS			0.58	0.68	
			[0.53]	[0.51]	
PostDisclosure * None			0.25	0.20	
			[0.66]	[0.67]	
PostDisclosure * ANSI					1.29
					[0.35]**
PostDisclosure * Big-I					0.55
					[0.13]**
PostDisclosure * ETSI					-0.25
					[0.07]**
PostDisclosure * IEEE					0.40
					[0.15]**
PostDisclosure * IETF					0.33
					[0.20]
PostDisclosure * Other					1.99
					[0.31]**
Patent Fixed Effects	Yes	Yes	Yes	Yes	Yes
Age-Year Effects	Yes	Yes	Yes	Yes	Yes
$E[\text{Citations}_{it}]$	2.81	3.03	2.81	3.03	2.81
Observations	160,279	74,728	160,279	74,728	160,279
Patents	12,200	5,604	12,200	5,604	12,200
R-squared	0.60	0.60	0.60	0.60	0.60

Robust standard errors (clustered on patent) in brackets. *Significant at 5%; **significant at 1%.

Table 10: Litigation Hazard Models

Outcome	Litigation Indicator				
Specification	Linear Probability (OLS)				
Estimation Sample	Declared SEP	Declared SEP	Declared SEP	Cite Matched	Cite Matched
	(1)	(2)	(3)	(4)	(5)
PostDisclosure	0.33 [0.10]**	0.30 [0.10]**	0.29 [0.10]**	0.23 [0.06]**	
Reassigned			1.23 [0.12]**		0.37 [0.07]**
Declared * Reassigned					0.80 [0.14]**
ln(Patent Refs)		0.08 [0.04]*	0.06 [0.04]		
ln(Non-patent Refs)		0.13 [0.04]**	0.13 [0.04]**		
ln(Claims)		0.32 [0.04]**	0.24 [0.04]**		
ln(Cites$_{t-1}$)			0.16 [0.03]**		
Declared Essential				0.22 [0.04]**	0.25 [0.03]**
Age Effects	Y	Y	Y	Y	Y
Year Effects	Y	Y	Y	Y	Y
Observations	70,732	70,732	70,732	156,757	156,757
Patents	6,691	6,691	6,691	12,196	12,196
Lawsuits	467	467	467	507	507

Robust standard errors (clustered on patent) in brackets. *Significant at 5%; **significant at 1%. Patents are dropped from the panel after first litigation event. Outcome equals 100 in litigation year, so coefficients are the average percentage point increase in patent-year probability of a lawsuit.

Table 11: Litigation Hazards: Heterogeneous Effects

Outcome	Litigation Indicator					
Specification	Linear Probability (OLS)					
Estimation Sample	Declared SEP	Declared SEP	Declared SEP	Cite Matched	Cite Matched	Cite Matched
	(1)	(2)	(3)	(4)	(5)	(6)
PostDisc * Upstream	0.36 [0.12]**			0.31 [0.09]**		
PostDisc * Unclassified	1.14 [0.27]**			1.09 [0.26]**		
PostDisc * Downstream	0.18 [0.10]			0.13 [0.06]*		
PostDisc * FRAND		0.29 [0.10]**			0.24 [0.06]**	
PostDisc * FREE		-0.22 [0.15]			-0.18 [0.13]	
PostDisc * Terms		0.43 [0.39]			0.47 [0.37]	
PostDisc * None		1.05 [0.44]*			0.59 [0.40]	
PostDisc * ANSI			0.72 [0.23]**			0.87 [0.23]**
PostDisc * Big-I			0.37 [0.14]**			0.46 [0.12]**
PostDisc * ETSI			0.13 [0.10]			0.08 [0.06]
PostDisc * IEEE			0.40 [0.14]**			0.31 [0.12]**
PostDisc * IETF			0.11 [0.15]			-0.00 [0.12]
PostDisc * Other			0.46 [0.19]*			0.32 [0.17]
Declared Essential				0.17 [0.04]**	0.17 [0.04]**	0.17 [0.04]**
log(Patent Refs)	0.07 [0.04]	0.08 [0.04]*	0.07 [0.04]	0.03 [0.02]	0.03 [0.02]	0.03 [0.02]
log(Non-patent Refs)	0.13 [0.04]**	0.13 [0.04]**	0.14 [0.04]**	0.05 [0.02]**	0.05 [0.02]**	0.06 [0.02]**
log(Claims)	0.32 [0.04]**	0.33 [0.04]**	0.32 [0.04]**	0.15 [0.02]**	0.15 [0.02]**	0.15 [0.02]**
Age Effects	Y	Y	Y	Y	Y	Y
Year Effects	Y	Y	Y	Y	Y	Y
Observations	70,732	70,732	70,732	156,715	156,715	156,715
Patents	6,691	6,691	6,691	12,194	12,194	12,194
Lawsuits	467	467	467	507	507	507

Robust standard errors (clustered on patent) in brackets. *Significant at 5%; **significant at 1%. Patents are dropped from the panel after first litigation event. Outcome equals 100 in litigation year, so coefficients are the average percentage point increase in patent-year probability of a lawsuit.

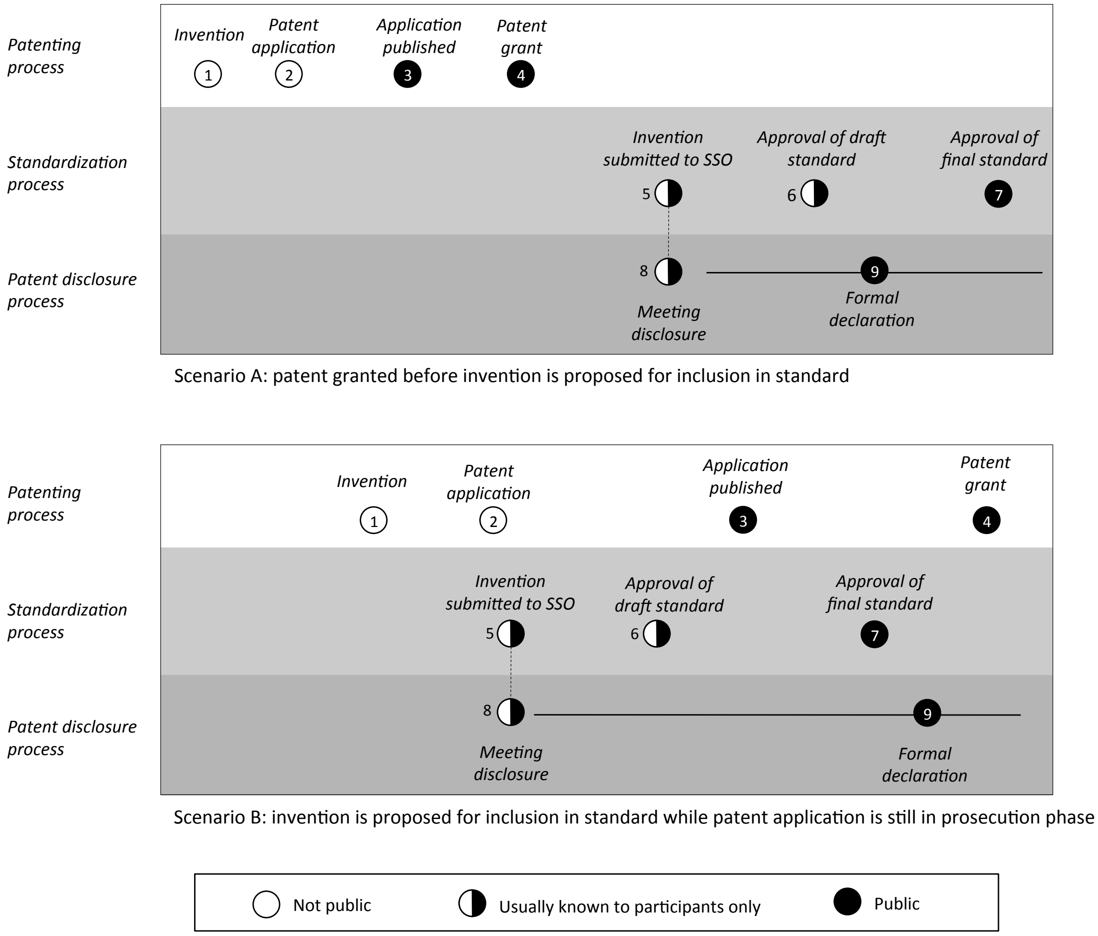

Figure 1: Two Disclosure Timing Scenarios

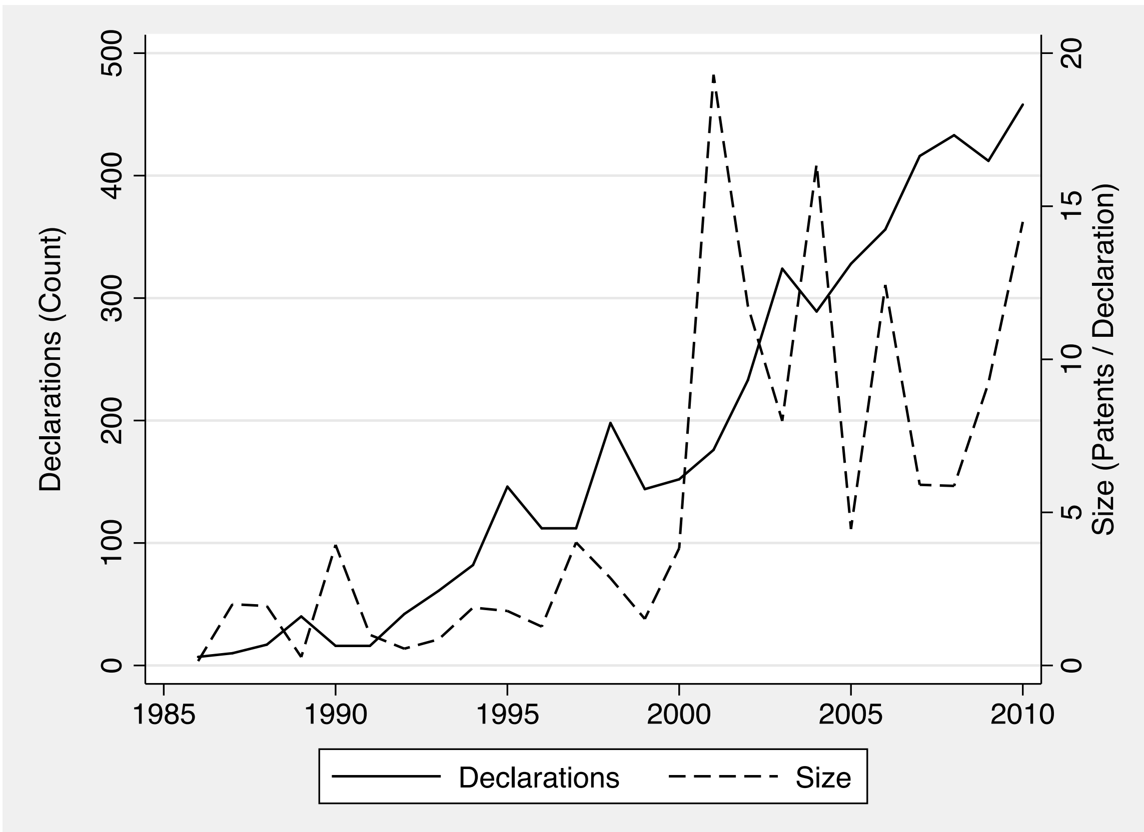

Figure 2: SSO IPR Disclosures: 1985 to 2010

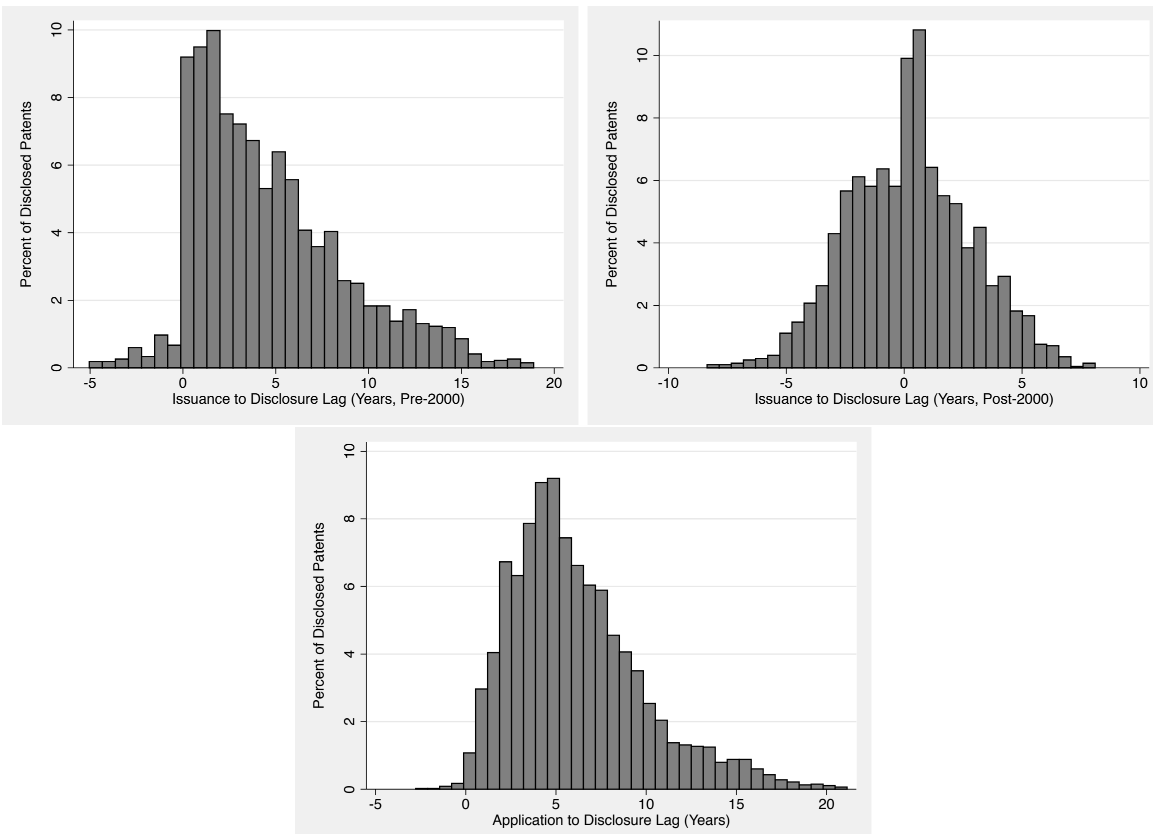

Figure 3: Disclosure Timing

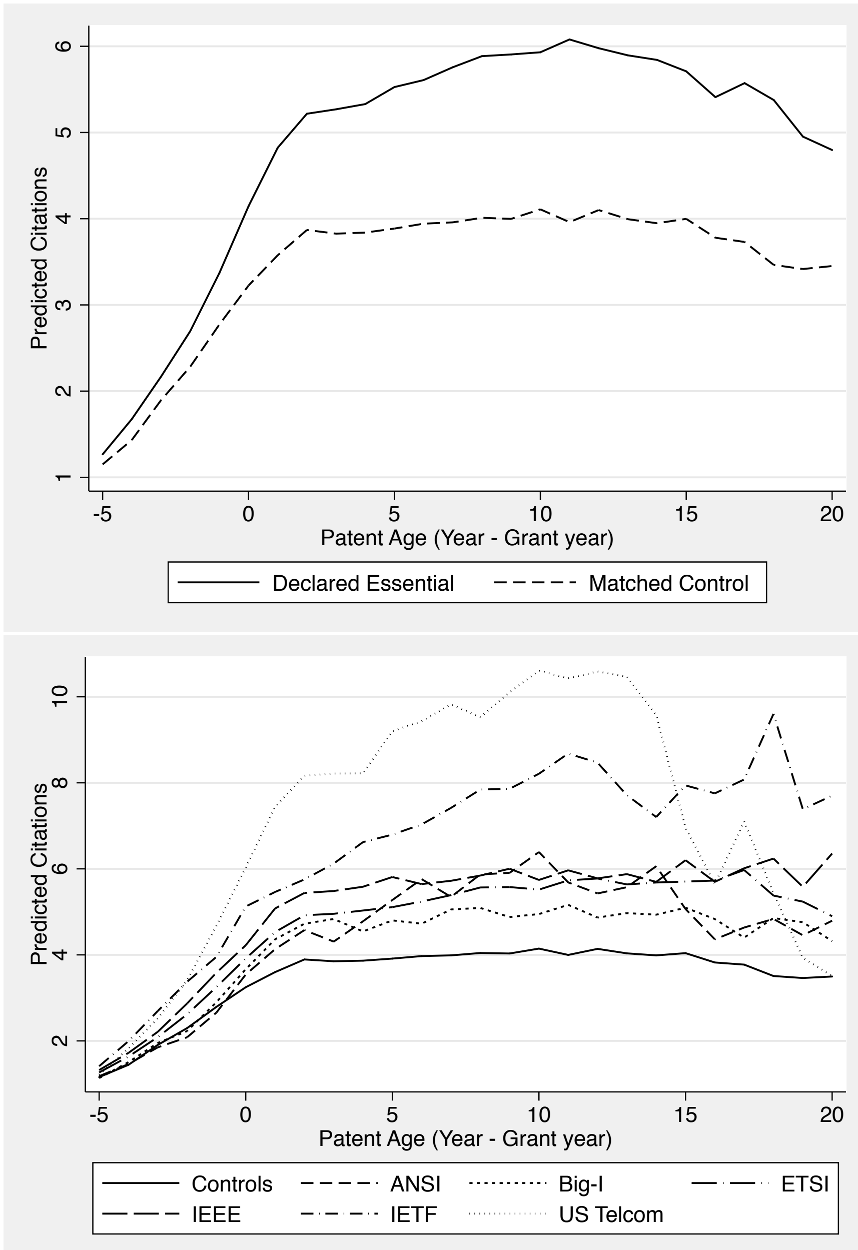

Figure 4: Citation Age Distribution (by SSO)

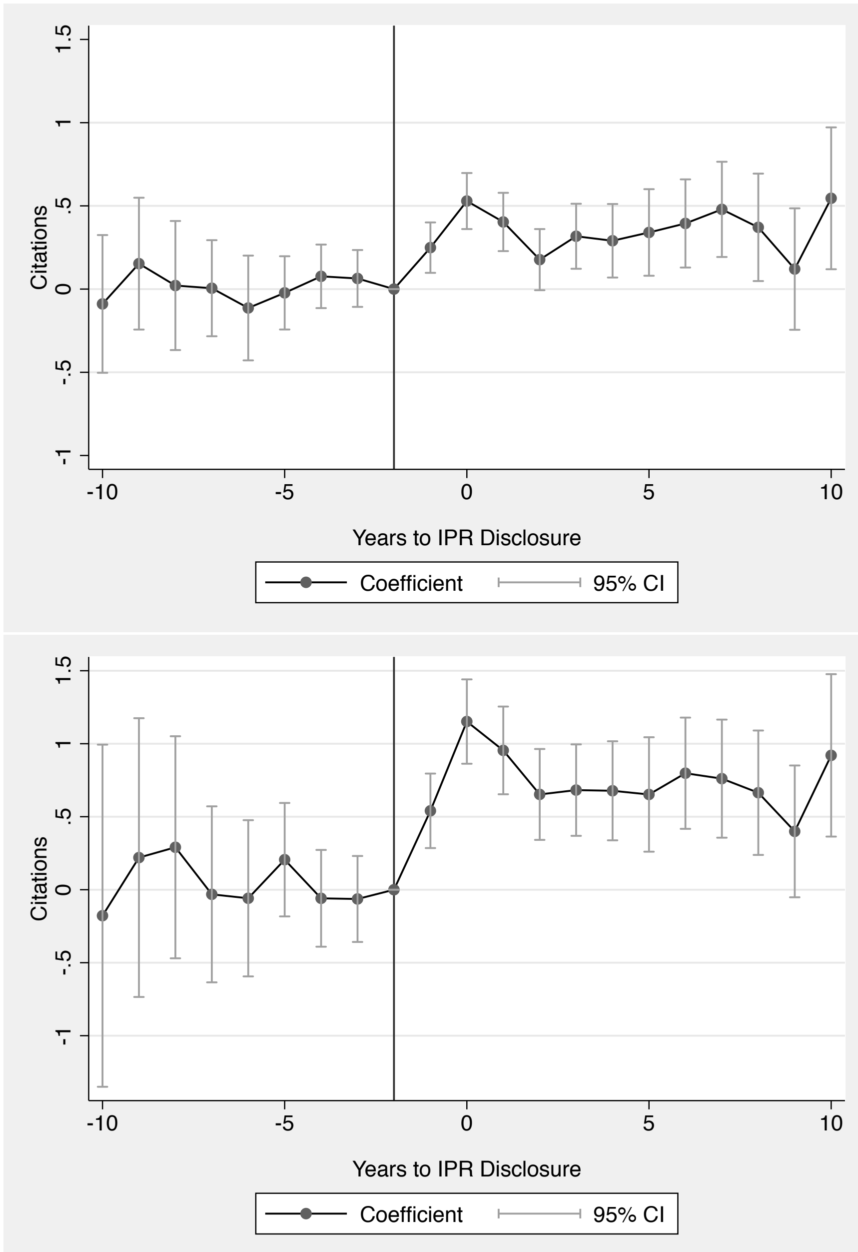

Figure 5: Disclosure Event Studies

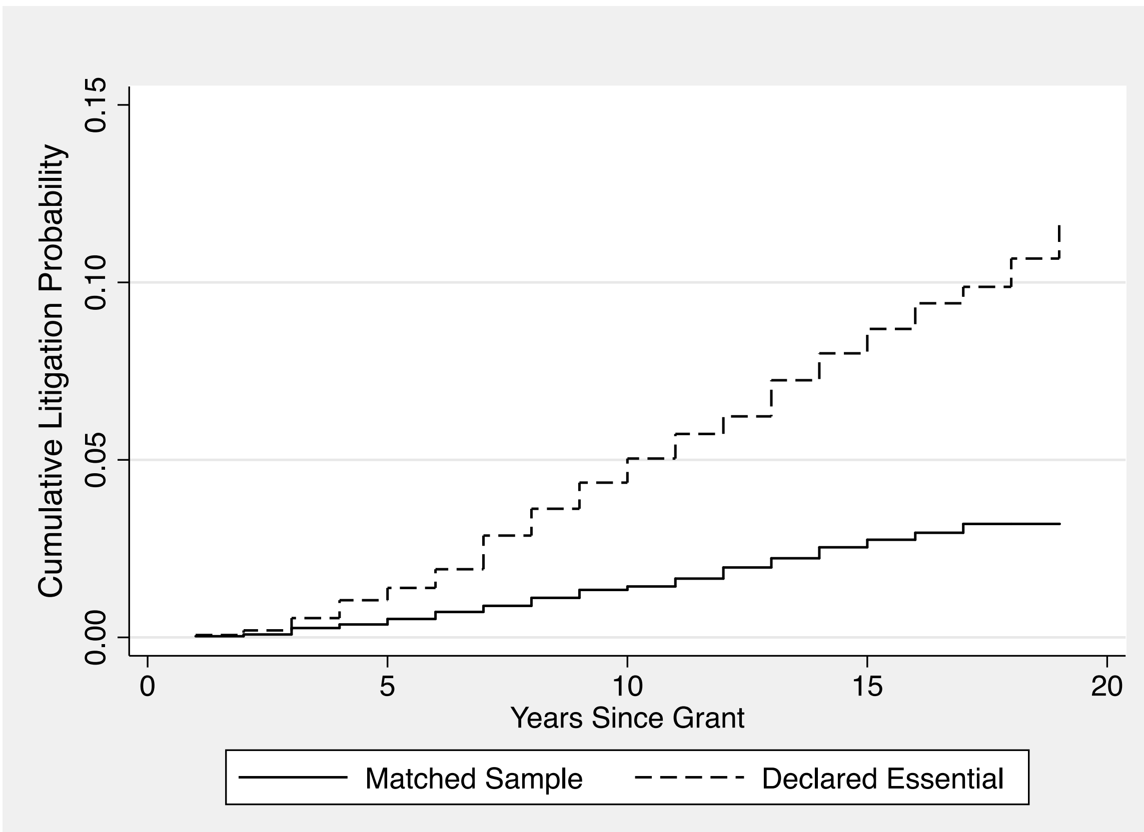

Figure 6: Cumulative Litigation Hazard for SSO and Cite-Matched Controls

Appendix A: The Declared Essential Patent (dSEP) Database

The data used in this paper were collected from the publicly available archives of thirteen major SSOs as of March 2011. The data were then cleaned, harmonized, and all disclosed USPTO or EPO patents or patent applications matched against patent identities in the PATSTAT database. The resulting data set is available for download, and anyone is free to use the data, provided that any resulting publication includes a citation to this paper.[46] The remainder of this appendix provides summary information and variable definitions for the dSEP database.

Overview

The dSEP database consists of a "Disclosures" table and a "Patents" table. The Disclosures table contains 45,349 records, where each record refers to a single patent, patent application or blanket disclosure statement made to a specific SSO on a specific date for a specific standard. The number of records in the dSEP Disclosure table is greater than the number of statements submitted to a single SSO by a single firm on a given date – what we call "declarations" in the paper – because each declaration may include multiple patents and/or blankets, referring to one or more standards.[47] The "Patent" table contains 6,900 records, where each record links a declared essential USPTO or EPO patent in our data set to the unique patent application identifier in the April 2014 release of the EPO's PATSTAT database.

[46] Although we took the greatest care in compiling the data, the authors cannot be held legally responsible for any error or inaccuracy.

[47] While some SSO archives are organized around disclosure events and other are not, our disclosure events are constructed from the data in a uniform way.

Table A-1: Variable Definitions for the dSEP Disclosures Table

Variable	Description
RECORD_IDENTIFIER	Unique ID for a firm-SSO-date-IPR, where an "IPR" may be a patent, patent application or blanket statement.
DISCLOSURE_EVENT	Unique ID for a firm-SSO-date. Disclosure events can refer more than one standard.
SSO	Name of Standard setting organization.
PATENT_OWNER (HARMONIZED)	Cleaned and harmonised name of disclosing organization (may differ from owner for third-party disclosures). Accounts for different spellings, but not changes in ownership.
PATENT_OWNER (UNHARMONIZED)	Name of the disclosing organization as it appears in the original disclosure.
DATEYR/MONTH/DAY	Year/Month/Day of that formal disclosure was submitted to SSO.
STANDARD	Name of the standard (if provided in the original disclosure).
COMMITTEE_PROJECT	Name of the committee for disclosed IPR (if provided).
TC/SC/WG_name	Name of Technical Committee, Standardization Committee or Working Group (if provided).
BLANKET_TYPE	Indicates scope of blanket disclosures: (0) No blanket, (1) Blanket for all SDO activities, (2) Blanket for a project, committee, subcommitee or technical committee, (3) Blanket for a specific standard or technical specification.
BLANKET_SCOPE	Name of the project, subproject, standard or technical specification that a blanket refers to (requires that BLANKET_TYPE have the value 2 or 3).
LICENSING_ COMMITMENT	Licensing commitment with respect to the disclosed patents
RECIPROCITY	Indicates that licensing commitment is offered conditional on licensee reciprocity (this condition may be automatically implied for some SSOs).
THIRD_PARTY	Indicates that disclosure was made by a third party.
COPYRIGHT	Indicates that disclosed IPR is a copyright instead of a patent.
PATENT_OFFICE	Patent office of the disclosed patent: US(PTO), EP(O), OR "OTHER"
FOR_OTHER_COUNTRIES	Name of Country when PATENT_OFFICE equals "OTHER"
SERIAL_CLEANED	Standardized serial number of US or EP patent application that was provided in the original disclosure (if any). To translate some serial numbers, we relied on http://www.uspto.gov/web/offices/ac/ido/oeip/taf/filingyr.htm
PUB_CLEANED	Standardized publication of US or EP patent that was provided in the original disclosure (if any).
TYPE	Type of patent information matched to PATSTAT: USPTO serial number, EPO serial number, USPTO publication number or EPO publication number.
MANUAL_REMOVAL	Indicates that publication or serial number was cleaned and formatted, but found to refer to a wrong patent in PATSTAT and thus removed.
PATSTAT_2014APRIL _APPLN_ID	Link to PATSTAT unique patent application ID (appln_id).

Table A-2: Variable Definitions for the dSEP Patents Table

Variable	Description
appln_id	Inique patent application ID (links to PATSTAT).
appln_auth	Patent office (US or EP).
appln_nr	Application number at the patent office.
appln_title	Title of the patent application
appln_filing_date	Application filing date.
appln_nr_epodoc	Harmonized number from PATSTAT that allows the application to be linked to other databases, such as the free EPO Espacenet web interface.
inpadoc_family_id	Unique ID for the INPADOC family of the disclosed patent application. INPADOC families group national and international patents sharing at least one priority document.
docdb_family_id	Unique ID for the DOCDB family of the disclosed patent application. DOCDB families group national and international patents having precisely the same set of priority documents.
associated publications	All publications associated with this patent application as present in PATSTAT. In general, the codes 'A', B1', 'B2' refer to granted patents, whereas 'A1', 'A2' refer to published patent applications. See the national patent office documentation for more details.

Appendix B: Mathematical Appendix

Derivation of Equation (1)

Given the Nash bargaining outcomes at $t = 2$, expected royalties under specific and blanket disclosure are:

$$E[r(v_1, v_2, e)|\text{Specific}] = (1-\sigma)[(1-\rho)\frac{v_1}{2} + \rho(\delta E[r(v_1, 0)] + (1-\delta)E[r(v_1, 1)])]$$
$$E[r(v_1, v_2, e)|\text{Blanket}] = (1-\sigma)(1-\gamma)[(1-\rho)\frac{v_1}{2} + \rho(\delta\theta E[r(v_1, 0)] + (1-\delta\theta)E[r(v_1, 1)])$$

Taking the difference and simplifying, we have that $E[r|\text{Specific}] > E[r|\text{Blanket}]$ if and only if

$$\gamma\left\{(1-\rho)\frac{v_1}{2} + \rho E[r(v_1, 1)]\right\} \geq \rho\delta(1-\theta(1-\gamma))E[r(v_1, 1) - r(v_1, 0)]$$

Specific Disclosure increases with v_1

Recall that v_2 has cumulative distribution $F(x)$. Using the Nash bargaining outcomes, we can write $E[r(v_1, 1)] = \frac{v_1}{2}F(v_1 + c) + \int_{v_1+c}^{\infty}(x-c)dF(x)$ and $E[r(v_1, 1) - r(v_1, 0)] = \int_c^{\infty}(x-c)dF(x)$. Plugging these expressions into (1) yields:

$$\gamma\left((1-\rho)\frac{v_1}{2} + \rho\left[v_1 F(v_1 + c) + \int_{v_1+c}^{\infty}(x-c)dF(x)\right]\right) > \rho\delta(1-\theta(1-\gamma))\int_c^{\infty}(x-c)dF(x) \quad \text{(A-1)}$$

Differentiating with respect to v_1 reveals that the left side of this inequality is increasing in v_1, while the right side is constant. Thus, so increasing v_1 leads to a greater probability of specific disclosure.

Derivation of Equation (2)

Recall that $\underline{G}$ and $\overline{G}$ are the probabilities that the SSO selects the firm's technology under a FRAND and royalty-free commitment respectively. The firm's expected profits are therefore:

$$E[\pi|\text{FRAND}] = \sigma\underline{G}(v_1 + b) + \sigma(1-\underline{G})v_2 + (1-\sigma)\underline{G}r(v_1, v_2, 0)$$
$$E[\pi|\text{Free}] = \sigma\overline{G}(v_1 + b) + \sigma(1-\overline{G})v_2$$

and taking the difference shows that $E[\pi|\text{Free}] > E[\pi|\text{FRAND}]$ if and only if $\sigma(\overline{G}-\underline{G})(v_1 - V_2 + b) > (1-\sigma)\underline{G}r(v_1, v_2, 0)$.

FRAND vs. Royalty-Free when $\varepsilon_1 = \varepsilon_2 = 0$

The SSO will always choose the substitute technology when $v_2 > v_1$, so the firm will offer a royalty-free commitment only if it has a superior technology, but the SSO would choose the substitute under FRAND. Because the firm cannot commit to a non-zero price cap at $t = 1$, the SSO selects the substitute technology whenever the firm makes a FRAND commitment and $v_2 > v_1 - r(v_1, v_2, 0)$. Recall that when the firm has a commercially essential patent, it can charge *ex post* royalties $r(v_1, v_2, 0) = \frac{1}{2}(v_1 - \max\{v_2 - c, 0\})$ before the SSO will switch.

In the case where, $v_2 < c$, so $r = \frac{v_1}{2}$, the firm will offer a royalty-free commitment if $\frac{v_1}{2} < v_2$. In the case where, $v_2 < c$, so $r = \frac{1}{2}(v_1 - v_2 + c)$, the firm will offer a royalty-free commitment if $v_1 - c < v_2$.

Note that in this complete information setting, the use of a royalty-free commitment is entirely driven by commitment and contracting problems. In particular, the firm would prefer to commit to some FRAND price $r^F \leq v_1 - v_2$ but cannot do so.

Existence of $\widehat{\sigma}(v_1, b)$

We mean to show that there is a critical value $\widehat{\sigma}(v_1, b)$ such that the probability of a FRAND commitment is increasing in c for all $\sigma < \widehat{\sigma}$ and decreasing in c for all $\sigma > \widehat{\sigma}$.

To begin, let M represent the cdf of $\varepsilon_2 - \varepsilon_1$, and note that $\underline{G} = M(v_1 - v_2 - r(c))$. Next note that only two terms in equation (2) depend upon $r(c)$. So, differentiating both sides of the inequality (and ignoring the case where $v_2 < c$, so there is no change in any term), we have $\frac{dr}{dc} = \frac{1}{2}$ on the left side, and $\frac{1}{2}\frac{\sigma}{1-\sigma}\frac{\overline{G}}{\underline{G}}\frac{m}{M}(v_1 - v_2 + b)$ on the right side. The critical value $\widehat{\sigma}(v_1, b)$ equates the two sides. When $\sigma > \widehat{\sigma}(v_1, b)$ increasing c leads a to a greater chance of royalty-free licensing, and conversely, when $\sigma < \widehat{\sigma}(v_1, b)$ increasing c leads the rim to favor FRAND.

Appendix C: Supplemental Tables and Figures

Table C-1: Disclosures by Firm

Company	Disclosures	Cum. Pct.
Nokia	283	5.76
Nortel Networks	235	10.55
Qualcomm	233	15.30
Cisco Systems	228	19.94
Ericsson	148	22.95
Motorola	122	25.44
Siemens	115	27.78
AT&T	101	29.84
Huawei Technologies	89	31.65
IBM	81	33.30
Alcatel	66	34.64
France Telecom	65	35.97
Microsoft	65	37.29
Philips	63	38.57
Alcatel Lucent	53	39.65
Total*	4,910	100.00

Disclosure is defined as a unique Company-Date-SSO combination. *The dSEP data contains disclosures from 926 unique companies.

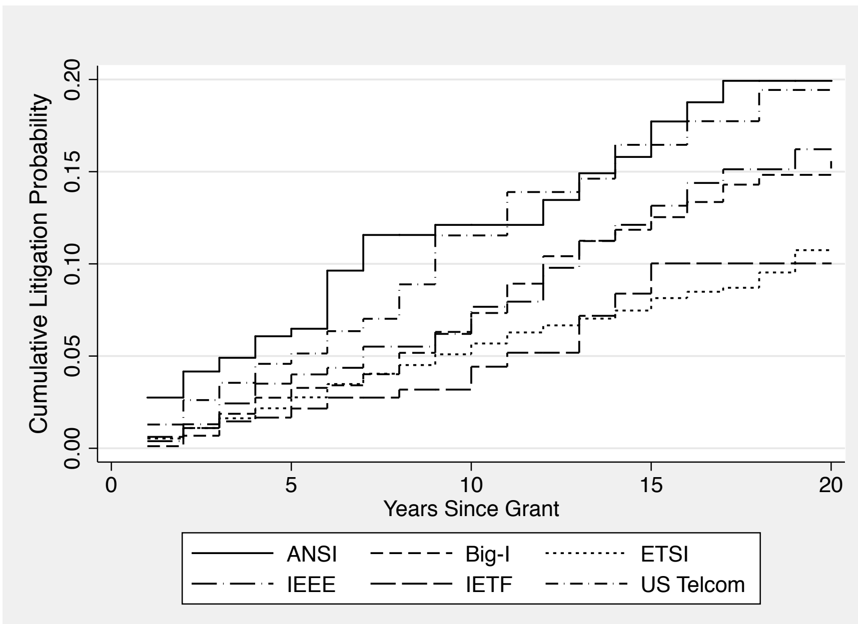

Figure C-1: Cumulative Litigation Hazard by SSO

Table C-2: Top 10 Firms by SSO Group

	ANSI		ISO/IEC/ITU	
1.	IBM	23	Nokia	70
2.	Nortel Networks	22	Siemens	52
3.	AT&T	19	Qualcomm	42
4.	Qualcomm	18	France Telecom	34
5.	Hewlett Packard	9	Nortel Networks	32
6.	Cisco Systems	9	Fujitsu	31
7.	Alcatel Lucent	9	Ericsson	29
8.	McDATA Corp	7	NTT	29
9.	Motorola	7	Philips	27
10.	Ericsson	6	Motorola	27
	Unique firms: 186	385	Unique firms: 487	1,808
	ETSI		IEEE	
1.	Nokia	70	Cisco Systems	38
2.	Qualcomm	54	Nortel Networks	35
3.	Siemens	43	Nokia	34
4.	Motorola	38	Motorola	18
5.	Nokia Siemens Networks	30	Broadcom	17
6.	Ericsson	25	IBM	15
7.	Alcatel	24	Philips	15
8.	Huawei Technologies	19	Qualcomm	14
9.	Samsung Electronics	19	AT&T	13
10.	Nortel Networks	18	Huawei Technologies	13
	Unique firms: 145	699	Unique firms: 248	716
	IETF		ATIS/TIA/OMA	
1.	Cisco Systems	147	Nortel Networks	87
2.	Nokia	71	Qualcomm	81
3.	Ericsson	53	Nokia	34
4.	Nortel Networks	41	Ericsson	25
5.	Huawei Technologies	33	Motorola	19
6.	Microsoft	31	AT&T	16
7.	Qualcomm	24	Siemens	8
8.	AT&T	21	NEC	8
9.	Certicom	19	Cisco Systems	7
10.	Alcatel Lucent	18	Philips	7
	Unique firms: 139	821	Unique firms: 119	481

Data from 1985 to 2011.

Table C-3: Disclosure Logit Marginal Effects

Outcome Specification	1[Royalty Free] Logit		1[Blanket] Logit	
	(1)	(2)	(3)	(4)
Unclassified	-0.002 [0.011]	0.015 [0.010]	-0.008 [0.021]	-0.042 [0.022]
Upstream	-0.051 [0.008]**	-0.021 [0.008]**	0.076 [0.020]**	0.072 [0.022]**
BIG-I		-0.021 [0.013]		0.071 [0.029]*
ETSI				-0.459 [0.029]**
IEEE		-0.038 [0.013]**		-0.097 [0.033]**
IETF		0.285 [0.024]**		0.017 [0.033]
OTHTEL		-0.036 [0.014]*		0.110 [0.035]**
Disc. Year Effects	Yes	Yes	Yes	Yes
Observations	4,731	4,033	4,731	4,731
Pseudo R-squared	0.05	0.25	0.01	0.11

Robust standard errors in brackets. *Significant at 5%; **significant at 1%. The omitted business model category is "Downstream" and the omitted SSO is ANSI.

Table C-4: Cross Sectional Citation and Litigation for Family Matched Sample

Outcome	Forward Citations			Percent Litigated		
Specification	Poisson			OLS		
	(1)	(2)	(3)	(4)	(5)	(6)
SEP Family	0.06 [0.05]			3.27 [0.55]**		
Declared SEP	0.47 [0.03]**			4.80 [0.44]**		
Declared SEP * FRAND		0.39 [0.03]**			4.47 [0.40]**	
Declared SEP * Free		0.52 [0.09]**			-0.82 [0.60]	
Declared SEP * Terms		0.48 [0.14]**			6.59 [4.73]	
Declared SEP * None		0.40 [0.17]*			10.35 [3.22]**	
Declared SEP * ANSI			0.22 [0.12]			12.82 [2.24]**
Declared SEP * Big-I			0.19 [0.11]			6.55 [1.34]**
Declared SEP * ETSI			0.19 [0.10]			3.36 [1.00]**
Declared SEP * IEEE			0.38 [0.11]**			7.80 [1.38]**
Declared SEP * IETF			0.56 [0.11]**			3.17 [1.22]**
Declared SEP * Other			0.95 [0.12]**			8.87 [1.78]**
Grant Year Effects	Yes	Yes	Yes	Yes	Yes	Yes
Patent Class Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11,744	11,744	11,744	11,744	11,744	11,744
(Pseudo) R-squared	0.44	0.43	0.45	0.05	0.05	0.06

Robust standard errors in brackets. *Significant at 5%; **significant at 1%.

Table C-5: Diff-in-Diffs for Self Citations

Outcome	$SelfCitations_{it}$				
Specification	OLS				
Estimation Sample	Cite Matched	Drop ETSI	Cite Matched	Drop ETSI	Cite Matched
	(1)	(2)	(3)	(4)	(5)
PostDisclosure * Family	0.03 [0.02]	0.06 [0.05]			
PostDisclosure * dSEP	0.08 [0.02]**	0.08 [0.02]**			
PostDisclosure * FRAND			0.07 [0.02]**	0.06 [0.02]**	
PostDisclosure * FREE			0.27 [0.07]**	0.26 [0.07]**	
PostDisclosure * TERMS			0.01 [0.13]	0.05 [0.13]	
PostDisclosure * None			0.06 [0.03]	0.06 [0.03]	
PostDisclosure * ANSI					0.13 [0.06]*
PostDisclosure * Big-I					0.03 [0.02]
PostDisclosure * ETSI					0.07 [0.03]*
PostDisclosure * IEEE					0.09 [0.04]*
PostDisclosure * IETF					0.17 [0.05]**
PostDisclosure * Other					0.06 [0.04]
Patent Fixed Effects	Yes	Yes	Yes	Yes	Yes
Age-Year Effects	Yes	Yes	Yes	Yes	Yes
$E[SelfCitations_{it}]$	0.27	0.24	0.27	0.34	0.27
Observations	160,279	74,728	160,279	74,728	160,279
Patents	12,200	5,604	12,200	5,604	12,200
R-squared	0.47	0.45	0.47	0.45	0.47

Robust standard errors (clustered on patent) in brackets. *Significant at 5%; **significant at 1%.

Table C-6: Citation Diff-in-Diffs

Outcome	$Citations_{it}$			
Specification	Poisson			
Estimation Sample	Random Match	Cite Matched	Cite Matched	Drop ETSI
	(1)	(2)	(3)	(4)
PostDisclosure	-0.02	0.12	0.08	0.19
	[0.04]	[0.03]**	[0.02]**	[0.03]**
Declared Essential	0.56	0.02		
	[0.04]**	[0.03]		
Patent Fixed Effects	No	No	Yes	Yes
Age-Year Effects	Yes	Yes	Yes	Yes
Observations	167,461	160,279	154,716	74,728
Patents	13,384	12,200	11,647	5,402

Robust standard errors (clustered on patent) in brackets. *Significant at 5%; **significant at 1%.

Table C-7: Diff-in-Diffs Poisson

Outcome			Citations$_{it}$		
Specification			Poisson		
Estimation Sample	Cite Matched	Drop ETSI	Cite Matched	Drop ETSI	Cite Matched
	(1)	(2)	(3)	(4)	(5)
PostDisclosure * Family	-0.07 [0.04]	-0.01 [0.06]			
PostDisclosure * dSEP	0.01 [0.02]	0.17 [0.03]**			
PostDisclosure * FRAND			0.00 [0.02]	0.17 [0.03]**	
PostDisclosure * FREE			-0.12 [0.06]*	-0.13 [0.06]*	
PostDisclosure * TERMS			0.39 [0.14]**	0.39 [0.13]**	
PostDisclosure * None			0.10 [0.19]	0.06 [0.20]	
PostDisclosure * ANSI					0.42 [0.10]**
PostDisclosure * Big-I					0.22 [0.05]**
PostDisclosure * ETSI					-0.15 [0.03]**
PostDisclosure * IEEE					0.06 [0.05]
PostDisclosure * IETF					-0.02 [0.06]
PostDisclosure * Other					0.32 [0.05]**
Patent Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes	Yes
Age Polynomial	Yes	Yes	Yes	Yes	Yes
Observations	150,531	70,316	150,531	70,316	150,531
Patents	11,047	5,081	11,047	5,081	11,047

Robust standard errors (clustered on patent) in brackets. *Significant at 5%; **significant at 1%.

Table C-8: Litigation Hazard Robustness

Outcome	Litigation Indicator			
Estimation Sample	Declared SEPs			
Specification	Cox	Cox	Logit	Logit
	(1)	(2)	(3)	(4)
PostDisclosure	0.33	0.33	0.43	0.32
	[0.14]*	[0.14]*	[0.14]**	[0.14]*
ln(Patent Refs)		0.04		0.08
		[0.06]		[0.06]
ln(Non-patent Refs)		0.14		0.17
		[0.04]**		[0.04]**
ln(Claims)		0.37		0.39
		[0.07]**		[0.07]**
ln(Cites_{t-1})		0.29		0.27
		[0.05]**		[0.05]**
Reassigned		1.29		1.33
		[0.10]**		[0.10]**
Age Effects	na	na	Y	Y
Year Effects	Y	Y	Y	Y
Marginal Effect (%)			0.28	0.27
Observations	64,041	64,041	70,106	70,106
Patents	6,659	6,659	6,691	6,691
Lawsuits	435	435	467	467

Robust standard errors (clustered on patent) in brackets. $^{+}$Significant at 10%; *Significant at 5%; **significant at 1%.