Competing on Standards? Entrepreneurship, Intellectual Property, and Platform Technologies

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Entrepreneurs often rely on intellectual property (IP) to earn a return on their innovations, and also compatibility standards, which allow them to supply specialized components for a shared technology platform. This paper compares the IP strategies of small entrepreneurs and large incumbents that disclose patents at 13 voluntary standard setting organizations (SSOs). These patents have a relatively high litigation rate. For small private firms, the probability of filing a lawsuit increases after disclosure to the SSO. For large public firms, the filing rate is unchanged. Although forward citations increase after disclosure for all firms, the size of this effect is the same for entrepreneurs and incumbents.

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These results suggest that standards increase the difference between large and small firms' incentives to litigate, rather than the relative value of their patents. We conclude that because specialized technology providers cannot seek rents in complementary markets, they defend IP more aggressively once it has been incorporated into an open platform.

1. Introduction

Entrepreneurs often develop innovations that are only valuable as part of a larger platform, such as the Internet, the personal computer, or the cellular phone network. For these complex systems to work well, new components must adhere to a set of shared design rules, which are often developed inside voluntary standard setting organizations (SSOs). This paper examines the intellectual property (IP) strategies of firms that participate in SSOs, and shows that small entrepreneurs litigate their IP more than large incumbents once it has been incorporated into a standard. Our findings suggest that the trade-off between "opening" a platform to create value and asserting IP to capture rents is different for large and small firms.

SSOs play an important role in information and communications technology markets. They provide a forum where interested parties can seek consensus on shared aspects of product design, and a mechanism for collectively endorsing new standards (David and Greenstein, 1990). To reduce bargaining costs and promote the adoption of completed standards, most SSOs offer their members a *quid pro quo*: in return for the opportunity to promote their proprietary technology, firms must disclose relevant IP, and if it becomes part of the standard, offer a nonexclusive license at "reasonable" rates (Lemley, 2002; Chiao et al., 2007). In principle, these policies reduce transaction costs in the market for technology. In practice, disclosure and licensing of standards-related IP has led to considerable controversy, including a number of public and private antitrust lawsuits (Farrell et al., 2007).

We study legal disputes over patents disclosed in the standard setting process. Our central hypothesis is that small entrepreneurs and large incumbents will have different IP strategies. Specifically, because small entrepreneurs compete in the market for technology through IP licensing and the sale of specialized components, they will have a high propensity to engage in IP litigation when an SSO develops a standard that incorporates their proprietary technology. Large integrated incumbents have weaker incentives to litigate, because participation in downstream markets—through systems integration, manufacturing, and marketing—allows them to seek rents elsewhere. Firms with substantial downstream market power should be especially keen to "cooperate on standards and compete on implementation"

(IBM, 2007); at least to the extent that cooperation implies reciprocal low-cost licensing.[1]

We test this hypothesis by examining litigation rates in a sample of 949 US patents disclosed at 13 SSOs between 1980 and 2004. There are three main results. First, the SSO patents have a high litigation rate—5.5 times greater than a random sample from the same vintage and technology class.[2] We interpret this finding as a selection effect: firms disclose their most valuable patents. Second, litigation rates increase after disclosure for patents assigned to small entrepreneurial firms, but remain unchanged (or perhaps even decline) for patents assigned to large public companies. This *divergence* in filing rates is identified by differences in the timing of litigation for a sample of 72 patents that were both disclosed and litigated in US courts, and differs from Lanjouw and Schankerman's (2004) finding that small firms are more litigious than large ones.

The increasing difference between large- and small-firm litigation rates suggests that compatibility standards have an asymmetric impact on demand, the incentives to file a lawsuit, or both. We attempt to sort out these alternative explanations by using forward citations as a proxy for demand. This leads to our third main result: there is no divergence in the forward citation rate of large- and small-firm patents following disclosure. The parallel citation path suggests that unobserved shifts in demand (or infringement) following disclosure have a similar impact on large- and small-firm patents. Thus, we attribute the divergence in litigation rates to shifts in firms' relative incentives to litigate essential IP once a standard has emerged.

Our findings highlight a tension between patents and standards: two institutions that support the division of innovative labor. Hall and Ziedonis (2001) and Arora et al. (2004, Chapter 3) describe the importance of IP for specialized innovation. By giving entrepreneurs a tradable asset, property rights support the market for ideas, and consequently promote innovation and entry. Standards also support specialized innovation, by providing a shared interface that allows many innovators to access a common platform. This can reduce entry costs, and will enhance the value of a platform when it leads to a large and diverse community of component suppliers. But IP and standards are not always compatible. We show that IP rights in interface technologies are often contested, and that stand-alone technology suppliers may

1. Of course, many large firms still promote their own IP in the standards process. And although proponents of "openness" often claim to hold the normative high ground, it can be hard to evaluate these welfare arguments given the well-known (but poorly measured) trade-off between *ex ante* innovation incentives and the *ex post* benefits of marginal cost (i.e., royalty-free) licensing.

2. The share of patents litigated tends to be small, ranging in the population from 1% to 4% (see Lanjouw and Schankerman, 2004).

have especially strong motives to enforce their IP once their proprietary technology becomes part of an industry standard.

The remainder of the paper is organized as follows: Section 2 describes the standard setting process and discusses our dependent variable (patent litigation). Section 3 presents the empirical methods. Section 4 discusses the data set and provides summary statistics. Section 5 presents our main results: models that show a significant divergence in the litigation rate for large- and small-firm patents after disclosure (along with several robustness checks). Section 6 concludes.

2. Formal Standards and IP Strategy

Standards play an important role in information and communications technology markets. This section describes how standards are used, explains why firms contribute IP to standards, and considers the drivers of standards-related patent litigation. To foreshadow our main argument, we propose that small entrepreneurial firms have strong incentives to defend their standards-related IP (relative to large incumbents) because they are typically unable to seek rents in complementary downstream markets.

2.1 Role of Compatibility Standards

At a basic level, standards exist to promote interoperability. For example, consumers expect any DVD player to work with a wide variety of television sets and to play DVDs released by any studio. Matutes and Regibeau (1988) were among the first to analyze the positive externalities associated with this type of "mix and match" compatibility, which is central to the basic idea of a platform.

Standards also help firms and consumers coordinate the transition between successive technology generations. In theory, markets with strong network effects might converge on inferior solutions or take "too long" to make a Pareto-improving switch (Farrell and Saloner, 1985; Arthur, 1989). In practice, SSOs work to solve these problems by seeking the best available technology, and issuing a formal endorsement that serves as a focal point for consumers, perhaps leading to bandwagons in the adoption process. For example, Greenstein and Rysman (2007) describe how the ITU helped break a standards deadlock that slowed the adoption of 56K modems.

Standards can also lower the cost of innovating. By specifying a set of boundaries or "modules," standards reduce opportunities for differentiation in some dimensions of product design and promote experimentation in others (Baldwin and Clark, 2000). For example, when IBM opened up the personal computer architecture—which become the "Wintel" standard—there was a great deal of entry and experimentation in the design of both PCs and peripheral devices (Bresnahan and Greenstein, 1999).

Finally, formal standards may be used to create or reinforce a position of market power. One such anticompetitive strategy is to delay or withhold important technical information from competitors. Mackie-Mason and Netz (2007) suggest that this strategy was used by members of the consortium that developed the USB 2.0 standard. Firms can also create market power by inserting patents into an industry standard. The most vivid example of this strategy comes from the Rambus case (Farrell et al., 2004; Graham, 2004). Rambus participated in an SSO called JEDEC that was developing an open standard for memory chips. The evidence suggests that Rambus participated partly to ensure that its patents would cover the standard, but withdrew from JEDEC when the work was nearly complete, possibly to avoid disclosure obligations. When Rambus sought to license its IP to firms using the JEDEC standard, there was a wave of litigation that focused on Rambus' obligation to disclose patent applications while participating in the SSO.[3]

2.2 Standards and Proprietary Technology

Although Rambus' "submarine" strategy and the resulting litigation drew much attention, it is important to recognize that JEDEC and most other SSOs do not prohibit IP in standards or licensing of essential patents. Rather, they encourage *ex ante* disclosure of relevant IP, so members can evaluate any trade-offs between technical quality and implementation cost. Most SSOs also require a promise that firms holding essential patents will license on "reasonable and non-discriminatory" or RAND terms, to promote adoption of the final standard.[4] Lemley (2002) suggests that RAND implies a commitment to refrain from exclusive licensing or the use of injunctions during patent litigation. However, the question of "reasonable" royalty rates is murkier, and in some cases has reached the courts.[5] Although pricing uncertainty might be resolved by having IP owners commit to a royalty rate before the standard is chosen, most SSOs prohibit any prospective discussion of licensing

3. Although a unanimous ruling by the US Federal Trade Commission found that Rambus violated JEDEC's membership rules, and placed royalty caps on the relevant patents, that decision was overturned by the Federal Circuit (FTC, 2003).

4. European SSOs often require a FRAND ("Fair" reasonable and non-discriminatory) licensing commitment. For a detailed discussion of how disclosure and licensing rules fit into the broader process of standards creation see, for example, Cargill (1997), Lemley (2002), or Simcoe (2006).

5. *Nokia Inc. vs. Qualcomm Inc. Civ. A. No. 2330-N (Delaware).*

terms—generally citing fears of antitrust litigation.[6] Thus, although bilateral negotiations may take place on the side, the formal standards process does not typically produce common knowledge of expected IP prices.

Small vertically specialized firms are among those that participate in SSOs and disclose IP. In some cases, these firms are "pure play" licensors, such as Rambus, Interdigital, MIPS, ARM, or DTS. Others like Qualcomm, Broadcom, Xilinx, RSA, or Certicom combine licensing with specialized component sales. For these firms, out-licensing standards-related IP can be particularly lucrative. The best example may be Qualcomm, which collects several billion dollars in annual royalties for patents that are essential to the CDMA cellular telephony standard, even though most of the patents are covered by RAND commitments.[7]

Firms that do not intend to out-license may still be anxious for an SSO to endorse their proprietary technology; particularly if it prevents an IP-rich competitor from controlling the standard, or leads to less costly cross-licensing. Some SSO participants even commit to give away their standards-related IP; usually via a royalty-free license or nonassertion covenant (subject to any licensee offering reciprocal terms). These firms often hope to benefit from product development lead times, backwards compatibility, or the existence of proprietary complements.

Our main hypothesis is that small vertically specialized "entrepreneurs" are more likely to aggressively out-license their standards-related IP. On one level, this is obvious: pure-play licensing firms have no interest in a royalty-free cross-license or nonassertion pact. However, even when smaller firms are focused on implementation, they are likely to face a difficult trade-off between opening a standard to encourage platform adoption and closing it to capture rents. For example, Henderson (2003, p. 15) describes the dilemma faced by the wireless networking startup Ember in the IEEE 802.15.4 standards process. Although Ember hoped that "getting characteristics of its own implementation adopted as part of the standard" would reduce subsequent design costs, the firm also feared that larger rivals hoped to "make an open standard of the network layer in which [their core IP] was implemented."

The trade-off between opening a standard to create value and closing it to reduce competition will be less salient to a large firm whose

6. This is changing. Some SSOs, such as the IEEE, now provide for the optional *ex ante* disclosure of royalty caps. SSOs' antitrust concerns have also been addressed through the Standards Development Organization Advancement Act of 2004 (H.R. 1086), and statements from various antitrust agencies: see, for example, Majoras (2005) or the discussion in the FTC's Rambus opinion (FTC, 2006, p. 36).

7. Between 2004 and 2006, Qualcomm's licensing division generated between 27% and 35% of total revenues that averaged $6 billion (2006 Annual Report, p. 38).

manufacturing, marketing or distribution capabilities allow them to capture rents downstream. Intuitively, this is an application of the "one monopoly rent" argument (Bowman, 1957). Schmidt (2006) extends this logic to a model of patent licensing with complementary upstream patents, a downstream oligopoly, and both specialized and integrated firms. Although models with upstream innovation on a shared platform can raise thorny welfare questions (Farrell, 2003; Farrell and Weiser, 2003), we focus on a straightforward prediction: once a standard is in place, firms that control a downstream bottleneck will favor more competition (i.e., weaker IP) in complementary technology markets.

Anecdotal evidence supports the idea that large integrated systems vendors are keen to compete on implementation when faced with a "thicket" of complementary upstream monopolies. Historically, this was accomplished through cross-licensing to ensure broad access to implementation rights; at least within a population of roughly symmetric firms (Hall and Ziedonis, 2001). Large customers and platform leaders with a strong position in complementary markets can also use the standards process to promote *ex post* competition in the market for technology. For example, Thomson (1954) describes the role of the major auto manufacturers in the standardization of many parts and subassemblies. Similarly, Intel participates in a wide variety of standards activities that could lead to new applications for its microprocessors, and IBM's increasingly cooperative patent licensing strategy reflects a broad move into consulting services.

This paper uses data from SSO patent disclosures to look for systematic differences in the IP strategy of large and small firms that participate in the formal standards process. A natural place to look for differences would be data on licensing. Unfortunately, most firms hold these agreements in strict confidentiality; often because of legal restrictions. As a result, we focus on patent litigation.

2.3 Patent Litigation

A patent lawsuit will only be filed if a patent holder asserts its IP and the bargaining process fails. There is often some confusion on the first point, because an accused infringer may file a patent invalidity suit. However, until the *Medimmune* case in 2007, invalidity suits required "an explicit threat or other action by the patentee [suggesting an imminent] infringement suit."[8] Thus, lawsuits in our data could only arise when a patentee was actively enforcing its rights.

8. Sierra Applied Scis., Inc. v. Advanced Energy Indus., Inc., 363 F.3d 1361, 1373 (Fed. Cir. 2004) (quoting BP Chems. Ltd. v. Union Carbide Corp., 4 F.3d 975, 978 (Fed. Cir. 1993)). Overturned by MedImmune, Inc. v. Genentech, Inc.,127 S. Ct. 764 (2007).

The second point raises a question that has received a great deal of scholarly attention: why don't litigants bargain to a more efficient outcome?[9] Theorists offer three explanations: hidden information (Nalebuff, 1987; Spier, 1992), divergent expectations (Priest and Klein, 1984; Yildiz, 2004; Galasso, 2007), and asymmetric stakes or positive litigation externalities (Meurer, 1989; Siegelman and Waldfogel, 1999; Lanjouw and Lerner, 1998). Studies of patent litigation typically emphasize the second and third factors, because litigants are often sophisticated parties with detailed knowledge of the relevant technology.[10]

We examine changes in a patent's litigation rate after it is disclosed to an SSO, and how these changes vary with firm size. If a disclosed patent is essential to the standard (i.e., hard to invent around) then demand for that IP should increase. This leads to increased litigation through two channels. The first is straightforward: greater demand creates more opportunities for infringement. The second involves reputational externalities; specifically, IP owners may become more anxious to file an *initial* lawsuit to obtain either a validity ruling or a reputation for "toughness" that lets them demand more royalties from the (now larger) pool of licensors. It is not clear how these effects will vary with firm size. Whether and how the "demand shock" varies with firm size is an empirical question. And while a reputation for toughness might be more important to small firms, strong patents (or reputations) could easily matter in cross-licensing among larger competitors.

For large vertically integrated firms, the creation of a new standard can also increase demand for complementary goods or services. This reduces the incentive to litigate essential IP. In the short run, foregone rents from a less aggressive IP strategy in the (upstream) technology market are offset by increased demand in the (downstream) market for complements. In the long run, large firms may want to avoid a reputation for driving off small competitors, in order to maintain the supply of complementary innovations. For instance, Gawer and Henderson (2007, p. 3) describe tensions within Intel between managers who are "encouraged to maximize profit within complementary markets... and their colleagues who actively subsidize the entry of competitors and refuse to use Intel's control of the architecture to advantage internal divisions."

9. The American Intellectual Property Law Association (2007) estimates that suits between $1 and $25 million in patent value cost litigants $2.5 million through discovery, and $5 million through trial.

10. The working paper version of this manuscript (Simcoe et al., 2008) contains a simple model of SSO patent litigation. For theories that develop a richer model of pretrial bargaining, see Bessen and Meurer (2006) or Farrell and Shapiro (2008).

The central hypothesis of this paper is that the small entrepreneurs and large incumbents who participate in SSOs will have different IP strategies. Specifically, because small firms are typically unable to seek rents in complementary downstream markets, they are more likely to litigate when the SSO develops a standard that incorporates technology covered by their IP.

The ideal approach to testing this hypothesis would be to identify a significant coordination problem, along with a feasible set of substitute technologies, and randomly assign one technology to be the standard. Given a large number of trials, we might compare the subsequent litigation rates for large and small IP holders. Unfortunately, we have neither a controlled experiment nor an instrumental variable that will exogenously cause SSOs to favor a particular technology as the standard. So, we turn to nonexperimental methods that exploit variation over time caused by the standards process itself.

3. Methods

Suppose that X_{ijt} is a vector of observed characteristics for patent i (assigned to firm j) at time t, and S_{it} is an indicator variable that equals one if i is essential to implement an industry standard. We model demand as the number of infringers $N(X,S) = \exp\{\beta_1 X_{ijt} + \eta S_{ijt}\}$ and the probability of litigation in a particular instance as $P(X,S) = \exp\{\beta_2 X_{ijt} + \theta S_{it}\}$. Thus, a simple model of litigation is

$$\log(Suits_{ijt}) = X_{it}(\beta_1 + \beta_2) + S_{it}(\theta + \eta) + \varepsilon_{it}. \quad (1)$$

Equation (1) highlights two empirical challenges. First, S_{it} is likely to be correlated with unobserved variables that enter the litigation process through ε_{it}. And second, the data do not separately identify the impact of standards on litigation incentives (θ) and demand (η). The latter distinction is important for testing whether large firms internalize the downstream benefits of open standards (i.e., have lower θ); because a simple alternative hypothesis is that they disclose low-quality IP, and realize a smaller increase in demand.

To address the first issue, we restrict attention to SSO patents and examine changes in the litigation rate following disclosure. In particular, we use patent fixed effects to control for time-invariant unobserved heterogeneity. Thus, the "standards effect" $(\theta + \eta)$ measures a change in the litigation rate of disclosed patents relative to patents that will eventually be disclosed, but are not yet. If the timing of the standards process were exogenous, we could interpret these estimates as the causal impact of disclosure on the litigation rate of disclosed patents (i.e., the treatment effect for the treated). However, the creation of new standards is presumably correlated with time-varying shocks in the importance of underlying technologies. So we focus on a different question: do large and small firms respond to these shocks differently?

To answer this question, we create an indicator E_j that equals one for small entrepreneurs and interact it with the time-varying disclosure dummy S_{it}. This leads to the following specification, where γ_k are patent fixed effects, $\lambda(t)$ is a flexibly parameterized time trend, α is the small-firm incentive effect, δ is the small-firm demand effect, and ε_{it} is a patent-specific time-varying error component that is uncorrelated with the explanatory variables:

$$\log(Suits_{ijt}) = \gamma_k + \lambda(t) + X_{ijt}(\beta_1 + \beta_2) + S_{it}(\theta + \eta + E_j(\alpha + \delta)) + \varepsilon_{it}. \tag{2}$$

In this specification, the main effect of firm size E_i is absorbed by the patent fixed effects. Thus, although small firms may be more litigious for a variety of reasons (e.g., they are not disciplined by repeated interactions, or lack a portfolio for cross-licensing), these unobserved factors will only influence our results if they change over time, and therefore enter (2) through the error term.

Equation (2) does not include patent age effects, which are colinear with the time trend and patent fixed effects. However, we do use a three-way interaction between age, a predisclosure dummy, and E_i to test for different predisclosure litigation trends at large and small firms. This is analogous to testing for exogenous treatment in a difference-in-differences model (e.g., Heckman and Hotz, 1989). Equation (2) is not a typical diff-in-diffs specification: we focus on treatment heterogeneity rather than a difference between observed and "counterfactual" outcomes. However, a significant difference in predisclosure litigation trends would suggest that we are not adequately controlling for unobserved factors that differ across the large and small firms in our sample.

Although equation (2) uses within-patent variation to control for time-invariant omitted variables, it does not address the second empirical challenge described above: the distinction between litigation incentives (α) and the demand for standards-related IP (δ). Without more data, it is not possible to disentangle these effects. So, the last step in our analysis uses patent citations as a proxy for demand (or infringement) to test the hypothesis that $\delta > 0$. Specifically, we re-estimate equation (2) using citations as the dependent variable, and interpret the interaction coefficient as the estimated difference between large- and small-firm demand effects. If we reject the null hypothesis that $\delta > 0$, we can be more confident that $\alpha + \delta$ places a lower bound on the difference in litigation incentives.

In practice, citations are a rough proxy for demand. Nevertheless, many studies link cites to the economic or technological significance of a patent (e.g., Harhoff et al., 1999; Hall et al., 2005). Building on that work, Rysman and Simcoe (2008) show that disclosure leads to a significant "citation bump" for SSO patents, and provide a lengthy discussion of possible interpretations. Lanjouw and Schankerman (2001) document a strong link between cites and subsequent litigation, and suggest that citations reflect the underlying value of a patent. Lerner (2007) uses cites to control for unobserved variation in patent "quality" that might influence litigation. Our approach is similar, but adds fixed effects to control for time-invariant quality differences. Because we are concerned that estimates of δ could be downward biased (which is equivalent to upward bias in α), our key assumption is that S_{it} is uncorrelated with omitted variables that produce an increase in the relative citation rate of large-firm patents.

4. Data

Our data set combines information from publicly available SSO IP disclosure archives, the NBER US patent database (Hall et al., 2001), the Derwent LIT/ALERT patent litigation database, the US Federal Judicial Center, Compustat, and Venture Economics. This section discusses our main data sources and presents a series of firm- and patent-level summary statistics.

4.1 SSOs and IP Disclosures

We began by identifying 14 SSOs (listed in Table I) with publicly accessible IP disclosure archives. The scale and scope of these institutions varies substantially, with two large umbrella organizations—the American National Standards Institute (ANSI) and the International Organization for Standards (ISO)—at one end of the spectrum and several small consortia such as the DSL Forum, ATM Forum, and Multi-Service Switching Forum (MSSF) at the other.

Collectively, these 14 SSOs have developed a large number of commercially significant standards. Prominent examples include Ethernet (IEEE), the 802.11 or Wi-Fi protocols for wireless networking (IEEE), core Internet protocols such as TCP/IP (IETF), and various modem protocols (ITU and DSL Forum). While the larger SSOs develop standards for safety and quality measurement as well as product compatibility,

Table I. Disclosure Summary Statistics by SSO

SSO	Total Discs	Blanket Discs	Total IPR	US Patents	US App's	Min Disc Year	Mean Disc Year	Mean Disc Age*	Large Firms*
ANSI	278	177	278	127	15	1971	1996	3.08	0.87
ATIS	58	38	51	20	2	1986	1996	2.68	0.82
ATM forum	25	1	90	45	1	1995	1998	4.22	0.92
IEEE	390	239	966	278	12	1983	2000	3.35	0.89
IETF	353	188	351	101	6	1995	2003	3.26	0.95
ITU	643	0	1,175	200	18	1983	1999	4.12	0.89
TIA	126	117	23	19	0	1989	1998	3.16	0.99
DSL forum	8	0	32	3	1	2000	2004	0.75	0.86
ISO	24	8	44	16	1	1980	1995	3.59	0.73
ISO/IEC JTC1	217	194	61	13	7	1992	1998	4.05	0.96
MSSF	13	7	15	3	0	1999	2002	0.33	1.00
OMA	44	0	185	53	1	1999	2004	3.63	0.72
VESA	55	0	62	7	0	1995	2001	1.14	0.88
Pooled sample	2,234	969	3,333	885	64	1971	2000	3.66	0.91

Notes: A blanket disclosure contains no patent or application numbers that would identify a specific piece of intellectual property. Total IPR is a count of all patents (United States and foreign) and application numbers listed in a disclosure. A large firm is publicly traded or has more than 500 employees.
*The unit of observation for these statistics is disclosed patents rather than a disclosure.

nearly all of the patent disclosures are related to information and communications technologies.[11]

For each SSO, we collected all disclosures made through July 2006. A disclosure is typically a letter or e-mail message indicating that a firm owns IP that it will license on RAND terms. Although these disclosures provide a unique window onto standards-related IP, they also have several shortcomings. First, although every disclosure contains a firm name and date, there are many "blanket" disclosures that do not provide any patent or application numbers.[12] Second, we do not observe whether a standard setting effort was successful, or a particular piece of IP was essential to the final specification. Thus, our sample of disclosed patents is likely to contain a number of false positives, where the standard failed or the SSO chose an alternative solution. This might be a problem for our empirical strategy if large firms are more often linked to these failed efforts, and therefore have less reason to litigate following disclosure. However, our citation results suggest the opposite pattern.

Third, disclosure is clearly not exogenous. We expect disclosed patents to be among the most important in a firm's IP portfolio, and disclosures to be concentrated in the most important and commercially relevant standards efforts. Thus, when we compare SSO patents to a "control" sample below, the controls are meant to provide a measure of the average patent, rather than a true counterfactual. And finally, because our results are based on patents that were specifically identified in a disclosure letter, they are not likely to reveal anything about the prevalence of "hold-up" strategies—where a patent holder pushes for a particular standard while keeping its IP secret, as in the Rambus case.

Figure 1 shows the increase in IP disclosure over time and Table I presents a number of summary statistics for our sample of disclosures.[13] The first two columns in Table I indicate that we reviewed 2,234 disclosure letters, of which 969 were blanket disclosures. Our review identified 949 granted US patents—885 disclosed directly, and 64 that were matched to disclosed US application numbers.

11. The Appendix Table AI contains a short description of the SSOs in our study. Table AII shows that 99% of the US patents in our data have a primary (three-digit) technology classification of computing, communications, electrical, or electronic technology.

12. Figures A1 and A2 in the Appendix reproduces two letters from our sample to provide a sense of the heterogeneity in disclosure practices.

13. We dropped one SSO (ETSI) from our sample because of large differences in disclosure norms. In particular, many firms appear to have "dumped" their patent portfolios into the ETSI standards process. We have run all regressions with ETSI included in the sample and find qualitatively similar results (which are available from the authors upon request).

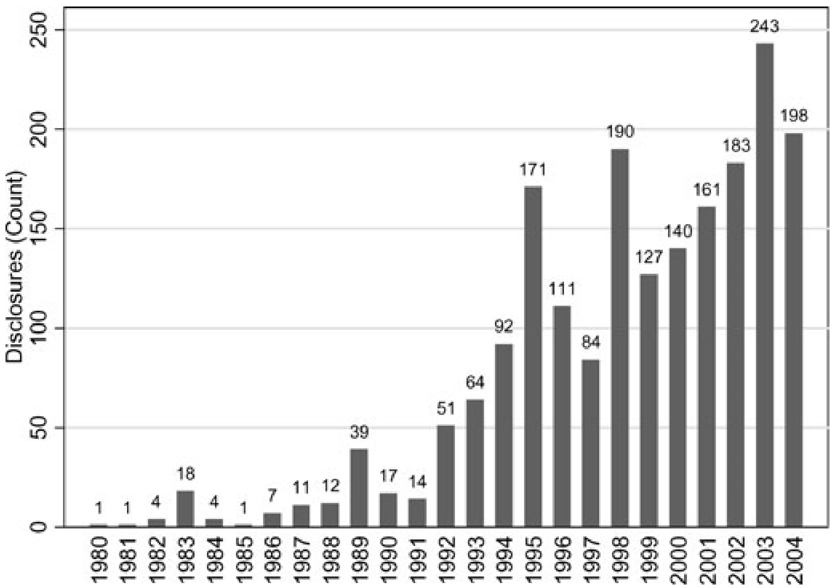


FIGURE 1. ANNUAL IPR DISCLOSURE AT 13 STANDARD SETTING ORGANIZATIONS

4.2 SSO Patents

We matched all of the US patents in our sample of disclosure letters to the Derwent LIT/Alert database as well as an augmented version of the NBER US patent database. The Derwent litigation data are based on court records provided to the USPTO, and their strengths and weaknesses are discussed in Lanjouw and Schankerman (2003).

Table II compares means for the SSO patents to a randomly selected control sample that matches on grant year, three-digit technology classification, and assignee country.[14] The first eight rows examine litigation patterns. SSO patents have a substantially higher litigation rate than an average patent (9.4% vs. 1.7%) and this difference increases with a patent's age (e.g., the difference is 14.2% vs. 2.0% for patents granted before 1994).[15] This age effect may reflect truncation, because older patents are exposed to the risk of litigation for a longer period

14. Our assignee countries are really continents, that is, either the United States or the rest of the world.

15. The litigation rates in our control sample are comparable to those reported by Lanjouw and Schankerman (2004) for electronics and computing. Our figures are slightly smaller because we compare SSO and control samples with an identical grant-year distribution rather than adjusting later cohorts for truncation.

TABLE II.
SAMPLE MEANS FOR SSO AND MATCHED CONTROL PATENTS

	SSO Patents	Random Match	*p*-value
Litigation rate (%)	9.38	1.69	0.00
Lit rate (grant pre-1994)	14.24	1.99	0.00
Lit rate (grant 1994–1998)	7.11	1.55	0.00
Lit rate (grant post-1998)	4.46	0.96	0.01
Lawsuits (count)*	1.97	2.06	0.87
Defendants (count)*	2.69	2.56	0.90
Litigation age (years)*	6.20	3.75	0.02
Predisclosure Lit (%)*	28.09		
Forward cites 1963–2006	33.88	16.84	0.00
Backward cites	10.75	10.36	0.56
Nonpatent cites	9.07	4.69	0.00
Claims	22.24	17.89	0.00
Continuation	0.43	0.31	0.00
Generality	0.51	0.44	0.00
US firm	62.17	61.54	0.78
US other	2.42	2.53	0.88
Non-US firm	26.87	27.82	0.64
Non-US other	2.53	1.58	0.15
Unassigned	6.01	6.53	0.64
Patents	949	949	

Notes: This table presents sample means and *t*-tests for SSO patents and one-to-one randomly matched control samples. Each control patent has the same grant year and technology class as its SSO twin. See text for additional description of the matching process.
*Statistics in these cells are conditional on litigation.

of time, or a selection effect, because past litigation may increase the probability of disclosure to an SSO. Conditional on litigation, there is little difference in the number of lawsuits or named defendants per patent. However, the SSO patents are roughly 2.5 years older than the controls when first litigated. Finally, we find that 28% of all litigated SSO patents are involved in a lawsuit *before* they are disclosed to an SSO. Because lawsuits tend to attract a great deal of attention, this last finding suggests that many disclosures are less about revealing essential IP than signaling the strength of a firm's patent portfolio.

The next six rows in Table II examine a number of patent quality measures, including forward citations (i.e., cites received), backwards citations, citations to nonpatent prior art, the number of claims, and the Jaffe et al. (1993) "generality" index, which indicates that a patent is cited by a more diverse array of future inventors. Not surprisingly, we find that SSO patents score substantially higher than an average patent along almost all of these quality dimensions. The last five rows in Table II compare the SSO and matched control patents in terms of assignee characteristics. While it is not surprising that the SSO and control samples are indistinguishable (this was the point of the matching exercise), it is worth noting that 11% of the SSO patents are assigned to individual inventors, universities, governments, or other noncorporate entities.

In addition to the results in Table V, we considered alternative matching schemes (such as sampling on patents with a similar citation rate or the same assignee) and find very similar results. Overall, these findings suggest that disclosure is correlated with unobserved patent characteristics that influence the litigation process. For this reason, our main analysis discards any pretence of constructing a matched control sample and focuses exclusively on patents disclosed to SSOs.

4.3 Entrepreneurs and Incumbents

Identifying individual firms represents a major challenge in any research that relies on patent data. We use the assignee codes contained in the NBER patent data as our starting point.[16] Unfortunately, many patents are assigned to subsidiaries or related entities, and ownership can change over time. As a result, we undertook an extensive effort to identify the parent firm for every assignee in our data, using a variety of corporate directories as well as the Internet. Through these efforts, we identified 190 unique parent firms that disclosed one or more SSO patents.

For 126 parent firms that were traded on a public stock exchange at some point in time, we also obtained CUSIP (Committee on Uniform Securities Identification Procedures) numbers, and (whenever possible) CompuStat data on Employees, Assets, and R&D expenditures.[17] Although we would like to track changes in patent ownership over time, this did not prove feasible. Thus, a potential weakness of our analysis is that each patent retains its affiliation with the original assignee; raising the question of whether small-firm patents are still held by entrepreneurs at the time of litigation. Including variables that might capture changes in ownership (e.g., dummy variables for entering or leaving the CompuStat database) produces no changes in our results. We also collected detailed information on the 26 litigated

16. These data have been updated and can be found on Bronwyn Hall's web site. We also used the Compustat name matching programs created by Bronwyn Hall and Megan MacGarvie as the starting point for our own name matching algorithms.

17. Wherever possible, these data are for the application year of a given patent, though we settled for the closest available year in several cases.

patents assigned to a small firm, and found that in 20 cases the assignee (or a closely related small firm) was either plaintiff or defendant on the first lawsuit.[18] Dropping the other six patents does not alter our main results.

Because our empirical tests focus on the difference between small entrepreneurs and large incumbents—where size proxies for vertical specialization—we construct a binary size variable that plays a central role in the analysis. Specifically, we classify 72 privately held firms and public companies with less than 500 employees (averaged over all years) as "small." The remaining 118 public companies are "large." Although the cutoff at 500 employees is arbitrary, our results do not change if we choose a random threshold anywhere between 50 and 3,000 employees. The main point is to distinguish several smaller firms that are publicly traded from the large enterprises with several thousand employees.

Table III compares sample means (at both the firm and patent level) by firm size. The first two rows show that small firms disclose to fewer SSOs and have a smaller cumulative patent portfolio. By comparing sample sizes in the top and bottom half of the table, we can also see that small companies disclose fewer US patents per firm. The third and fourth rows in the top panel use a Herfindahl measure (based on three-digit technology classes) to show that small-firm patent portfolios are more concentrated, which is consistent with our assumption that they are more specialized.[19] The final rows in the top panel show that large firms are older, have more employees, and are less likely to have received venture capital funding (i.e., appear in the Venture Economics data).

The bottom panel of Table III presents patent-level summary statistics. The first row shows that patents disclosed by small firms have a significantly higher litigation rate—particularly those granted before 1998. The difference between large- and small-firm filing rates is comparable to estimates by Lanjouw and Schankerman (2004), who find that small (unlisted) companies are 4.5 times more likely to litigate a given patent, though baseline filing rates are much higher for the SSO patents.

18. For all litigated patents, the assignee was a plaintiff or defendant in over 80% of the cases. Of the six small-firm patents that changed hands prior to litigation, one was acquired by Hughes Electronics, two by Texas Instruments, and three by Cisco. All of these ownership changes were associated with acquisitions, as opposed to a sale of the patent.

19. The Appendix Table AIII lists the top 10 large and small firms in our data based on a count of disclosed patents. Several of the small entrepreneurs are clearly vertically specialized. For example, Interdigital earns all of its revenue from licensing, and Verisity Design is a "fabless" semiconductor firm.

Table III. Sample Means for SSO Patents by Firm Size

Firm-Level Means	Large Firms	Small Firms	*p*-value
SSO count	1.69	1.06	0.00
Patent grants (1967–1906)	4,899.40	39.40	0.00
HHI 1995	0.12	0.34	0.00
HHI 2000	0.13	0.38	0.00
Public firm	100.00	11.11	0.00
IPO year	1,980.34	1,990.89	0.01
log employees	9.80	5.36	0.00
VC match	27.12	36.11	0.20
Total firms	118	72	

Patent-Level Means	Large Firms	Small Firms	*p*-value
Litigation rate (%)	6.67	17.31	0.00
Lit rate (grant pre-1994)	10.09	37.93	0.01
Lit rate (grant 1994–1999)	4.98	12.6	0.02
Lit rate (grant post-1998)	4.57	4.23	0.90
Lawsuits*	1.98	2.11	0.82
Defendants*	2.67	2.59	0.90
Litigation age*	6.11	4.78	0.20
Predisclosure litigation*	32.61	25.93	0.55
Disclosure age (since grant)	3.44	3.16	0.45
Forward cites 1963–2006	31.14	33.68	0.46
Backward cites	10.46	12.80	0.10
Nonpatent cites	8.33	13.54	0.11
Claims	22.07	24.31	0.21
Continuation dummy	0.36	0.78	0.00
Generality	0.51	0.49	0.62
Forward cites/year	3.07	3.80	0.04
Cites/claim/year	0.21	0.24	0.38
Backward cites/claim	0.78	0.93	0.28
Nonpatent cites/claim	0.53	1.42	0.14
Total patents	690	156	

Note: This table presents sample means and unpaired two-sample *t*-tests that examine differences between the large firms (systems vendors) and small firms (entrepreneurs) disclosing one or more patents to an SSO in our sample.

Table III shows little difference in the numbers of lawsuits or named defendants per litigated patent by firm size. Although large-firm patents are 5% more likely to be litigated before disclosure, this difference is not statistically significant. Small- and large-firm patents receive a similar number of forward cites, but small-firm patents have later grant years, and so are cited slightly more often per year. Finally, the small firms are more likely to use the continuation procedure—potentially a method for "hiding" a patent inside the USPTO—when acquiring a disclosed patent (Graham and Mowery, 2004).

5. Results

This section begins with a set of descriptive probit regressions before turning to the main analysis outlined in Section 3 and a series of robustness checks.

5.1 Descriptive Probits

We begin by estimating a series of probit regressions in order to characterize the cross-sectional litigation patterns in our sample. These results are primarily descriptive, because firm- and patent-level unobserved heterogeneity presumably play an important role in the litigation process. In Table IV we report marginal effects from these probit models, along with robust standard errors (clustered by disclosure), and a baseline litigation rate calculated at the means of the independent variables (for a complete set of variable definitions and summary statistics, see Table AIV in the Appendix).

The first column in Table IV emphasizes variation in the size of the "selection effect" (i.e., the difference between SSO and matched control patents) across SSOs. For this model, the estimation sample includes all patents in the first panel of Table II, and we create five SSO categories; one for each of the four largest organizations (ANSI, IEEE, IETF, and ITU) and a composite group (Other) that includes the remaining SSOs. The specification includes an unreported set of main effects to capture between-SSO variation in the control patent litigation rates (e.g., from differences in technology), a full set of interactions to measure the SSO-specific selection effects, and a full set of assignee-type effects.

The first column of Table IV shows that small-firm patents are more likely to be litigated (an increase from 3.4% to 9.2%). The SSO effects are substantial. ANSI has the largest selection effect—almost 30 percentage points—and the group with the smallest SSO effect (ITU) still doubles the baseline litigation rate. Wald tests do not reject the hypotheses that all of the SSO effects are equal. Although we do not report those assignee-type effects that are not statistically significant, it is worth noting that SSO patents assigned to individual inventors and universities are litigated somewhat more often than those assigned to firms.

In the second column of Table IV, we drop the matched control patents from our estimation sample (noting that the baseline litigation

Table IV. Probit Models of Patent Litigation

Unit of Observation = Patent
DV = Litigation Dummy

Sample	All SSO and Match	All SSO Firms	Small Firms	Large Firms	Public Firms
Baseline probability	0.0338	0.0593	0.0402	0.0495	0.0423
Small firm	0.058	0.076			
	(0.02)***	(0.03)**			
US firm	0.014	−0.008	0.046	−0.017	−0.019
	(0.01)*	(0.03)	(0.03)*	(0.03)	(0.03)
Disclosure age		0.002	0.009	−0.001	−0.004
		(0.00)	(0.01)	(0.00)	(0.00)
Disclosure year		0.002	−0.001	0.002	0.009
		(0.00)	(0.01)	(0.00)	(0.00)*
Continuation dummy		0.074	0.025	0.075	0.054
		(0.03)***	(0.03)	(0.03)**	(0.02)**
Log(claims)		0.011	0.002	0.012	−0.004
		(0.01)	(0.02)	(0.01)	(0.01)
Log(forward cites)		0.041	0.047	0.034	0.030
		(0.01)***	(0.02)***	(0.01)***	(0.01)***
Log(backward cites)		0.005	0.014	−0.000	0.001
		(0.01)	(0.02)	(0.01)	(0.01)
Log(nonpatent cites)		−0.003	−0.037	0.005	0.005
		(0.01)	(0.01)***	(0.01)	(0.01)
Log(employees)					−0.007
					(0.00)
Log(assets/employee)					−0.046
					(0.02)**
Log(patents/employee)					0.025
					(0.01)**
ANSI	0.293				
	(0.12)**				
IEEE	0.096	−0.041	−0.038	−0.024	−0.065
	(0.04)**	(0.02)*	(0.03)	(0.03)	(0.02)***
IETF	0.120	−0.037	−0.046	−0.020	−0.028
	(0.10)	(0.03)	(0.02)**	(0.03)	(0.02)
ITU	0.062	−0.016	−0.050	0.001	−0.033
	(0.03)*	(0.03)	(0.02)**	(0.03)	(0.02)*
Other	0.122	−0.019	0.098	−0.027	−0.036
	(0.05)**	(0.02)	(0.09)	(0.02)	(0.02)**
Grant year effects	Y	Y	Y	Y	Y
Assignee-type effects†	Y				
SSO main effects†	Y				
N (patents)	1,848	846	156	690	626
Pseudo R^2	0.1367	0.1399	0.4013	0.0968	0.1827
Chi-square	84.48	69.90	53.68	39.42	58.95

Notes: This table presents marginal effects from patent-level probit regressions. Column 1 compares SSO to control patents. Columns 2 through 5 exclude all patents not assigned to a US or foreign firm.
*10% significance; **5% significance; ***1% significance (robust SEs clustered on disclosure).
†See text for a discussion of the specification in column 1.

rate nearly doubles) and add a series of patent-level control variables. Once again, the marginal effect for a small-firm dummy is large and statistically significant. We find no correlation between the litigation rate and a patent's age at disclosure or disclosure year, though it is possible that trends in the overall litigation rate are picked up by the grant-year effects. We do find a significant positive correlation between litigation and forward citations. Litigation is also correlated with the continuation procedure, perhaps indicating that lawsuits select for patents with an early priority date.

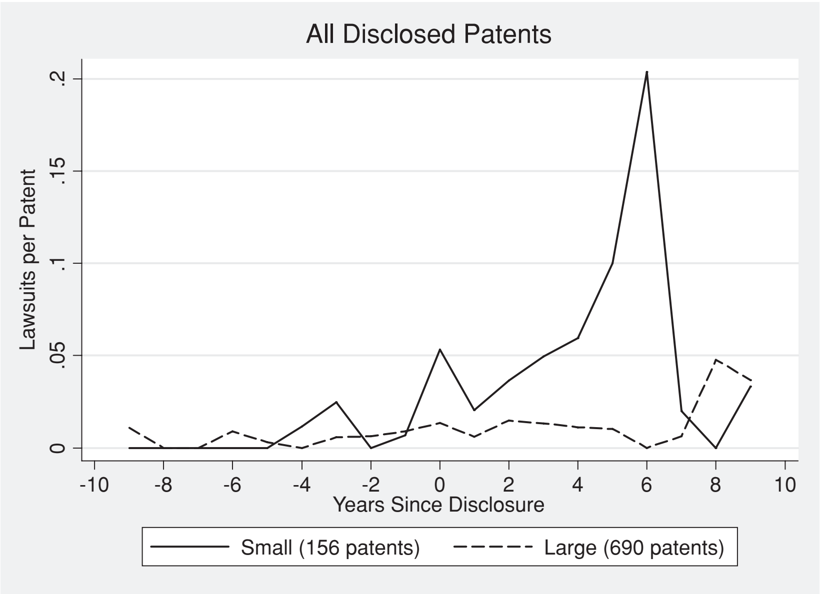
In the third and fourth column of Table IV, we divide the sample into small- and large-firm patents and re-estimate the model of column 2. We find that the correlation between litigation and use of the continuation procedure is primarily driven by large-firm patents. This result is not surprising in light of Table III, which shows that the continuation rate for small-firm patents is almost 80%. For small-firm patents, there is a strong negative correlation between nonpatent prior art citations and litigation. Finally, it is interesting to compare the SSO effects across columns 3 and 4 (noting that ANSI is the omitted category and the baseline litigation rates are similar). Although large-firm patents are more likely to be litigated at the ITU, there is a substantial (though imprecise) increase in litigation among small-firm disclosures in the "Other" group.

The last column in Table IV adds firm size and financial variables for a subsample of 626 patents that could be matched to CompuStat.[20] These patents are concentrated among the large firms by construction, because CompuStat contains only publicly listed firms. Once again, the results suggest a negative correlation between firm size and litigation. In particular, the coefficient on the log of assets per employee is negative and significant, whereas patenting intensity (patents per R&D dollar) produces the opposite sign. When these measures are excluded, the coefficient on the log of employees becomes more negative and statistically significant.

5.2 Disclosure and Patent Litigation

Although the descriptive probits suggest that small-firm SSO patents are more likely to be litigated, this could easily reflect differences in disclosure strategy. In particular, because large firms own and disclose more patents, the marginal disclosed patent may be less important, and therefore less likely to be litigated. In this subsection we address these selection problems using patent fixed effects.

20. Wherever possible, these data are taken from the patent's grant year.

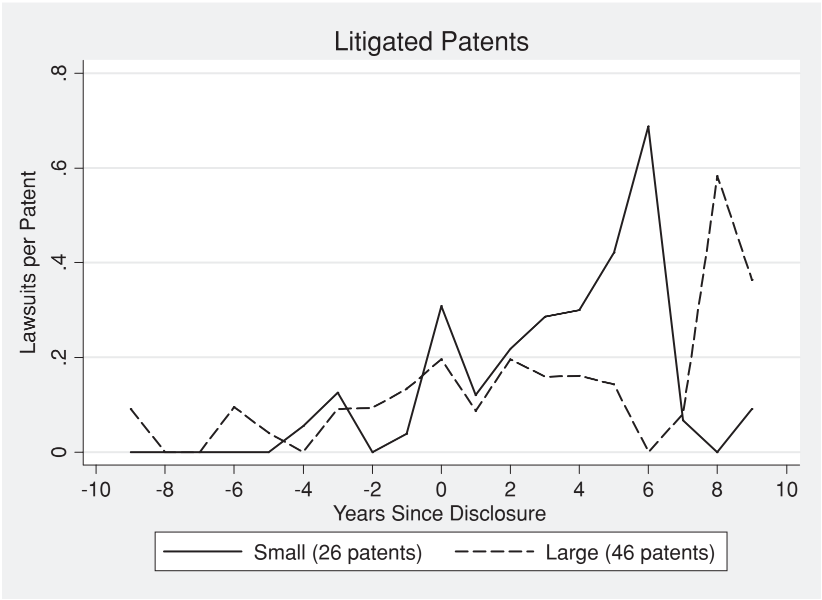


Note: Unbalanced sample. See Figures A3 and A4 for observations by patent-year.

FIGURE 2. PRE/POST-DISCLOSURE LITIGATION RATES BY FIRM SIZE (ALL PATENTS)

Figures 2 and 3 provide a graphical intuition for our identification strategy and the main results. These figures compare the litigation rate (i.e., lawsuits per patent) for patents assigned to small and large firms over a 20-year window, centered on the year of disclosure (Figure 2 shows the litigation rate for all patents; only litigated patents enter the denominator in Figure 3). In both graphs, there is a sharp increase in the litigation rate for small-firm patents in the disclosure year, followed by a substantial increase over the next 5 or 6 years. In contrast, the large-firm litigation propensity seems to increase slightly before disclosure, remains unchanged in the period immediately surrounding the disclosure year, and then tails off again. The result is a large increase in the relative litigation rate of small-firm patents in the period immediately following disclosure.

In Table V, we present a series of regression results that capture the basic pattern seen in Figures 2 and 3 while controlling for calendar effects and other sources of potentially confounding variation. Our basic specification is a Poisson quasi-maximum likelihood model with conditional fixed effects (Wooldridge, 1999). Like the more common



Note: Unbalanced sample. See Figures A3 and A4 for observations by patent-year.

FIGURE 3. PRE/POST-DISCLOSURE LITIGATION RATES BY FIRM SIZE (LITIGATED PATENTS)

negative binomial fixed-effects model, the coefficients have an elasticity interpretation.[21] Because the conditional fixed-effects specification discards all unlitigated patents, the results in Table V are based on a relatively small sample of 72 disclosed and litigated patents.[22] However, we obtain similar results using OLS fixed-effects models that retain all unlitigated patents.

The first two columns in Table V tell the main story. For the 26 patents assigned to small firms that were litigated, there is a substantial increase in litigation following disclosure. For the 46 litigated patents assigned to large firms, there is a large but statistically insignificant decline in the litigation rate following disclosure. Each of these models

21. The Poisson estimator is arguably preferable to a negative binomial because it is consistent under a weaker set of assumptions, robust to arbitrary forms of heteroskedasticity and does not suffer from the fixed-effects serial correlation issues highlighted by Betrand et al. (2004).

22. Figures A3 and A4 in the Appendix plots the number of large- and small-firm observations by age relative to disclosure.

Table V.
Poisson Models of SSO Disclosure and Patent Litigation

Unit of Observation = Patent Year
DV = Count of New Lawsuits

Sample	Small Firms	Large Firms	All Firms	All Firms	All Firms	All Firms
Specification	*Poisson*	*Poisson*	*Poisson*	*Poisson*	*Poisson*	*Poisson*
Disclosure	1.570***	−0.831	−0.278	−0.276	−0.693	−0.906
	(0.58)	(0.59)	(0.52)	(0.52)	(0.58)	(0.66)
Small firm × disclosure			1.216*	1.310	2.478**	2.189**
			(0.73)	(0.94)	(0.99)	(0.98)
Small × age × predisc.				0.0395	−0.114	
				(0.19)	(0.23)	
Small × age × post-disc.					−0.205**	
					(0.093)	
Small firm× age						0.0760
						(0.37)
Age squared						−0.00652
						(0.0053)
Small × age squared						−0.0276
						(0.028)
log (cites, $t-1$)						−0.299
						(0.22)
Year effects (chi-square, 4 *df*)	7.52	8.23*	12.54**	12.47**	17.75***	13.16**
Patent effects	Y	Y	Y	Y	Y	Y
Patents	26	46	72	72	72	72
Observations	317	588	905	905	905	905
Log likelihood/*N*	−0.334	−0.311	−0.202	−0.328	−0.328	−0.322

Notes: This table presents coefficients and robust standard errors (clustered by disclosure) from Poisson quasi-maximum likelihood regressions with patent (conditional) fixed effects. These models exclude all unlitigated patents. All specifications contain a fourth-order polynomial in calendar years to control for common unobserved time trends.
*10% significance; **5% significance; ***1% significance (robust SEs clustered on disclosures).

includes a fourth-order polynomial in time (i.e., calendar year minus 1995) to control for underlying trends in the legal environment.[23]

The third column in Table V pools the small- and large-firm patents to estimate the model specified in equation (2), where disclosure is interacted with a small-firm dummy variable. The coefficient on this interaction term is large but statistically significant only at the 90% confidence interval. This result suggests that the calendar-year effects differ in the large- and small-firm subsamples (because the coefficient on this interaction term in a fully interacted model would equal the sum of the disclosure coefficients in the first two columns). Because the calendar-year polynomial also captures correlations between patent age and the litigation rate—which could easily differ for large and small firms—we consider several models that provide some additional flexibility in these age effects.

In the fourth column of Table V, we test for a difference in the predisclosure litigation trend. Specifically, we interact a time trend (age) with the small-firm dummy and an indicator for the predisclosure period. The coefficient on this variable is small and not statistically significant, indicating no difference in predisclosure litigation trends between the large and small firms. This result is reassuring evidence that differences in the postdisclosure litigation rate are driven by the standards process, rather than preexisting differences in the underlying trends.

The next column in Table V includes a differential time trend in both the pre- and post-disclosure periods. Although we continue to find no difference in the predisclosure trends, the postdisclosure trend difference is both negative and statistically significant. Moreover, there is a sharp increase in the disclosure effect. The explanation for this effect can be seen in Figures 2 and 3. Although there is a sharp increase in small-firm litigation rates during a 5- to 6-year period following disclosure, the relative increase in litigation disappears by years 7 and 8. This leveling may reflect technology life cycles, reversion to the mean, firm-level age processes, or negative state dependence (e.g., litigation reveals information about patent quality that leads to more negotiated settlements). Whatever the cause, the result is a "bump" in the relative litigation rate of small-firm patents immediately after disclosure. In our regressions, this bump in the litigation rate is captured

23. Although we would have preferred a complete set of calendar-year dummies, the presence of several years with no litigation makes this approach infeasible. We experimented with various ways of aggregating calendar-year dummies and found that they produce the same results.

by a large positive coefficient on the interaction between the "small-firm" and "disclosure" dummy variables and a negative coefficient on the postdisclosure interaction between firm size and patent age.

The last column in Table V shows that it is also possible to generate the small-firm "bump" described above by including a set of interactions between the small-firm indicator variable and a quadratic in patent age. Once again, there is a large statistically significant coefficient on the interaction term corresponding to the sum $(\alpha + \delta)$ in equation (5).

In Table VI we consider a variety of robustness checks. One possible concern with our analysis is sensitivity to outliers; particularly because the dependent variable is a litigation count that equals zero for most patents in most years. We address this question by estimating a series of fixed-effects logit models, in which the dependent variable is a dummy variable that equals one in years when a new lawsuit is filed. The results are presented in the first four columns of Table VI. Interestingly, we find that the disclosure effect for large-firm patents is negative and statistically significant in this specification. However, there is no change in our main results.

The fifth column in Table VI uses a count of defendants (rather than lawsuits) as the dependent variable. Although this variable might pick up differences in the propensity to file multiparty lawsuits, it does not produce a meaningful change in our main results. Finally, the last column in Table VI presents estimates from a negative binomial regression.[24] Not surprisingly, the point estimates are quite similar to the Poisson coefficients.

To summarize, we consider a variety of different models and find a persistent increase in the relative litigation rate of small-firm patents following disclosure. We obtain even stronger results in less conservative models (firm fixed-effects and pooled cross-sectional regressions) that are not reported here. These findings suggest that large and small firms use their standards-related IP differently. In the next subsection we ask whether these differences in IP strategy are driven by variation in demand or by a divergence of litigation incentives.

5.3 Citation Models

The models in Tables V and VI measure the joint impact of demand and litigation incentives, as described in Section 3. In this subsection, we use patent citations as a proxy for demand, and argue that our previous

24. Because we could not cluster on disclosure, standard errors for this model may be underestimated.

Table VI.
Robustness of the Disclosure Results

	Unit of Observation = Patent Year DV = New Lawsuit (Dummy) or Defendants (Count)					
Sample	Small Firms	Large Firms	All Firms	All Firms	All Firms	All Firms
Dependant Variable	*Dummy*	*Dummy*	*Dummy*	*Dummy*	*Count*	*Count*
Specification	*Logistic*	*Logistic*	*Logistic*	*Logistic*	*Poisson*	*Neg Bin*
Disclosure	2.029***	−0.966**	−0.278	−0.803*	−0.682	−0.540
	(0.67)	(0.48)	(0.44)	(0.47)	(0.63)	(0.40)
Small firm × disclosure			1.389*	3.214***	2.902***	2.184***
			(0.80)	(0.97)	(1.09)	(0.61)
Small × age × predisc.			0.051	−0.149	−0.127	−0.159
			(0.18)	(0.20)	(0.24)	(0.17)
Small × age × postdisc.				−0.309***	−0.259**	−0.227***
				(0.091)	(0.11)	(0.071)
Year effects (chi-square, 4 *df*)	11.60**	7.14	11.14**	12.62**	11.30**	11.86**
Patent effects	Y	Y	Y	Y	Y	Y
Patents	26	46	72	72	72	72
Observations	317	588	905	905	905	905
Log likelihood/*N*	−0.227	−0.231	−0.239	−0.231	−0.412	−0.306

Notes: This table presents models similar to Table V with variations in the specification and dependent variable. These models exclude all unlitigated patents. All specifications contain a fourth-order polynomial in calendar years to control for common unobserved time trends. Note that it is not possible to cluster the standard errors by disclosure for the fixed-effects logistic or negative binomial model.
*10% significance; ** 5% significance; *** 1% significance.

Table VII.
Poisson Models of SSO Disclosure and Patent Citations

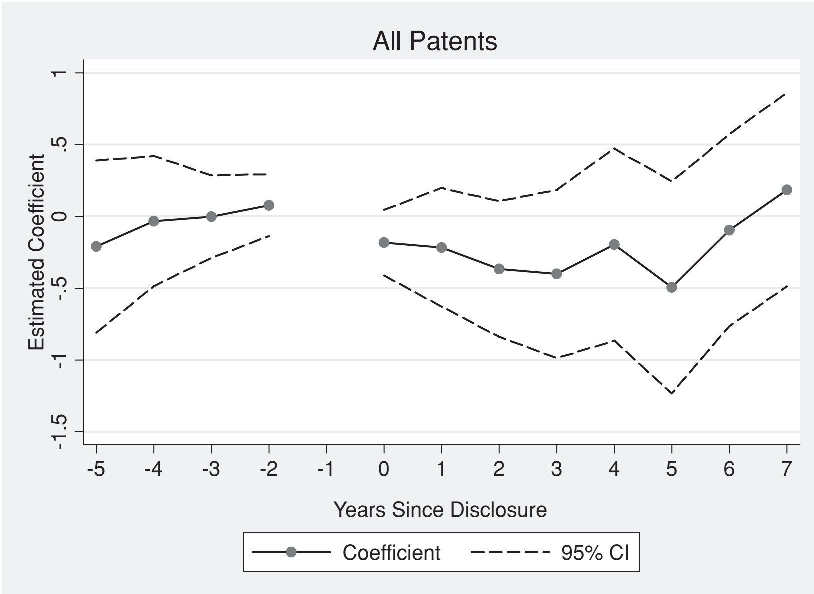
Unit of Observation = Patent Year DV = Forward Citation Count				
Sample	*Litigated SSO Patents*	*Litigated SSO Patents*	*All SSO Patents*	*All SSO Patents*
Small firm × disclosure	−0.0278	−0.0420	−0.278	−0.363*
	(0.32)	(0.29)	(0.23)	(0.22)
Litigation dummy		−0.310		−0.00350
		(0.20)		(0.17)
Litigation × small firm		0.0489		0.425*
		(0.24)		(0.25)
Patent fixed effects	Y	Y	Y	Y
Age-since-disc. effects	Y	Y	Y	Y
Patents	70	70	803	803
N (patent years)	892	892	8,994	8,994

Notes: This table presents coefficients and robust standard errors (clustered by disclosure) from Poisson quasi-maximum likelihood regressions with patent (conditional) fixed effects. These models exclude all uncited patents. All specifications contain a full set of age-since-disclosure effects.
* 10% significance; ** 5% significance; *** 1% significance. Robust standard errors.

estimates actually provide a lower bound on the divergence in litigation incentives associated with the formal standards process.

We estimate (2) on a sample of SSO patents, focusing on a 13-year window that includes the 5 years prior to disclosure, along with 7 postdisclosure years. We also include a complete set of age-relative-to-disclosure dummies (omitting the year prior to disclosure), and a set of nonlinear age (since grant) variables to capture well-documented nonlinearities in the citation age profile. In this specification, changes in the counterfactual citation rate of a disclosed patent are estimated by changes in the citation rate of undisclosed SSO patents with the same age. Once again, we use a Poisson specification with individual-patent (conditional) fixed effects and robust standard errors clustered on disclosures.

We are primarily interested in measuring the difference between large- and small-firm citation rates following disclosure. We do this in two ways: first by including a simple interaction between a *Small Firm* and *Disclosure* dummy variable, which we report in Table VII; and second, by including a complete set of age-relative-to-disclosure interactions for the small-firm patents, which we present in Figures 4 and 5.



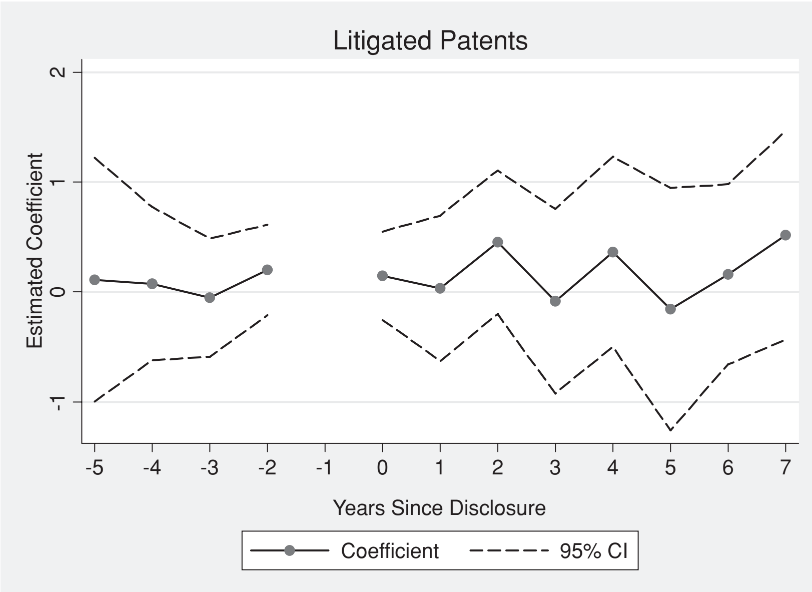
Note: Estimation sample is identical to Table VII column 3. See text for model details.

FIGURE 4. CITATION RATE DIFFERENCES (SMALL FIRM INTERACTIONS, ALL PATENTS)

The first column in Table VII shows the coefficient for the small-firm disclosure interaction in the sample of litigated patents (i.e., the sample used to generate our main results). Although the point estimate suggests that small-firm patent citations drop by 3% relative to those of large firms following disclosure, the upper bound of the 95% confidence interval corresponds to a 60% increase. In the second column we add a postlitigation dummy and its interaction with the small-firm indicator. The results are not meaningfully different. The third and fourth columns in Table VII repeat this exercise for the full sample of disclosed patents. For this broader sample, the point estimates indicate a 30% decline in the relative citation rate of small-firm patents after disclosure, with the upper bound corresponding to an 18% increase.[25]

Figures 4 and 5 present a similar set of results in graphical form. In particular, we estimated the model used in Table VII, including a complete set of interactions between the *Small Firm* dummy and the *Age*

25. The unreported baseline age coefficients in these regressions are very similar to the results in Rysman and Simcoe (2008); there is a 15% to 20% increase in the citation rate in the year before disclosure, followed by an upward trend that adds another 20% over the next 3 to 5 years.



Note: Estimation sample is identical to Table VII column 1. See text for model details.

FIGURE 5. CITATION RATE DIFFERENCES (SMALL FIRM INTERACTIONS, LITIGATED PATENTS)

(relative to disclosure) coefficients—again omitting the dummy for the year before disclosure. This approach allows for a very flexible citation response to disclosure in both the small- and large-firm subsamples. We then plotted the coefficients on these interaction terms (along with a 95% confidence interval). Figure 4 shows the results for the full set of disclosed patents. We observe a distinct small negative break just before disclosure. In the second panel, which includes only litigated patents, there is neither an apparent trend, nor a break in the relative citation rates.

These results provide some assurance that our main findings are not driven by heterogeneity in the demand shock produced by standardization, or by "publicity effects" whereby litigation is tied to a larger change in the industry's general awareness of small-firm IP. In particular, the negative point estimates obtained for the full sample of disclosed patents suggest that the main results in Table V provide a lower bound on the divergence in litigation incentives (α). However, we offer two caveats. First, citations are a crude proxy for the level of infringement. And second, although the point estimates of δ in these citation models are close to zero, we cannot typically reject the null hypothesis of a moderate positive shock to the relative demand for small-firm IP, especially in the small sample of litigated patents.

5.4 Litigation Patterns

As a last stop in our exploration of SSO patent litigation, we use data from the Federal Judicial Center (FJC) to compare trial outcomes for SSO patents to those in a matched control sample. We formed the control sample by selecting a random patent case filed in the same court within 10 days of each SSO patent suit filing (with replacement). However, because the FJC data are collected at case termination (whereas the Derwent data are reported at filing), there is a substantial truncation problem in the matching process. So, for this exercise, we reintroduced the ETSI patents, and were able to match 102 out of 151 total lawsuits.

Table VIII shows a series of univariate tests for differences in litigation outcomes between the SSO and control samples. In general, the results show the processes to be quite similar. The average case duration—from filing to termination—is 61 days (14%) shorter for the SSO patents, but that difference is not statistically significant. The share of cases that terminate during *discovery* (the initial phase of the suit in which parties are permitted to collect information, including documentary and depositional) is 31% for SSO patents and 36% in the control (non-SSO) sample, but again this difference is not statistically significant.[26] We do find that SSO patent suits are more likely (significant at the 5% level) to end with a settlement order (i.e., an order requested and agreed upon by both parties). This difference may indicate that SSO patent litigants desire added institutional support for their settlement agreements.

We observe too that lawsuits in the SSO and control sample have an identical likelihood of reaching trial (4.9%). However, we find a large disparity in plaintiff win rates. In particular, plaintiffs win 54% of the SSO patent cases compared to 24% in the control sample (significant at the 10% level). The SSO cases appear less likely to end in a defendant victory or a shared victory.[27] However, it is difficult to interpret these findings because the patent holder might be either

26. Note that the outcome shares are not intended to sum to unity (for instance, the "reached trial" share is a subset of the "final verdict" share of cases).

27. A shared victory may occur, for instance, when a defendant is found to be infringing some of the patent claims, but the plaintiff's patent is found to have other claims that are invalid.

Table VIII.
Litigation Outcomes

	SSO Lawsuits	Non-SSO Lawsuits	Difference	p-value
Duration: Filing to termination (days)	449.99	511.52	−61.53	0.34
Outcome shares ($N = 102$)				
Terminated during discovery	0.314	0.363	−0.049	0.46
Settlement order	0.431	0.294	0.137	0.05
Reached trial	0.049	0.049	0.000	1.00
Final verdict (after trial or motion)	0.127	0.167	−0.040	0.43
Final verdict ($N = 13$ SSO, 17 non-SSO)				
Plaintiff victory	0.538	0.235	0.303	0.09
Defendant victory	0.231	0.412	−0.181	0.31
Shared victory	0.231	0.353	−0.122	0.49

Note: This table provides descriptive statistics for outcomes of SSO patent lawsuits and a matched sample of non-SSO patent lawsuits drawn from the same court within 10 days of the SSO lawsuit filing date.

a plaintiff or defendant in these cases (depending on whether it is an infringement or validity suit). Overall, we interpret the summary statistics in Table VIII as evidence that SSO patent lawsuits are not particularly different from other types of patent litigation.

6. Conclusion

This paper examines the IP strategy of firms that participate in the formal standards process. Patents disclosed to SSOs have relatively high litigation rates in general. However, there is a divergence in litigation rates following disclosure to the SSO: patents assigned to small vertically specialized entrepreneurs are litigated more often, whereas there is no change (or perhaps even a slight decline) for patents assigned to large incumbents. Although this result is identified by the timing of lawsuits in a small sample of 72 patents that were both disclosed to an SSO and litigated in US courts, the size of the effect is striking. Finally, although citations to SSO patents increase at time of disclosure, there is no change in the relative citation rate of patents assigned to large versus small firms.

These findings suggest that the standard setting process leads to a divergence in licensing and litigation strategies for standards-related IP, as opposed to a shift in relative demand. Our explanation for this change emphasizes large firms' presence in complementary markets, which allows them to internalize the benefits of *ex post* openness (i.e., low-cost licensing), whereas small vertically specialized companies face a more difficult trade-off between opening a standard to create value and closing it to capture rents.

Although these results shed some light on IP strategy and the emergence of open platforms, they do not have clear welfare implications. On the one hand, our findings suggest that patents are truly important to entrepreneurs, and thus play an important role in promoting the division of innovative labor. At the same time, they suggest that large firms are often more willing to sacrifice some of the value in their IP to produce a more "open" technology input market. Although the trade-off between the dynamic benefits and static costs of IP protection is well known, our results suggest that large and small firms will have different views about the optimal policy; particularly in cases where they share a common technology platform.

Our results also highlight the challenging nature of setting an SSO's IP policies. It is perhaps ironic that we find very high litigation rates among disclosed patents, because one goal of SSOs is to promote openness in the form of widespread access to standardized components. But without a clear definition of "reasonable" royalties or a mechanism for patent holders to make *ex ante* pricing commitments, litigation may be the price of success: widespread implementation leads directly to infringement, and the sunk costs of technology development give patent holders a strong incentive to bargain hard *ex post*. A few SSOs now encourage firms to state an *ex ante* royalty cap as part of their IP disclosure. It will be interesting to see whether firms use this option, or if it becomes required, whether some choose to opt out of the formal standards process.

Finally, our results raise a number of questions about the organization and dynamics of open platform development that call for further research. In particular, what strategies can platform leaders adopt to encourage entry by entrepreneurs (who may be better poised to provide critical complements) while preserving the benefits of platform openness? Will competition between SSOs working on similar problems lead to a more efficient set of IP policies, or will it produce technical fragmentation and coordination failures? How do SSOs compare to patent pools (Lerner et al., 2003) as a mechanism for contracting around the problem of complementary upstream monopolists? We are hopeful that the increasing availability of data on patents and the formal standards process will lead to further empirical work on these issues.

Appendix

Table AI. Short SSO Descriptions

Acronym	Description
ANSI	American National Standards Institute: The umbrella organization that certifies US standards developing organizations (SDO).
ATIS	Alliance for Telecommunications Industry Solutions: ANSI-accredited US SDO that develops telecommunication standards.
ATM Forum	Asynchronous Transfer Mode Forum: Consortium promoting a high-speed Internet switching technology.
ETSI	European Telecommunications Standards Institute: Develops cellular telephony standards, including GSM and CDMA protocols used widely in Europe.
IEEE	Institute of Electrical and Electronic Engineers: Engineering trade groups that also sponsors ANSI-accredited standards activities for a variety of information technologies, including the 802.x series of computer networking standards.
IETF	Internet Engineering Task Force: Large independent SSO that develops core Internet protocols for applications, routing, and transport.
ITU	International Telecommunication Union: The primary international organization for voluntary governance and standardization of the public switched telephone network.
TIA	Telecommunications Industry Association: ANSI-accredited US SDO that develops telecommunications industry standards, particularly for wireless/cellular applications.
DSL Forum	Digital Subscriber Line Forum: A consortium for high-speed modem standards.
ISO	International Organization for Standards: Large umbrella organization for international standards development.
ISO/IEC JTC1	Joint committee of ISO and the International Electrotechnical Commission (IEC) where all ISO-sponsored work on information technology standards occurs.
MSSF	Multiservice Switching Forum. Consortium for “next generation” networking standards.
OMA	Open Mobile Alliance. Consortia to promote mobile telephone application interoperability.
VESA	Video Electronics Standards Organization: Promotes industry-wide interface standards designed for the PC, workstation, and other computing environments.

Table AII. Technology Classification of Disclosed Patents

Technology Category	SSO Patents
Chemical	3
Communications	426
Computers (HW/SW and other)	377
Drugs and medical	4
Electrical and electronic	98
Mechanical other	34
Total patents	942

Note: This table shows the distribution of patents in our sample over a set of broad technology areas, whose definitions are based on the US Patent and Trademark Office's technology classification scheme. These patents primarily cover information and communications technologies.

Table AIII. Common Firms

Top 10 Large Firms	Pat Discs	Employees*	Top 10 Small Firms	Pat Discs	Employees*
Ericsson	276	71,981	Interdigital Technology	170	185
Nokia	181	44,780	Snaptrack	33	
Qualcomm	172	5,949	Int'l Mobile Machines	30	87
Motorola	105	87,656	Tecsec, Inc.	12	
AT&T	77	108,953	Hybrid Networks	11	65
IBM	66	312,643	Verisity Design	10	190
Toshiba	46	147,217	Stac Electronics	9	
Alcatel	45	143,744	Netergy Networks	8	113
Apple Computer	41	10,477	SCS Mobilecom	5	
Philips	41	299,382	Digital Theater Systems	5	

Top Plaintiffs	Lawsuits	Top Defendants	Lawsuits
Elonex IP Holdings	13	Interdigital Technology	5
US Philips	7	Acer Inc	2
RSA Data Security	5	Broadcom Corp	2
Lucent Technologies	5	Ciena Corp	2
Qualcomm Inc.	5	Compal Electronics	2
Interdigital Technology	3	Dallas Semiconductor	2
Compression Labs	3	Dell Computer	2
Agere Systems	3	Ericsson, Gateway, Microsoft, Motorola, Novell	2

Note: This table provides the names of the top 10 large and small firms in our data set (ranked by the number of disclosed patents). It also lists the most frequent plaintiffs and defendants out of 206 total lawsuits.

Table AIV. Variable Definitions and Summary Statistics

	N	Mean	SD	Min	Max	Definition
Small firm	949	0.21	0.40	0	1	Dummy: private firm or public company with less than 500 employees (in year of patent grant).
US firm	949	0.70	0.46	0	1	Dummy: parent firm located in the United States.
Disclosure age	949	3.50	3.87	–5	33	Years between patent grant and first disclosure.
Disclosure year	949	1,999.23	5.03	1974	2006	Calendar year of first disclosure.
Continuation dummy	949	0.27	0.45	0	1	Dummy: patent application filed as a continuation or continuation-in-part.
Claims	949	22.24	17.90	0	199	Count of individual claims contained in the patent.
Forward cites	949	33.88	45.11	0	500	Cumulative citations received from other US patents.
Backward cites	949	10.75	14.97	0	198	Count of citations made to other US patents.
Nonpatent cites	949	9.07	31.83	0	565	Count of citations made to nonpatent materials (e.g., scientific papers).
Employees (000s)	635	101	111	0	430	Compustat employees of parent firm in patent grant year.
Assets ($M)	635	30,234	33,534	4	164,863	Compustat assets of parent firm in grant year ($millions).
Patents	892	2,587	3,689	1	23,038	Five-year stock of granted patents.
Generality	807	0.51	0.33	0	1	One minus a Herfindahl measure based on the 3-digit US patent classification of citing patents.

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December 12, 1995

Ms. Cynthia Fuller
ASC X9 Secretariat
American Bankers Association
1120 Connecticut Avenue, N.W.
Washington, DC 20036

Re: United States Patent 4,107,653

Dear Ms. Fuller:

This is to advise you that Unisys Corporation is willing to grant to any requesting party a non-exclusive license under the claims of Unisys U.S. Patent No. 4,107,653, the infringement of which is recommended to properly make, use or sell Magnetic Signal Level Measuring Instruments used for the manufacture and/or calibration of secondary reference documents which are used to carry the signal level reference for the calibration of production signal level measuring equipment as referenced in ANS X9.27 - 1995, when approved and published. Please forward a copy of this letter to ANSI for their use.

Each grant will be under separate agreement, at a royalty rate of one percent (1%) applied to the net selling price or fair market value of the equipment sold. Also, each requesting party must be willing to grant Unisys Corporation an option to a license of the same scope on similar terms, conditions and charges under the requesting party's patents.

Upon adoption of the ANSI standard, parties who wish a license should contact my office.

Sincerely,

Mark T. Starr

Mark T. Starr

MTS/cdt

FIGURE A1. SAMPLE DISCLOSURE LETTER 1

Heather Benko

From: smontgomery@tiaonline.org
Sent: Wednesday, January 12, 2005 4:18 PM
To: hbenko@ansi.org
Cc: smontgomery@tiaonline.org
Subject: IPR/Patent Holder Statement

Document Information

Reference Doc. No.	PN-3-3972-UGRV.SF1 (refer to Project Number, Standards Proposal Number or title--one form per document. Note, may fill one statement for a document with multi-parts.)
Publication ID	TIA-733-A [SF1]
Document Title	Software Distribution for TIA-733-A - High Rate Speech Service Option17 for Wideband Spread Spectrum"

General Information

Your Name	Michael Wang
Your Title	
Company	Nortel Networks
Company Phone	972-684-2848
IPR Contact	Michelle Lee
Address1	Mail Stop 036NO151
Address2	8200 DIXIE ROAD SUITE 100
City	BRAMPTON
State	ONTARIO
Zip	L6T 5P6
Country	CANADA
Phone Number	905-863-1148"
Fax Number	
Email	mleelaw@nortelnetworks.com

Nortel Networks states:

2b. A license under any Essential Patent(s) or published pending patent application(s) held by the undersigned company will be made available under reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants only and to the extent necessary for the practice of the TIA Publication.

3a. The commitment to license above selected will be made available only on a reciprocal basis. The term 'reciprocal' means that the licensee is willing to license the licensor in compliance with either (2a) or (2b) above as respects the practice of the TIA Publication.

FIGURE A2. SAMPLE DISCLOSURE LETTER 2 (BLANKET DISCLOSURE)

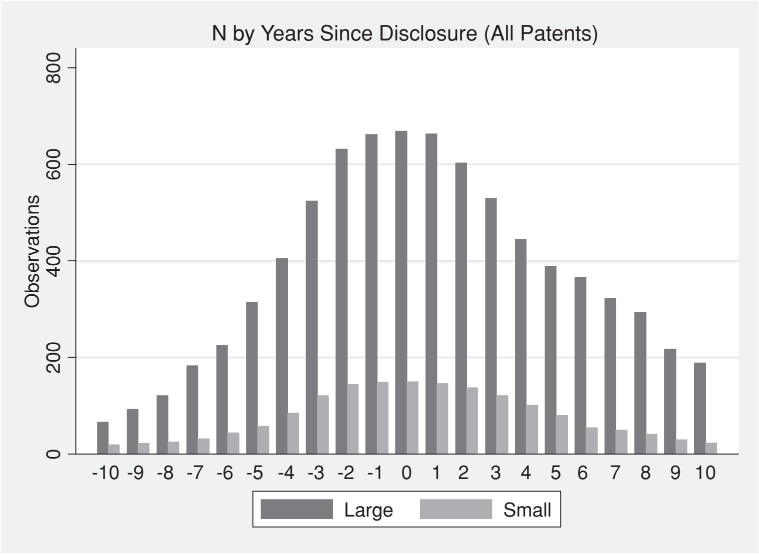

FIGURE A3. OBSERVATIONS BY AGE AND FIRM SIZE (ALL PATENTS)

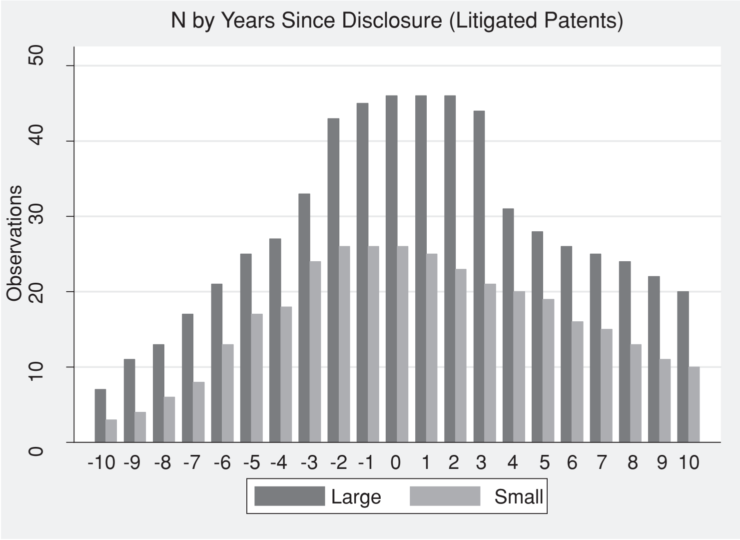

FIGURE A4. OBSERVATIONS BY AGE AND FIRM SIZE (LITIGATED PATENTS)

References

American Intellectual Property Law Association, 2007, *Report of the Economic Survey*.

Arora, A., A. Fosfuri, and A. Gambardella, 2004, *Markets for Technology: The Economics of Innovation and Corporate Strategy*, Cambridge, MA: The MIT Press.

Arthur, W.B., 1989, "Competing Technologies, Increasing Returns, and Lock-In by Historical Events," *The Economic Journal*, 99, 116–131.

Baldwin, C. and K. Clark, 2000, *Design Rules: The Power of Modularity*, Cambridge, MA: The MIT Press.

Bessen, J. and M. Meurer, 2006, "Patent Litigation with Endogenous Disputes," *American Economic Review*, 96(2), 77–81.

Bowman, W., 1957, "Tying Arrangements and the Leverage Problem," *Yale Law Journal*, 67(1), 19–36.

Bresnahan, T. and S. Greenstein, 1999, "Technological Competition and the Structure of the Computer Industry," *Journal of Industrial Economics*, 47(1), 1–40.

Cargill, C.F., 1997, *Open Systems Standardization: A Business Approach*, Upper Saddle River, NJ: Prentice Hall PTR.

Chiao, B., J. Lerner, and J. Tirole, 2007, "The Rules of Standard Setting Organizations: An Empirical Analysis," *RAND Journal of Economics*, 38, 905–930.

David, P. and S. Greenstein, 1990, "The Economics of Compatibility Standards," *Economics of Innovation and New Technology*, 1, 3–41.

Farrell, J., 2003, "Integration and Independent Innovation on a Network," *American Economic Review*, 93(2), 420–425.

——, J. Choi, A. Edlin, S. Greentein, B. Hall, and G. Saloner, 2004, "Brief Amicus Curiae of Economics Professors and Scholars in the Matter of Rambus, Inc," U.S. Federal Trade Commission Docket No. 9302.

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

—— and G. Saloner, 1985, "Standardization, Compatibility, and Innovation," *RAND Journal of Economics*, 16(1), 70–83.

—— and C. Shapiro, 2008, "How Strong Are Weak Patents?" *American Economic Review*, 98(4), 1347–1369.

—— and P. Weiser, 2003, "Modularity, Vertical Integration and Open Access Policies: Towards a Convergence of Antitrust and Regulation in the Internet Age," *Harvard Journal of Law and Technology*, 17(1), 86–134.

FTC (Federal Trade Commission), 2003, *In the Matter of Rambus Incorporated*, U.S. Federal Trade Commission Docket 9302.

FTC (Federal Trade Commission), 2006, "Opinion of the Commission in the Matter of Rambus, Inc. (Docket No. 9302)." Available at http://www.ftc.gov/os/adjpro/d9302/060802commissionopinion.pdf (accessed June 1, 2009).

Galasso, A., 2007, "Broad Cross-License Agreements and Persuasive Patent Litigation: Theory and Evidence from the Semiconductor Industry," STICERD discussion paper EI-45.

Gawer, A. and R. Henderson, 2007, "Platform Owner Entry and Innovation in Complementary Markets: Evidence from Intel," *Journal of Economics & Management Strategy*, 16(1), 1–34.

Graham, S., 2004, "Continuation, Complementarity, and Capturing Value: Three Studies Exploring Firms' Complementary Uses of Appropriability Mechanisms in Technological Innovation," Dissertation, University of California, Berkeley, Spring 2004.

—— and D. Mowery, 2004, "Submarines in Software? Continuations in U.S. Software Patenting in the 1980s and 1990s," *Economics of Innovation and New Technology*, 13(5), 417–442.

Greenstein, S. and M. Rysman, 2007, "Coordination Costs and Standard Setting: Lessons from 56K Modems," S. Greenstein and V. Stango, eds., *Standards and Public Policy*, Cambridge, UK: Cambridge University Press, 123–159.

Hall, B.H., A. Jaffe, and M. Trajtenberg, 2001, "The NBER Patent Citation Data File: Lessons, Insights, and Methodological Tools," NBER Working Paper 8498.

——, ——, and ——, 2005, "Market Value and Patent Citations," *RAND Journal of Economics*, 36(1), 16–38.

—— and R. Ziedonis, 2001, "The Patent Paradox Revisited: An Empirical Study of Patenting in the US Semiconductor Industry, 1979–1995," *RAND Journal of Economics*, 32(1), 101–128.

Harhoff, D., F. Narin, F.M. Scherer, and K. Vopel, 1999, "Citation Frequency and the Value of Patented Inventions," *Review of Economics and Statistics*, 81(3), 511–515.

Heckman, J. and V. Hotz, 1989, "Choosing Among Alternative Non-Experimental Methods for Evaluating the Impact of Social Programs: The Case of Manpower Training," *Journal of the American Statistical Association*, 65(2), 161–194.

Henderson, R., 2003, "Ember Corp: Developing the Next Ubiquitous Network Standard" Harvard Business School Case 9–703–448.

IBM, 2007, "An Open E-Business Foundation," Technical report. Available at www.ibm.com/developerworks/cn/websphere/download/pdf/openappframework.pdf. (accessed June 1, 2009).

Jaffe, A., M. Trajtenberg, and R. Henderson, 1993, "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations," *The Quarterly Journal of Economics*, 108(3), 577–598.

Lanjouw, J. and J. Lerner, 1998, "The Enforcement of Intellectual Property Rights: A Survey of the Empirical Literature," *The Annales d'Economie et de Statistique*, 49/50, 223–246.

—— and M. Schankerman, 2001, "Characteristics of Patent Litigation: A Window on Competition," *RAND Journal of Economics*, 32(1), 129–151.

—— and ——, 2003, "Enforcement of Patent Rights in the United States," Patents in the Knowledge-based Economy: Proceedings of the Science, Technology and Economic Policy Board. W. Cohen and S. Merrill.

—— and ——, 2004, "Protecting Intellectual Property Rights: Are Small Firms Handicapped?" *Journal of Law and Economics*, 48(1), 45–74.

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

Lerner, J., 2007, "Trolls on State Street?" mimeo. Available at http://www.people.hbs.edu/jlerner/Trolls.pdf

——, M. Strojwas, and J. Tirole, 2003, "Cooperative Marketing Agreements Between Competitors: Evidence from Patent Pools," Harvard NOM Working Paper No. 03-25.

Mackie-Mason J. and J. Netz, 2007, "Manipulating Interface Standards as an Anticompetitive Strategy," in S. Greenstein and V. Stango, eds., *Standards and Public Policy*, Cambridge, UK: Cambridge University Press, 231–259.

Matutes, C. and P. Regibeau, 1988, "Mix and Match: Product Compatibility Without Network Externalities," *RAND Journal of Economics*, 19(2), 219–234.

Majoras, D., 2005, "Recognizing the Procompetitive Potential of Royalty Discussions in Standard Setting," *Standardization and the Law: Developing the Golden Mean for Global Trade*. Available at http://www.ftc.gov/speeches/majoras/050923stanford.pdf (accessed June 1, 2009).

Meurer, M., 1989, "The Settlement of Patent Litigation," *RAND Journal of Economics*, 20, 77–91.

Nalebuff, B., 1987, "Credible Pretrial Negotiation," *RAND Journal of Economics*, 18, 198–210.

Priest, G. and B. Klein, 1984, "The Selection of Disputes for Litigation," *Journal of Legal Studies*, 8, 1–56.

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

Schmidt, K., 2006, "Licensing Complementary Patents and Vertical Integration," Working Paper, University of Munich.

Seigelman, P. and J. Waldfogel, 1999, "Toward a Taxonomy of Disputes: New Evidence Through the Prism of the Priest/Klein Model," *Journal of Legal Studies*, 28(1), 101–130.

Simcoe T., 2006, "Explaining the Increase in Intellectual Property Disclosure," S. Bolin, ed. *The Standards Edge,* Vol. 3. Chelsea, MI: The Bolin Group, 153–162.

Simcoe, T., S. Graham, and M. Feldman, 2008, "Competing on Standards? Entrepreneurship, Intellectual Property and the Platform Paradox," NBER Working Paper 13632.

Spier, K., 1992, "The Dynamics of Pre-Trial Negotiation," *Review of Economic Studies*, 59(1), 93–108.

Thomson, G., 1954, "Intercompany Technical Standardization in the Early American Automobile Industry," *Journal of Economic History*, 14(1), 1–20.

Wooldridge, J. M., 1999, Distribution-Free Estimation of Some Nonlinear Panel Data Models, *Journal of Econometrics*, 90(1), 77–97.

Yildiz, M., 2004, "Waiting to Persuade," *Quarterly Journal of Economics*, 119(1), 223–249.