Declared essential patents

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Abstract

Firms often collaborate to produce inter-operability standards so that independently designed products can work together. When this process takes place in a Standard Setting Organization (SSO), participants are typically required to disclose any intellectual property rights (IP) that would be infringed by a proposed standard, and asked for a commitment to license their essential IP on fair, reasonable and non-discriminatory terms. This paper describes the IP disclosure process, and provides an overview of a publicly available IP disclosure dataset that the authors have compiled using the archives of thirteen major SSOs. We use these new data to illustrate several major trends in standards development, and to show how "declared essential" patents differ from randomly matched patents from the same vintage and technology classes. Declared essential patents receive more citations and are much more likely to be litigated than a typical patent from the same technology class. However, these associations vary across SSOs, and are related to the terms of the licensing commitment.

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

JEL Codes: L15, O31, O34, K41.

1 Introduction

Firms often collaborate to produce inter-operability standards so that independently designed products can work together. Compatibility standards are especially important in the Information and Communications Technology (ICT) sector, where they help launch new markets and promote major upgrades to existing platforms. However, new standards may fail to produce these catalytic effects if users fear that 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.

This paper uses data from the publicly available intellectual property disclosure records of thirteen SSOs to characterize the IP disclosure process, describe several broad trends in ICT standard setting, and explore the unique characteristics of patents that are "declared essential" to industry standards. The authors are placing these data into the public domain to promote research on standards and intellectual property. Thus, a main goal of this paper is to simply describe the data set, which combines information from 4,970 declarations listing 6,761 unique US and European patent publications, primarily covering digital information and communication technologies.[1] We use these new data to document a number of stylized facts about the disclosure and litigation of declared essential patents. Some of these facts may be relevant to ongoing policy discussions. However, since they often admit several interpretations, our primary aim is to provide new measurements and enumerate possible explanations, rather than to adjudicate between theories or use our findings to propose new policy measures.

We begin the paper by describing how differences in SSOs' IPR disclosure policies influence the contents of a typical declaration. Some SSOs require firms to indicate the specific patent(s) that would be infringed by implementing a proposed standard, while others allow general disclosure statements (so-called "blankets") that do not identify specific patents or pending applications. These rules are naturally correlated with number of declared essential patents in our data. We also describe the types of licensing commitments allowed at different SSOs. While the overwhelming majority of declarations contain a "Fair Reasonable and Non-Discriminatory" or FRAND licensing commitment, our data reveal many variations on this common theme, as well as a significant number of royalty-free commitments.

After describing how IPR policies are linked to variation in the contents of a typical disclosure, we examine two broad longitudinal trends. The first trend is a remarkable growth in the

[1] These data are available for download at www.ssopatents.org.

total amount of IP declared to our sample of thirteen SSOs. We argue that the increase in total IP declarations over time reflects a combination of factors, including growth in patenting; increased antitrust enforcement; increased demand for standards (driven by the growth of shared platforms such as the Internet and cellular telephony); and a strategic "race" to own essential patents. The second broad trend we examine is vertical or business model specialization. We find that roughly one-third of the declared essential IPR in our data comes from "upstream" technology developers (e.g. patent holding companies, component suppliers and research institutes). Most of the remainder comes from firms with an integrated or downstream business model (e.g. equipment vendors and systems integrators).

In the final section of the paper, we turn from broad trends in disclosure to detailed patent-level comparisons. In particular, we show how "declared essential" patents differ from a random sample of patents of the same vintage covering similar technology. We find that our sample of SSO Patents receive twice as many citations and are almost four times more likely to be asserted in litigation than a set of matched controls. The SSO Patents also contain more claims, and cite more patent and non-patent prior art than the control sample. The difference in citation and litigation rates between SSO and "control" patents varies substantially across SSOs in our dataset, and we offer some speculation on the potential causes. We also show that patents declared with a royalty-free (RF) licensing commitment receive more cites and are less likely to be litigated than those declared under the more common FRAND alternative. Finally, we examine the timing of IP declarations relative to the patent review process. While the median declaration occurs 1.5 years after a patent issues, a substantial number of disclosures occur shortly after the application is filed.

Although this is primarily a descriptive paper that aims to provide a quantitative overview of the IP disclosure process, our findings suggest several novel hypotheses and avenues for future research. First, the observed increase in IP disclosure over time, both within and between SSOs, could have several explanations. Future research might examine the relative contribution of these factors to the growth in "declared essential" IPR and the potential for interactions between them.

A second stylized fact that clearly emerges from our descriptive analysis is the relative importance of declared essential patents. Compared to an average patent with similar age and technology characteristics, patents declared to SSOs score considerably higher on a range of metrics that are correlated with value or importance. A key question for evaluating both the importance of SSOs 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). While Rysman and Simcoe (2008) use citations and the timing of IP disclosures to address this question, much more could be done. Efforts to link IP disclosures to particular standards, and to identify the dates of key technical decisions (as in Bekkers et al., 2011) promise to yield better estimates of causal effects, and to show how they vary across SSOs, markets and technologies.

Finally, many of the patterns revealed in our exploration of these data illustrate the challenges that SSOs face in crafting an effective intellectual property policy. For example, we find that rules regarding "blanket" disclosures (i.e. licensing commitments that do not list any specific patents or patent applications) have a substantial impact on the amount of IP declared. This is natural, since it will typically be cheaper, and perhaps less risky, for firms to issue a blanket FRAND commitment that does not claim specific IPRs.[2] However, blanket FRAND commitments are not very transparent, and may simply shift the costs of discovery onto other members of a standards committee or prospective licensors. Similarly, we find that a great deal of IP disclosure occurs before a patent issues, when there may still be considerable uncertainty about the scope of its claims. On the other hand, allowing later disclosure may increase the risks of patent hold-up.[3] We view these timing and specificity problems, combined with the economic importance of essential patents and the ambiguity of the FRAND commitment, as the joint causes of the high observed litigation rates of declared essential IPR. Additional work that carefully examines the circumstances behind individual lawsuits might shed light on the relative importance of these factors.

2 Intellectual Property in Voluntary Standards Development

In one of the first systematic studies of SSO intellectual property polices, 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.[4]

Disclosure rules specify how and when firms must notify other SSO participants that they own IP that may be infringed by a standard. Licensing rules specify the commitments that IP holders are requested to make regarding future licensing activities, the conditions that can

[2] As discussed below, firms often make an informal announcement about 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.

[3] 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 et al. (2007) for an overview of the extensive literature on this topic.

[4] See National Academies (2013) 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.

be attached to those commitments, and the methods of enforcement. Table 2.1 provides an overview of the IPR policies for the SSOs in our data set, and Appendix A goes into greater detail.

The first two columns in Table 2.1 show that the thirteen SSOs in our data set take different approaches to patent disclosure specificity. Every SSO in our data allows specific disclosure statements that list one or more patents (or pending patent applications) that may be infringed by a standard. Both 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 an SSO participant believes it owns relevant IP, without listing any patents or pending applications.

Blanket disclosure is clearly less costly for patent holders, who do not have to search through their patent portfolios to identify relevant patents and patent applications as the standard setting process unfolds. Thus, allowing blanket disclosure can be efficient if the main purpose of a disclosure policy is to reassure prospective implementers through licensing commitments. On the other hand, blanket disclosure can shift search costs from a patent holder (who presumably has the comparative advantage at finding their own essential patents) onto other interested parties. These other parties could include: prospective licensees who wish to evaluate the scope and value of a firm's declared essential patents; SSO participants seeking to make explicit cost-benefit comparisons of alternative technologies before a standard is chosen; and courts that might use information on firm's essential patent holdings as part of a reasonable royalty determination.

Table 2.1: Disclosure and Licensing Commitment 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.

Policies that require or encourage specific disclosure typically apply to any patent that an SSO member believes to be technically essential, meaning that it is not possible to implement the standard without infringing the patent.[5] However, SSO participants are not necessarily required to disclose commercially essential patents, which cover methods of implementation that produce 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 weak) alternative. This distinction can be complex in practice. For example, many standards have both mandatory and optional features, and specify a menu of choices for certain features, leaving the final technology choice to implementers.[6] Most SSOs regard patents that are indispensable for optional features or alternative implementations to be essential, but do not require the patent owner to indicate whether a disclosed patent is essential to a mandatory feature or (only) an optional feature or specific implementation profile.[7]

The timing of IP disclosure is another issue that quickly becomes complicated. Most SSOs encourage early disclosure of essential patents. 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, there is a "call for patents" at the start of each technical committee meeting, and 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 essential patents for a specific standard or draft. Although patent disclosures and licensing commitments are conceptually distinct, most SSO participants offer a licensing commitment along with the formal disclosure. Our data come from these letters, which we henceforth refer to as "declarations."

Figure 2 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

[5]A patent is considered essential if it is infringed by *any* (as opposed to *every*) compliant implementation. 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.

[6]These technology menus that reduce scope for differentiation without mandating a specific technology choice are called *implementation profiles*. One well-know example is the IEEE 802.11 (Wi-Fi) standard, which specifies three possible air interfaces, though only one on them is widely deployed.

[7]None of the SSOs in our data require participants to indicate whether their IPR covers mandatory features or (only) optional features of a standard.

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 trial. 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). 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. Patent applications are not immediately published for third-party review, and most SSOs have no explicit rule on the timing of formal disclosure. So, If applicants are inclined to delay the formal declaration until after a patent application is published (e.g. so they can make a specific disclosure), the first public notice of essential IPR might happen after a draft standard is already approved. Thus, while formal IPR declarations can provide a great deal of information (see Appendix A), it is important to recognize that SSOs may receive them long-after the date when the IPR was first disclosed to a technical committee, or the date when the key technical decisions that determine a patent's essentiality were made.[8]

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

The most common form of license commitment is a promise to license on Reasonable and Non-Discriminatory (RAND) or Fair, Reasonable and Non-Discriminatory (FRAND) terms. There is a substantial legal and economic literature, reviewed by Farrell et al. (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. Most of the SSOs in our data allow, but do not require, more stringent types of licensing commitments. 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. 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 makes the FRAND commitment conditional on receiving similar terms from an implementers who also holds essential

[8] 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.

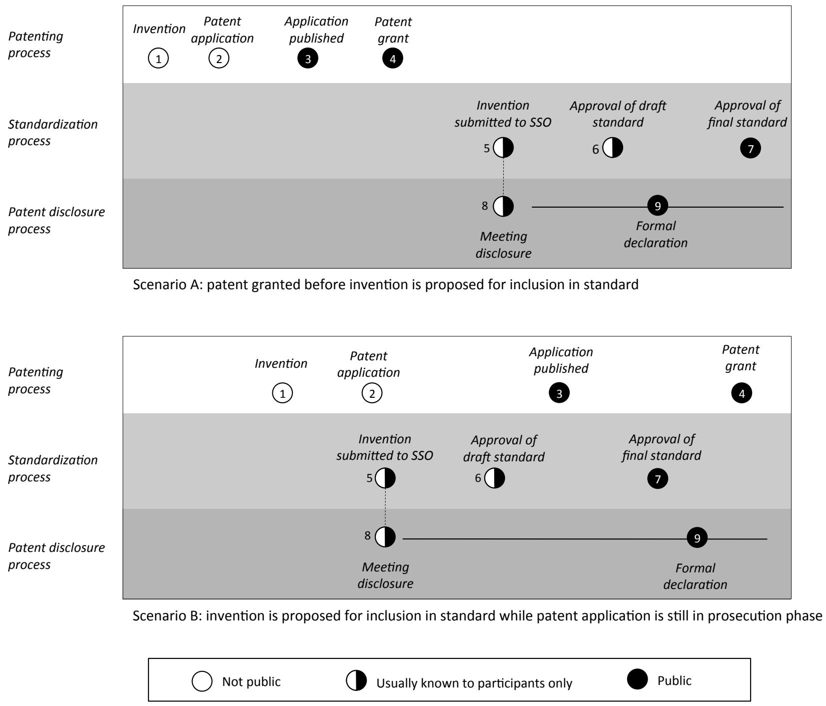


Figure 2.1: Two Disclosure Timing Scenarios

patents). However, our sample of declarations also contains a wide variety of different licensing conditions, including field-of-use restrictions, and GPL-like provisions that make the offer of a royalty-free license conditional on reciprocal royalty-free commitments from any prospective implementer. Over time, commonly used conditions may become part of an SSO's IPR policy, for example, as an option on a standardized form used to collect declarations.

Licensing commitments also vary in scope, depending on the type of disclosure as well as the IPR policy at the SSO. For a specific disclosure, the licensing commitment may apply to only the disclosed patents, or members of the same patent family. For a blanket disclosure, the licensing commitment could apply to a particular standard (document), to all work by a particular technical committee (Working Group), or even to the entire SSO. Many declarations combine a specific disclosure with a blanket FRAND commitment that covers all work on a particular standard.

SSOs' 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.[9]

The data we examine below come from publicly available IP disclosure records, and most SSOs provide a set of standard disclaimers with their disclosure data. 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.

Beyond these standard disclaimers, SSOs differ in what they require, what they (explicitly) allow, and what they seem to tolerate in practice. 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.

3 Disclosures

This section uses our database of intellectual property declarations to document a number of stylized facts about the evolution of standards and intellectual property over the last two decades. We focus on three broad patterns: (i) the sustained growth in IPR declarations, (ii) a growing emphasis on communications technology, and (iii) vertical business model specialization.

Our analysis is carried out using the IP disclosure dataset described in Appendix A. These data contain 45,349 disclosures (general or specific licensing statements) that can be grouped into 4,970 declarations (statements submitted to a single SSO by a single firm on a given date). Table 3.1 summarizes the total number of declarations and declared essential patents in our data, and Table 3.2 shows the individual firms that make the most declarations.[10]

These tables show that the distribution of declarations across SSOs and firms is very uneven. Some SSOs have large numbers of declared essential patents, while others hardly any. These differences reflect the scope of the work carried out within the SSO, the different IP policies summarized in Table 2.1 and differences in the patenting propensity of member firms. The ten most active firms account for 33 percent of the declarations (and a larger share of declared

[9]To some extent, SSOs and their members can also rely on third-party enforcement. Antitrust authorities have brought several cases against firms that conduct "patent ambush" by seeking a license after they failed to disclose essential patents. Recently, courts have 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.

[10]See Table B-1 for a list of the largest firms by SSO Group.

Table 3.1: Disclosure Summary Statistics

SSO	Total Declarations	Percent Blanket	Mean Size	Unique IPR	Percent FRAND	Percent Free	Percent Other	SSO Group
ANSI	346	0.57	1.31	273	0.82	0.08	0.10	2
ATIS	99	0.66	5.06	217	0.80	0.08	0.12	6
BBF	23	0.26	5.61	44	0.87	0.09	0.04	2
CEN	5	0.00	4.20	5	1.00	0.00	0.00	2
CENELEC	11	0.73	0.36	4	1.00	0.00	0.00	2
ETSI	699	0.10	39.17	3,839	0.98	0.00	0.02	3
IEC	362	0.55	3.88	402	0.02	0.02	0.95	1
IEEE	716	0.46	2.57	712	0.95	0.02	0.03	4
IETF	821	0.57	2.67	694	0.53	0.37	0.10	5
ISO	519	0.64	2.26	341	0.66	0.03	0.32	1
ITU	927	0.68	1.89	586	0.94	0.06	0.01	1
OMA	100	0.00	9.19	295	1.00	0.00	0.00	6
TIA	282	0.91	1.39	94	0.95	0.01	0.04	6
Total	4,910	0.52	7.77	6,761	0.77	0.09	0.14	

Blanket declarations list no specific IPR. Specific (defined as a US or EPO patent or patent application number). Mean Size is the average number of specific IPR per non-blanket disclosure. The "Free" licensing commitments include both royalty-free license pledges and non-assertion covenants. The "Other" licensing category includes both specific terms and conditions, and a small number of cases where a commitment was withheld.

essential patents), but there is a total of 926 disclosure events (i.e. unique firm-SSO-date combinations) in the data, and the "long tail" of small organizations is collectively substantial.

Table 3.1 also shows that the majority of the declarations in our dataset contain a FRAND licensing commitment (in some cases because that is the only option allowed by an SSO). However, thirty-seven percent of the IETF declarations contain a royalty-free license commitment, and 32 percent of the ISO declarations provide specific terms and conditions.

In several of the patent-level analyses below, we group SSOs together to obtain a larger sample of declarations and disclosed IP. The last column in Table 3.1 shows the grouping. Our first group ate 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. The IEEE, ETSI and IETF each constitute their own group. And the final group consists of several smaller forums that develop mobile telecommunications standards.

3.1 Growth in Disclosures

Figure 3.1 shows the total number of declarations in our data, starting in 1985. This figure exhibits two striking features: the sustained growth (and acceleration) in total declarations,

Table 3.2: 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.

and the 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 effect pattern is a rapidly increasing number of disclosures, both within between SSOs, and rapidly expanding base of declared essential patents. The remainder of this section considers several potential explanations for the ongoing "disclosure boom."

3.1.1 Changes in Disclosure Policy and Enforcement

Between 1990 and 2010 many SSOs altered or clarified their disclosure policies in ways that encouraged declaration. For instance, the first patent disclosure at the IETF occurred in 1995, and it took several years for the organization to settle on its current policy, which only allows for blanket disclosure if a firm is willing to make a royalty free licensing commitment. The IEEE revised its IPR policy in 2007 (and again in 2015). Among other reforms, the 2007 IEEE policy allows *ex ante* disclosure of specific licensing terms during the standardization process, and encourages disclosure of third-party patents

The enforcement of SSO IP disclosure policies has also changed over the last two decades.

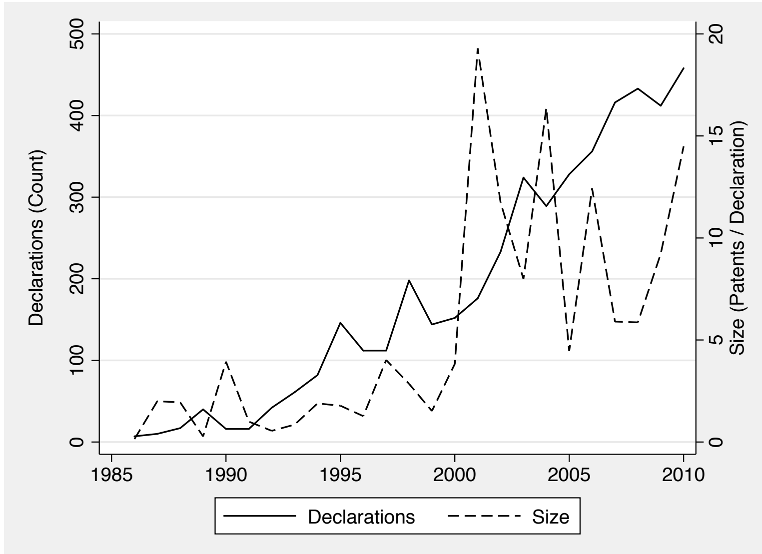


Figure 3.1: SSO IPR Disclosures: 1985 to 2010

In general, SSOs have limited powers of enforcement. While they might threaten to expel firms that fail to comply with an IPR policy, we could find no examples of this approach. Several SSOs indicate that they may withdraw support for a standard if an essential IP holder refuses to commit to RAND licensing. However, this threat will be weak for standards that have already achieved market acceptance. In practice, few firms are unwilling to make a RAND commitment, perhaps because it leaves them with considerable pricing flexibility.

Nevertheless, enforcement of SSO IPR policies was strengthened, starting in the early 1990s, as the result of several court cases.[11] In 1993, Mitsubishi prevailed in a suit against Wang Labs, who had claimed infringement of two patents that were not disclosed to an SSO. In 1995, the FTC settled a similar matter against Dell Computer, who ultimately agreed to waive certain IP rights that it had failed to disclose. Perhaps the most famous recent case on this issue is the matter of Rambus, which raises a host of thornier questions about when a firm comes under the obligation to disclose IP, and what types of IP it must reveal. The cumulative effect of these cases is a reasonable fear that failing to disclose essential patents could lead to forgone licensing revenue. Thus, firms may have become more vigilant regarding IP disclosure beginning in the mid 1990s.

[11]See Kobayashi and Wright (2010) for an overview of the legal issues.

3.1.2 Standardization Activity

The volume of IP disclosures is clearly tied to the number of standards under development, and there is anecdotal evidence of an increase in standards development during the 1990s as a number of important markets coalesced around "open" product architectures. For example, Bresnahan and Greenstein (1999) describe the transition to an open architecture for personal computers in the mid 1980s. Simcoe (2012) shows that the emergence of the commercial Internet around 1995 is linked to a substantial increase in the size of the IETF. This period also saw important standards work in the rapidly advancing field of wireless telecommunication, especially within ETSI and 3GPP.

Together, the IETF, IEEE and ETSI account for a substantial share of the growth in total IPR declarations in our database. These three SSOs are closely associated with the Internet, the 802.11 wireless networking standard, and cellular telephony. This suggests a link between platform growth and increasing amounts of IP disclosure.[12]

3.1.3 Patenting and Licensing

Increased patenting is another potential explanation for the growth in IP disclosure at SSOs. The long-term increase in US patent issuance is widely documented, and scholars have suggested several underlying causes. For example, Hall (2007) suggests there was a structural break in the growth rate of US patent applications in 1984, shortly after the creation of the Court of Appeals for the Federal Circuit. Texas Instruments famously began its aggressive licensing strategy in 1985.

Firms also became more sophisticated in their use of patents between 1990 and 2010. One example is the reappearance of patent pools in 1997 with the creation of a pool for the MPEG-2 digital video standard.[13] Almost every subsequent pool has formed to license patents that are essential for industry standards. Several firms have also been very successful at unilaterally licensing their standards essential patents. The leading example is Qualcomm, whose portfolio of CDMA patents earned billions of dollars in annual licensing revenue during the mid 2000s. Large implementers and systems integrators have also worked to create portfolios of essential patents, partly for "defensive" use in cross-licensing negotiations. Table 3.2 lists the companies holding the most declaring essential patents in our data. In Section 4, we examine a number of patent-level outcomes (e.g. citations and litigation) that illustrate the strategic value of

[12] An interesting topic for future research is whether declared essential patents cover "core" technologies that are essential to the underlying platform (e.g. networking protocols), or adaptations that make the platform more useful in specific markets or applications, and how this shifts over time.

[13] Lerner et al. (2003) describe how pools were common in the early 1900s, but disappeared around the 1950s due to antitrust concerns.

declared essential patents.

3.1.4 Industry Structure and Business Models

Changes in industry structure are a final contributing factor to the boom in IP disclosure. Prior to the 1990s there may have been less need for IP disclosure as part of the standards process, because the firms developing and implementing standards were often large, vertically integrated companies that exchanged rights under broad cross-licensing agreements. The emergence of more "open" platforms (with more-or-less free entry into the provision of complements), and the growth in markets for technology, have led to more vertical dis-integration through outsourcing the design and manufacture of components for many ICT products.

Intellectual property naturally receives more attention in a vertically dis-integrated industry structure, since it helps determine the distribution of profit across the value chain. For example, specialized technology developers, such as Qualcomm, Rambus, or the fabless semiconductor firms described in Hall and Ziedonis (2001), rely heavily on IP rights to capture a share of innovation rents, and recognize the potential value in holding essential patents. At the same time, standards implementers who license key inputs will recognize IP disclosure and licensing commitments as tools for promoting *ex ante* competition among technologies and avoiding *ex post* hold-up by licensors.

To examine the role of vertical specialization, we attempted to classify the "business model" of 331 different organizations that filed one or more declarations in our data set. Specifically, we assigned each disclosing organization to one of nine business model categories. While any such classification is inherently subjective, we found that it was often (though not always) relatively easy to assign organizations to a particular category. We also focused on firms that made more than a handful of declarations, so that our sub-sample of 331 organizations account for just over 80 percent of all declared essential IPR.

Table 3.3 shows the distribution of different business models , along with some characteristics of their disclosures. Between 1990 and 2010, 40 percent of all claimants came from four "upstream" categories: patent holding companies, individual patent holders, component suppliers and research institutes. These organizations made roughly 20 percent of the declarations in our sample, and those declarations listed roughly 30 percent of the declared essential patent families. Firms in two "downstream categories" — product and equipment suppliers and service providers — comprise 50 percent of claimants, made 70 percent of the declarations, and their declarations contain 66 percent of the declared essential patents.

Downstream organizations are more likely to use blanket declarations when possible. In particular, 60 percent of the declarations from integrators and equipment providers are blankets,

Table 3.3: Disclosure Summary Stats by Business Model Category

Organizational Category	Examples	Claimants (Percent)	Declarations (Percent)	Blankets (Percent)	Avg. Size (Count)	Patents (Percent)
Pure upstream R&D, patent holding	Dolby, DTS, InterDigital	8.46	3.62	4.44	15.4	10.57
Universities, public research institutes	Columbia Univ., Fraunhofer Inst.	11.48	3.99	4.74	0.9	0.72
Components (incl. semiconductors)	Qualcomm, Intel Harting	12.69	12.76	15.40	7.4	17.74
Software and s/w-based services	Microsoft, Sun, Oracle	4.83	5.71	5.93	2.8	3.66
Product & equipment, suppliers, integrators	Ericsson, Nokia, Dell, HP	40.79	59.99	57.43	4.0	60.81
Service providers (telecom, radio, etc.)	Vodafone, BBC, Comcast	9.67	11.20	9.32	1.8	5.57
SSO, consortia, technology promoters	Konnex Assoc., ETSI	12.10	0.32	0.40	1.0	0.06
Individual Patent owner		7.55	0.81	0.60	1.0	0.24
Instruments, testing and Measurement,	Tektronix, Rhode & Schwarz	1.51	0.22	0.05	1.5	0.14

and that is nearly four times the rate of component suppliers, who at 15 percent have the next highest share of blanket declarations. Table 3.3 also shows differences in the number of unique patents or applications listed in a declaration. While "pure upstream" patent holders account for a small share of total declarations (3.6 percent), they tend to list a large number of individual IPRs, leading to a much greater 10.6 percent share of total declared essential patent families. At 7.4 unique IPRs per declaration, component suppliers also have a relatively large average disclosure size. We also examined the geographic distribution of these organizations, and found that the United States has a relatively large share of the pure upstream patent holders, component suppliers (including semiconductor) and software firms. Service providers are evenly distributed between the US, Europe and Asia, as one might expect. Research institutes and equipment suppliers are the most fragmented and geographically diverse business model categories.

Overall, this section has illustrated and offered some explanations for the dramatic increase in IP disclosure over the two decades, and presented a variety of new statistics that show how declarations of essential IP are distributed across technologies, firms and business models. Specifically, we identified four broad factors that are driving the ongoing growth in IP disclosure to standards organizations: changing policies, increased demand for standards, increased patenting and changing industry structure. Each of these trends are part of a mutually reinforcing set of changes in the structure of IT and telecommunications markets, and it is likely that all of them have contributed to the ongoing "disclosure boom."

4 Declared Essential Patents

This section takes an initial look at 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 6,633 granted US patents that were either declared essential, or share a common priority application with an EP declared essential patent. The United States was 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 the SSO Patents.

As a point of comparison, we also created a sample of "Control Patents" by randomly choosing an undeclared US patent with the same primary (3 digit) technology class, application year, patent type (i.e. utility or reexamination) and roughly the same number of claims as each of the SSO Patents.[14] This one-to-one matching procedure ensures that the joint distribution of technology classes, application years and claims is balanced in the two samples. To be clear, the "control" patents are not meant to provide an estimate of the counter-factual outcomes for SSO Patents had they not been declared essential. Rather, these controls yield an estimate of the "average outcome" in a set of patents with similar ages and technical characteristics. Rysman and Simcoe (2008) discuss this type of matching in detail, and note that a simple comparison of the SSO and Control patents will measure both selection effects (differences that would exist regardless of the SSO) and marginal effects (i.e. differences caused by disclosure and/or standardization).

Since the IP declarations are an not ideal data source in all respects, it is worth reiterating several caveats before presenting the results of our 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, short of a thorough search based on a particular standard. Second, our sample of SSO Patents almost certainly contains patents that are not truly essential. 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 "over declare" out of caution (since non-disclosure could render their IP unenforceable) or because they have a strategic motive to inflate their declared essential patent counts, possibly with an eye towards future

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

license negotiations. Finally, when we examine disclosure timing, it is important to recall that declaration dates are only loosely connected to the underlying standards 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.[15]

All of our patent-level outcomes data come from USPTO, with the exception of the data on patent litigation, which was obtained from the Thomson Innovation database in December 2015.

4.1 SSO Patent Significance

Table 4.1 provides an initial comparison of the SSO and Control Patents. The main message of this table is that SSO Patents score higher than Control Patents on a variety of metrics used to proxy for value and technological significance.

Table 4.1: Declared Essential vs. Matched Control Patents

	Declared Essential	Matched Controls	T-stat	Normalized Difference
Percent litigated	7.27	1.81	15.23	0.19
Forward citations	65.89	38.57	15.97	0.20
Inventors (count)	2.75	2.47	9.31	0.11
Backward patent cites	29.28	20.72	9.51	0.12
Backward non-patent cites	9.31	5.02	8.97	0.11
Claims	23.20	22.48	2.24	0.03
Application Year	2000.1	2000.0	0.69	0.01
Issue Year	2003.6	2003.6	0.00	0.00
Observations	6,633	6,633		

Control patents are a 1-1 random sample matched on patent type, grant year, 3-digit US primary technology class, and number of claims. The normalized difference between sample means $\overline{X_1}$ and $\overline{X_2}$ is defined as $(\overline{X_1}-\overline{X_1})/\sqrt{(\sigma^2_{X_1}+\sigma^2_{X_2})}$.

The first two rows in Table 4.1 examine "long run" differences between SSO and Control patents. The first row shows that the probability of litigation is roughly four times higher in the sample of SSO Patents: 7.27 percent versus 1.81 percent.[16] The second row shows that SSO Patents are cited as prior art by other US patents at roughly twice the rate of Control

[15]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.

[16]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.

Patents. It is important to note that the SSO and Control patents have the same distribution of application year (and as the table shows, issuance year 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 and rarely show differences of the size and statistical significance observed in this comparison.

The next two rows in Table 4.1 examine indicators of the perceived value of a patent to an applicant when it issues. The SSO patents make more references to both patent and non-patent prior art. Also, if we had not matched on claims, the SSO patents would also have a larger total number of claims than the randomly selected controls. These findings suggest that the SSO Patents are "broader" than the controls and that applicants were more careful to delineate the underlying innovation (relative to prior patents) in an SSO patent application.

Any large *ex ante* differences between SSO and control patents (e.g. in terms of claims and prior-art references) suggest a large selection effect. In other words, SSOs attract high-value technologies. However, Bekkers et al. (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 reflect an SSO's influence. To see whether "simultaneous" application and disclosure had a large impact on our results, we re-ran the analysis in Table 4.1 on the sub-sample of SSO patents (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 4.1, suggesting that there is a substantial element of selection on observable (to the patent-holder) quality in the sample of SSO Patents.

4.2 Cross-sectional Regressions

The remaining patent-level analyses will examine how difference in the two long-run outcomes (litigation and citations) vary according across SSOs, licensing commitments and disclosure timing. We continue to use the matched control patents as a way to adjust for differences in technology class, application year and the total number of patent claims. However, we now adopt the following regression framework

$$Y_{ij} = Declared_i \beta_j + \alpha_j + \lambda_g + \gamma_c + \varepsilon_i \qquad (4.1)$$

where Y_{ij} is an either a citation count or a litigation indicator for patent i in group j, and $Declared_i$ is an indicator variable that equals one if patent i was declared essential to an SSO. We focus on three groups (indexed by j): SSOs, Licensing Commitment Types, and application-to-disclosure lag categories.[17] 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 4.2 reports estimates of α_j, using both citations and litigation as outcomes, and examining heterogeneity across both disclosure terms and SSOs. For the citation models, we estimate equation (4.1) as a Poisson regression with robust standard errors.[18] For the litigation outcome, we us a linear probability model. Columns (1) and (4) in Table 4.2 basically replicate the comparison of SSO and control patents in Table 4.1. The coefficient of 0.53 in column (1) indicates that SSO patents receive about 69 percent more forward citations than controls, and the coefficient of 0.55 in column (4) indicates that the difference in probability of a lawsuit is 5.5 percentage points.[19]

Columns (2) and (5) in Table 4.2 examine how these correlations vary according to the terms of the licensing commitment. We consider three types of commitment: FRAND; Free, which includes both a royalty-free license and a non-assertion covenant; and "Other," which includes commitments to offer specific terms and conditions, along with a few cases where a commitment was withheld. Column (2) shows that the difference between SSO and Control patent forward citations is largest for commitments to license the patents free of charge. Patents subject to FRAND and Other licensing commitments still receive about 65 percent more citations than their matched Controls. Column (5) shows how the probability of litigation varies with the terms of the licensing commitment. For patents under a Free licensing commitment, there is no difference in the probability of litigation between SSO and matched Control patents. However, the FRAND patents have a 5.5 percentage point increase in litigation probability (roughly 300 percent compared to the baseline litigation rate for the Controls), and the Other patents are 9.2 percentage points more likely to be litigated.

The fact the 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 more likely to be litigated than their matched controls).[20] However, the larger citation increase for royalty free declared essential patents is somewhat

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

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

[19] The Poisson coefficients can be translated into a percentage change by exponentiating and subtracting one, i.e. $e^{0.53} - 1 = 0.69$.

[20] 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.

Table 4.2: Cross Sectional Patent-level Regressions

Outcome	Forward Citations			Litigation Indicator		
Specification	Poisson			OLS		
	(1)	(2)	(3)	(4)	(5)	(6)
Declared SEP	0.53 [0.03]**			0.055 [0.004]**		
Declared SEP * FRAND		0.52 [0.03]**			0.054 [0.004]**	
Declared SEP * Free		0.82 [0.09]**			0.007 [0.006]	
Declared SEP * Other		0.60 [0.07]**			0.092 [0.015]**	
Declared SEP * ANSI			0.64 [0.11]**			0.129 [0.023]**
Declared SEP * Big-I			0.49 [0.10]**			0.063 [0.014]**
Declared SEP * ETSI			0.53 [0.09]**			0.040 [0.011]**
Declared SEP * IEEE			0.72 [0.10]**			0.073 [0.015]**
Declared SEP * IETF			0.97 [0.11]**			0.032 [0.013]*
Declared SEP * Other			1.25 [0.11]**			0.086 [0.018]**
Grant Year Effects	Yes	Yes	Yes	Yes	Yes	Yes
Patent Class Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,266	13,266	13,266	13,266	13,266	13,266

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

provocative, as it 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). While the FRAND and Other commitments are not different in terms of citations, the higher litigation rate for Other probably reflects the fact that this category contains a small number of cases where the disclosing organization withheld a licensing commitment, or announced very stringent terms and conditions. Those cases have a very high litigation rate.

Columns (3) and (6) in Table 4.2 examine differences across the "SSO Groups" defined in Table 3.1 and discussed above. Column (3) shows that SSO Patents receive more citations than their matched controls at every SSO group. However, the size of the difference varies considerably across SSOs. 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 SDOs. This variation in the citation gap may reflect differences in either selectivity or the "treatment effect" of different SSOs or some combination of the two. 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.

Column (6) examines heterogeneity in litigation rate differences between SSO 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 litigation. The gap is smaller at IETF, where one third of the commitments are royalty-free, and at ETSI, where a specific disclosure rule yields large numbers of declared essential patents, and perhaps also a high rate of "false positives" in terms of true essentiality.

While one might have expected the estimated citations and litigation coefficients to co-vary positively across SSOs, Table 4.2 does not show any obvious relationships. For example, ANSI has the largest litigation gap and the second-lowest 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, and firms may well view the choice between a blanket and specific declarations strategically.

4.3 Disclosure Timing

Our final patent-level analyses examine how citation and litigation outcomes vary with disclosure timing. Ideally, we would measure the timing of initial IP disclosure relative to the dates of key technical decisions for a particular standard. Unfortunately, we do not have that information. As an alternative measure of disclosure timing, we use the gap between patent application and declaration date. Patents that are declared essential immediately after application (and often well before they issue) are likely, though not certainly, motivated by the ongoing standards process. Patents that are declared long after applied for are more likely to cover technologies whose relationship to a proposed standard only became apparent over time. Thus, we view the application-to-declaration lag as a noisy estimate of our "ideal" timing measure.

Figure 4.1 shows the histogram of the time-lag between application and formal declaration (left panel) and between grant and formal declaration (right panel). The two histograms show that most declared essential patents are disclosed between zero and ten years after the application is filed, with a substantial peak in disclosures just after the patent issues. The

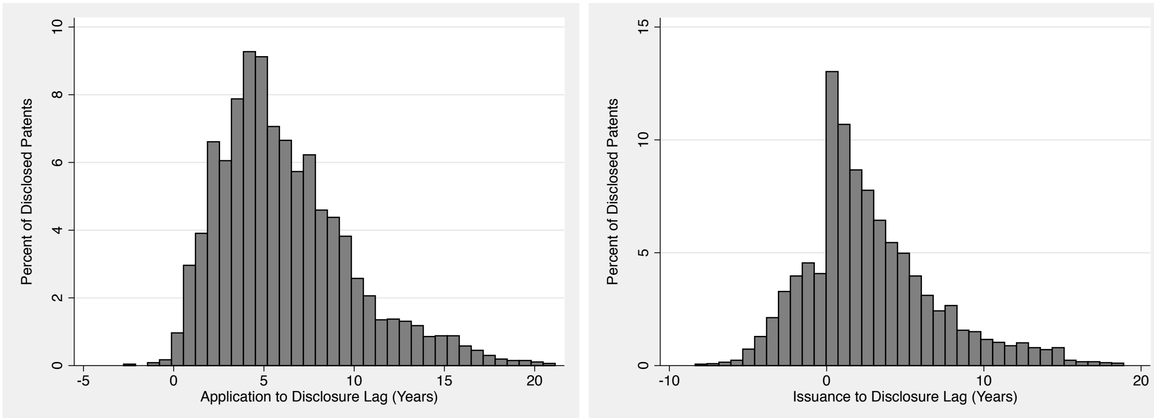


Figure 4.1: Disclosure Timing

small number of patents declared essential before their application date are primarily US family members of declared essential EPO patents with an earlier priority date. The second histogram shows a large peak just after declared essential patent is granted. This discontinuity is driven by patent applications filed before 1999 (roughly half of our sample), since under US law these applications could remain secret until a patent was granted, and firms rarely disclosed unpublished applications except as part of a blanket declaration.[21]

To examine the relationship between disclosure-timing and either citations or litigation, we divided the distribution of application-to-disclosure lags shown in the left panel of Figure 4.1 into four quartiles, created indicator variables for whether a patent was in each quartile of the distribution, and used those quartile dummies as the group indicator (indexed by j) in equation (4.1). Poisson and linear probability model estimates are shown in Table 4.3.

Column (1) of Table 4.3 shows that the application-to-disclosure lag has a strong positive association with citation rates. Patents declared essential shortly after an application is filed receive fewer cites (relative to a set of matched controls) than patents declared essential 7 or more years after application. This finding suggests that selection on quality is stronger when SSOs discover older patents that cover an attractive approach to some problem. When disclosure occurs just after application, the citation gap between SSO and Control Patents is smaller, suggesting that when firms file patents and immediately submit the invention to an SSO, the underlying ideas are relatively less important. Of course, this provocative interpretation rests on the maintained assumption that citations are a good proxy for patent value, which the literature suggests to be true on average, but will not hold in every case.

Column (1) of Table 4.3 examines the correlation between disclosure timing and litigation

[21] To see how the right panel looks for patents with an application year before and after the law change resulting in publication of applications, see Figure B-2 in the Appendix.

Table 4.3: Heterogeneity by Application-to-Disclosure Lag

Outcome Specification	Forward Citations Poisson	Litigation Indicator OLS
	(1)	(2)
Declared SEP * [Lag<2.4 yrs]	0.17 [0.07]*	0.028 [0.006]**
Declared SEP * [2.4<Lag<4.8]	0.50 [0.07]**	0.033 [0.007]**
Declared SEP * [4.8<Lag<7.6]	0.58 [0.07]**	0.026 [0.007]**
Declared SEP * [Lag>7.6 yrs]	0.76 [0.07]**	0.052 [0.008]**
Grant Year Effects	Yes	Yes
Patent Class Effects	Yes	Yes
Observations	13,208	13,208

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

rates. We find that patents with a long lag between application and declaration to an SSO have a higher litigation rate (relative to their matched controls) than patents with a shorter lag. Once again, if we take litigation as a proxy for perceived patent value, this suggests that longer application-to-disclosure lags are correlated with better patents. An alternative, and perhaps more provocative, interpretation of this finding is that long-lags are associated with hold-up, since delays allow time for a standard to diffuse and for implementers to make substantial technology-specific investments. However, we cannot rigorously test the hold-up hypothesis without better information on standardization dates, implementation rates and the true essentiality of declared essential patents.

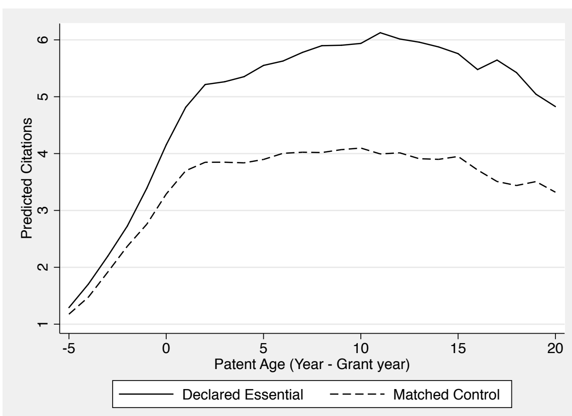
5 Disclosure Effects

Up to this point, we have emphasized that disclosure timing is not tightly linked to the adoption of a standard. Some patents are disclosed lang 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 in section 3.1.1) provide reasonably strong 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 some evidence of a "Disclosure Effect" on citations using difference-in-differences regression, and on litigation using a Cox hazard model.

5.1 Citations

To explore the relationship between disclosure and citations, we created a panel data set that contains one observation per year for each SSO and Control patent with an age between -5 and 20 (where age is defined as calendar-year minus issue-year). Our outcome variable will a count of references from all issued patent applications filed in year t to each SSO or Control patent i.

Figure 5.1 graphs the average annual citation rate by age for SSO and Control patents in the raw data. The left panel in this figure shows that SSO patents receive roughly 20 percent more citations than Control patents by the time they issue. This gap widens for about 10 years, as the SSO patent average annual citation rate climbs from 5 to 6, and the Control patent rate stays constant at about 4. The righthand panel in Figure 5.1 provides a separate annual citation rate for age SSO, and shows that much of the "bump" in the lefthand panel is linked to two SSO groups: IETF, and the "telecom" group consisting of ATIS, TIA and OMA.



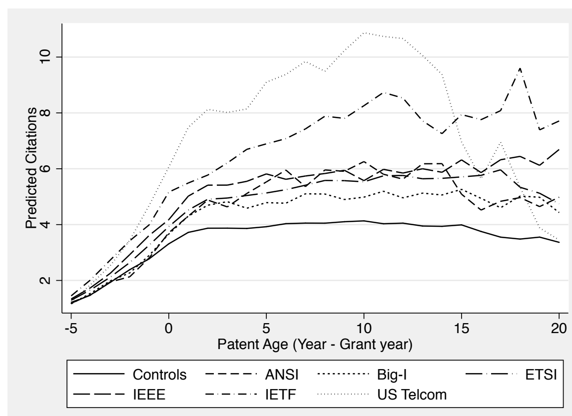


Figure 5.1: Citation Age Distribution (by SSO)

Overall, these graphs suggest that there is *both* a substantial selection effect, whereby SSO patents 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 turn to difference-in-difference panel regressions, building on the approach developed in Rysman and Simcoe (2008). Our regression specification is

$$Cites_{it} = PostDisclosure_{it}\beta_j + \alpha_i + \gamma_{ay} + \varepsilon_{it} \tag{5.1}$$

where $PostDisclosure_{it}$ is an indicator for an SSO Patent that has been declared essential; α_i is a patent-level fixed effect; 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 are interested in β_j, the disclosure effects, which are once more allowed to vary across different types of SSOs and licensing commitments.

Because this specification includes two high-dimensional vectors of unobserved effects, for both patents (α_i), and age-years (γ_{ay}), we take two different approaches to estimation. The first approach is to estimate (5.1) via OLS.[22] Our second approach replaces the age-year effects, with a much smaller set of age effects (γ_a), controls for secular trends by including the nonlinear terms[23] from a fourth-order polynomial in calendar-years, and estimates Poisson model with patent-level conditional fixed effects. In all of these regressions we also include a dummy for prior litigation as a time-varying control. The litigation dummy has a large impact on citations, but because it is a relatively rare event, dropping the control has no qualitative impact on the overall results.

The difference-in-differences results are presented in Table 5.1. Columns (1) through (3) show OLS estimates while columns (4) through (6) display the Poisson estimation results. The estimates in columns (1) and (4) show that there is statistically significant, though rather small, increase in citations following disclosure to an SSO. For example, the 0.13 citations per-year estimate in column (1) amounts to a 2.5 percent increase in a baseline rate of 5 cites per year, as suggested in Figure 5.1. This is consistent with the estimate of a 3 percent increase in annual citations shown in column (4).

[22] We use a Stata package and estimator described in Guimaraes and Portugal (2010).

[23] The linear calendar year terms are not identified in this model because calendar year is co-linear with patent age and application year (which is contained in the fixed effect).

Table 5.1: Disclosure Diff-in-Diffs

Outcome	Citations$_{it}$			Citations$_{it}$		
Specification	OLS			Poisson		
	(1)	(2)	(3)	(4)	(5)	(6)
PostDisclosure	0.13 [0.05]*			0.03 [0.02]*		
PostDisclosure * FRAND		0.11 [0.06]			0.03 [0.02]	
PostDisclosure * FREE		0.16 [0.18]			0.01 [0.06]	
PostDisclosure * Other		0.35 [0.21]			0.12 [0.07]	
PostDisclosure * ANSI			1.25 [0.32]**			0.39 [0.08]**
PostDisclosure * Big-I			0.26 [0.13]*			0.15 [0.05]**
PostDisclosure * ETSI			-0.27 [0.06]**			-0.09 [0.02]**
PostDisclosure * IEEE			0.49 [0.20]*			0.09 [0.05]
PostDisclosure * IETF			0.09 [0.19]			-0.01 [0.05]
PostDisclosure * Other			1.86 [0.29]**			0.37 [0.05]**
PostLitigation	1.21 [0.36]**	1.21 [0.36]**	1.15 [0.37]**	0.20 [0.04]**	0.20 [0.04]**	0.18 [0.04]**
Patent Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Age-Year Effects	Yes	Yes	Yes	No	No	No
Year Effects	No	No	No	Yes	Yes	Yes
Age Polynomial	No	No	No	Yes	Yes	Yes
Observations	164,668	164,668	164,668	152,455	152,455	152,455
Patents	13,266	13,266	13,266	11,462	11,462	11,462
R-squared	0.59	0.59	0.59			

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

Columns (2) and (5) suggest that there is some heterogeneity in disclosure effects based on the terms of the licensing commitment, but these estimates are not very precise. More interesting are the results in columns (3) and (6), showing substantial heterogeneity across SSOs. The most notable finding here is the *negative* disclosure effect for patents declared essential to ETSI. As noted above, ETSI is the only major SSO that prohibits blanket disclosure, and it is therefore responsible for around half of the patents in our sample. If ETSI is dropped from the estimation sample the coefficients in columns (1) and (4) increase to 0.65 and 0.18 respectively, suggesting a more respectable 18 percent post-disclosure increase in the citation rate. One possible explanation for the anomalous ETSI coefficient is that a policy encouraging explicit disclosure can increase both the rate of "false positives" and the probability of design around.

Setting aside ETSI, we find larger "disclosure effects" at ANSI and the mobile consortia (ATIS, TIA, OMA), a somewhat smaller and less precisely estimated effects at the Big-I organizations, IEEE and IETF. Overall, if one is willing to maintain the assumptions that citations reflect value and disclosure proxies for standardization, these results suggest that SSOs are *both* selecting high quality patents and contributing to their long-term importance.

5.2 Litigation

Our final set of analyses will examine the relationship between disclosure and patent 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 the 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 5.2 shows the 20-year cumulative hazard of litigation for declared essential and 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 SSO patents 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 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

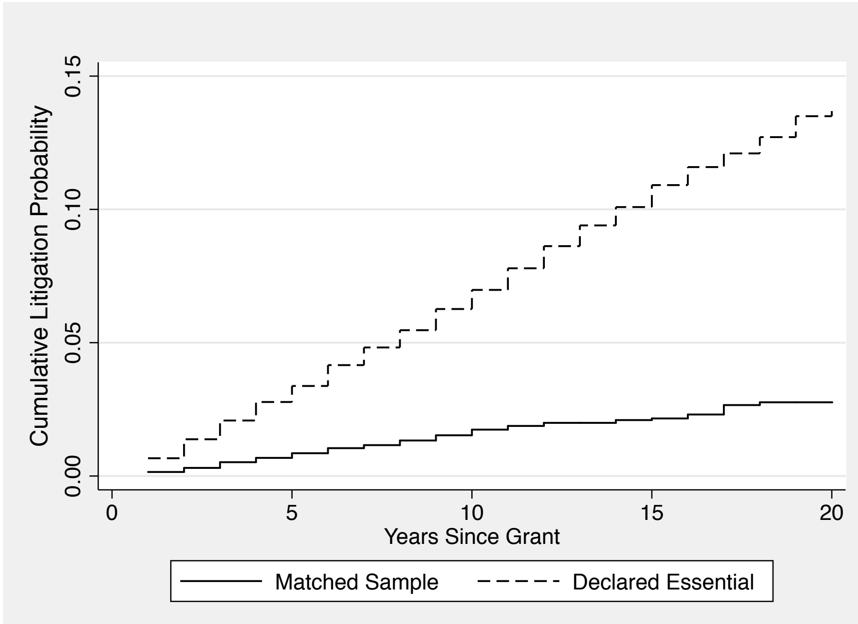


Figure 5.2: Cumulative Litigation Hazard

the SSO Patent 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 an litigation, we use a Cox proportional hazard model, discarding the Control patents in order to examine the time-to-first lawsuit for all declared essential patents. The basic specification is:

$$h_i(t) = \lambda(t) \exp\{PostDisclosure_{it}\beta_j + ln(1 + CumCites_{i(t-1)})\theta + f(y; \lambda)\} \tag{5.2}$$

where $h_i(t)$ is the hazard rate for patent i at age t (with $t = 0$ in a patent's grant-year); $\lambda(t)$ is the baseline hazard of litigation across all SSO patents; and $f(y; \lambda)$ is a calendar-year polynomial to control for changes in the overall litigation propensity over time. We are interested in the coefficients (β_j) on time-varying disclosure dummy, just as in the previous difference-in-differences specification. While we include lagged cumulative citations as a control for the evolving importance of patent i in all of our models. However, omitting the citation control does not qualitatively change the results, which are reported in Table 5.2

The coefficient in column (1) shows the probability of first-lawsuit for an SSO patent increases following disclosure, controlling for age, calendar-year time trends and lagged citations. This provides some additional evidence for the theory that SSO's are influence long-term outcomes fro declared essential patents, and not merely selecting high value patents that are likely

Table 5.2: Cox Hazard Models of Litigation

Outcome Specification	Litigation Cox Proportional Hazard		
	(1)	(2)	(3)
PostDisclosure	0.33 [0.14]*		
PostDisclosure * FRAND		0.28 [0.14]*	
PostDisclosure * FREE		-1.29 [0.73]	
PostDisclosure * Other		0.92 [0.20]**	
PostDisclosure * ANSI			0.89 [0.21]**
PostDisclosure * Big-I			0.57 [0.17]**
PostDisclosure * ETSI			0.03 [0.15]
PostDisclosure * IEEE			0.37 [0.18]*
PostDisclosure * IETF			-0.08 [0.26]
PostDisclosure * Other			0.33 [0.22]
ln(Cites_{t-1})	0.39 [0.05]**	0.40 [0.05]**	0.41 [0.05]**
Observations	62,833	62,833	62,833
Patents	6,571	6,571	6,571
Lawsuits	434	434	434

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

to experience those outcomes.

Column (2) examines heterogeneity across different types of licensing commitments. Consistent with our findings in Section 4, we observe a decline in the litigation hazard following any disclosure that contains a royalty-free licensing commitment. There is an increase in litigation propensity for FRAND encumbered patents, and a much larger increase for declared essential patents that commit to specific terms and conditions or withhold a licensing commitment. While the coefficient on "Free" disclosures is not precisely estimated, chi-square tests reject the null-hypothesis that any pair of coefficients in column (2) are equal to one another at the 5 percent significance level.

Column (3) examines heterogeneity is 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 at design 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.

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 models suggest that many SSO Patents 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 in our data. Nevertheless, if one views SSO intellectual property policies through a contractual lens, our view is that both the high overall dispute rate, and the positive correlation between disclosure and litigation, call into question the presumption that these contracts are optimally incomplete (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. This paper provides an overview of disclosure policies, describes a new database containing information on declared essential IPRs, and illustrates some of the ways that these data can be used.

We find that the number of IP declarations in our sample of 13 major SSOs has been steadily accelerating for the last two decades, and explore a number of potential causes, including changes in IPR policies and their enforcement, increased patenting, greater demand for standards and the increasingly vertically dis-integrated structure of many ICT markets. We show that the 6,633 declared essential US patents in our data score much higher than a set of "average" patents with similar age and technology profiles on a variety of indicators of patent value or technical significance. We also show that the difference between SSO Patents and their matched controls varies across SSOs, licensing commitments and disclosure timing.

Notably, patents declared under a royalty-free licensing commitment were cited at twice the rate of controls, and were much less likely to be asserted in a lawsuit. Patents declared to an SSO 7.7 or more years after application were cited more frequently and litigated more often than patents declared essential shortly after the application was filed.

Many of our results highlight heterogeneity in the disclosure and licensing policies of various SSOs. For example, the only SSO in our data that mandates specific disclosure of all potentially essential IP is ETSI, and the pattern of citation and litigation for these patents are very different from the other SSOs that allow for blanket declarations. Similarly, we see substantially less litigation and more royalty-free disclosure at the IETF, which has a history and culture that emphasizes open and free access to the extent possible.

As noted in the introduction, this paper offers a first look at a new data source. All of our results are descriptive, and many have several plausible interpretations. We hope others will soon use these data to study questions related to standard setting, intellectual property strategy and the economics of the ICT sector.

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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 at http://www.ssopatents.org. Anyone is free to use the data, provided that any resulting publication includes a citation to this working paper.[24] 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.[25] 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.

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

[25] 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 (UN-HARMONIZED)	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: Supplemental Tables and Figures

Table B-1: 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.

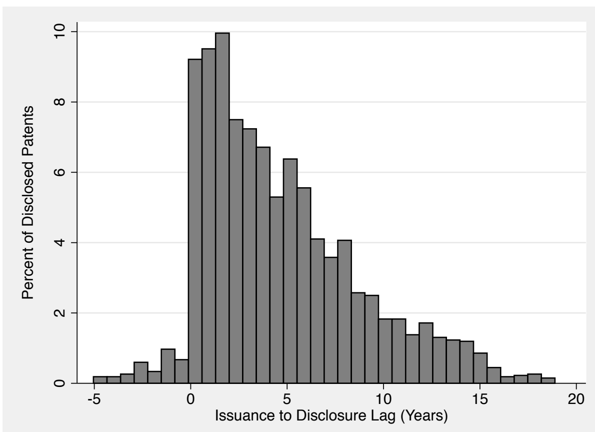

Figure B-1: Disclosure Timing (Pre 2000)

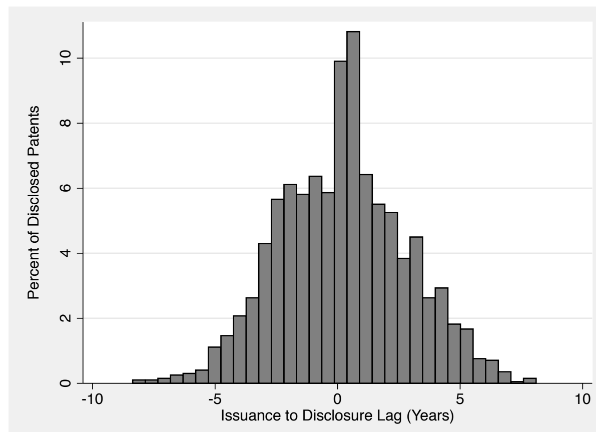

Figure B-2: Disclosure Timing (Post 2000)