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Disclosure rules and declared essential patents☆

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ABSTRACT

Many standard setting organizations (SSOs) require participants to disclose patents that might be infringed by implementing a proposed standard, and commit to license their "essential" patents on terms that are fair, reasonable and non-discriminatory (FRAND). Data from SSO intellectual property disclosures have been used in academic studies to provide a window into the standard setting process, and in legal proceedings to assess the relative contribution of different parties to a standard. We describe the disclosure process, discuss the link between SSO rules and patent-holder incentives, and analyze disclosure practices using a novel dataset constructed from the disclosure archives of thirteen major SSOs. Our empirical results suggest that subtle differences in SSO policies influence which patents are disclosed, the terms of licensing commitments, and ultimately long-run citation and litigation rates for the underlying patents. Thus, while policy debates sometimes characterize SSOs as a relatively homogeneous set of institutions, our results point in the opposite direction – towards the importance of recognizing heterogeneity in SSO policies and practices.

1. Introduction

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

Data from declared essential patents have been used in academic studies to provide a window into the standard setting process, and in legal proceedings to assess the relative contribution of different parties

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[1] Although many authors call any patent disclosed to a SSO a Standard Essential Patent (SEP), we use the acronym dSEP to emphasize that some patents that are disclosed as essential may not be actually essential for reasons we explain below.

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to a standard.[2] Because standard-setting is a form of horizontal coordination, the rules for disclosure and licensing of dSEPs have also attracted the interest of antitrust authorities.[3] In this paper, we study how SSO intellectual property policies are associated with the selection of patents to disclose, the licensing commitments offered for those patents, and their long-term citation and litigation rates.

Our analysis is exploratory, and proceeds in two stages. First, we create a cross-section of disclosures from thirteen SSOs and use it to study two outcomes: (i) the choice between listing specific patents and making a generic (or "blanket") disclosure, and (ii) the choice between Fair Reasonable and Non-Discriminatory (FRAND) and royalty-free licensing commitments. Both outcomes vary significantly across SSOs, reflecting differences in the policies and practices of each institution. We also classify SSO participants into two groups — upstream licensors and component producers, or downstream suppliers of finished goods — and show that upstream firms are less likely to make royalty-free licensing commitments and more likely to use blanket disclosure. These results, we argue, suggest that upstream input suppliers are more reliant on intellectual property to appropriate the returns to innovation, and therefore manage their dSEPs more conservatively.

The second stage of our analysis explores forward citation and litigation rates for US patents declared essential to our sample of SSOs. We start by showing that, on average, dSEPs receive more forward citations, and are more likely to be litigated, than a set of non-SEPs randomly selected from the same application-year cohort and technology class. The difference in litigation rates is greater for dSEPs disclosed by upstream firms, and (perhaps not surprisingly) disappears when there is a royalty-free licensing commitment.

Next, we estimate a series of difference-in-difference models to explore how the correlation between disclosure and citations varies across SSOs, business models, and licensing terms. We find a positive association between disclosure and forward citations for all SSO's except the European Telecommunications Standards Institute (ETSI), where the relationship is negative. Because ETSI requires specific disclosure, we interpret this finding as evidence of selection: ETSI's list of dSEPs is more likely to include patents that are not truly essential and therefore gain no citation boost from inclusion in the standard. We also find that disclosure has a larger correlation with self-citations when there is a royalty-free licensing commitment. This result, we argue, may reflect another type of selection: firms are more likely to offer royalty-free access to dSEPs when they own complementary technologies (i.e. the citing patents) that build upon a standard.

This paper makes several contributions to the literature on standards and intellectual property. First, our study complements the recent work of Baron and Spulber (2018), who characterize the IP policies and procedures of numerous SSOs, and discuss the importance of accounting for institutional heterogeneity in working with SSO administrative data. Like those authors, we have made our data publicly available to promote follow-on research.

To our knowledge, we provide the first empirical evidence linking business models (which we operationalize as a firm's location in the value chain) to dSEP licensing commitments and litigation. These findings complement the results in Simcoe et al. (2009) showing that small firms are more likely to assert their dSEPs. We also extend the difference-in-difference specification used in Rysman and Simcoe (2008) by allowing the association between disclosure and outcomes to vary by type of licensing commitment or business model. Our results reinforce their conclusion that SSOs both select important technologies and contribute to their value. It is not surprising that royalty-free licensing commitments reduce the likelihood of post-disclosure dSEP litigation. However, the finding that disclosure has a larger association with self citations when accompanied by a royalty-free licensing commitment provides novel evidence that firms may be more "open" in dSEP licensing when they expect to develop proprietary complements that build on a standard.

Our research also complements work by Lerner et al. (2016), who develop a formal model predicting that firms will use blanket disclosure when they have lower quality patents or a larger downstream presence. Our finding that disclosure has a negative association with citations at ETSI — the only SSO in our sample to mandate specific disclosure — is broadly consistent with their prediction about patent quality (though we emphasize that, in practice, opportunities for late disclosure make it difficult to distinguish between selection on quality versus essentiality). Our finding that upstream firms are more likely to use blanket disclosure contradicts their analysis, and we discuss several ways to reconcile these divergent results below.

Collectively, our findings suggest that variation in SSO rules can influence firms' patent disclosure and licensing practices, thereby shaping commercial and legal outcomes for individual dSEPs. Thus, while policy debates sometimes characterize SSOs as a relatively homogeneous set of institutions, our results point in the opposite direction — towards the importance of recognizing heterogeneity in SSO policies and practices. In that sense, our findings contribute to a broader literature on disclosure as a policy instrument (e.g., Fung et al., 2007; Dranove and Jin, 2010), which has consistently found that small changes in disclosure rules can have large impacts on economic outcomes. We also contribute to a broad literature on non-market institutions that shape trade in knowledge or technology, such as biological resource centers (Furman and Stern, 2011), or patent pools (Lampe and Moser, 2010, 2016). Whereas that literature has focused on measuring impacts of institutions on innovation, this paper's message is that we should not let the emphasis on estimating average treatment effects obscure organizational differences that can shape agents' behavior and innovation outcomes in important ways.

The rest of the paper is structured as follows: Section 2 describes SSO policies and shows how disclosure choices vary across SSOs and firms. Section 3 examines dSEPs, first in a set of cross-sectional comparisons to similar non-SEPs, and then using matched-sample difference-in-differences regression to estimate the association between disclosure and citation and litigation rates. Section 4 concludes.

2. Intellectual property policies and the disclosure process

This section provides an overview of SSO intellectual property policies, and examines how disclosure scope, timing, and licensing commitments vary across the firms and SSOs in our data. Lemley (2002), Bekkers and Updegrove (2012), and Baron and Spulber (2018) provide broader and more detailed discussions on SSO policies.

2.1. SSO policies

In one of the first systematic studies of SSO intellectual property policies, Lemley (2002) suggests that they typically have three components: search, disclosure and licensing rules. Search rules specify to what degree parties need to engage in efforts to find out whether they own IP that may be infringed by implementing a standard. Disclosure rules specify how and when firms must notify other participants in an SSO of such IP. Licensing rules specify the commitments that patent holders are requested to make regarding future licensing, the conditions that can be attached to those commitments, and the methods of enforcement.

[2] Academic studies include Rysman and Simcoe (2008), Kang and Bekkers (2015), Baron et al. (2016), Kuhn and Thompson (2019) and a number of others cited below. For an example of a court that used declared essential patent counts to apportion royalties, see *In re Innovatio IP Ventures, LLC*, No. 11 C 9308, slip op. at 82–84 (N.D. Ill. Sept. 27, 2013).

[3] See, for example, the remarks of FTC Chair Deborah Platt Majoras (2005), the docket in *F.T.C.* vs. *Rambus* (https://www.ftc.gov/enforcement/cases-proceedings/011-0017/rambus-inc-matter) and the competition policy brief on dSEPs by the Competition Directorate-General of the European Commission (European Commission, 2014).

Table 1
SSO intellectual property policies.

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

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

Table 1 provides an overview of the IPR policies for the SSOs in our data set.[4]

2.1.1. Search rules

SSOs take different approaches when it comes to identification of IP that may be infringed by a standard. While no SSO obliges parties to perform a full patent search, ETSI has the widest obligation and specifies that a member must engage in 'reasonable endeavors' to identify relevant IP. Other organizations use less demanding language, such as 'known to the party participating' (ISO, IEC and ITU), 'personally aware' (IEEE), or 'reasonably and personally know' (IETF) (Bekkers and Updegrove, 2012).

2.1.2. Disclosure rules

SSOs also take different approaches to disclosure specificity. All of the organizations that we study allow for specific disclosure statements that list one or more patents (or pending applications) that may be infringed by a standard. Two of the SSOs in our sample (ETSI and the Open Mobile Alliance (OMA)) require specific disclosures, and the IETF requires specificity unless the disclosure is accompanied by a royalty-free licensing commitment. The ten remaining SSOs also allow general patent disclosure statements, or "blankets." A blanket disclosure indicates that a participant believes it owns relevant IP, without revealing any identifying information about specific patents or patent applications.[5]

Although none of the thirteen SSOs in our sample have a mandatory search rule, blanket disclosure is clearly less costly for patent holders, since they do not have to search through their patent portfolios to identify relevant IP as the standardization process unfolds. Thus, allowing blanket disclosure can be efficient if the main purpose of a disclosure policy is to reassure prospective implementers that a license will be available. On the other hand, blanket disclosure shifts search costs from the patent holder (who presumably has a comparative advantage at finding its own essential patents) onto other interested parties, such as prospective licensees who wish to evaluate the scope and value of a firm's dSEPs; other SSO participants seeking to make explicit cost-benefit comparisons of alternative technologies before committing to a standard; and regulators or courts that might use information about relevant dSEPs to determine reasonable royalties.

Most SSOs encourage early disclosure. For example, ETSI seeks disclosures "in a timely fashion" and the ANSI IPR Policy Guidelines (ANSI, 2006) encourage "early disclosure." However, few SSOs provide explicit

[4] See Bekkers and Updegrove (2012) for additional information on policies governing search, 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.

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

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

If a dSEP issues before the patented invention is proposed for inclusion in a standard, the owner may respond to the call for patents at the meeting where this proposal is discussed. Although that response would not leave a public paper trail, the patent holder is typically required to provide a formal declaration (which we do observe) sometime after the publication of a draft standard, and preferably before the final specification is approved (though Layne-Farrar (2014) suggests that some disclosures occur much later in practice). However, many dSEPs remain under review at the patent office while the standardization process proceeds.[6] Thus, while formal IPR declarations can provide a great deal of information, it is important to recognize that SSOs may receive them well-after the date when the IPR was first disclosed to a technical committee, or when the key technical decisions that determine a patent's essentiality were made.

Policies that encourage or require specific disclosure typically apply to any patent or patent application that an SSO member believes might be technically essential, meaning that infringement would be necessary to produce a compliant implementation of the standard. However, SSO participants are not necessarily required to disclose commercially essential patents, which cover methods of implementation that deliver dramatic cost reductions or quality improvements. Patents covering both mandatory and optional features of a standard are normally (though not always) considered essential, as are patents required to implement only a certain category of products.[7] However, patent owners are not typically required to indicate whether dSEPs apply to optional features, or to certain product categories.

SSOs do not adjudicate essentiality, and many dSEPs are not in fact essential. Disclosure of non-essential patents is often caused by changes in a draft standard or in the claims of a patent application during the standardization process. Mandatory specific disclosure policies also create incentives to err on the side of inclusivity by creating a risk that undisclosed essential patents become legally unenforceable, while providing no penalty for disclosure of patents that are only vaguely related to a standard. Because courts ultimately determine essentiality, it is hard to estimate the share of dSEPs that are truly essential. In a recent study, Brachtendorf et al. (2020) explored the use of artificial intelligence to predict actual essentiality. In its 2017 communication on Standard Essential Patents, the European Commission (EC) expressed its concerns about the lack of transparency regarding actual essentiality (European Commission, 2017), and in a study carried out for the European Commission, the feasibility of setting up a system to generate public, transparent data on actual essentially was investigated (Bekkers et al., 2020). Although studies by Goodman and Myers (2005) and Van Audenrode et al. (2017) suggest that only 20 to 40 % of the patents disclosed to ETSI are essential, we expect that these figures vary across SSOs and over time.

2.1.3. Licensing commitments

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

The most common form of licensing commitment is a promise to license on Reasonable and Non-Discriminatory (RAND) or Fair, Reasonable and Non-Discriminatory (FRAND) terms.[8] There is a substantial legal and economic literature, reviewed by Farrell et al. (2007) and the papers in Contreras (2017), as well as considerable controversy over the precise meaning of FRAND. Many economists take the position that FRAND commitments limit a dSEP holder's access to injunctive relief, and are meant to constrain prices to an *ex ante* competitive rate that reflects the value of essential patents relative to alternatives available at the time of standardization (e.g. Swanson and Baumol, 2005; Contreras and Layne-Farrar, 2017). This position is not universal, however, and the question of FRAND compliance often emerges in dSEP litigation.

Most of the SSOs in our data allow, but do not require, more stringent types of licensing commitments than FRAND. For example, many firms promise to grant a royalty-free license to any standards implementer, or provide a covenant not to assert their essential patents. Some firms add conditions to their licensing commitments, though SSOs vary in their willingness to allow free-form declarations.[9]

Licensing commitments can also vary in scope. Some commitments only apply to specifically disclosed patents, while others apply to a particular standard (document), all work by a particular technical committee (Working Group), or even to the entire SSO. One very common type of declaration combines a specific disclosure with a blanket FRAND licensing commitment that covers all work on a particular standard.

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

The data we examine come from public IP disclosure records, and most SSOs provide a set of standard disclaimers with their disclosure data.[10] Beyond common disclaimers, SSOs differ in what they require, what they (explicitly) allow, and what they seem to tolerate in practice.[11]

2.2. Disclosure characteristics

SSO participants generally face three choices when disclosing dSEPs: what to disclose, when to disclose it, and what licensing terms to offer. In

6 Fig. B-1 provides a graphical depiction of these two scenarios.

7 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.

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

9 Common conditions include defensive suspension provisions (which terminate the FRAND commitment if an implementer sues the essential patent holder for infringement) and reciprocity requirements (which make a FRAND commitment conditional on receiving similar terms from any implementer who also holds essential patents).

10 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.

11 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.

this subsection, we explore variation across SSOs along each of these margins. Our data come from the public archives of the 13 SSOs listed in Table 1, and contain 45,349 disclosures (general or specific licensing statements) that can be grouped into 4910 declarations (statements submitted to a single SSO by a single firm on a given date) from 926 unique organizations.[12] Appendix A provides a detailed description of our hand-collected data on individual disclosures.

Before analyzing the variation in disclosure practices, it is worth pausing to discuss the origins of the substantial heterogeneity in SSO polices described above. A recent report by the European Commission (Baron et al., 2019) highlights numerous factors that shape SSO governance, both broadly and in the specific area of intellectual property. Salient factors include technological and market considerations, legal and regulatory constraints, competition, the history and organization of the SSO, and its relationship to other standard-setting organizations. Because changes to IPR policies often require super-majority support from an SSO's membership, they tend to evolve slowly. In the remainder of this paper, we will treat the intellectual property policies of SSOs in our sample as fixed, while recognizing that this broader set of factors may influence both the choice of rules and the behavior of agents within any particular SSO.

2.2.1. Variation across SSOs

Table 2 tabulates disclosure-related summary statistics by SSO. The thirteen organizations in our sample standardize different types of technology. Broadly speaking, ATIS, ETSI and TIA focus on cellular (or wide-area) wireless networking. The IEEE standardizes a wide variety of technologies, though many of its IP disclosures relate to the highly successful 802.11 local-area networking protocol. Likewise, ISO, IEC, and ITU all have very broad scope, though in practice many ISO/IEC disclosures relate to encoding and decoding of audio, video, and image formats. OMA develops application-layer protocols related to mobile phones. Finally, the IETF, ITU, and Broadband Forum develop a range of computer networking standards. Prior literature (e.g. Bekkers and Updegrove (2012)) and the organizations' web sites provide more detail on the use case for individual protocols developed by each SSO.

The first column in Table 2 shows that the distribution of declarations across SSOs is very uneven. While several SSOs have 500 or more declarations, others have only a handful. The next three columns provide information about disclosure scope. About half of all declarations in our data are blankets. The share of blanket disclosures is very low for ETSI and OMA, which both have mandatory specific disclosure rules, and over 90 % at TIA.[13] The remaining SSOs in our sample have a blanket disclosure share between 40 and 60 %, suggesting that it is a reasonably popular option where allowed.

Conditional on making a specific disclosure, we observe substantial variation in the number of patents listed in a declaration. For example, the average disclosure size at ETSI is almost 40 patents or patent applications, which is four times larger than the next largest SSO. ETSI's outlier status likely reflects the scope of its work, the existence of an active licensing market for cellular dSEPs, and its policy mandating specific disclosure. Among other SSO's, we see more patents-per-declaration at ATIS and OMA, with fewer at ANSI, CENELEC and TIA.

The next three columns in Table 2 focus on the terms of licensing commitments. Across the entire sample, 89 % of disclosures offer a FRAND commitment. In some cases, such as ETSI, that is the only option allowed. However, we do see that 9 % of all licensing commitments are royalty-free, 2 % withhold a licensing commitment, and 1 % provide specific terms and conditions. When looking across SSOs, the clear outlier is the IETF, where more than one third of the declarations provide a royalty-free commitment. Once again, this appears to reflect differences in SSO policy. In particular, many IETF Working Groups have a stated preference for royalty-free standards, though others will consider royalty-bearing technology if justified on technical merits.

The next two columns in Table 2 examine disclosure timing. Many SSOs encourage early patent disclosure in order to reduce uncertainty about the scope of patent protection prior to committing to a standard. Ideally, we would like to measure disclosure timing based on the date when an SSO decides what technology to include in a standard. Unfortunately, we are not aware of any data set that captures the timing of SSOs' key design decisions. As an alternative, we construct two measures of age-at-disclosure for individual patents, based on application- and grant-dates respectively. Two novel facts emerge from examining the distribution of disclosure age across SSOs. First, although patents are declared five years after application on average, there is considerable dispersion around that mean. For instance, the mean disclosure age is 3 years at ANSI compared to 8.5 years after application at TIA. Second, many patents are declared before they issue. While the average lag from grant to disclosure is 1.6 years, the mean lag is negative at ATIS, BBF, and IETF.

Given that most of these SSOs encourage early disclosure, the observed variation in disclosure timing probably reflects differences in the timing of the standards process relative to the evolution of underlying technology, and perhaps also differences in firms' intellectual property strategies. Disclosure of dSEPs before the patent issues also illustrates one challenge for SSO participants who might otherwise seek to "design around" a patented technology: while the patent application is still under review, they face a moving target.

The last column in Table 2 shows how we group the thirteen SSOs in our analyses below, due to the small number of declarations and dSEPs associated with some organizations. Our first group are the three "Big I" international Standards Developing Organizations, IEC, ISO and ITU. These large international SSOs share a common patent policy. Our second group contains the regional umbrella organizations CEN/CENELEC for Europe and ANSI for the US, along with the Broadband Forum. IEEE, ETSI and IETF each constitute their own group. The final group consists of three smaller forums (ATIS, OMA, TIA) that develop mobile telecommunications standards.

2.2.2. Variation across participants

To examine disclosure choices of SSO participants, we created a variable that captures whether a firm is primarily a "downstream" standards implementer, as opposed to an "upstream" licensor or component vendor. While any such distinction is inherently somewhat arbitrary, we found it relatively easy to classify the most active firms into a handful of business model categories, and have made the data public so that interested readers can experiment with alternative classification schemes. In our scheme, R&D specialists, licensing entities, universities, semiconductor producers and individual inventors were classified as upstream organizations. Original Equipment Manufacturers (OEMs), software producers, and service providers were classified as downstream organizations.[14] We placed all entities that made five or more declarations into a category, and believe that most of the remaining unclassified observations would fall into the "upstream" basket, based on inspecting the data and because scale economies in implementation lead most downstream firms to be familiar brands.[15]

We analyze SSO participants' disclosure strategies using the following linear probability (OLS) model

[12] Tables A-3 and A-4 show the most active firms in our data, in aggregate and by SSO. The ten most active firms account for 33 % of the declarations (and an even larger share of dSEPs), but the "long tail" of small organizations is collectively substantial.

[13] ETSI does offer firms the option to make a blanket license assurance, which explains the 10 % of declarations to that SSO that do not list patents.

[14] See Table A-5 for summary statistics related to our business model categories.

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

Table 2
Disclosure summary statistics.

SSO	Total	Percent	Mean	Unique	Commitment terms (percent)				Disclosure lag (years)		SSO
	Declarations	Blanket	Size	IPR	FRAND	Free	Specific	None	App-Disc	Grant-Disc	Group
ANSI	346	57	1.3	273	83	8	5	4	3.0	0.4	2
ATIS	99	66	5.1	217	84	8	1	7	3.4	−0.1	6
BBF	23	26	5.6	44	87	9	0	4	2.6	−1.8	2
CEN	5	0	4.2	5	100	0	0	0	5.3	1.2	2
CENELEC	11	73	0.4	4	100	0	0	0	5.3	3.0	2
ETSI	699	10	39.2	3839	100	0	0	0	5.5	2.0	3
IEC	362	55	3.9	402	98	2	0	0	5.9	2.6	1
IEEE	716	46	2.6	712	95	2	1	2	4.2	1.0	4
IETF	821	57	2.7	694	57	37	0	6	3.5	−0.5	5
ISO	519	64	2.3	341	96	3	0	1	7.5	4.4	1
ITU	927	68	1.9	586	94	6	0	0	5.0	2.0	1
OMA	100	0	9.2	295	100	0	0	0	5.4	2.0	6
TIA	282	91	1.4	94	96	1	0	3	8.6	6.1	6
Total	4910	52	7.8	6723	89	9	1	2	5.0	1.6	

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

$$Y_i = \beta_1 Upstream_{f_i} + \beta_2 Unclassified_{f_i} + \alpha_{SSO_i} + \lambda_{t_i} + \varepsilon_i \quad (1)$$

where Y_i indicates a choice for disclosure *i*. The indicator variable $Upstream_{f_i}$ equals one if the firm *f* making disclosure *i* is classified as an upstream organization, and $Unclassified_{f_i}$ equals one if firm *f* is not classified (so downstream is the omitted category). The α_{SSO_i} are SSO-group fixed effects (with ANSI the omitted category), λ_{t_i} are disclosure-year fixed effects, and ε_i is an econometric error term. We consider two outcomes for Y_i, an indicator for Blanket disclosures and an indicator for Royalty Free commitments.[16] Both outcomes are multiplied by 100 to ease the interpretation of the coefficients as percentage-point changes. Table 3 reports coefficient estimates.[17]

The results in column (1) show that upstream firms are 6.3 percentage points less likely to offer a royalty-free licensing commitment. This is a large change compared to the unconditional mean of 9 %. Unclassified firms are indistinguishable from downstream firms. Column (2) adds SSO-group effects, and the correlation between business model and licensing commitment declines in magnitude, but remains statistically significant. Not surprisingly, there is also a very large and statistically significant 30 percentage point increase in royalty-free commitments at the IETF. We interpret this finding as evidence that upstream inventors, licensors and component producers are more reliant on intellectual property to capture the returns from inventions used in a standard, at least relative to downstream firms that are more likely to view standards as inputs to the production of differentiated products.

Table 3
Disclosure choice models.

Specification outcome	OLS			
	Royalty free (%)		Blanket (%)	
	(1)	(2)	(3)	(4)
Unclassified	−0.3	1.2	−0.8	−4.0
	[1.2]	[1.1]	[2.1]	[2.1]
Upstream	−6.3	−2.3	7.6	6.1
	[1.0]**	[0.9]**	[2.0]**	[1.8]**
BIG-I		−2.6		7.0
		[1.5]		[2.9]*
ETSI		−6.7		−46.1
		[1.4]**		[3.0]**
IEEE		−4.6		−9.6
		[1.5]**		[3.2]**
IETF		30.0		1.6
		[2.2]**		[3.2]
Other		−4.0		10.9
		[1.5]**		[3.4]**
Disclosure year FEs	Yes	Yes	Yes	Yes
Observations	4731	4731	4731	4731
R-squared	0.02	0.21	0.01	0.14

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

Columns (3) and (4) in Table 3 show that upstream licensors are 6–7 percentage points more likely to make a blanket disclosure, even after controlling for SSO fixed effects. Viewed through the lens of Lerner et al. (2016), this suggests that downstream firms own higher quality patents. We are reluctant to embrace that interpretation, however, and our results seem to contradict those authors' finding that larger *downstream* firms are more likely to use blankets. The difference in our results could be explained by differences in the estimation sample, or in the measurement of each firm's location within the supply chain. They also use a specification where the downstream indicator is interacted with a measure of firm size. In general, we do not have strong views about how to interpret the results in columns (3) and (4), which could reflect underlying differences in patent quality, search costs, or strategic behavior by individual firms. Our main conclusion is that blanket disclosure constitutes a good topic for further research.

3. Declared essential patents

This section examines the dSEPs disclosed to our sample of thirteen SSOs. While the declarations list patents from many countries, we limit our patent-level analyses to a group of 6723 granted US patents that were either declared essential, or share a common priority application with a European declared essential patent.[18] The United States is the

[16] We also explored disclosure-timing in a set of unreported regressions. Differences in mean disclosure age for upstream and downstream firms were generally less than one year and not statistically significant.

[17] Table B-1 shows that we obtain nearly identical estimates of the marginal effects from a logit specification.

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

most common issuing country in our overall dataset, and limiting the analysis to US patents keeps the presentation and interpretation of statistics relatively simple. All of our patent-level outcomes data come from the USPTO, with the exception of the data on patent litigation in US district courts, which was obtained from the Thomson Innovation database in April 2016.[19]

As an initial point of comparison, we created a "control" sample by randomly choosing an undeclared US patent with the same primary (3 digit) technology class, grant year, patent type (i.e. regular utility or reissue utility patent), and roughly the same number of claims as each dSEP.[20] This one-to-one matching procedure ensures that the joint distribution of technology classes, grant years, patent type and claims is balanced in the two samples. To be clear, these randomly selected patents are not meant to provide an estimate of counter-factual outcomes for dSEPs had they not been declared essential. Rather, the comparison group yields an estimate of the "average outcome" in a set of patents with similar age and technical characteristics.

The first two rows in Table 4 examine "long run" differences between the SSO and Control patents using two outcomes that are informative about the consequences of different policies: forward patent citations (a common measure of technology impact) and patent litigation (which indicates more aggressive patent assertion and subsequent disputes). The first row shows that SSO Patents are cited as prior art by other US patents 70 % more than the random matches. The second row shows that the probability of litigation in the sample of SSO Patents is four times higher than the random matches (7.27 % versus 1.76 %).[21] While it is hard to place a value on a forward citation, or understand the precise significance of a particular lawsuit, these measures are widely used by innovation researchers and rarely show differences of the size and statistical significance observed in our analysis.

The remainder of Table 4 shows that there are statistically significant differences between dSEPs and controls for the probability of reassignment (i.e. transfer of patent ownership), family size, the number of inventors, and the number of patent and non-patent prior art references. The very large difference in family size suggests that dSEP owners perceive these patents to have above-average value, since each new patent in a family comes at some non-trivial cost. The differences in both patent and non-patent prior art references suggest that dSEPs are "broader" than the controls, and that applicants were more careful in delineating the underlying innovation (relative to prior patents) in their application.

Table 4
dSEPs vs. matched control patents.

	dSEP	Control	T-stat	Norm Diff
Forward citations	67.77	39.29	16.40	0.28
Percent litigated	7.20	1.76	15.40	0.27
Reassigned Dummy	0.30	0.28	3.13	0.05
Family Size	13.09	4.47	33.98	0.59
Inventors (count)	2.76	2.44	10.93	0.19
Patent References	29.32	21.05	8.88	0.15
Non-patent References	9.30	4.63	11.80	0.20
Claims	23.23	22.70	1.68	0.03
Application year	2000	1999	0.57	0.01
Issue year	2003	2003	0.00	0.00
Observations	6723	6723		

Controls are a randomly select 1–1 match to dSEPs based on patent type (regular utility or reissue utility), grant year, 3-digit US primary technology class, and number of claims. The normalized difference of sample means $\overline{X_1}$ and $\overline{X_2}$ is defined as $(\overline{X_1}-\overline{X_2})/\sqrt{\frac{1}{2}\left(\sigma^2_{X_1}+\sigma^2_{X_2}\right)}$.

Overall, Table 4 illustrates that dSEPs score higher than the controls on a variety of metrics used to proxy for value and technological significance. Before turning to a set of analyses that unpack this observation, it is worth reiterating several caveats about the sample of dSEPs. First, these data do not contain all essential patents, since many SSOs allow blanket disclosure. We know of no easy way to identify undeclared essential patents, including those in blanket disclosures. Second, any sample of dSEPs will contain some patents that are not technically essential. As described above, both standards and patent applications change over time, so a patent or pending application that was essential to a particular draft may no longer be infringed by the time an SSO settles on the final specification. Firms may also "overdeclare" out of caution (since non-disclosure could render their IP unenforceable) or because they have a strategic motive to inflate their dSEP counts, possibly with an eye towards litigation or future negotiations.

3.1. Cross-sectional comparisons

Our first set of patent-level analyses examine differences in long-run outcomes (i.e. citations and litigation) between dSEPs and matched controls using the following regression framework:

$$Y_{ij} = Declared_i\beta_j + \alpha_j + \lambda_g + \gamma_c + X_i\theta + \varepsilon_i. \tag{2}$$

In this specification, Y_{ij} is either a citation count or a litigation indicator for patent i in group j. The "groups" indexed by j correspond to four types of heterogeneity: (1) specifically declared dSEPs versus undeclared dSEP family members, (2) the business model of the claimant, (3) the type of licensing commitment, and (4) the SSO where disclosure first occurred. The variable $Declared_i$ is an indicator that equals one if patent i is a dSEP; λ_g and γ_c are issue-year and technology class fixed-effects; α_j are group-level main effects; and X_i is a vector of control variables that includes the number of claims, patent references and non-patent prior art references made by each patent. For patent citations, we estimate Eq. (2) as a Poisson regression with robust standard errors. For litigation, we use a linear probability model.[22]

The coefficients β_j in Eq. (2) measure a group-specific difference between dSEPs and their matched controls. These differences may reflect both selection (where firms declare more important patents to SSOs) and treatment effects (where incorporating a patented technology into a standard leads to more value or greater attention for the patent). Because we do not distinguish selection from causation, we are typically more interested in understanding how β_j varies across different groups of dSEPs than in the precise magnitude of the coefficient.

Columns (1) and (5) in Table 5 compare patents that were actually listed as dSEPs to family members that were not specifically declared. Both groups, on average, receive more citations and are more likely to be litigated than the controls (estimates statistically significant at conventional levels), though the coefficients are much larger for the dSEPs. A coefficient of 0.55 in column (1) indicates that dSEPs receive about 73 % more forward citations than the controls, compared to around 14 % for

[19] We combine data from various sources, including PATSTAT, PatentsView (http://www.patentsview.org), the USPTO Patent Assignment Dataset (Marco et al., 2015), the Harvard Patent Dataverse and the Fung Institute GitHub website (Li et al., 2014). We exclude from the Thomson Innovation data the information regarding reexaminations, interferences, and reissues, and identify the date of the first litigation case in a US district court. Details are available upon request.

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

[21] 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.

[22] Table B-2 shows robustness to using a logit specification rather than OLS for the litigation outcome.

Table 5
Cross-section comparison of dSEPs vs. matched control patents.

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

Robust standard errors in brackets. The omitted business-model category is a separate category for the control patents, whose owners we did not attempt to code. Additional Controls are log(Patent References), log(Non-patent References) and log(Claims).

* Significant at 5 %.

** Significant at 1 %.

their family members.[23] The coefficient of 5.56 in column (5) indicates that the difference in probability of a lawsuit is 5.6 percentage points. These results suggest that either some part of the difference in outcomes between dSEPs and matched controls is driven by the dSEPs' greater visibility, or that firms are more careful to declare the US family member for more significant inventions.

Columns (2) and (6) in Table 5 examine the relationship between the patent holder's business model and dSEP citation and litigation rates.[24] In column (2), we see that patents disclosed by pure-licensors, universities and component producers receive more citations than those disclosed by downstream implementers. Column (6) shows that firms with upstream business models are also more likely to assert their dSEPs in litigation. The results are similar, but with even larger magnitude, for unclassified patent-holders. We take these results as further support for the idea that upstream technology developers are more reliant on patent monetization as part of their overall business model.

Columns (3) and (7) in Table 5 examine how dSEP citation and litigation rates vary with the licensing commitments. The difference in forward citations is largest for royalty-free commitments, although small sample sizes lead to large standard errors for all three types of non-FRAND licensing commitment. Column (7) shows that we cannot reject the hypothesis that there is no difference in the probability of litigation between dSEPs declared under a royalty-free licensing commitment and their matched control. The FRAND patents, however, have a 5.1 percentage point increase in litigation probability (roughly 300 % compared to the baseline litigation rate for the controls), and the patents with no licensing commitment are 9.6 percentage points more likely to be litigated.

The fact that royalty free patents are less likely to be litigated may not be surprising: there is little incentive to sue if a patent can be freely infringed (though defensive suspension provisions and applications of the patented technology outside of the scope of the standard may explain why these patents are still litigated in some cases).[25] Taken in conjunction with the citation results, however, there is some indication that follow-on inventors may be more willing to "build on" royalty free technology (as long as one is prepared to accept that relatively common interpretation of patent citations). These results also suggest that FRAND offers some additional certainty relative to patents where no licensing commitment was provided.

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

[24] We created a separate business-model category for the control patents, whose owners we did not attempt to code, and use that as the omitted category in these regressions.

[25] 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.

Columns (4) and (8) in Table 5 examine differences across the "SSO Groups" defined in Table 2 and discussed above. Column (4) shows that dSEPs receive more citations than their matched controls at every SSO, though the magnitude of the difference varies considerably. The citations gap between declared essential and "average" patents is greatest for the "Other" group containing Open Mobile Alliance, TIA and ATIS, and also at the IETF. The citations gap is notably smaller for ETSI, ANSI, and the Big-I international organizations. Column (8) examines heterogeneity in litigation rates between dSEPs and control patents. Once again, we see considerable variation across SSOs. The difference in litigation probabilities between Control and SSO Patents is largest at ANSI, where there is a 12.06 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 mandatory specific disclosure may lead to disclosure of weaker patents and a lower rate of *ex post* technical essentiality.

While one might have expected the estimated citations and litigation coefficients to co-vary positively across SSOs, Table 5 does not show any obvious relationship. For example, ANSI has the largest litigation gap and the second-lowest gap in citations, while the patents declared to IETF are cited at a very high rate relative to their controls, and have one of the smaller litigation gaps. This may say something about the relative efficacy of alternative disclosure policies. However, we remain cautious about placing a causal interpretation on any of these comparisons. In particular, all of the measured associations could be driven by differences in selection or impact of alternative institutions, and are likely a combination of both. Moreover, we have no way of knowing the citation or litigation rates for patents declared under a blanket disclosure.

3.2. Disclosure timing and outcomes

Up to this point, we have emphasized that disclosure timing is not tightly linked to the adoption of a standard. Some patents are disclosed long after a standard has emerged, and in other cases, SSO participants may be aware that sponsors of a proposal own related IP well before a formal declaration is made. Nevertheless, most of the SSOs in our data encourage early disclosure, and a pair of "patent ambush" cases filed by the U.S. Federal Trade Commission against Dell and Rambus provide strong incentives to comply.[26] 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 impacts long-term outcomes for declared essential patents.[27] This section provides evidence of a relationship between disclosure timing and outcomes such as citations and litigation using difference-in-differences regressions. As emphasized above, this relationship may reflect either a standardization effect, a separate salience or "visibility" effect, or both.

3.2.1. Citations

For this analysis, we created a panel data set that contains one observation per year for each dSEP and Control patent with an age between -5 and 20 (where age is defined as calendar-year minus issue-year). Our outcome variable is a count of references from all issued patent applications filed in year t to each dSEP or control patent i. Fig. 1 graphs the average annual citation rate by age for dSEP and the random matched control patents in the raw data. The first panel in this figure shows that dSEPs receive roughly 20 % more citations than control patents by the time they issue. This gap widens for about 10 years, as the dSEPs' average annual citation rate climbs from 5 to 6, and the control patent rate stays constant at about 4. The second panel in Fig. 1 provides a separate annual citation rate for each SSO, and shows that much of the "bump" in the first panel is linked to two groups: IETF, and the "telecom" group consisting of ATIS, TIA and OMA. Overall, these graphs suggest that there is *both* a substantial selection effect, whereby dSEPs receive a higher baseline citation rate prior to standardization, and a smaller standardization effect (perhaps concentrated in particular SSOs) whereby citations increase after a patent is declared essential.

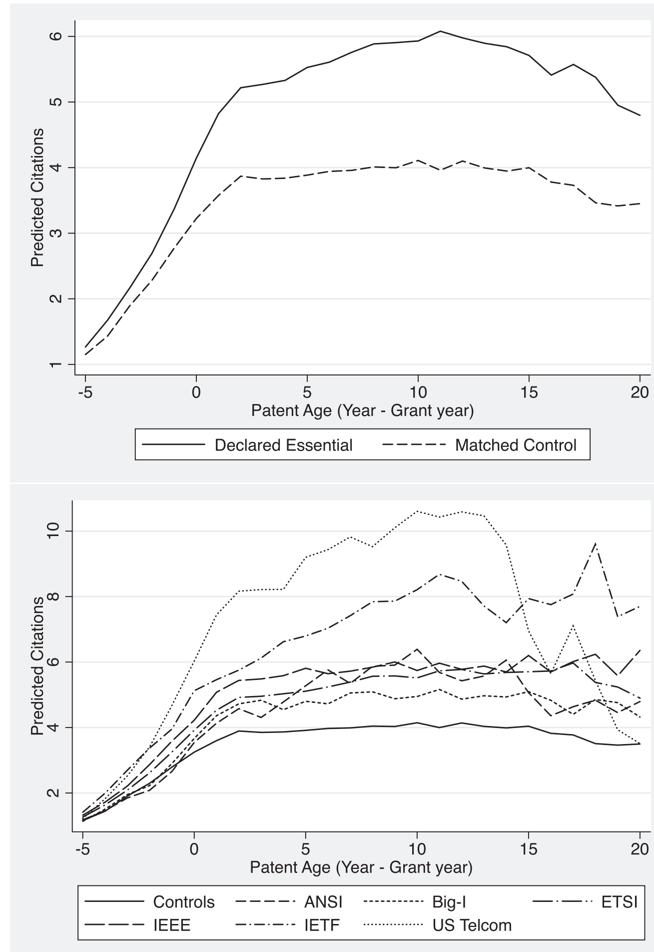

Fig. 1. Citations for dSEPs and matched controls.
Top panel shows mean citation rate conditional on age for all dSEPs and matched controls. Bottom panel shows separates the citation rate by SSO.

To further explore the standardization effect, we created an additional set of *citation matched* control patents that have the same pre-disclosure citation rate as the dSEPs. To construct this additional control set, we draw a single patent having the same application year and technology class as each dSEP, and also having the same number of cumulative patent citations two years prior to disclosure. If the dSEP is disclosed eight or more years after the corresponding application is filed, we also match on cumulative citations eight and three years prior to disclosure. Because this matched control sample is constructed to have the same pre-disclosure citation trends as the dSEPs, it is more plausible to assume that these controls provide a valid estimate of the counterfactual post-Disclosure outcomes for the declared essential patents.

Our analysis builds on the difference-in-difference specification proposed by Rysman and Simcoe (2008),

$$Cites_{it} = PostDisclosure_{it}\beta_j + Declared_i\alpha + \gamma_{ay} + \varepsilon_{it} \quad (3)$$

[26] See *In Re Dell Computer* and FTC vs. Rambus. In particular, the outcome of *Dell Computer* suggests that firms that fail to disclose essential IP may lose the right to assert their patents.

[27] 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.

where $PostDisclosure_{it}$ is a time-varying indicator that equals one after a dSEP has been declared essential to an SSO; $Declared_i$ is a dSEP indicator; and γ_{ay} is a full set of age-by-year effects that should absorb both secular trends in the overall citation rate and the underlying shape of the citation-age distribution. In this regression, α measures the selection effect, which can only be estimated if we do not include patent fixed effects. The associations between standardization and outcomes are measured by β_j, which we allow to vary across groups indexed by j, as above.

Columns (1) and (2) in Table 6 show how pre-disclosure citation-matching helps address selection effects. If we use the randomly matched control sample, the regression suggests a very strong selection effect of 1.3 citations per year (on a baseline of 2.3 cites per year), but no post-disclosure increase in citations. However, when we switch to the citation matched controls, there is no pre-disclosure difference in cites by construction, and we estimate a 12 % increase in citations following disclosure to the SSO. In column (3) we add patent fixed effects, and the estimated post-disclosure increase in citations falls to 0.17 citations per year (around 5 %).[28]

Thus far, the results in Table 6 are broadly consistent with the findings in Rysman and Simcoe (2008), indicating that SSOs produce both a strong selection effect, by choosing patented technologies that are *ex ante* more valuable, as well as a disclosure effect by encouraging coordinated adoption of those technologies. The main contribution we make relative to that study is the construction of a citation-matched control sample. In the last column of Table 6, however, we show that if dSEPs disclosed to ETSI are dropped from the estimation sample, there is a four-fold increase in the disclosure effect. One interpretation of this finding is that ETSI's mandatory specific disclosure rule leads to the disclosure of more non-essential patents that do not exhibit a post-disclosure increase in citations. In particular, the option to use blankets may lead companies to make specific disclosures only when they are confident about the potential essentiality of an individual patent, whereas ETSI's policy encourages firms to disclose patents for which they are less confident, resulting in more false positives.

Table 6
Citation diff-in-diffs.

Specification outcome	OLS			
	$Citations_{it}$			
Estimation sample	Random match	Cite matched	Cite matched	Drop ETSI
	(1)	(2)	(3)	(4)
PostDisclosure	−0.13	0.34	0.17	0.65
	[0.08]	[0.09]**	[0.06]*	[0.10]*
Declared essential	1.33	0.07		
	[0.09]**	[0.10]		
Patent fixed effects	No	No	Yes	Yes
Age-year effects	Yes	Yes	Yes	Yes
$E[Citations_{it}]$	2.34	2.81	2.81	3.03
Observations	167,461	160,279	160,279	74,728
Patents	13,384	12,200	12,200	5604
R-squared	0.08	0.06	0.60	0.60

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

Fig. 2 provides additional evidence on the relationship between the timing of disclosure and citations, as well as the impact of excluding ETSI from the sample. To create the figure, we estimated a series of event study regressions, based on the following specification

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

and plot the coefficients β_k, where k indexes years-to-disclosure (i.e. calendar year minus the year when a patent is declared essential), normalizing $\beta_{-2} = 0$.[29] The bottom left panel is based on the full sample of dSEPs, omitting the patent fixed effects (α_i). There are three notable features of this graph. First, even without patent fixed effects, it is clear that our citation-matching procedure produces a good match in the pre-disclosure citation levels and trends. In particular, none of the β_k for $k < -2$ is statistically significantly different from zero. Second, we see a sharp increase in cites starting the year before formal disclosure. And third, following disclosure we observe a long-term persistent difference in the citation rate of the dSEPs and the citation-matched controls. That is, the coefficients β_k are all statistically different from zero for $k = -1$ to 10. We interpret this pattern as suggesting that the standardization process may have a direct impact on the economic and technical importance of declared essential patents.

The top left panel in Fig. 2 adds patent fixed-effects to control for unobserved time-invariant heterogeneity. The results are similar, although the magnitude of the post-disclosure citation increase is smaller. The two panels in the right half of Fig. 2 show that when ETSI is removed from the estimation sample, we observe the same general pattern — no visible pre-trends until the sharp increase in citations starting one year before disclosure — but with much larger estimated post-disclosure increases in citations.

Our final set of citation analyses return to the specification in Eq. (3), allowing the post-disclosure change in citations to vary by SSO and type of licensing commitment. The results are shown in Table 7. Columns (1) and (2) examine heterogeneity across different types of licensing commitment. Not surprisingly, for the FRAND patents that comprise 90 % of our estimation sample, the results are very similar to Table 6. The third column in Table 7 shows that if we estimate a separate post-disclosure coefficient for each SSO group, we find an increase in citations everywhere except ETSI, where the coefficient is negative and statistically significant.

One way to rationalize ETSI's post-disclosure decrease in citations is if citations respond to *potential* essentiality, but drop off for non-essential patents after the SSO makes its selection. This explanation is consistent with the idea that dSEPs are highly cited even before disclosure, and with the anticipation effects observed in Fig. 2. It also finds some support in a recent study by Brachtendorf et al. (2020) that was motivated in part by our finding of a post-disclosure decrease in citations for ETSI. As a proxy for essentiality, they construct measures of the textual similarity between dSEPs and the underlying standards. Then, they show that patents disclosed to ETSI exhibit an increase in citations after disclosure when they are more textually similar to ETSI standards, and a decrease if they have less overlap. In other words, if textual similarity is a valid proxy for essentiality, then the post-disclosure decrease in citations for ETSI appears to be driven by non-essential patents.

The last three columns in Table 7 use self-citations as the outcome variable. We find that the increase in self-citations after disclosure is larger when accompanied by a royalty-free licensing commitment (and at IETF, where most of the royalty free pledges are made). While the terms of the commitment are clearly endogenous, a plausible

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

[29] We chose this normalization because both the data and our discussions with standards practitioners suggest that committee members obtain information about potentially essential patents during the year before disclosure, although normalizing $\beta_{-1} = 0$ produces similar results. Matched controls are assigned the same “disclosure date” as their corresponding dSEP.

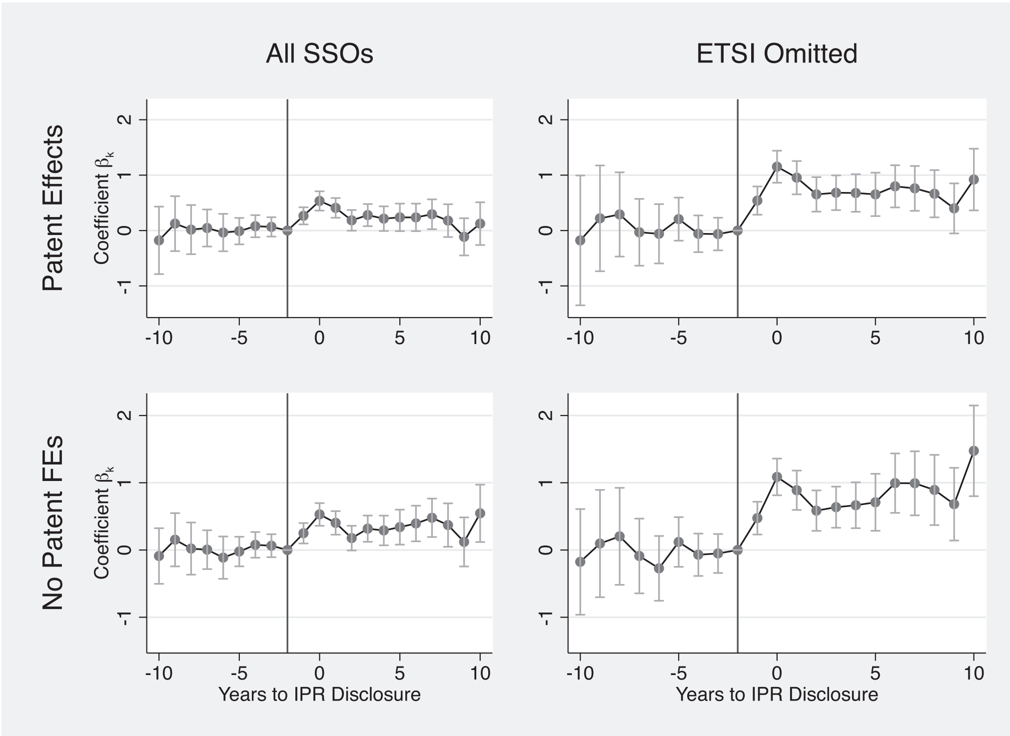

Fig. 2. Disclosure event studies.
Each panel graphs coefficients (β_k) from the event-study difference in difference specification described in the text (see Eq. (4)), for a sample that includes SSO and citation-matched control patents. Specification for the top row includes patent fixed effects, while bottom does not. Estimation sample for left column includes all SSOs, while right column excludes ETSI patents and their matched controls.

Table 7
Citation diff-in-diffs: heterogeneity by licensing commitment and SSO.

Specification outcome	OLS					
	$Citations_{it}$			$SelfCitations_{it}$		
Estimation sample	Cite matched	Drop ETSI	Cite matched	Cite matched	Drop ETSI	Cite matched
	(1)	(2)	(3)	(4)	(5)	(6)
PostDisclosure * FRAND	0.17	0.70		0.07	0.06	
	[0.06]**	[0.11]**		[0.02]**	[0.02]**	
PostDisclosure * FREE	0.20	0.20		0.27	0.26	
	[0.18]	[0.19]		[0.07]**	[0.07]**	
PostDisclosure * TERMS	0.58	0.68		0.01	0.05	
	[0.53]	[0.51]		[0.13]	[0.13]	
PostDisclosure * None	0.25	0.20		0.06	0.06	
	[0.66]	[0.67]		[0.03]	[0.03]	
PostDisclosure * ANSI			1.29			0.13
			[0.35]**			[0.06]*
PostDisclosure * Big-I			0.55			0.03
			[0.13]**			[0.02]
PostDisclosure * ETSI			−0.25			0.07
			[0.07]**			[0.03]*
PostDisclosure * IEEE			0.40			0.09
			[0.15]**			[0.04]*
PostDisclosure * IETF			0.33			0.17
			[0.20]			[0.05]**
PostDisclosure * Other			1.99			0.06
			[0.31]**			[0.04]
Patent fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Age-year effects	Yes	Yes	Yes	Yes	Yes	Yes
$E[Y_{it}]$	2.81	3.03	2.81	0.27	0.34	0.27
Observations	160,279	74,728	160,279	160,279	74,728	160,279
Patents	12,200	5604	12,200	12,200	5604	12,200
R-squared	0.60	0.60	0.60	0.47	0.45	0.47

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

interpretation of this finding is that companies are more likely to offer free licenses when they expect to own proprietary complements (i.e. the citing patents) that provide alternative means for capturing the value produced by a standard.

3.2.2. Litigation

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

Fig. 3 shows the 20-year cumulative hazard of litigation for declared essential and the citation-matched control patents. The dramatic divergence over time illustrates the same gap in litigation probabilities that we saw with the cross-sectional results in Section 3. However, where the cross-sectional models report a difference in litigation rates averaged over patents at different ages, this Figure shows that the difference in the propensity to litigate dSEPs versus controls grows larger over time. By age 20, the cumulative difference in litigation probabilities is considerably larger than the 5 to 7 percentage point difference reported in Section 3, reflecting the fact that litigation probabilities increase over time for declared essential patents, and that we have many "young" patents in the entire sample.

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

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

$$Litigation_{it} = PostDisclosure_{it}\beta_j + \gamma_a + \lambda_y + X_{it}\theta + \varepsilon_{it} \quad (5)$$

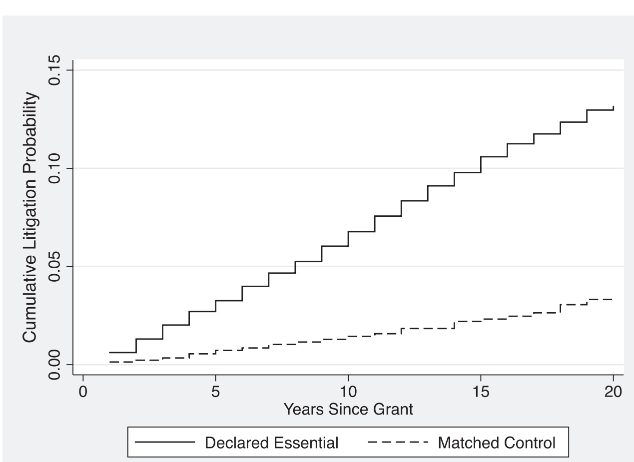

Fig. 3. Litigation for dSEPs and matched controls.
Figure shows the cumulative litigation hazard (beginning at grant-year) for dSEPs and citation-matched controls.

where $Litigation_{it}$ equals 100 in any year where a patent is first litigated, so coefficients represent a percentage-point increase in the hazard rate. The parameters γ_a measure age effects (or equivalently the baseline hazard), starting in the grant-year when a patent is first eligible for assertion. The parameters λ_y are calendar year effects, and the vector of controls X_{it} includes Claims, Patent References and Non-Patent References (which are all fixed at patent grant), as well as lagged citations and a dummy for Reassignment, which indicates a change in patent ownership. Table 8 presents the results.[30]

We begin by focusing on the full sample of dSEPs, omitting all controls. The coefficient in column (1) shows that the probability of first-lawsuit for a dSEP increases by 0.33 percentage points following disclosure, controlling for age, and calendar-year time trends. In column (2) we add time-invariant controls and find little change in the estimated association between disclosure and litigation. Columns (3) to (6) in Table 8 re-introduce the citation-matched control sample, and use a difference-in-differences specification to examine the litigation rate of dSEPs before and after disclosure relative to the controls. In column (3) we see that dSEPs are 0.22 percentage points more likely to be litigated than the controls *before* disclosure, and that this rate increases by 0.23 percentage points following disclosure. In column (4), we see that the post-disclosure increase in litigation is larger for firms that focus on licensing, as opposed to downstream implementation, and is particularly large for the small firms that are difficult to classify.

Column (5) presents some evidence in-line with our priors regarding the role of licensing commitments. For patents disclosed under a royalty-free licensing commitment, there is no change in litigation rates. Indeed, the point estimate is negative. Patents disclosed under FRAND terms see a 0.24 percentage point increase in the litigation hazard. This is similar to the estimate for patents disclosed with specific licensing terms and conditions, although the small sample of specific patents leads to imprecise estimates. Finally, Column (6) examines heterogeneity in the link between disclosure and litigation across SSO groups. We find a large statistically significant correlation for ANSI, the Big-I organizations, and IEEE. There is no evidence of a correlation between disclosure and litigation for ETSI and IETF. The latter result is interesting because it suggests at least two different mechanisms. At ETSI, the absence of a relationship may be due to the disclosure of many non-essential patents. 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.

Bargaining models suggest that, all else equal, the probability of litigation increases with the amount at stake (Priest and Klein, 1984). Thus, the positive correlation between disclosure and litigation supports the view that standardization increases the technical and economic significance of dSEPs. Our litigation results also show that upstream firms are more likely to assert their dSEPs, consistent with the idea that those firms are more reliant on IP. Finally, consistent with the broader theme of this study, we observe substantial differences among SSOs that may reflect differences in technology, industry structure, SSO IP policies, firm strategy, or some combination thereof.

4. 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 and an exploratory analysis of disclosure practices at thirteen SSOs.

We document large differences in the scope and timing of dSEP disclosures, as well as the nature of licensing commitments, among the SSOs in our sample. We also show that upstream licensors and component producers are more likely to use blanket disclosures (where available), and less likely to offer royalty-free licenses. We then examine dSEPs' long-term citation and litigation rates, and find evidence that both citation rates and the probability that a patent is asserted in litigation in US courts increase following disclosure.

[30] Appendix C, Table B-5 shows robustness to Cox and Logit specifications using the declared essential patents.

Table 8
Litigation hazard models.

Specification outcome	Linear probability (OLS)					
	100 × litigation indicator					
Estimation sample	Declared SEP	Declared SEP	Cite matched	Cite matched	Cite matched	Cite matched
	(1)	(2)	(3)	(4)	(5)	(6)
PostDisclosure	0.33 [0.10]**	0.30 [0.10]**	0.23 [0.06]**			
Declared essential			0.22 [0.04]**	0.17 [0.04]**	0.17 [0.04]**	0.17 [0.04]**
PostDisc * Upstream				0.31 [0.09]**		
PostDisc * Unclassified				1.09 [0.26]**		
PostDisc * Downstream				0.13 [0.06]*		
PostDisc * FRAND					0.24 [0.06]**	
PostDisc * FREE					−0.18 [0.13]	
PostDisc * Terms					0.47 [0.37]	
PostDisc * None					0.59 [0.40]	
PostDisc * ANSI						0.87 [0.23]**
PostDisc * Big-I						0.46 [0.12]**
PostDisc * ETSI						0.08 [0.06]
PostDisc * IEEE						0.31 [0.12]**
PostDisc * IETF						−0.00 [0.12]
PostDisc * Other						0.32 [0.17]
Age effects	Y	Y	Y	Y	Y	Y
Year effects	Y	Y	Y	Y	Y	Y
Other controls	N	Y	N	Y	Y	Y
Observations	70,732	70,732	156,757	156,715	156,715	156,715
Patents	6691	6691	12,196	12,194	12,194	12,194
Lawsuits	467	467	507	507	507	507

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

Exploring heterogeneity in these results uncovers a number of novel patterns. First, the increases in citations and litigation following disclosure are smaller for two SSOs – ETSI and the IETF – and we argue that this reflects two fundamentally different mechanisms. ETSI has a mandatory specific disclosure policy that leads to disclosure of more patents that are less likely to be truly essential, leading to smaller post-disclosure increases in citations and litigation. At the IETF, there is a preference for royalty-free access that influences both the selection of dSEPs and the terms of licensing commitments.

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

Our findings have implications for the academic literature that uses data from dSEPs, for courts that rely on dSEP data in damage calculations, and for SSOs (or antitrust agencies) evaluating alternative disclosure rules. In particular, several of our results illustrate the trade-offs that SSOs face in crafting an effective intellectual property policy. For example, we find that allowing blanket disclosures can have a substantial impact on the amount of IP declared. This is not surprising, since it will typically be cheaper and less risky for firms to make a blanket licensing commitment, even if that leads to an incomplete picture of the overall patent landscape. At the same time, mandatory specific disclosure rules may increase the likelihood that disclosed patents are not actually essential. Similarly, we find that a substantial amount of disclosure occurs before patents issue, when there can still be considerable uncertainty about the scope of their claims. In some cases, later disclosure would reduce uncertainty, but could also increase the risk of hold-up. We view these timing and specificity problems, combined with the economic importance of dSEPs and the difficulty of determining a FRAND price after a standard is widely deployed, as jointly causing the high dSEP litigation rate.

For researchers, our findings suggest several novel hypotheses and avenues for future investigation. First, since many of our results are descriptive, there is room for papers that seek to measure impacts of SSO policies, firm business models, or dSEP licensing commitments. Second, factual essentiality is a topic that merits further investigation. One mechanism that we propose to rationalize our findings is that ETSI's mandatory specific disclosure policy generates large differences in the rate of true essentiality across SSOs. This points towards research that seeks to measure essentiality, and uses such measures to test our proposed mechanism. Finally, our findings highlight the need for more research into the factors that produce variation in SSO policies and procedures, particularly in the area of licensing commitments. By introducing data on licensing terms for individual dSEPs, and combining them with methods used in prior studies, our paper takes a first step in this direction. Future research could also examine how differences in patenting and patent licensing practices for different standards and technologies both influence, and are influenced by, the IPR policies of relevant SSOs. Our hope is that by making our data public we will encourage researchers in this space to further explore questions related to the economics of standard setting and intellectual property strategy.

CRediT authorship contribution statement

All co-authors share equally in the credit for this research, and accept equal responsibility for any flaws.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Financial support for this research was provided by the Hoover IP2 initiative. Timothy Simcoe has consulted for various companies, including as a paid expert witness for Apple, Microsoft, LG Electronics and HTC, on matters related to topic of this study. Rudi Bekkers has consulted for various companies and served as an expert witness on several court cases related to the topic of this study. Christian Catalini, Arianna Martinelli and Cesare Righi have no interests to declare.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.respol.2022.104618.

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