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Technical Standards, Standards-Setting Organizations and Intellectual Property: A Survey of the Literature (with an Emphasis on Empirical Approaches)

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CHAPTER __

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A Survey of the Literature (with an Emphasis on Empirical Approaches)

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Introduction

Technical interoperability or compatibility standards specify design features that enable products manufactured by different vendors to work together in a manner that is largely invisible to the consumer. Physical product configurations from railroad gauges to drill bits to electrical plugs have been standardized for more than a century (Shapiro and Varian (1999), Ernst (2012), Russell (2014)). More complex, but equally important, are the many networking (USB, Wi-Fi, Bluetooth), Internet (TCP, IPv6, HTML), and telecommunications (CDMA, GSM, UMTS, LTE) standards that are essential to the global technology infrastructure. Broadly-adopted standards such as these can produce efficiency-enhancing network effects and other benefits (Katz and Shapiro (1985), Shapiro and Varian (1999), Shapiro (2001), Shapiro and Lemley (2007)).

Standards may be developed in a variety of settings. Many health, safety and environmental standards are developed by governmental agencies. The large majority of interoperability standards, however, are developed in the private sector. Individual firms may develop proprietary technologies that, through broad market adoption, become *de facto* standards. In several well-known cases (Betamax vs. VHS, HD-DVD vs. Blu-ray, Internet Explorer vs. Netscape Navigator, etc.), competing firms have engaged in so-called "standards wars" to determine which of their proprietary formats would eventually prevail and become essential features of products in the marketplace (Shapiro and Varian (1999), Breshnahan and Yin (2007)). Over the past two decades, however, most interoperability standards have been developed by groups of market participants that collaborate within voluntary associations known as standards-development organizations (SDOs) or standards-setting organizations (SSOs). The resulting standards are often referred to as "voluntary consensus standards", which will be the principal focus of this chapter.

Despite their potential benefits, voluntary consensus standards have over the past decade become the subject of significant private litigation, regulatory enforcement and policy debate. Much of the current controversy centers on the perceived proliferation of patents covering standardized technologies, potentially abusive enforcement of such patents against manufacturers and users of standardized products, and the terms on which patent holders may be required to license the use of those patents to others. This chapter offers an overview of the empirical, legal and economic literature concerning the interaction of interoperability standards and standards-setting organizations with intellectual property rights (primarily patents, with attention to copyrights and trademarks as well).[2]

[2] This Chapter focuses principally on law, policy and organizations that are active in North America and Europe, as well as case law developments in the United States and Europe. There is a growing body of literature discussing standardization bodies and practices in Asia, particularly China, Japan, Korea and India, that is beyond the scope of this Chapter. Recent literature on standardization in different Asian

I. *Standards and the Standard-Setting Landscape*

A. *Standards-Setting Organizations*.

1. *The Voluntary Standard-Setting Ecosystem*. Standard-setting organizations vary greatly in size and composition. Some, which are sometimes referred to as consortia or special interest groups, consist of just a few firms that collaborate on a narrow set of technical specifications, sometimes for a single product. Standards for consumer electronics devices and media such as the DVD disc and player were developed in this manner. Other SSOs have thousands of members and oversee multiple standardization activities at any given time.

The European Commission (2014) places SSOs into three broad categories: (1) those that are formally recognized by governments (e.g., the European Telecommunications Standards Institute (ETSI) and the International Organisiation for Standardisation (ISO)), (2) "quasi-formal" groups that are typically large and well-organized and share many of the characteristics of formally recognized groups, but lack official governmental recognition (e.g., the IEEE Standards Association and the Internet Engineering Task Force (IETF)), and (3) smaller, privately-organized consortia (also known as special interest groups or fora). In addition, the work of individual SSOs is sometimes coordinated at national and international levels. For example, in the U.S., the American National Standards Institute (ANSI) oversees, accredits and establishes policy for national SSOs that wish to develop American National Standards.

This international standard-setting "ecosystem" and its principal components are described in greater detail by David and Shurmer (1996), Mattli and Büthe (2003), Nickerson and zur Muehlen (2006), Cargill and Bolin (2007), Biddle et al (2012), Ernst (2012), EC (2014), Lundqvist (2014) and Gandal and Régibeau (2015). Gandal and Régibeau (2015) identify 548 active SSOs worldwide across a range of industries. When less formal consortia are counted, Updegrove (2015) catalogs nearly 1,000 standards-development groups operating in various fields. The increasing prominence of consortia in the standards-development world, and the impact of consortia on innovation in standardized technologies, is analyzed along various axes of accountability, transparency, efficiency, consensus and flexibility by Updegrove (1995), Egyedi (2001a), Baron and Pohlmann (2013), Bar

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jurisdictions is summarized, among others, in assorted chapters of NRC (2013) and Contreras (2017). Even with this degree of selectivity, the literature of standards, standardization and IP is too large and rapidly developing to cover comprehensively in this chapter. By way of illustration, between March 2013 and December 2016, more than 400 papers were distributed via SSRN's *Law, Policy & Economics of Technical Standardization* eJournal (https://www.ssrn.com/link/Law-Policy-Econ-Tech-Standards.html), with more than 100 in 2016 alone and more than 500 papers in the journal's online repository. In addition, in 2016 no fewer than four major reports commissioned by the European Commission in the area of standards and IP were released (Pentheroudakis and Baron (2017), Pohlmann and Blind (2016), JRC (2016) and CRA (2016)). And this is just a subset of the still-growing worldwide literature in this field.

and Leiponen (2014), Baron, Meniere and Pohlmann (2014), and Delcamp and Leiponen (2014).

2. *SSO Membership*. Standards development is conducted primarily by personnel employed by firms active in relevant product markets, with the occasional involvement of academic and governmental participants. Baron and Spulber (2015), using membership data from 195 different SSOs, find that the median SSO had 114 members, and only five SSOs had membership levels greater than 1,000. They observe that several large firms in the computing, semiconductor and electronics industries were, as of 2013, actively engaged in fifty or more different SSOs. In 2003, Updegrove (2003) found that two major computing firms were each involved in more than 150 SSOs. Contreras (2014), observing rates of Asian participation in IETF, finds that participation in Internet standardization by Japanese and Korean firms has remained meaningful but steady over the years, while participation by Chinese firms has increased from virtually nil in 2003 to a position in 2013 second only to U.S. firms.

3. *SSO Processes*. The consensus standardization process was first modeled by Farrell and Saloner (1988) as a war of attrition. Though this process was shown to result in greater coordination than decentralized activity, it is cumbersome. Simcoe (2007b, 2012) explores the length of the standardization process at IETF and the impact of Internet commercialization on standards development. Farrell and Simcoe (2012) further explore and expand the war of attrition model for standard-setting.

Though the processes for voluntary consensus standard-setting may vary among SSOs, some common features are prescribed by law. Following a series of cases in the 1980s involving abuses of the standardization process (*Hydrolevel* (1982), *Allied Tube* (1988)) the U.S. Supreme Court established that in order to avoid antitrust liability, SSOs should observe a certain level of transparency, openness and due process. These requirements have since been embodied in OMB Circular A-119 (1998), which governs U.S. federal agency use of private sector standards, as well as guidance from U.S. antitrust enforcement agencies (DOJ-FTC (2000), DOJ-FTC (2007)). Similar requirements have also been adopted in the ANSI Essential Requirements (2016), which establish minimum policy and due process requirements for ANSI-accredited SSOs.

Case studies of individual SSOs and their processes for standards and policy development include the following:

Table 1

SSO	**Case Studies**
DVB	Eltzroth (2008)
ECMA/JCT1	Egyedi (2001a, 2001b)
ETSI/3GPP	Besen (1990), Shurmer and Lea (1995), Bekkers and Smits (1997), Bekkers and Liotard (1999), Bekkers, Duysters and Verspagen (2002), Iversen (2002), Cowhey, Aronson and Richards (2006), Leiponen (2008), Bekkers and West (2009), Bar and Leiponen (2014), Caviggioli et al (2015), Baron, Gupta and Roberts (2015)
HDTV[3]	Farrell and Shapiro (1992), Neil et al. (1995)
IEEE	DeLacey et al. (2006), Wright (2008), Contreras (2013a)
IETF	Lehr (1995), Froomkin (2003), Nickerson and zur Muehlen (2006), Simcoe (2007b), Contreras and Housley (2008), Ernst (2012), Simcoe (2012), Contreras (2013a, 2014, 2016a), Russell (2014), Wen et al. (2015)
INCITS	Ernst (2012)
ISO/IEC	Murphy and Yates (2009), Blind (2011), Choi and Jang (2014), Lundell et al. (2015)
ITU (56k modems, H.265)	Gandal, Gantman and Genesove (2007), Greenstein and Rysman (2007), Egyedi (2016)
MISMO	Steinfield, et al. (2007)
OASIS	Blind (2011), Ernst (2012)
SEMI	Langlois (2007)
VITA	Contreras (2013a)
W3C	Egyedi (2001a), Russell (2011), Contreras (2016a)

B. *Standards in Technology Markets*.

As noted above, standards are pervasive in technology markets today, particularly computing, networking, semiconductors and telecommunications. Baron and Spulber (2015) collect data on more than 750,000 standards documents from 90 SSOs. They find that large formal SSOs produced the majority of standards documents, with two groups (CEN and ISO) producing more than 100,000 documents each. The largest single-sector SSO (ETSI) produced more than 85,000 documents in the area of telecommunications standardization (Id.). The authors recognize, however, that the sheer quantity of standards documents produced may not be indicative of an SSO's commercial and technological significance, as major SSOs such as IETF (Internet standards) and IEEE (Wi-Fi), have produced fewer than 5,000 standards documents each (Id.), yet have shaped large areas of technical development.

[3] HDTV, the U.S. high definition television standard adopted by the Federal Communications Commission (FCC), was developed through a series of interactions among the FCC and different U.S., European and Japanese SSOs.

In addition to aggregate studies of standards documents, studies have been conducted regarding the prevalence of standards in particular product categories. Biddle, White and Woods (2010) identify more than 250 standards embodied in a single laptop computer, and Armstrong, Mueller and Syrett (2014) provide a catalog of the standards embodied in the different functional subsystems of a smart phone.

C. *Open Standards*.

The term "open standards" originally arose in the context of governmental procurement regulations to describe policies whereby governmental agencies may procure software or other technology systems only if they utilize open (as opposed to "proprietary" or "closed") standards. Various studies cited by Shah and Kesan (2007) predict significant cost savings for agencies utilizing open standards, which can theoretically reduce costs of document format incompatibility and conversion.[4] Recently, however, use of the term "open standards" has expanded beyond government procurement into general discussions of standards and standardization. Russell (2014).

Despite its widespread use, there is no generally accepted definition of "open standards" and numerous definitions exist. See generally Ernst (2012), Updegrove (2012), Baron and Spulber (2015) and Lundell et al. (2015). Shah and Kesan (2007) define open standards by reference to three criteria: public availability, licensing on FRAND terms, and development in a process open to public participation. West (2007) offers an economic analysis of openness along several dimensions including access, competition and cost. Krechmer (2011) identifies 17 related attributes of open standards, classified according to the requirements of different interest groups (SSOs, commercial implementers, end users, economists and attorneys). And Baron and Spulber (2015) consider any commonly available standard developed by an SSO, rather than owned by a single firm, to be "open".

In the procurement arena, a number of governmental bodies around the world have mandated that open standards must be available on a royalty-free basis. Updegrove (2012). Particularly notable in this regard are recent policy initiatives by India and South Africa. DeNardis (2009), Rens (2011). Ghosh (2011) presents evidence from a survey of 955 public officials in 13 European states regarding practices and attitudes in software procurement. Notwithstanding EU policies favoring openness, he finds that a substantial percentage of respondents continue to support proprietary software solutions. Governmental open standards policies are inherently political, and Shah and Kesan (2007) present a case study of an attempt by the Commonwealth of Massachusetts to implement an open standards policy in the face of significant opposition by proprietary software vendors.[5]

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[4] Nevertheless, Shah and Kesan (2012) find significant interoperability problems even with document format standards touted as "open".

[5] The standards war between the ODF and OOXML open document formats is further described in

II. *Patents and Standards*

A. *Patenting Standards*.

While standards themselves are not generally patentable, products manufactured in accordance with the protocols and parameters specified by standards (often referred to as standards-compliant products) generally satisfy the statutory requirements for patent protection. The owners of patents covering these standardized technologies are typically the firms and institutions that employ individuals who make particular inventive contributions to standards.[6] Some of these contributions may be made jointly and owned by multiple firms, but in most cases firms individually submit technical contributions to the standard-setting process and own the resulting patents. Because standards documents are often quite lengthy and complex, sometimes running to hundreds or thousands of pages, multiple inventive concepts are frequently embodied in the same standard, leading to the possibility of multiple patents covering any given standard.

B. *Quantifying Standards Essential Patents*.

Numerous efforts have been made to estimate the number of patents that cover particular standards. Several SSOs permit or require their participants to disclose patents that are likely to be necessary for the manufacture and use of a standards-compliant products (see discussion of SSO disclosure requirements in Part IV.A below). SSO databases of these "standards-essential patents" or "SEPs" thus provide much of the raw data that is used to calculate the patent coverage of standards developed at these SSOs.

Aggregate Statistics. One of the first studies seeking to quantify aggregated SEP data was conducted by Simcoe (2007a), who reviewed approximately 1,300 patent disclosures at nine telecommunications-focused SSOs between 1981 and 2004. This data shows a dramatic increase in patent disclosures beginning in the early 1990s, with the greatest number of disclosures occurring at ETSI, IEEE and ITU. Blind et al (2011) reviewed approximately 8,000 patent disclosures made at eleven large European and U.S.-based SSOs. They find that the large majority of these disclosures were made at SSOs focusing on telecommunications standards, of which the lion's share were disclosed at ETSI. Baron and Pohlmann (2015) collected more than 200,000 patent disclosures from 19 major SSOs. Of these, nearly 170,000 were disclosed at ETSI alone (relating to more than 1,300 different standards). Other SSOs identified by Baron and Pohlmann as having more than 1,000 patent disclosures each were BluRay, ISO, IEEE, ITU, and DVB Forum (Id.)

Blind (2011) and Ernst (2012).

[6] SSO themselves seldom if ever seek to claim any patent rights in standards that they produce.

Organizations. Each of these authors also studied the organizations making SSO patent disclosures. Blind et al. (2011) identifies 292 such patent holders, the top five being Nokia, Qualcomm, InterDigital, Ericsson and Motorola. Baron and Pohlmann (2015), utilizing their larger data set, identify more than 2,000 different patent holders, led by Qualcomm, InterDigital, LG Electronics, Nokia, Samsung and Ericsson. Simcoe (2007a) observes a significant increase in patent disclosures by small firms over the period of his study (1981-2004), suggesting a rise in the activity of small, specialized technology firms that participate in a few select SSOs.

Geographic Distribution. Baron and Pohlmann (2015) tabulate the number of SEP declarations by country/region, finding that in the aggregate, the greatest number of declared SEPs were filed in the U.S. (over 50,000), followed by Japan, China and Europe. Pohlmann and Blind (2016), analyzing the same data set over time, observe that while the greatest number of declared SEPs in the 1990s originated in the U.S., Europe and Japan, since the early 2000s the number of SEPs from China, Korea and Taiwan have increased, with a comparative decline of SEPs from Germany, Japan and the U.S. Focusing on IETF, Contreras (2014) finds that between 2001 and 2012, patent disclosures by Japanese firms remained relatively constant, while disclosures by Chinese firms increased from zero before 2006 to 23% of all IETF patent disclosures in 2012.

Case Studies. The industry-wide surveys described above are complemented by a number of case studies quantifying patent disclosure at individual SSOs. Bekkers and West (2009) compare patenting activity in ETSI's GSM program (finalized in 1990) with its subsequent UMTS standardization program (finalized in 1999). They find an eightfold increase in the number of disclosed essential patents for UMTS (1,227) over GSM (140), as well as a threefold increase in the number of patent holders (23 to 72). Despite these increases, they find that firm-level concentration of patents increased materially between the GSM and UMTS projects, with CR4 concentration ratios[7] increasing from 52% for GSM to 72% for UMTS, and CR8 ratios increasing from 73% for GSM to 92% for UMTS. A similar case study was conducted by Caviggioli et al. (2015) on approximately 13,000 patents disclosed with respect to later versions of the 4G LTE standard. In contrast to the earlier study, they find a lower degree of concentration with respect to LTE SEPs than earlier ETSI standards (CR4 concentration of 47%), which they attribute to recent market entry by firms ranging from Apple to smaller Asian manufacturers. Cyber Creative (2013), a Japanese firm, further analyzes data on nearly 6,000 LTE SEP declarations by SEP holder, country of origin and year of declaration.

[7] CR4 and CR8 concentration ratios measure the total output produced in a given market by a specified number of firms (four in the case of CR4 and eight in the case of CR8). Thus, a higher ratio indicates that the top firms in the market produce a greater share of total output.

C. *The Value of Standards-Essential Patents.*

As the above studies indicate, the disclosure of standards-essential patents at SSOs, at least in certain high technology sectors, has increased over the past two decades. This increase can potentially be explained if SEPs are perceived to have a higher value than non-SEPs. Several authors have hypothesized that SEPs are valuable both as bargaining chips in cross-licensing negotiations as well as forming the basis for direct licensing revenue (Bekkers, Bongard and Nuvolari (2011), Pohlmann and Blind (2016)). Accordingly, numerous studies have sought to measure the value of SEPs based on a variety of metrics.

Maintenance. Pohlmann and Blind (2016), using a sample of more than 200,000 declared SEPs and a matched sample of non-SEPs from corresponding patent offices, observe that holders of SEPs are more likely to pay required maintenance fees to keep SEPs in force (67% of SEPs versus 76% of non-SEPs lapsed due to non-maintenance). This finding suggests that SEPs are, on average, viewed as more valuable than non-SEPs, thereby warranting the expenditure of fees to maintain them.

Transfers. Pohlmann and Blind (2016) also find, using the same samples, that SEPs were somewhat more likely to be transferred by their owners (12% of SEPs versus 10% of non-SEPs transferred at least once during their lifetimes), suggesting a higher value or utility for SEPs, at least in the perception of the transferees. Pohlmann and Blind also identify the most active purchasers (Google, Qualcomm, Apple, Blackberry and Intel) and sellers (Motorola, Nokia, Ericsson, Interdigital and Panasonic) of SEPs in their sample.[8]

Market Share. Bekkers, Duysters and Verspagen (2002) observe a positive correlation between the ownership of patents covering the 3G GSM standard and firms' share of the European market for telecommunications equipment. Bekkers, Verspagen and Smits (2002) also analyze the impact of patents on development of the GSM standard, noting in particular the ability of Motorola to enter and exert influence over the largely European standardization effort due to its strong patent portfolio. They attribute the intensification of patenting activity in the telecommunications sector, in large part, to Motorola's demonstrated success at influencing the GSM standardization process in the early 1990s. These studies suggest that, at least in the case of GSM, patents contributed to the commercial success of firms in the market for standardized products.

Citations. A number of studies seek to assess the quality of disclosed SEPs on the basis of forward citations, or the number of times that a particular SEP is cited as prior art by later patent applications.[9] Rysman and Simcoe (2008) study 724

[8] See also Part V.E discussing transfer of FRAND and other SSO licensing commitments.

[9] The number of times a patent is cited as prior art in subsequent patent applications has become a widely used measure of the value of a patent in economic analyses. Trajtenberg (1990), Albert et al.

patents disclosed as essential at four major SSOs. They find that, even before disclosure at the SSO, SEPs receive twice as many citations as non-SEPs in the same technical field and year of application, suggesting that SSOs select important technologies for standardization. After disclosure at the SSO, SEPs gained an additional 19%-47% increase in citations, suggesting that the fact that a technology becomes standardized itself increases the value of the underlying patents.[10] Consistent results showing greater citation frequency for SEPs are obtained by Simcoe, Graham and Feldman (2009), Layne-Farrar (2011), Baron and Pohlmann (2015), Caviggioli et al. (2015) and Pohlmann and Blind (2016). Bekkers, Bongard and Nuvolari (2011) study a sample of approximately 10,000 patents, approximately 750 of which were disclosed as essential to ETSI's W-CDMA standard. They determine that both patent quality (measured in terms of forward citations), as well as the patent holder's involvement in the standardization activity, are strong determinants that a patent will be disclosed as essential to the SSO.[11]

In a somewhat contrary vein, Bekkers and West (2009) analyze SEPs disclosed in ETSI's GSM and UMTS standardization programs. They detect a decline in the number citations of UMTS SEPs as compared with the earlier GSM SEPs, despite the substantial increase in patents disclosed in the UMTS program. They posit that this decline in citations (and, in theory, value) may be due to a proliferation of patents claiming only incremental or minor technical advances.

Litigation. Another measure of the potential value of SEPs is the frequency with which such patents are litigated. In theory, once a technology becomes standardized and is thus harder to design around, infringement of patents covering that technology should also increase. Validating this hypothesis, Simcoe (2007a) finds that SEPs are ten times more likely than comparable non-SEPs to be litigated, and Simcoe, Graham and Feldman (2009) find that the rate at which SEPs are litigated is 9.4% versus 1.7% for comparable non-SEPs. Pohlmann and Blind (2016), using a large sample of SEPs and comparable non-SEPs, find that the average number of litigated SEPs in the sample was 1.93%, compared to 0.45% in the control group. Pohlmann and Blind (2016) also tabulate the number of declared SEPs subject to litigation by owner, finding that the majority of litigated SEPs are held by a handful of large players (e.g., Qualcomm (20,678 SEPs and 888 litigated SEPs), Interdigital (12,522 SEPs and 978 litigated SEPs), Nokia (13,393 SEPs and 557 litigated SEPs), Panasonic (6,326 SEPs and 572 litigated SEPs), Samsung (10,618 SEPs and 502 litigated SEPs) and Ericsson (9,396 SEPs and 467 litigated SEPs).[12] Gupta and Snyder (2014) offer a contrasting view in the context of the

(1991), Harhoff et al. (1999).

[10] This effect has been referred to as the "value of the standard". See Siebrasse and Cotter (2017), Sidak (2016).

[11] See Part IV.A.2 regarding differing definitions of essentiality and over-declaration of patents as essential to certain standards.

[12] Interestingly, several large Asian firms appearing in Pohlmann and Blind's study hold large numbers of SEPs, but have asserted none of them in litigtation: NTT Docomo (4,216 SEPs), NEC (2,299 SEPs), ZTE (1,640 SEPs), Datang (458 SEPs) and NTT (454 SEPs). Even more surprising is Texas Instruments,

"smart phone wars", in which they argue that litigation is driven primarily by non-SEPs covering implementation or design features of particular devices, and that fewer than one-third of patents involved in smart phone litigation are SEPs.

Firm Performance. Pohlmann, Neuhäusler and Blind (2015) and Mallinson (2015) approach the question of SEP value from the standpoint of firm financial performance. Polhman, Neuhäusler and Blind analyze the return on asset (ROA) performance of 134 firms involved in standards-development over an 8-year period. They find a curvilinear (inverse U) relationship between a firm's disclosure of SEPs and ROA, indicating that SEPs contribute positively to a firm's ROA up to a point, but that excessive SEP disclosure (over-disclosure) is correlated with diminished performance. They also find that the marginal impact of SEPs is stronger when disclosed to informal SSOs than formal, recognized SSOs. Mallinson collects data on R&D spending and licensing revenue from major holders of SEPs covering the 4G LTE standard, as well as other statistics regarding the smart phone market, to argue that patent licensing fees in this market are modest by comparison to overall innovation-based gains.

Pohlmann and Blind (2016) combine a variety of the above factors including market coverage, technical relevance, citation count and litigation, to measure the value of individual firms' SEP portfolios using the proprietary IPLytics platform.

D. *Acquisition and Declaration of Standards-Essential Patents*.

Given the potential value of SEPs and the market benefits that they confer on their owners, firms have significant incentives to maximize the number of SEPs that they hold.[13] Several authors have hypothesized that firms participating in SSOs may thus manipulate the patent prosecution process in order to obtain patents that are likely to be SEPs (Hunt, Simojoki and Takalo (2007)). Hovenkamp (2008) cites the allegations made in the *Rambus* cases[14] to argue that liberal continuation and division practices in patent prosecution enable opportunistic applicants to circumvent SSO disclosure policies and obtain patents directed to specific technical features under discussion at an SSO. To test a similar hypothesis, Berger, Blind and Thumm (2012) analyze the prosecution history of approximately 300 SEPs disclosed at ETSI. Compared to similar non-SEPs, they find that the SEPs have substantially more claims and longer pendency times. They argue that these results suggest that patent applicants participating in SSOs strategically shape their claims

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one of the earliest firms to seek to monetize its patent portfolio, which holds 487 SEPs, with none litigated within the parameters of the study.

[13] This Part focuses on patenting behavior by firms that are involved in the SSO standardization process. Wen et al (2015) offer evidence supporting the hypothesis that standardization in a technical area tends to reduce defensive (strategic) patenting by firms that are not engaged in the standardization process, presumably due to a lower need for patent assets as countermeasures against infringement claims by SSO participants that are bound to license SEPs to such non-participants.

[14] According to the complaint filed by the FTC, Rambus allegedly shaped its patent claims to cover technical discussions being held contemporaneously at JEDEC. See Section IV.A below.

to cover standards under development and drag out the prosecution process in order to ensure that their claims cover the latest possible version of the standard. Similar delays were observed by Caviggioli et al. (2015) in their study of LTE SEPs.

Kang and Bekkers (2015) studied the behavior of 939 individual participants from 53 different firms who attended 77 3GPP meetings over a 12-year period during which the W-CDMA and LTE wireless telecommunications standards were developed. They observed a phenomenon that they term "just-in-time-patenting": SSO participants apply for patents of "low technical merit"[15] in large quantities immediately before an SSO meeting, then send participants to the meeting to negotiate the inclusion of the patented technology into the standard. They further observe that this tactic is concentrated among vertically integrated firms, typically those who champion the incumbent standard.[16]

The foregoing studies suggest that patent holders involved in SSOs may opportunistically seek to maximize the number of SEPs that they obtain and declare. Layne-Farrar (2011), however, challenges this conclusion based on an analysis of approximately 1,200 U.S. patents declared as essential to the ETSI UMTS standard both before (ex ante) and after (ex post) finalization of the standard. She finds that firms did not increase their rates of patenting after this technology had been standardized. When viewed together with the higher citation counts found for SEPs, Layne-Farrar hypothesizes that ex post patenting may be attributable to some combination of innovation and opportunism, but in proportions that are not well understood.

E. *Effect of Patents on Standardization Activity*

A few studies have attempted to assess the effect of SEPs on standardization processes within SSOs using a range of methods including case studies, interviews and empirical data analysis. Egyedi (2001a, 2001b) studied Java standardization at ECMA International during the 1990s and cites several instances in which fear of intellectual property claims (both patent and copyright) stifled cooperation within the SSO, eventually leading to the collapse of the standardization process. Contreras (2008, 2016a) discusses particular instances at IETF and W3C in which threats of patent disputes were the impetus for policy amendments at these two organizations. Contreras (2013a) also surveyed members of VITA (a small SSO with relatively few declared SEPs) and found that policy amendments that gave members greater visibility into the maximum royalties that would be charged by SEP holders

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[15] Forward citation rates of SEPs filed by SSO participants in the week before and during an SSO meeting were significantly lower than those of a control group.

[16] These observations were validated by the authors' direct observations as well as reports from participants at SSO meetings, including one former manager who explained at a public conference "how he would send staff to a standardization meeting, and right after the meeting, in the hotel room, they would brainstorm how to combine elements mentioned by other participants, and then immediately prepare patent applications on these."

(a so-called *ex ante* licensing disclosure policy) were perceived to improve a variety of standardization processes and outcomes.

Egyedi (2016) interviewed participants in ITU's H.265 standardization process and found that technical design choices were made for a range of practical and business reasons often having little to do with the technical merit or inventiveness of a particular solution. It is not clear, however, the degree to which patents were declared essential to the H.265 standard or what impact, if any, those patents may have had on these decisions.

Baron et al (2013) analyzed 3500 standards released between 1998 and 2008 and found that higher concentrations of SEPs caused standards to be less likely to be replaced, but increased the likelihood that they would be upgraded through new version releases. They attribute this effect to frictions and vested interests in existing patented technologies (i.e., a lock-in effect based on SEP ownership).

The foregoing studies suggest that the existence of patents covering technologies being standardized has an impact, generally negative or neutral at best, on the standardization processes studied. It is important to note, however, that none of these studies focused specifically on the most patent-intensive standards developed at ETSI, ITU and IEEE, nor was the value of patented technologies to such standards assessed. Further research would be beneficial regarding the interplay of patents and standardization processes.

F. *Standards as Prior Art.*

One of the challenges that faces patent offices examining applications for patents covering standardized technologies is the unavailability of SSO documents that may shed light on the originality and inventorship of such technologies. Thus, while internal SSO documents can serve as valuable prior art in the examination of such patent applications, these documents are often inaccessible to patent offices or, even if accessible, are not indexed or searchable in a useful manner.

To address these concerns, the European Patent Office (EPO) has entered into cooperative arrangements with several leading SSOs including ETSI, ITU and IEEE. EC (2014), NRC (2013). Under these arrangements, the SSOs have agreed to share a variety of documentation with the EPO for use in patent examinations. As reported by Pohlmann and Blind (2016), in 2015 the EPO cited over 19,000 standards-related documents as prior art. Other standards bodies may have other arrangements. For example the U.S. Patent and Trademark Office and the EPO are both members of the DVB Project. Their membership gives them access to all DVB technical documents. In addition, new collections of SSO documents aggregated and organized by academic researchers may be of use in patent office examinations. Baron and Spulber (2015).

G. *Potential Market Effects: Hold-Up, Hold-Out and Stacking*. There is significant debate across the industry and academy regarding the impact of patents on the development and distribution of standardized products. CRA (2016) classifies these potential issues and gauged their relative importance to a range of stakeholders using a consultation exercise involving 40 respondents and a series of 36 interviews. They found that injunctions, hold out, hold up, royalty stacking and over-declaration of SEPs were perceived as the "main problems" caused by SEPs. Each of these issues is discussed in greater detail below.

1. *Hold-Up*. There is a large and varied theoretical literature concerning the potential effects that patents covering standards may have on product development and markets. One of the principal areas of debate concerns the potential for SEP owners to "hold-up" the market by demanding excessive royalty rates after a standard has been widely adopted and manufacturers who have made investments in the standardized technology have become "locked-in" (Shapiro (2001), Swanson and Baumol (2006), Farrell et al. (2007), Lemley and Shapiro (2007), Lichtman (2010), Chien and Lemley (2012), Chien (2014)). In addition to raising costs for potential competitors, it has also been theorized that patent hold-up can increase consumer prices and hinder innovation. The potential for standards-based patent hold-up has been echoed by antitrust and competition authorities in the U.S., Europe and elsewhere (DOJ-FTC (2007), FTC (2011), FTC (2012), EC (2014)), as well as by courts adjudicating standards-related cases (*Microsoft* (2013), *Ericsson* (2014)). Ernst, Lee and Kwak (2014), taking an international perspective, argue that strategic patenting of standardized technologies can stifle economic development, particularly in less-developed economies. Siebrasse (2017) offers a comprehensive survey of the theoretical literature concerning hold-up for standardized products.

Nevertheless, systematic evidence of standards-based patent hold-up in the market has not been collected, and reports of hold-up by individual firms are criticized as unreliable or too specific to support general conclusions. As a result, several commentators have questioned whether the threat of patent hold-up should be of concern, citing, among other things, a lack of empirical evidence of systematic hold-up in ICT industries (Geradin and Rato (2007), Spulber (2008), Sidak (2008), Gupta (2013), Kieff and Layne-Farrar (2013), Layne-Farrar (2014b), Sidak (2015a, 2015b)). In a recent study, Galetovic, Haber and Levine (2015) measure market characteristics that have traditionally been associated with industries subject to hold-up (high quality-adjusted prices and low rates of innovation) in markets characterized by significant patenting and standards (SEP-reliant industries). They find that SEP-reliant industries such as digital communications exhibit significantly faster price reductions and higher levels of innovation than held-up industries such as electrical power, tending, they assert, to refute the hold-up hypothesis. Epstein, Kieff and Spulber (2012) are particularly critical of governmental agencies that have taken action in response to perceived threats of hold-up, and view these agencies as themselves introducing various market inefficiencies.

Commentators have also drawn attention to the potential for opportunistic behavior by standards implementers (licensees), which has been referred to as "reverse hold-up" or "hold-out" (Geradin (2010), Kieff and Layne-Farrar (2013), Camesaca et al. (2013), Chien (2014), Cotter (2014), Sidak (2015a)). In hold-out situations, a potential licensee may refuse to pay a "reasonable" royalty rate to use a SEP in a standards-compliant product. If the SEP holder itself is bound to charge no more than a reasonable royalty, and if it is unable to seek injunctive relief to prevent the implementer's infringement, the SEP holder has little recourse but to sue the implementer for patent infringement and recover, at most, the reasonable royalty that it would have received in the first place.[17] Thus, under this theory, standards implementers would have a significant incentive to hold out for as long as possible. The potential for hold-out behavior by standards implementers has been recognized by governmental agencies (FTC (2011), DOJ-PTO (2013)). The FTC identifies hold-out situations as instances in which it may be reasonable for SEP holders to seek injunctive relief to prevent ongoing infringement by recalcitrant implementers (*Motorola and Google* (2013)). Nevertheless, like hold-up, there is little empirical evidence relating to the prevalence of hold-out in standard-setting environments.[18]

2. *Royalty Stacking*. As described by the U.S. Court of Appeals for the Federal Circuit, "[r]oyalty stacking can arise when a standard implicates numerous patents, perhaps hundreds, if not thousands. If companies are forced to pay royalties to all [patent] holders, the royalties will "stack" on top of each other and may become excessive in the aggregate" (*Ericsson* (2014)). Lemley and Shapiro (2007) have argued that stacking will result in higher prices for consumers because (a) patent holders and product manufacturers will each seek to maximize their margins (a phenomenon, which is not unique to patent licensing, known as "double marginalization"), and (b) holders of complementary patents will increase their royalties to a level that, in the aggregate, will depress sales of end products and, in turn, reduce their individual profits (the well-known problem of "Cournot complements"). They also argue that stacking is likely to exacerbate and amplify patent hold-up behavior by introducing multiple patent holders with potential hold-up power.

Interestingly, though the large number of patents covering various standardized technologies has been amply documented (see Part II.B above), relatively little public data is available regarding aggregate patent royalty rates for standardized products. In the mid-2000s, a number of SEP holders voluntarily disclosed their standard licensing rates for wireless telecommunications standards (Contreras 2015c, Table 4), and there was at least one attempt by a group of network operators to establish maximum aggregate royalty rates for

[17] Contreras and Gilbert (2015) argue that FRAND royalties should be calculated in essentially the same manner as reasonable royalty damages.

[18] In one early interview-based study, Blind and Iversen (2004), found that of large companies involved in standardization, 40% responded that their licensing conditions had not been accepted, and 35% had experienced infringements of their patents.

certain wireless standards through the Next-Generation Mobile Networks (NGMN) consortium (Contreras 2013a, 178-79). More recently, evidence regarding SEP royalty rates has emerged in litigation over SEP licensing terms (see Part IV.B.1 below). For example, in *Microsoft* (2013), the court, in analyzing the patent holder's proposed royalty rates, found "significant stacking concerns." Specifically, it observed that

> [t]here are at least 92 entities that own 802.11 [standard-essential patents]. If each of these 92 entities sought royalties similar to [the patent holder's] request of 1.15 % to 1.73 % of the end-product price, the aggregate royalty to implement the 802.11 Standard, which is only one feature of the Xbox product, would exceed the total product price.

On this basis, the court determined that the royalty sought by the patent holder was unreasonable, because "if everyone wanted the same deal, it would quickly make the end-product price untenable commercially" *Microsoft* (2013).[19] In *Innovatio* (2013b), the court was also required to calculate the "reasonable" royalty for patents covering different aspects of the 802.11 standard. In doing so, it considered "the total royalties an implementer would have to pay to practice the standard" and "whether the overall royalty of all standard-essential patents would prohibit widespread adoption of the standard." Bartlett and Contreras (2017) discuss the methods used to determine FRAND royalties in five different reported cases involving the 802.11 standard, suggesting not only that royalty stacking for this standard may be an issue, but that judicial royalty determinations, as they are currently undertaken, are both inconsistent and unpredictable.

Outside of judicial proceedings, however, data regarding patent royalty rates is typically protected by confidentiality agreements, making the collection and analysis of such data difficult. Given these constraints, Contreras et al. (2016) have proposed mechanisms for making more royalty data available to researchers and policy makers.

Notwithstanding the difficulty of obtaining FRAND royalty data, there is a growing body of empirical literature seeking to quantify the aggregate patent royalty burden for various standardized technologies. Geradin, Layne-Farrar and Padilla (2008) review earlier (non-standards based) empirical studies of royalty stacking in industries such as semiconductors, software and biomedicine, finding that stacking, while present, did not seriously impair those industries. They also assess the potential for royalty stacking on ETSI's 3G WCDMA and IEEE's 802.11 Wi-Fi standards, generally disputing estimates of stacking offered by Lemley and Shapiro (2007).

Stasik (2010) analyzes the aggregate royalty burden on ETSI's 4G LTE standard, as to which several major patent holders have voluntarily announced

[19] But see Layne-Farrar and Wong-Ervin (2014), using numerical examples to critique this approach.

royalty rates or ranges. Based on early announcements by nine major LTE SEP holders, Stasik finds an aggregate royalty burden of 14.8% of the end product price. Armstrong, Mueller and Syrett (2014) quantify the royalty "stack" for smart phone devices by identifying and aggregating known and estimated royalty rates for the different functional subsystems of such devices. They find that, absent cross-licensing and other royalty-reducing measures, the aggregate patent royalty for a hypothetical $400 smart phone would be $120, or 30% of the end product price.[20]

Other authors, however, contest the evidence of royalty stacking in standardized technologies. In addition to disagreement over the theoretical claims made by Lemley and Shapiro (2007), they observe that despite the large number of patents covering standards for technologies such as 3G and Wi-Fi, these technologies have flourished in the marketplace, suggesting that in practice royalty stacking may not present a significant market risk. Geradin, Layne-Farrar and Padilla (2008), Sidak (2008), Gupta (2013), Mallinson (2015).

Galetovic and Gupta (2016) look to secondary market effects to draw conclusions about whether royalty stacking has occurred in the mobile wireless industry. They observe that from 1994 to 2013, the number of firms holding SEPs covering ETSI's 2G, 3G and 4G standards increased from 2 to 130. At the same time, they observe that the number of devices implementing these standards sold annually increased by approximately 20%, average selling price dropped by up to 24.8% annually on an adjusted basis, and the number of device manufacturers grew from one to 43. These indicia, they contend, suggest that the market is not subject to royalty stacking.

In an effort to link claims of harm arising from royalty stacking to actual evidence of harm, the court in *Ericsson* (2014) required that claims alleging damage due to royalty stacking must be supported by actual evidence of such harm to the claimant. Sidak (2016). The court's reasoning is questioned by Contreras (2015d), who argues that royalty stacking with respect to a standard may have an impact on the reasonableness of any particular SEP holder's individual royalty rate, irrespective of the magnitude of royalties paid by the implementer at the time of an infringement suit by the SEP holder. Requiring the implementer to show specific harm from royalty stacking could thus result in a race to the courthouse by SEP holders, each seeking to levy a royalty before the aggregate paid by the implementer becomes unreasonably high.

H. *Patent Pools and Standards.*

[20] Mallinson (2015) challenges this result, estimating an aggregate smart phone royalty burden of approximately 5%, based on estimated industry-wide annual U.S. smart phone SEP licensing revenue of $19 billion. Layne-Farrar (2014b) also disputes the analysis undertaken by Armstrong, Mueller and Syrett (2014) on several counts.

Several important standards, particularly in the consumer electronics industry, were developed by small groups of firms that make their standards-essential patents available through patent pools. Well-known patent pools exist for popular families of standards such as MPEG, CD and DVD. Patent pools have also been formed for standards that were developed in larger SSOs, often containing only a subset of the known SEPs covering those standards. Examples include the Via Licensing and Sisvel pools for IEEE's 802.11 standard and MPEG-LA's pool for ITU's H.264 standard. *Microsoft* (2013), Bekkers and Updegrove (2012). The DVB Forum offers a unique example of a developer of voluntary consensus standards, all members of which participate in a patent pool. Eltzroth (2008).

Patent pools offer numerous efficiencies in licensing and are generally characterized by license terms (including royalties) that are published and uniform across all licensees, though care must be taken to avoid anticompetitive collective activity in the formation and operation of such pools. Shapiro and Varian (1999), Shapiro (2001), Contreras (2013b), Lundqvist (2014). Despite the potential benefits offered by pools, relatively few patent pools have been formed around technical interoperability standards. Biddle, White and Woods (2010) find that of 251 standards implemented in a typical laptop computer, only 3% were subject to patent pools, with the remainder subject to FRAND or royalty-free licensing commitments. Polhmann (2016), analyzing more than 200,000 individual SEP declarations, finds that only 9% of declared SEPs are pooled. There are several possible explanations for the relative scarcity of patent pools in the field, including significant up-front costs associated with evaluating pooled patents for essentiality.[21] Contreras (2013b). There is a large empirical and theoretical literature devoted to patent pools, both standards- and non-standards related, which is discussed in Chapter x of this volume.

Though not a patent pool *per se*, another novel structure that sought to offer aggregated SEP licenses was Intellectual Property Exchange International (IPXI), a trading exchange that offered unitized license contracts covering 194 patents declared essential to IEEE's 802.11n standard. For various financial and business reasons, IPXI ceased operations in 2015 (Contreras 2016c).

I. *Patent Assertion Entities (PAEs) and Standards-Essential Patents*

A significant amount of recent empirical literature seeks to measure the quantity and effect of litigation activity by so-called patent assertion entities (PAEs). FTC (2016), JRC (2016). Most of this work is centered in the U.S. and Europe.

[21] Unlike SEPs subject to licensing commitments by the patent holder, current interpretations of antitrust law require that patents contributed to a pool must be found to be essential to the standard by an objective evaluator. DOJ-FTC (2000), DOJ-FTC (2007). CRA (2016) reports that the estimated cost of a third party patent essentiality assessment is approximately EUR 9000 (p.50), and that imposing such a cost on ETSI's 2G/3G/4G standards would result in an aggregate cost of approximately EUR 427.5 million (p.59).

Concurrently, there have been numerous proposals to amend legislation and regulations to address perceived issues arising from PAE litigation. Several prominent reported cases involve assertion of SEPs by PAEs, including *N-Data* (2008) and *Innovatio* (2013). However, there has been comparatively little empirical work studying the accumulation and assertion of standards-essential patents by PAEs.

The first empirical study of SEP assertion by PAEs appears to be that conducted by Contreras (2016b). This study measured assertion of SEPs covering seven widely-adopted standards in U.S. district courts from 2000-2015. It found that 77% of these assertions were initiated by non-practicing entities (NPEs), most of which were PAEs, and that both NPEs and practicing entities asserted significant numbers of SEPs unencumbered by FRAND or other licensing obligations. Contreras et al. (2017) have extended this study to cover SEP assertions in Germany and the UK.

In 2016, the European Commission's Joint Research Centre published a study of PAE behavior in Europe (JRC (2016)), which found through 18 in-depth interviews that PAEs in Europe are acquiring and asserting significant numbers of SEPs, particularly in the telecommunications sector. Likewise, Pohlmann and Blind (2016) find that several NPEs (IP Asset Trust, Cluster Technology, Sisvel, Unwired Planet, Innovative Sonic) are among the largest acquirors of SEPs (Table 5). Interestingly, these results were not observed by the U.S. FTC in a study released in the same year (FTC 2016). The FTC, based on surveys distributed to 22 selected PAEs whose identities were not disclosed, found that less than 1% of the patents held by such PAEs were SEPs. This finding led the FTC to conclude that its survey sample did not include any PAEs that focused on monetizing SEPs (pp. 136-37).

J. *Patents and Non-ICT Standards*.

The vast majority of literature relating to patents and technology standardization has focused on the information and communications technology (ICT) sector. As reported, however, by Blind et al. (2011), NRC (2013), EC (2014) and Baron and Spulber (2015), significant standardization activities occur outside of ICT. At least two significant actions by the U.S. Federal Trade Commission have involved the potential assertion of patents in non-ICT fields (*Unocal* (gasoline additives) and *Bosch* (automotive electronics)). Nevertheless, on the whole patents have played a relatively modest role in SSOs and standardization in non-ICT fields. Blind et al. (2011) find that among seven large formal SSOs studied, 98% of patent disclosures applied to ICT standards. These results are confirmed by Baron and Pohlmann (2015) and Pohlmann and Blind (2016).

Several recent case studies of standards in non-ICT technology fields show a similarly small, but potentially growing, role for patents: Torrance and Kahl (2014) (synthetic biology) Kumar and Rai (2007) (synthetic biology), Contreras (2013c) (bioinformatics), Contreras and McManis (2013) (sustainable building materials), Jillavenkatesa, Evans and Wixon (2012) (nanotechnology), Contreras (2012) (smart grid). Several of these authors observe, however, that patents could play an increasingly prominent role in standardization in non-ICT industries as these industries mature and spur larger product markets, and emphasize the desirability of open standards frameworks in these industries (Contreras (2013c, 2012), Kumar and Rai (2007)). In contrast, Blind and Iversen (2004) map standards intensity and patent intensity for nine different technology-focused industries including ICT, aeronautics, optoelectronics, nanotechnology, pharmaceuticals and biotechnology (Fig. 4.4-1). They conclude that issues relating to patents and standards are the most heated in industries with the highest levels of standardization and patent intensity, namely ICT, and that issues are less pressing at lower intensity industries such as nanotechnology.

III. *Private Ordering and SSO Patent Policies*

Over the past two decades, SSOs have responded to the increasing number of patents covering standardized technologies and the perceived threats of patent hold-up and stacking by adopting a series of policy measures intended to address these concerns.[22] EC (2014) identifies seven distinct goals of SSO patent policies: (1) enabling informed decisions about technology inclusion, alternatives and design-around, (2) ensuring that licenses for SEPs are available, (3) preventing patent hold-up, (4) preventing patent "ambush" and blocking, (5) preventing excessive cumulative royalties (stacking), (6) preventing discrimination among implementers of a standard, and (7) ensuring transparency about SEPs. Bekkers and Updegrove (2012) find, however, that few SSOs explicitly state the goals or intended purposes of their patent policies.

SSO patent policies today fall into two general categories: disclosure policies and licensing policies, and often include elements of both. Disclosure policies typically require participants in the standards development process to disclose patents they hold that are believed to be essential to the implementation of the standard. Licensing policies typically require that participants grant implementers licenses under their standards-essential patents on terms that are "reasonable and nondiscriminatory" (RAND) or "fair, reasonable and nondiscriminatory" (FRAND).[23]

A. *Cataloging SSO Patent Policies*

Numerous efforts have been made to catalog and classify the provisions of SSO patent policies. Lemley (2002) reviewed the policies of 43 SSOs across a range of industries and classified them based on features including whether they included a disclosure requirement, whether participants were required to search their patent

[22] SSO policies are generally assumed to be binding on SSO participants through a series of legal mechanisms including contract, estoppel and antitrust/competition law. Lemley (2002), Contreras (2015a).

[23] The terms RAND and FRAND are, for all practical purposes, synonymous (DOJ-PTO (2013)).

portfolios to identify SEPs, and whether they included a licensing requirement (RAND or royalty-free)). Chiao, Lerner and Tirole (2007) assess the policies of 59 SSOs and code for features including form of membership (corporate versus individual), decision making rule (majority or consensus), and SSO age and scope (single or multi-purpose). Bekkers and Updegrove (2012) offer an in-depth survey of the policies of 12 SSOs representing a cross section of organizational models, geographic region, and technology focus. They describe in detail the many variants that SSOs have adopted regarding the mechanics of patent disclosure (timing, knowledge, level of detail, definition of essentiality, updating) and licensing commitments (FRAND vs. royalty-free, beneficiaries, duration, field of use, geographic scope, transfer with underlying patents, suspension of licenses, requirements that licensees license-back their own patents (reciprocity), and the patent holder's ability to opt-out of granting licenses under certain circumstances). Many of these variants are also discussed in detail in ABA (2007), which was compiled by a committee of experts involved in standardization activities. Blind et al. (2011) analyze the policies of 22 SSOs of varying sizes and geographic scope (including one SSO based in China) in a similar fashion. Baron and Spulber (2015) code the policies of 36 different SSOs in the ICT sector for inclusion of various key terms pertaining to patent disclosure and licensing, as well as other procedural aspects of SSO operation including voting mechanics, openness, and balance of interests. CRA (2016, Ch.3) maps different SSO policy provisions (FRAND licensing, ex ante disclosure of royalty rates, etc.) to underlying economic issues (e.g., hold-p, hold-out, patent ambush, etc.) and assesses the impact of such provisions on the identified issues.

B. SSO Policy Features: FRAND Licensing Terms

The above studies present a wealth of information regarding the policy features of SSO. Among the most notable results is the prevalence of SSO policies that require licensing of SEPs on terms that are at least FRAND. Of 36 SSO patent policies reviewed by Lemley (2002), 29 contained FRAND commitments; and of 251 laptop standards identified by Biddle, White and Woods (2010), 75% were subject to FRAND commitments. In their recent study of 36 SSO policies, Baron and Spulber (2015) find 9 SSOs that require FRAND licensing and 23 that permit the licensor to choose from a menu of licensing options, with FRAND licensing being the least restrictive. Pohlmann and Blind (2016) find, based on analysis of more than 200,000 SEP disclosures across a range of SSOs, that 68% of such disclosures contain FRAND licensing commitments.

Though less common than SSO policies permitting SEP holders to charge royalties at FRAND rates, some SSOs require their participants to license patents on reasonable terms that are royalty-free (RF). This phenomenon is discussed in detail in Part V.C, below.

Much has been written regarding the meaning of FRAND, both with respect to the level of royalties that qualify as "fair" and "reasonable", what degree of similar treatment of licensees is required to comply with the "non-discrimination" prong of FRAND, as well as the reasonableness of other terms included in license agreements (e.g., reciprocity, grant-backs, transfer of patents, confidentiality, and the like). A full discussion of these licensing terms is beyond the scope of this review. Where litigation over FRAND terms has arisen, specific issues are discussed in greater detail in Part IV.B below. Comprehensive discussions of the many diverse terms found in FRAND licensing agreements can be found in Pentheroudakis and Baron (2017), NRC (2013), Bekkers and Updegrove (2012) and ABA (2007).

C. *SSO Policy Evolution and Amendment*

SSO patent policies, far from being static documents, are amended and adapted with some regularity. Tsai and Wright (2015) find that many SSOs amend their patent policies as frequently as once per year or more. Most of these amendments, however, are not significant. Major amendments to SSO patent policies have often been prompted by prominent industry litigation or enforcement actions. Layne-Farrar (2014a) identifies substantial patent policy amendments at 10 major SSOs and assesses whether they are proactive, reactive or non-responsive to four general trends in antitrust enforcement: patent ambush,[24] excessive royalty rates, transfer of patents subject to SSO licensing commitments and attempts to obtain injunctions on patents subject to licensing commitments. She finds that while the first two concerns (patent ambush and royalty rates) have largely been addressed by the SSOs studied, the last two concerns (patent transfer and injunctions), which have emerged more recently, have not yet been addressed fully. Tsai and Wright (2015) study SSO policy amendments pertaining to licensing rules and disclosure at 11 SSOs. They rate the amendments based on their reduction of ambiguity in policy language (significant reduction, moderate reduction, no reduction, increase in ambiguity) and find a gradual reduction in policy ambiguity across the board. On the basis of these findings, both Layne-Farrar and Tsai and Wright urge enforcement agencies to moderate their enforcement actions in order to give SSOs time to amend their policies to address concerns.

In their review of 36 SSO patent policies, Baron and Spulber (2015) observe a general strengthening of SSO licensing requirements over time, with four SSOs moving to royalty-free or non-assertion requirements after permitting royalties to be charged on SEPs, and two moving to a mandatory licensing requirement from no licensing obligation at all. They observe no significant modification to disclosure requirements over the period studied. Contreras and Housley (2008), however, discuss a clarifying amendment to the IETF patent disclosure policy prompted by an alleged failure of a participant to disclose a patent covering an optional portion of a draft IETF standard.

A few recent SSO patent policy amendments have generated significant controversy. The first of these involved VMEbus International Trade Association

[24] See Section IV.A.1, below.

(VITA), a medium-sized SSO focusing on avionics and defense electronics. In 2006, VITA developed a draft patent policy amendment requiring that its participants disclose not only patents essential to the implementation of VITA standards, but also the maximum royalty rates they would charge for those patents (a so-called "ex ante" licensing disclosure policy – see Part V.A, below). VITA submitted its proposed policy amendment to the U.S. Department of Justice, which issued a favorable business review letter approving the policy as proposed (DOJ 2006). Nevertheless, one of VITA's founding members objected to the change and withdrew from the organization as a result (Contreras (2013a)). A dispute ensued in which opponents led an unsuccessful campaign to have VITA's ANSI accreditation revoked.[25] Within the next several months, both IEEE and ETSI also adopted *ex ante* licensing disclosure policies. However, due to internal opposition, these two SSOs made *ex ante* disclosures of royalty rates optional rather than mandatory (Contreras (2013a), Tapia (2010)). The DOJ approved IEEE's policy amendment in 2007. DOJ (2007).

In 2015, the IEEE adopted another set of major policy revisions. These included various clarifications regarding the meaning of the licensing commitments made to IEEE, limiting the ability of participants to seek injunctive relief against willing licensees, requiring commitments by transferees of committed patents, and permitting the arbitration of disputes over licensing terms (IEEE (2015)). The DOJ approved these amendments as having "the potential to benefit competition and consumers by facilitating licensing negotiations, mitigating hold up and royalty stacking, and promoting competition among technologies for inclusion in standards" (DOJ (2015)). Nevertheless, there was strong opposition to the amendments, both from industry and commentators, much of which focused on the DOJ's approval of the IEEE amendments, rather than the content of the amendments themselves. Lindsay and Karachalios (2015), Sidak (2015b).

D. *SSO Patent Policy Influences on Firm Membership Decisions*

By and large, SSOs are voluntary membership organizations. Thus, members are free to leave, or decline to join, SSOs that have adopted policies that they view to be sufficiently adverse to their interests to outweigh the benefits of membership. Several authors have attempted to correlate SSO patent policy terms with firm decisions to participate in collaborative standardization activities and to model competition for membership among SSOs by means of differentiated policy documents.

Based on a survey of 149 European firms across industries, Blind and Thumm (2004) find that firms with greater rates of patenting activity are less likely to join collective standardization efforts due, in part, to the disclosure and licensing

[25] Despite opposition by a vocal minority, both the approval vote at VITA (35-2 in favor of the amendments, 12 abstaining) and survey data compiled by Contreras (2013a) indicate that a substantial majority of VITA members supported the amendments.

requirements imposed by SSOs. These results, however, are not necessarily borne out by more focused studies of firms in the ICT sector, in which the value of participating in SSOs is perceived to be high (Delacey et al. (2006)). Lerner and Tirole (2006) develop a model, supported by interviews with SSO participants, in which differing SSO rules regarding the disclosure and licensing of patents may impact an organization's choice of which SSO to join. That is, they view SSOs as competing for members on the basis of their patent and other policies. Chiao, Lerner and Tirole (2007) empirically test some of the predictions made by Lerner and Tirole (2006) using a sample of 59 SSO policies. Among other things, they find that SSOs that are oriented toward a small group of sponsor firms are less likely to demand policy-based concessions from members.

Two recent case studies have examined the effects of specific SSO patent policy changes on SSO membership. Contreras (2013a) tested predictions that VITA's adoption of a mandatory *ex ante* licensing disclosure policy (see Part III.C above) would drive members from the organization. He finds that, other than the single member that most strenuously objected to the policy change, no members departed the SSO as a result of the change, and overall membership increased substantially in the years following the change. Stoll (2014) examines the effects of a policy shift at OASIS, an SSO focused on software standards, from requiring FRAND licensing to allowing individual working groups to require royalty-free licensing of SEPs. He finds that, following the OASIS policy amendment, overall membership levels dropped and member composition shifted, with the number of software producers decreasing and the number of research organizations and systems integrators increasing. These studies may be informative for future research, particularly as the impact of IEEE's 2015 policy amendments is observed.

IV. *SSO Patent Policy Disputes*

As discussed in Section III above, many SSOs have adopted policies that require their participants to disclose patents that are essential to the SSO's standards, and/or to license those patents to others on terms that are either royalty-free (RF) or subject to FRAND royalties. Disputes and enforcement actions concerning SSO patent policies have generally arisen in two waves: the first, roughly from the mid-1990s to the mid-2000s, dealing with the scope and contours of the disclosure obligation, and the second, roughly from the mid-2000s to the present, dealing with the meaning of the FRAND licensing commitment.

A. *Disclosure Disputes*

1. Intentional Nondisclosure – Patent Ambush. Four principal U.S. cases – *Dell* (1998), *Rambus* (2003 and 2008), *Unocal* (2005) and *Qualcomm* (2008) - characterize the disputes regarding SSO disclosure policies that emerged from the mid-1990s to the mid-2000s.[26] Of these, *Dell*, *Rambus* (2008) and *Unocal* were enforcement actions brought by the FTC against patent holders for allegedly anticompetitive conduct in violating SSO disclosure requirements, and *Rambus* (2003) and *Qualcomm* were private actions in which the patent holder's alleged violation of SSO disclosure rules was raised either as a defense to patent infringement or as an affirmative private antitrust claim. In each of these cases, an SSO's rules were alleged to require disclosure of SEPs held by its participants, one of the SSO's participants failed to disclose one or more patents covering the SSO's standards, and the participant thereafter sought to exploit those patents by licensing or enforcing them against implementers of the standard. This pattern of conduct has been referred to as "patent ambush" or, as one commentator colorfully puts it, "snake in the grass." Merges and Kuhn (2009).

One of the principal issues raised in each case was the degree to which the relevant SSO's policy actually required disclosure of the patents in question. In *Dell*, the Video Electronics Standards Association (VESA) required individual meeting attendees to certify that all known SEPs were disclosed. Dell's representative to VESA signed the required certification but did not disclose any patents. When Dell later sought to collect royalties under a patent covering the VL-bus standard, the FTC brought an action accusing Dell of engaging in unfair methods of competition under Section 5 of the FTC Act. The FTC action resulted in the entry of a 1996 consent decree permanently enjoining Dell from enforcing its VL-bus patents against any third party. The *Dell* case is controversial, as there was no allegation that Dell's representative to VESA knew of Dell's patent when the VL-bus standard was adopted. In response, SDO policies today often specify that searches of corporate patent portfolios are not required to comply with SSO disclosure requirements, and that disclosure be limited to the "knowledge" of the individuals participating in standards development at the SSO (ABA (2007), Bekkers and Updegrove (2012)).

The *Rambus* and *Qualcomm* disputes also centered on the language of SSO disclosure policies. In *Rambus* (2003), the Federal Circuit sharply criticized the patent policy of the Joint Electron Device Engineering Council (JEDEC), an SSO in which Rambus, Inc. participated in the early 1990s. Though Rambus was accused of concealing patents that it filed specifically to cover nascent JEDEC standards, the court declined to find that Rambus had committed fraud because JEDEC's patent policy did not clearly impose a disclosure requirement. The court criticized the policy as suffering from "a staggering lack of defining details" that left SSO participants with only "vaguely defined expectations as to what they believe the policy requires". The court concluded that, while Rambus's attempt surreptitiously to patent JEDEC standards might "impeach Rambus's business ethics, the record does not contain substantial evidence that Rambus breached its duty under the …

[26] Other cases that are discussed less frequently in the literature include *Wang v. Mitsubishi,* 860 F. Supp. 1448 (C.D. Cal. 1993) and *Stambler v. Diebold,* 1988 WL 95479 (E.D.N.Y. 1988). For a brief summary, see Contreras (2011).

policy." *Rambus* (2003).[27] The holding in the *Rambus* (2003) case served as a wake-up call to the SSO community and prompted many SSOs to clarify their patent policies in an effort to avoid some of the perceived weaknesses of the JEDEC policy (Tsilas (2004), ABA (2007), Layne-Farrar (2014a)).

Qualcomm (2008) involved a similar interpretive dispute over whether an SSO policy that "encouraged" participants to disclose their essential patents actually *required* such disclosures. Basing its decision on the practices and expectations of SSO participants, other language concerning "best efforts" to disclose, and the rules of related SSOs, the court held that the SSO policy imposed an affirmative obligation to disclose, and that Qualcomm had breached that obligation (p.1019).

2. Essentiality. A key element of all SSO policies that require either disclosure or licensing of SEPs is the manner in which patent claims are classified as "essential" to the relevant standard. The determination whether a particular patent is, indeed, essential to a particular standard is typically left to the patent holder. Bekkers and Updegrove (2012). Due to resource constraints, SSOs rarely review or validate their participants' determinations of essentiality.[28]

Compounding the problem of unverified self-reporting is the range of definitions of essentiality used by different SSOs. Bekkers and Updegrove (2012) identify thirteen different features of SSO essentiality definitions which varied considerably over the ten SSOs they studied.[29] One major divide among SSOs is whether they define an "essential" patent claim as covering a technology that must, as a technical mater, be included in a product implementing the standard (technical essentiality) or whether that patented technology, though not strictly required as a technical matter, is the only commercially feasible way that the standard can be implemented (i.e., considering cost, efficiency, reliability, manufacturability, etc.) (commercial essentiality). ABA (2007), Bekkers and Updegrove (2012), Contreras (2013b), Kesan and Hayes (2014).

Given the incentives that firms have to obtain and disclose patents that are essential to standards, potential penalties for failing to disclose potentially essential

[27] In a subsequent action, the FTC found Rambus liable, among other things, for attempted monopolization in violation of Section 2 of the Sherman Act and deceptive conduct under Section 5 of the FTC Act (*Rambus* (2008)). The FTC's decision, however, was reversed by the Court of Appeals for the District of Columbia, which held that Rambus's attempt to increase prices following adoption of a standard did not amount to anticompetitive conduct unless such conduct also resulted in adoption of the standard, which was not shown. This decision has been criticized, both on the basis of its antitrust analysis and as a matter of public policy. Citations to literature discussing the case are collected in Contreras (2011).

[28] This situation is different than that observed in patent pools, in which significant up-front costs are incurred to verify the "essentiality" of all patents proposed to be included in the pool in order to comply with relevant antitrust requirements. Contreras (2013b), Lundqvist (2014). Estimated costs of such essentiality analyses are presented in CRA (2016) (see note 21, above).

[29] Some of these variations involved the degree to which copyrights and other intellectual property, in addition to patents, could be considered essential to a particular standard.

patents (see Part IV.A.1 above),[30] and the lack of verification of claims of essentiality by SSOs, some authors suggest that the many patents disclosed as essential to standards are not actually necessary for the implementation of those standards. This phenomenon is known as "over-disclosure". Goodman and Myers (2005) and Fairfield (2007, 2010) find that only 27, 28 and 50 percent of patent families declared "essential" to ETSI's GSM, WCDMA and LTE standards, respectively, are actually essential to implementation of those standards.[31] Cyber Creative (2013) independently evaluated a sample of 2,129 SEPs declared essential to the LTE standard (representing 36% of the 5,919 total declared SEPs). It found that 56% of the sampled SEPs were "truly" essential to the standard, while 29% were partially essential and 15% were not essential at all. The investigators then calculated the ratio of essential to non-essential declared SEPs for each major contributor to the standard, finding that several firms including Apple, Alcatel-Lucent, Freescale and Nortel had essentiality ratios of 40% or less, while ZTE, CATT, NTT Docomo and InnovativeSonic had ratios above 80%. The average essentiality ratio observed was 56.6%, or 53.8% when only issued patents were considered.

Interviews conducted by Blind et al. (2011) also point to widespread over-disclosure of patents at SSOs. As noted above, CRA's (2016) interviews identified over-disclosure as a significant area of concern for stakeholders in standardization.

Challenges to claims of essentiality can be raised in litigation if and when those patents are asserted by their owners. One such challenge occurred in *Innovatio* (2013), in which the court found that 168 disputed patent claims were "essential" to the 802.11 standard, reasoning, with respect to many of such claims, there was "no commercially feasible alternative to using the … claims to implement the standard". [32] Eltzroth (2008) also discusses claims brought before the European Commission challenging a declaration submitted by Sun Microsystems to ETSI. The challenger asserted, among other things, that the patent declared was not essential.

To begin to address over-disclosure, CRA (2016) has proposed a number of possible approaches, including increasing the cost of declaring SEPs, limiting the number of patents that any SSO participant may declare as essential, and instituting random essentiality testing of patents declared as essential.[33] Contreras (2013b) has proposed an aggregate royalty system in which other holders of SEPs may challenge

[30] Cases such as *Dell, Rambus* and *Qualcomm* (see Section IV.A above) gave a strong message to industry that failing to disclose standards-essential patents could be viewed by antitrust enforcement authorities as deceptive and anticompetitive conduct. There appears to be no similar legal disincentive to over-disclosing patents to an SSO, though it is theoretically possible that intentional over-disclosure could support a claim of fraud or deception, especially if the patent holder sought to charge royalties on patents that were not essential to the standard. Contreras (2013b).

[31] The methodology of the first such study has been critiqued in an unpublished working paper by Martin and DeMeyer (2006).

[32] IEEE has a "commercial essentiality" requirement. IEEE (2015).

[33] It is not clear whether such testing would be conducted by the SSO, the SEP holder or a governmental regulator.

each others' essentiality determinations, with penalties assessed against over-declaration.

B. *FRAND Licensing Disputes*

As noted in Part III.B above, many SSOs require participants to grant patent licenses to standards implementers on terms that are FRAND. But despite their prevalence, few, if any, SSOs define FRAND with sufficient detail to fully specify the scope of the obligation.[34] Not surprisingly, disagreements have arisen regarding the scope and details of SSO participants' FRAND licensing obligations. A good survey of worldwide FRAND-related litigation can be found in Pentheroudakis and Baron (2017).

1. *Royalty Rates*. Much FRAND litigation centers on whether a SEP holder has breached its FRAND licensing commitment by charging (or demanding) royalties that are too high to be considered "reasonable" under the relevant SSO's policy. Such claims may be raised either in an affirmative breach of contract action by an implementer seeking a license under those SEPs (*Microsoft* (2013), *Apple* (2012)) or as an affirmative defense to an infringement action brought by the SEP holder (*Ericsson* (2014)).

The analysis of "reasonable" royalty rates for purposes of FRAND commitments has been substantially informed by a long line of cases and extensive analysis of reasonable royalty damages in patent infringement cases. This analysis generally takes as its starting point the 15-factor analytical framework introduced in *Georgia-Pacific* (1970), as modified to accommodate perceived unique characteristics of FRAND commitments. *Microsoft* (2013), *Innovatio* (2013), *Ericsson* (2014). A detailed analysis of these cases and their royalty calculation methodologies can be found in Pentheroudakis and Baron (2017), Cotter (2014), Layne-Farrar and Wong (2014), NRC (2013) and Sidak (2013).

A significant body of theoretical work also exists regarding FRAND royalty rates and the pricing of SEP licenses. Notable contributions to this literature include Swanson and Baumol (2005), Geradin, Layne-Farrar and Padilla (2007), Farrell et al. (2007), Lemley and Shapiro (2007), Layne-Farrar, Padilla and Schmalensee (2007), Elhauge (2008), Lichtman (2010), Sidak (2013, 2016), Cotter (2014), Contreras and Gilbert (2015), CRA (2016), Bartlett and Contreras (2017) and Siebrasse and Cotter (2017). A summary of much of these theoretical debates can be found in Siebrasse (2017).

The principal empirical data relating to FRAND royalty rates has emerged as a result of evidence presented in litigated cases. The court in *Microsoft* (2013), in particular, conducted a detailed analysis of numerous "comparable" licensing

[34] For implications of this lack of specificity on the contract law analysis of FRAND commitments, see Lemley (2002) and Contreras (2015a).

arrangements to determine FRAND royalty rates and ranges for two important standards (ITU's H.264 audio-video encoding standard and IEEE's 802.11 Wi-Fi standard). These comparable licenses included both bilateral license agreements and licenses granted by patent pools. Likewise, the court in *Innovatio* (2013) considered various comparable license agreements to benchmark royalty rates in making its FRAND determination. Less data on industry royalty rates emerges from cases in which FRAND rates are determined by a jury rather than the bench,[35] as were the determinations in *Ericsson* (2013) and *Realtek* (2013).

The use of comparable license agreements to determine patent royalty rates in litigation has been the subject of some controversy, with some commentators supporting the use of comparable licenses as the best available evidence of the royalty rates that the parties would have agreed in a hypothetical negotiation (Sidak (2016), Geradin and Layne-Farrar (2011)). Others, however, express concern that license agreements between different parties are unreliable, non-transparent and seldom comparable enough to be useful in determining royalties that would have been agreed by the parties in litigation (Masur (2015)).

In addition to litigation data, a few studies of FRAND royalty data have been conducted in standards-heavy industries. Stasik (2010) compiles royalty rates for patents essential to the ETSI 4G LTE standard, Armstrong, Mueller and Syrett (2014) report known and estimated patent royalty rates for the various components of a smart phone, and Mallinson (2015), refuting Armstrong, Mueller and Syrett, compiles data regarding publicly announced licensing rates for various standards included in mobile wireless devices. Blind et al. (2011), rather than relying on published royalty rates, conducts structured interviews to develop profiles of typical licensing rates for different telecommunications standards. These interviews confirm the variability of licensing royalty rates from firm to firm and technology to technology, as well as factors, such as cross-licensing, that tend to affect rates.

2. *Royalty Base and Apportionment*. Closely related to the question of royalty rate in FRAND discussions is that of royalty "base", the amount to which the royalty rate is applied. Royalty base is a critical variable in patent licensing discussions, as it directly impacts the revenue received by the licensor, and it has recently become the subject of U.S. litigation over the proper measure of "reasonable royalty" damages in patent infringement suits (see Chapter x, this volume). The crux of the problem is that hundreds or even thousands of patents often cover a single technology product. Though each such patent typically claims only a small subset of the overall product's functionality, in commercial license agreements royalties are often measured on the basis of the end product's sale price.

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[35] Contreras (2015b) discusses considerations around judicial versus jury determinations of FRAND royalties.

Under longstanding U.S. precedent, "reasonable royalty" patent damages must be "based on the incremental value that the patented invention adds to the end product" (*Ericsson* (2014). This incremental value approach requires the court to determine the portion of the overall product value that is contributed by the patented feature, in view of all the other features of the product (id.). This analysis is often referred to as "apportionment". See Pentheroudakis and Baron (2017), Sidak (2016). As an aid to juries seeking to apportion damages in this manner, courts may instruct them to apply the determined royalty to the "smallest saleable patent practicing unit" [SSPPU] of a product" *Ericsson* (2014)[36]. In contrast, royalties should be payable on the entire market value of the end product (the "entire market value rule" or EMVR) when the value of the entire product is attributable to the patented feature (id.).

There has been considerable debate over the propriety and application of the SSPPU principle to cases involving standardized products. In its 2015 policy amendments, IEEE stated that the determination of reasonable royalty rates should include consideration of the contribution made by the patented feature to the value of the SSPPU (IEEE 2015). In its approval of the amendments, the DOJ noted that such considerations support the appropriate valuation of technologies subject to a FRAND commitment (DOJ 2015). Nevertheless, numerous commentators have criticized the application of the SSPPU principle, particularly in cases involving standardized products. Petit (2016), Teece and Sherry (2016) and Sidak (2014) argue that the SSPPU rule runs contrary to commercial licensing practice and needlessly increases transaction costs and uncertainty in licensing transactions. CRA (2016) argues that different royalty bases may be appropriate in different market situations, making governmental rules relating to the vertical level of licensing "misguided".

From an empirical standpoint, Putnam and Williams (2016) sampled patents declared by Ericsson as essential to ETSI 2G, 3G and 4G standards and found, among other things, that the majority of the sampled patent claims read on more than one system or component, calling into question the use of the SSPPU methodology with respect to such patents.

3. *Nondiscrimination*. While much of the debate concerning FRAND licensing has centered on the "reasonableness" of royalty rates, increasing attention has focused on the "nondiscrimination" prong of the FRAND commitment. The issue has arisen largely in connection with some SEP holders' desire to deny licenses to "upstream" component vendors in order to collect royalties from more lucrative "downstream" vendors.

In general, a patent holder may choose to license its patent, and charge a royalty, to any producer in the supply chain for a product, or to the product's end

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[36] The SSPPU doctrine originated in Cornell Univ. v. Hewlett-Packard Co., 698 F.Supp.2d 279 (N.D.N.Y. 2009).

users. However, due to the doctrine of patent exhaustion,[37] the patent holder can only collect a royalty once per patented product. As soon as the patented technology is sold by the patent holder or its authorized licensee, the patent is "exhausted" and no further royalties can be collected. For example, the holder of a patent covering an aspect of a wireless communications standard could license either the manufacturer of the wireless chipset that embodies that standard, the manufacturer of a smart phone that incorporates that chipset, or the consumer who uses the smart phone's wireless communications capability. Thus, the patent holder's hypothetical 2% royalty on the sale price of the $600 smart phone would yield the patent holder $12, while the same 2% royalty applied to the $50 wireless chipset inside the smart phone would yield the patent holder only $1. Yet if the patent holder licenses the chipset vendor, the patent is "exhausted" and no royalty can be charged to the smart phone manufacturer that incorporates the chipset into its phone, or the consumer who uses the phone.[38]

This is the classic supply chain issue faced by patent holders. To address it and maximize royalty revenue, patent holders often seek to license the entity that is furthest "downstream," or selling products at the highest price, while declining to grant licenses to suppliers of low-priced intermediate components. While this practice is within a patent holder's rights in the ordinary course of business, it is not clear that the practice is permitted when patents are subject to a FRAND commitment. That is, if a FRAND commitment implies that a patent holder must grant or at least offer licenses to all who request them, then refusal to grant a license to a low-value component vendor could constitute impermissible "discrimination" (Carlton and Shampine (2013), Contreras (2015b)). The court in *Microsoft* (2013) adopted a similar view, and the IEEE recently clarified that its patent policy requires the grant of licenses to all applicants (IEEE (2015)).

Patent holders that prefer to select which implementers to license have taken the position that, absent express SSO policy language to the contrary, they are permitted to choose their licensees under their FRAND commitments (*Ericsson* (2013)). They argue, among other things, that the purpose of the FRAND "nondiscrimination" requirement is to ensure that all licenses that are granted have comparable, if not identical, terms. While the question whether or not FRAND commitments generally imply the licensing of all applicants remains open, most commentators agree that some variation among FRAND licensing terms will be tolerated by the "non-discrimination" requirement, and that all FRAND licenses need not be identical (Layne-Farrar (2010), Gilbert (2011), Carlton and Shampine (2013), Contreras (2015b)). Gilbert (2011) proposes that greater transparency of FRAND licensing terms may ensure greater compliance with the non-discrimination

[37] Quanta Computer, Inc. v. LG Elecs., Inc., 553 U.S. 617 (2008).

[38] Of course, from an economic standpoint, the particular point in the supply chain at which a royalty is charged is irrelevant, as the royalty rate can be adjusted to yield an equivalent charge no matter what the royalty base is. Teece, Grindley and Sherry (2013).

requirement, a requirement that has, in some cases, been alleged to have been breached (*Qualcomm* (2008)).

4. *Injunctions*. Much of the global controversy concerning FRAND licensing relates to a SEP holder's ability to seek injunctive relief to prevent the ongoing infringement of a SEP after a FRAND commitment has been made. The question arises because a SEP holder that has made a FRAND commitment has agreed, in theory, to grant licenses under its SEPs to implementers of relevant standards. Seeking an injunction to prevent such an implementer from practicing the SEP would therefor be contrary to the SEP holder's FRAND obligation. An argument can thus be made that a SEP holder subject to a FRAND commitment should not be permitted, as a matter of remedies law, to seek an injunction against an implementer of a standard, and that if it does seek an injunction, doing so may violate the FRAND commitment and antitrust/competition laws.

A sizeable body of theoretical literature and advocacy has been produced to address this question and is summarized in NRC (2013), Cotter (2014) and Sidak (2015a). Some of the principal legal and theoretical arguments against permitting such injunctions are outlined in Lemley and Shapiro (2007), Lemley (2007), Miller (2007), Shapiro (2010), Michel (2011) and Chien and Lemley (2012), while arguments against the limitation of such injunctions can be found in Sidak (2008, 2015a), Epstein, Keiff and Spulber (2012), Camesaca (2013) and Layne-Farrar (2014).

The issuance of injunctions on FRAND-committed patents has now been considered by the U.S. federal courts (*Apple* (2014)), the International Trade Commission (ITC) (*Samsung ITC* (2013)), the FTC (*Motorola and Google* (2013)), the European Commission (*Samsung EC* (2014)) and the European Court of Justice (*Huawei* (2015)), and the courts and enforcement agencies of China, Japan and Korea. While there is still some disagreement over the precise standards for review, a consensus appears to be forming among courts and agencies that making a FRAND commitment with respect to a SEP is generally inconsistent with seeking an injunction to prevent ongoing infringement of that patent by an implementer of the standard, and that such injunctions should, as a general matter, be issued only when the infringer is unwilling to negotiate for a FRAND license, refuses to pay a FRAND royalty or is beyond the jurisdictional reach of the relevant court or agency.

Despite the surge of recent empirical work investigating the award of injunctive relief in patent cases generally (see Chapter x), relatively little of this work has focused on SEPs. This may be because, as some commentators have pointed out, few if any injunctions have been issued with respect to FRAND-encumbered SEPs. Layne-Farrar (2014b).

Most of the debate regarding the appropriateness of injunctive relief in the face of FRAND commitments has focused on the interpretation and application of legal rules and procedure, in the absence of express guidance from SSO policies. A significant amount of commentary has emerged in Europe in the wake of *Huawei* (2015), but the case and its aftermath are still too new to draw any firm conclusions. For a discussion of the European case law following *Huawei*, see Pentheroudakis and Baron (2017).

On the policy side, IEEE was the first major SSO to amend its patent policy (see Part III.C above) to prohibit its participants from seeking injunctive relief against any implementer of an IEEE standard unless the implementer refused to pay the FRAND royalty rate determined by a court (IEEE (2015)). Such a rule will now, presumably, guide courts and agencies regarding requests for injunctive relief made by patent holders with respect to IEEE standards. It remains to be seen how many other SSOs, if any, follow this lead.

V. *Other SSO Policy Features and Proposals*

In addition to patent disclosure and FRAND licensing (see Section IV), several other issues emerging from SSO patent policies have recently received attention from commentators and agencies.

A. *Ex Ante Licensing Disclosure*.

Many SSO disclosure policies require that patent holders disclose to the SSO patents that are essential to the implementation of the SSO's standards. Though such policies often permit patent holders to grant licenses on FRAND terms, very few require the patent holder to disclose in advance (*ex ante*) the royalty rates that it intends to charge. Rather, these and other key contractual terms are left to bilateral negotiations between the patent holder and individual implementers of the standard, and are usually protected by confidentiality restrictions that prevent this information from being shared with others.

In the early 2000s, some commentators began to caution that royalty rates left unspecified during standardization could lead to hold-up situations characterized by excessive royalty demands following industry lock-in to a particular standard (Ohana, Hansen and Shah (2003), Skitol (2005), Updegrove (2006), Lemley (2007)). As a result, proposals were made at several large SSOs including IEEE and ETSI, as well as the smaller VMEBus International Trade Association (VITA), to require the disclosure of royalty information prior to approval of a standard (Contreras (2013a)). Due to internal opposition as well as the specter of liability for encouraging anticompetitive price collusion (Sidak (2009)), IEEE and ETSI amended their patent policies to permit, but not require, the disclosure of royalty and other licensing information (see Part III.C). VITA, in contrast, proceeded with its policy amendments requiring mandatory *ex ante* disclosure of maximum patent licensing rates. Both VITA and IEEE requested, and received, business review letters from the DOJ approving their proposed policy amendments (DOJ (2006, 2007)). There was at least one coordinated attempt by a group of European network operators to reveal maximum aggregate royalty rates for certain wireless standards through the Next-Generation Mobile Networks (NGMN) consortium (Contreras 2013a, 178-79).

As noted in Part III.C above, at least one large VITA member withdrew from the organization as a result of the adoption of the *ex ante* policy. Some commentators predicted that the adoption of *ex ante* disclosure policies would have the effect of driving other members away from SSOs adopting such policies, in addition to reducing the efficiency and quality of the standards development process at such SSOs (Skitol (2005), Tapia (2010), Herman (2010)). Contreras (2013a) empirically tested these predictions at VITA, IEEE and IETF, a large SSO that permits voluntary *ex ante* disclosures, finding no evidence of the predicted process deterioration. In interviews with VITA participants, there was moderate to strong support for the *ex ante* policy. Blind et al. (2011) and CRA (2016) both interviewed SSO participants regarding *ex ante* disclosure policies, receiving a range of responses both positive and negative.

Potential antitrust liability has often been raised when *ex ante* disclosure policies are discussed. Specifically, requiring a patent holder to disclose its licensing terms *ex ante* could enable potential licensees (implementers of a standard) to collectively exert anticompetitive pressure on the patent holder to reduce its royalties toward zero, resulting in the devaluation of patents covering the standard.[39] Sidak (2008). This type of improper buyer cartel is avoided when patent holders are permitted to negotiate license terms with implementers on a bilateral basis, constrained only by FRAND guidelines. Given these arguments, Skitol (2005), Lemley and Shapiro (2007) and Contreras (2013b) propose that antitrust authorities should more clearly authorize limited degrees of collective royalty negotiation in the context of SSOs.

To date, few if any additional SSOs have adopted *ex ante* disclosure policies, likely due to a combination of inertia, antitrust concerns and internal opposition from patent holders. Contreras (2013a). Given these market realities, Lerner and Tirole (2015) propose that SSOs be mandated by law to require patent holders to make *ex ante* maximum royalty commitments (what they call structured price commitments).[40]

B. *Aggregate Royalty Caps*.

As discussed in Section II.G.2, the principal risk associated with royalty stacking is that individual patent holders, each acting to maximize its own profit,

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[39] Contreras (2013a) finds no evidence that VITA's mandatory *ex ante* disclosure policy caused patent holders to reduce their requested royalty rates.

[40] Ganglmair, Froeb and Werden (2012) propose that optimal hold-up avoidance and innovation could be achieved if patent holders and implementers entered into formal "option-to-license" contracts before the implementer makes investments in the standardized technology. While this solution is theoretically attractive, significant transaction costs are involved in licensing negotiations, making the widespread use of such pre-implementation contracts unlikely.

will in the aggregate charge a cumulative royalty that is above efficient levels. To address this risk, proposals have been made to cap the aggregate royalties chargeable with respect to a given standard or product. Some firms, in order to promote the adoption of particular standards, have voluntarily committed to such caps. Bekkers and West (2009) and Contreras (2015c) describe such commitments made by firms in the wireless telecommunications sector, and Layne-Farrar (2014c) offers a case study of commitments relating to ETSI's LTE standard. Tapia (2010) and Bekkers and West (2009) also discuss efforts made to impose aggregate royalty caps at ETSI for 3G and 4G telecommunications standards, but these efforts were ultimately unsuccessful as major patent holders were unwilling to participate.

In addition to these industry efforts, commentators have proposed more coordinated approaches to containing royalties at the SSO level. Lemley (2007) proposes a "step-down" royalty structure in which each successive patent holder seeking to charge royalties on a particular standard would be entitled to seek an increasingly diminished royalty. Contreras (2013b) proposes collective agreements among SSO members on aggregate royalty caps for particular standards, with proceeds divided among SEP holders and meaningful penalties for over-disclosure. CRA (2016) and Lerner and Tirole (2015) likewise make proposes regarding agreement on aggregate royalty caps for particular standards. In contrast, Herman (2010) and Blind et al (2011) list arguments that have been made against aggregate royalty caps, including their potentially disproportionate impact on patent holders. CRA (2016, Sec. 5.1.2) summarizes various royalty cap approaches as well as stakeholder reactions to these proposals.

C. *Royalty-Free Licensing*.

Much recent litigation concerning standards and patents revolves around appropriate levels for, and methods of calculating, FRAND royalty rates. These challenges, as well as the risk of patent hold-up by SSO participants, are alleviated if patent holders covenant not to assert their standards-essential patents, or commit to license them on a royalty-free basis. Such royalty-free licensing requirements might be commercially advantageous in some settings, as when standards developers value widespread interoperability more highly than patent-based revenue generation (Blind et al. (2011), Updegrove (2012), Contreras (2016a)) or wish to promote the adoption of a new technology platform or infrastructure (Contreras (2015c).

The obvious trade-off of royalty-free requirements is that patent holders seeking a financial return on their patent portfolios may not wish to participate in such SSOs, thereby depriving such SSOs of skilled developers, technology inputs and exposing implementers of SSO standards to infringement of these patents without even the cold comfort of a FRAND licensing commitment (Herman (2010), Bekkers and West (2009)).[41] Moreover, in some technology areas, it may not be feasible to

[41] Rysman and Simcoe (2011) propose a model in which SEPs would be licensed at FRAND rates for

develop technically adequate standards without the inclusion of at least some royalty-bearing patented technology. In this vein, Choi and Jang (2014) discuss the challenges of developing a royalty-free codec. Finally, Chiao, Lerner and Tirole (2007) observe that SSOs with royalty-free licensing requirements tend to have fewer patent disclosure requirements, as the effort of identifying and disclosing patents may be considered less critical under a royalty-free regime. Greenbaum (2016) raises questions regarding the availability of legal remedies when royalties are not charged under a license agreement.

Despite these potential drawbacks, royalty-free SSO licensing policies are not uncommon. Biddle, White and Woods (2010) find that of 251 standards embodied in a typical laptop computer, 22% were available on a royalty-free basis. Of 36 SSOs coded, Baron and Spulber (2015) identify 5 that require royalty-free licensing or patent non-assertion, at least at the working group level. They also find that four SSOs that previously permitted royalty-bearing FRAND licensing have moved to royalty-free or patent non-assertion policies.

Significant SSOs that require non-assertion or royalty-free licensing of SEPs include the Worldwide Web Consortium (W3C), the Bluetooth Special Interest Group, the HDMI forum, and the USB Forum. Other groups, such as software standards developer OASIS, permit technical committees to determine, upon formation, whether they will require FRAND or royalty-free licensing commitments from their participants. Bekkers and Updegrove (2012) find that of 83 active OASIS committees, all had selected a royalty-free licensing approach, and none had selected a royalty-bearing FRAND licensing approach.

The above discussion relates to *de jure* royalty-free policies, which are imposed by SSOs on their participants. In addition to *de jure* royalty-free standards , it is also possible that standards developed at SSOs permitting royalty-bearing FRAND licensing may, as a practical matter, also be free from royalty demands. This could be because a standard is simply not covered by patents held by SSO participants, thus avoiding the need for any licenses at all, or because the holders of patents covering the standard have elected not to assert those patents or seek licenses from implementers. The second scenario arises frequently in the case of IETF, which requires neither FRAND nor royalty-free licensing, but expressly prefers standards that are available on a royalty-free basis (Contreras (2016a)). Contreras (2013a) finds that between 2007 and 2010, approximately 59% of all patent disclosures made at IETF were accompanied by a voluntary commitment not to assert patents or to license them on a royalty-free basis.

Another instance of royalty-free standards usage is associated with the so-called "sleeping dog" phenomenon: some patent holders simply do not wish to

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an initial period, after which licenses would become royalty-free. This Non-Assertion After Specified Time, or "NAASTy", pricing model could enable innovators to recoup development costs, while thereafter promoting widespread adoption of a standard and eliminating disputes regarding FRAND royalty rates.

expend the substantial time and resources necessary to pursue a patent licensing program. Contreras (2013a). It is currently not known how many SEPs declared at different SSOs are held by sleeping dogs, but they, together with voluntary royalty-free commitments made at SSO such as IETF, may result in a meaningful body of "*de facto*" royalty-free patents in the marketplace.

D. *Alternative Dispute Resolution*.

Given the increase in litigation concerning standardization and SSO policies, several commentators have suggested the use of alternate dispute resolution (ADR) mechanisms to streamline the resolution of disputes relating to SEPs. Kühn, Scott Morton and Shelanski (2013). The FTC and European Commission have also recognized arbitration as a suitable method for resolving SEP-related disputes. *Mororola and Google* (2013), *Samsung EC* (2014).

As a matter of implementation, Lemley and Shapiro (2013) propose that disputes regarding FRAND royalty rates be settled by binding "final offer" or "baseball" arbitration. In such proceedings, each party provides the arbitrator with a sealed "final offer," of which the arbitrator must choose only one, without modification. This approach is supported by CRA (2016, p.80), who offer the alternative of 'night baseball', in which the arbitrators are not informed of the parties' offers, but must make an independent assessment of the royalty level, after which the royalty is set at the party's offer that is closest to the arbitrator's assessment. Larouche, Padilla and Taffet (2014) challenge baseball arbitration as unnecessary and likely to undermine the standardization process. Contreras and Newman (2014) develop a framework for conducting arbitration concerning standards and standards-essential patents. Among other issues, they raise concerns regarding the general confidentiality of arbitral awards.

A few SSOs have adopted ADR mechanisms in their rules and policies. The DVB Forum has had such a policy in place since 1995. Eltzroth (2008). Contreras and Newman (2014) identify and describe four long-standing SSO ADR policies. Most recently, IEEE amended its patent policy to permit, but not require, arbitration of SEP-related disputes. IEEE (2015).

In addition to SSOs, several international arbitration bodies have begun to modify their practices and policies to accommodate proceedings concerning SEPs and standardization. The most ambitious of these has been the World Intellectual Property Organization (WIPO), which has developed a bespoke procedure specifically addressed to SEP disputes. Greenbaum (2015).

E. Transfer of Commitments

When a SEP holder makes a commitment to license SEPs to manufacturers of standardized products, it is not always clear whether that commitment applies only to the SEP holder making the commitment, or whether it binds subsequent holders of the SEP. As observed by CRA (2016), "a FRAND commitment is not worth much if an SEP can be sold without transferring the commitment" (p. 71). Yet, the legal basis for the transfer of such commitments is not entirely clear.

The FTC has taken the position that a party acquiring a SEP with the knowledge of a prior FRAND commitment must abide by that commitment, and that a failure to do so constitutes an unfair method of competition in violation of Section 5 of the FTC Act (*N-Data* (2008)). This matter was settled, however, before any judicial ruling on the question. The issue arose again in 2011, when bankrupt Nortel Networks, a major contributor to several SSOs, proposed the sale of its remaining assets, including approximately 4,000 patents, on a "free and clear" basis. *Nortel* (2011). Several product vendors, together with IEEE, argued that Nortel's "free and clear" sale could invalidate patent licensing commitments that Nortel had previously made to SSOs. Ultimately, the purchaser of the patents, a consortium including several large product vendors, agreed to abide by Nortel's prior licensing commitments and the issue was not adjudicated.

Because courts have not yet definitively ruled on the binding nature of SEP licensing commitments on subsequent SEP holders, the state of the law is unsettled in this regard. As a result, an increasing number of SSOs have required in their internal policies that participants that transfer SEPs as to which licensing commitments have been made must ensure that those commitments are binding on successive owners of the SEPs. Bekkers and Updegrove (2012) catalog SSOs that impose such transfer requirements, and NRC (2013) discusses the variety of SSO policy provisions that can be employed in this regard. The IEEE's 2015 policy amendments are an example of such provisions. Most commentators who have considered the matter support the implementation of voluntary policy mechanisms to ensure the binding nature of SEP licensing commitments following a transfer of the SEPs. Kühn et al. (2013), NRC (2013), Kesan and Hayes (2014), Contreras (2015c), CRA (2016).

In some cases, SSO participants have transferred SEPs to patent assertion entities (PAEs) for the purpose of monetization and assertion (this practice is sometimes referred to as "privateering"). Lundqvist (2014), Golden (2013). JRC (2016) found that approximately 80% of patents asserted by PAEs were obtained from operating companies. In one recent case, a product manufacturer has alleged that a SEP holder conspired with a number of PAEs in violation of its FRAND commitments and U.S. antitrust laws to subdivide a portfolio of SEPs in order to collect excessive licensing fees. *Apple* (2016). These issues will bear close scrutiny as such cases progress.

VI. *Non-Patent Intellectual Property and Standards*

Though the vast majority of literature concerning standards and intellectual property has focused on patents, a few significant copyright and trademark issues have recently gained the attention of scholars, regulators and the public. Only a few scholars have attempted to address multiple forms of intellectual property protection for standards. De Carvalho (2015) offers a holistic view of patents, copyrights and trademarks on standards within an international competition law framework, while Contreras and McManis (2013) assess the interplay of patents, copyrights and trademarks covering materials sustainability standards.

A. *Copyright*.

Because most technical standards take the form of written documents, it is generally understood that they are considered copyrightable works of authorship and protected by copyright law.[42] While various individuals and firms make textual and other contributions to standards, the relevant SSO often claims ownership of the collective work embodied in a published standard. While several SSOs make their standards freely available to the public via the Internet, others exercise tight control over their published standards, often charging for access and prohibiting copying and distribution.

1. *Incorporation by Reference*. The control exercised by some SSOs over standards documents has become controversial with respect to standards that have been incorporated by governmental agencies into legislation and regulation. Such incorporation by reference (IBR) frequently occurs in the case of local building, safety and electrical codes, which often reference and incorporate standards developed within SSOs. Mendelson (2015) estimates that there are more than 9,000 of these IBR standards within various federal regulatory codes and agency rules. Bremer (2015) collects data regarding the pricing of various IBR standards.

A circuit split currently exists in the U.S. courts regarding the copyright status of standards that have been incorporated into law (*Practice Management* (1998), *Veeck* (2002)). Nevertheless, in 2012 a petition was filed with the Office of the Federal Register seeking a rule that technical standards referenced in federal regulations be made freely available via the Internet. Strauss (2013). In 2012, a public interest group began to reproduce IBR standards and make them freely available online, leading to copyright infringement suits by several SDOs (Strauss (2013), Bremer (2015)). In an effort to mediate this dispute, ANSI has established a controlled-access (read only) online portal for IBR standards. ANSI (2014), Bremer (2015). Other proposals have been made, including hosting of IBR standards by federally-controlled web sites (Mendelson (2015)).

2. *Software in Standards*. Some technical standards include software code that must be implemented in products in order for them to conform to the standard. Other standards include reference or exemplary software code that illustrates the means by which the standard may be implemented in software.

[42] Samuelson (2007) challenges this assumption arguing, among other things, that standards documents are functional and should not have the benefit of copyright protection.

Contreras and Updegrove (2016). Both of these uses of software within standards raise issues relating to the ownership and licensing of copyrights. Conflicts over copyrights and software in standards arose as early as the 1990s over Sun Microsystems's efforts to standardize the Java programming language at ECMA and JCT-1 (Egyedi (2001b), Lemley and McGowan (1999)).

These issues are further complicated when such software is intended for use in open source code products, which often impose their own demanding licensing conditions. Vetter (2007), Updegrove (2009). Lundell et al. (2015) studied the effect of ISO's use conditions, as well as filed patent disclosures, on the implementation of three ISO standards (PNG, JPEG 2000, and TIFF/EP) in open source software, and their potential adoption under national regulations calling for open standards. They found that while PNG (which was also recognized by W3C) could be considered an "open" standard, JPEG 2000 and TIFF/EP would present problems regarding open implementation and were not compatible with typical open source code licensess.

Given the increasing importance of open source software to the global technology infrastructure, further research in this area is needed.

B. *Trademarks and Certification Marks*.

The names and designations of standards that are widely adopted, such as Bluetooth, Blu-ray and USB, can acquire substantial market value. SSOs often retain ownership of these trademarks and license their use in connection with products conforming to the standard. In some cases, a standard or series of standards may be associated with a mark not originated by the SSO, such as the well-known Wi-Fi® designation for IEEE's 802.11 series of wireless networking standards, which is owned and licensed by an independent organization.[43]

A large area of activity surrounds the testing and certification of products for conformity to different standards. Barnett (2012) discusses certification markets and the sometimes imperfect role played by intermediary firms in certifying third party products and services. Often, when a product is certified as compliant with a standard, its manufacturer is permitted to display a designated logo or certification mark on that product. Well-known examples include the Underwriters Laboratories' "UL" certification for electrical products and the Green Building Council's "LEED" certification for new buildings.

The proliferation of certification marks on certain categories of products, especially "green" or "eco-friendly" products, has been cataloged and critiqued by Chon (2009) and Contreras and McManis (2013). Fischer and Lyon (2014) compare environmental certification labels developed by non-governmental organizations versus industry bodies. However, little empirical literature exists regarding the

[43] The Wi-Fi® trademark is controlled by Wi-Fi Alliance, a non-profit organization formed in 1999 and which is independent of IEEE.

impact of product certification and certification marks on technology products and markets, an area that is ripe for further research.

Conclusions

Important theoretical work relating to standards has been done in the areas of SSO dynamics, firm behavior, market effects of patents, and royalty pricing. This work has been supplemented by a significant body of research and empirical data on the acquisition and disclosure of patents within SSOs, particularly in the ICT sector. Several important catalogs and analyses of SSO patent policies now exist, together with rich databases of SSO membership and policy data.

Despite this large body of literature, there are numerous areas at the confluence of intellectual property and standardization that warrant further investigation. These include: the influence and internal organization of consortia and other informal standards groups; the prevalence and market impact of *de jure* and *de facto* royalty-free standards; the effect of patents on standardization in growing fields outside of ICT including clean technology, medical devices and automotive infrastructure; the interaction of technology standards with open source software; the impact of product certification and certification marks on technology products and markets; and the institutional, legal and policy landscape of standardization outside of North America and Europe, particularly in China and other Asian economies.

In addition, more public data is needed regarding patent licensing and royalty rates for standardized technologies. The data that currently exists is gleaned largely from public sources such as litigation records, government licenses and public securities filings. This data, however, represents only the tip of the iceberg. The largest and most meaningful accumulation of data concerning patent licensing is locked within the files of private firms, subject to strict confidentiality restrictions, and beyond the reach of researchers, policy makers, enforcement agencies and courts. Greater public access to this data has the potential to lower licensing transaction costs, reduce the number of disputes regarding FRAND royalty rates, improve the accuracy of judicial damages determinations, inform agency enforcement decisions, and improve policy making. As such, it is in the interest of all participants in the standardization ecosystem to contribute to the growing public data resources in this important area of economic activity.

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