Does Patent Monetization Promote SSO Participation?*

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Abstract

We study the impact of Standard Setting Organization (SSO) intellectual property rights (IPR) policies on standardization and innovation. Specifically, we conduct a pair of event studies for two well known IPR policy revisions: a switch from Fair Reasonable and Non-Discriminatory (FRAND) to Royalty-Free licensing at the World Wide Web Consortium in 2003, and an update of the Institute of Electrical and Electronic Engineers Standards Association's IPR policy in 2015. Overall, we find little evidence that these policy changes caused a decline in participation by patent licensors or reduced innovation in patent-intensive parts of either SSO. This pattern holds for both W3C and IEEE, across numerous measures of participation and innovation, and for a variety of different "treatment" and "control" group comparisons. We interpret these findings as evidence that any link between IPR policies, innovation, and SSO participation is much weaker than purely theoretical arguments to the contrary often suggest. JEL Codes: L15, O3.

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1 Introduction

Standard Setting Organizations (SSOs) provide a forum where companies evaluate new technology and seek consensus on key aspects of product design. SSO participants sometimes seek to standardize patented technology, and that prospect raises concerns that a patent owner might withhold access or demand excessive compensation after users become locked into a standard. To address these concerns, SSOs have intellectual property rights (IPR) policies that govern the inclusion of patented technology in standards and the licensing of so-called Standard Essential Patents (SEPs).

The proper interpretation of SSO intellectual property policies is a hotly debated topic. Advocates for SEP licensors often claim that stricter IPR policies will reduce the incentive to develop new technologies and contribute to SSOs. Advocates for implementers typically respond that since many SSO contributors do not seek to monetize their patents, standards development would suffer little or no harm if SEP owners earned somewhat lower royalties.

This paper examines the link between IPR policies, innovation, and SSO participation. Specifically, we study two well-known IPR policy revisions: a switch from Fair Reasonable and Non-Discriminatory (FRAND) to Royalty-Free licensing at the World Wide Web Consortium (W3C) in 2003, and an update of the IEEE Standards Association's IPR policy in 2015.[1] In each case, we estimate "difference in difference" regressions that compare outcomes before and after the policy-change for companies (or parts of the standard or SSO) that we expect to be differentially affected by the

[1]There is some legal debate about whether the IEEE's policy revisions are "changes" (and therefore apply only to licensing commitments made after 2015) or merely "clarifications" that resolve ambiguity about the meaning of prior commitments. We take no position on that question, and use the terms "change", "revision", or "update" inter-changeably to describe revisions to the text of the IEEE and W3C IPR policies.

IPR policy revision.

Overall, we find little evidence that these policy changes caused a decline in participation by SEP licensors or reduced innovation in patent-intensive parts of the SSO. This pattern holds for both W3C and IEEE, across numerous measures of participation and innovation, and for a variety of different "treatment" and "control" group comparisons. We interpret these results as evidence that any link between IPR policies, innovation, and SSO participation is much weaker than purely theoretical arguments to the contrary often suggest.

The remainder of this short paper is structured as follows: Section 2 reviews relevant theory and related literature, Section 3 provides an overview of the IEEE and W3C policy revisions, Section 4 describes our data and empirical strategy, Section 5 presents the results of the empirical analysis, and Section 6 offers concluding remarks.

2 Theory and Literature Review

There is a substantial literature in the fields of law and economics examining the interaction between standards and patents.[2] Early contributions to this literature include Carl Shapiro's description of the patent holdup problem[3] and Mark Lemley's survey of SSO IPR policies.[4] Lemley found that 29 of the 36 IPR policies in his study required SEP holders to commit to provide FRAND licenses. Whether because of the prevalence of FRAND, or because of its use at several economically significant SSOs, much of the subsequent literature has considered the problem of how to interpret and

[2]For a summary, see *The Cambridge Handbook of Technical Standardization Law*, 2017, Contreras, J., ed., Cambridge University Press.

[3]Shapiro, Carl. "Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting." *National Bureau of Economic Research, Innovation Policy and the Economy*, 2001(1): 119-150.

[4]Mark A. Lemley, "Intellectual Property Rights and Standard-Setting Organizations" *California Law Review*, 2002, Vol. 90(6):1889-1980.

implement the idea of "fair reasonable and non-discriminatory" licensing.

Many economists have endorsed the idea that the "fair and reasonable" prong of FRAND implies a cap on SEP royalties at the incremental value of the patented technology relative to substitutes that could have been included in the standard.[5] In principle, this approach preserves for users the benefits of *ex ante* technological competition. The incremental value approach is also consistent with U.S. legal precedent that FRAND royalties should not reflect "any value added by the standard's adoption of the patented technology"[6] and the more general idea that reasonable royalties (for SEPs and non-SEPs alike) are limited by the presence of technological substitutes.

Not all observers favor the incremental value approach, however, and critics have argued that a more lenient interpretation of FRAND could promote innovation and SSO participation. For example, Layne-Farrar, Llobet and Padilla develop a formal theory where an incremental value rule leads SEP owners to (inefficiently) refrain from joining an SSO because it strengthens their bargaining position.[7] Froeb, Ganglmair and Werden also propose a model where enforcing RAND commitments through an *ex post* damages remedy can depress up-front innovation incentives.[8] Building on these ideas, many advocates argue that allowing SEP owners to capture a greater

[5]For example, "the concept of a 'reasonable' royalty for purposes of RAND licensing must be defined and implemented by reference to *ex ante* competition, i.e., competition in advance of standard selection." (D. Swanson and W. Baumol, "Reasonable and Nondiscriminatory (RAND) Royalties, Standards Selection, and Control of Market Power" *Antitrust Law Journal*, 2005, (73):9-18); or "the ex ante framework asks what is the incremental value of the patented technology relative to the alternatives available prior to the standard being set. The goal is to preserve the benefits of any competition that was actually or potentially present prior to the standard being set." (J. Ordover and A. Shampine, "Implementing the FRAND Commitment" *The Antitrust Source*, 2014, p. 8.)

[6]*Ericsson Inc. v. D-Link Systems, Inc.*, 773 F.3d 1201 (2014), at 1232.

[7]A. Layne-Farrar, G. Llobet and J. Padilla (2014) "Payments and Participation: The Incentives to Join Cooperative Standard Setting Efforts" *Journal of Economics and Management Strategy*, 23(1):24-49.

[8]B. Ganglmair, L. Froeb and G. Werden (2012) "Patent Hold-Up and Antitrust: How A Well-Intentioned Rule Could Retard Innovation" *Journal of Industrial Economics*, 60(2): 249-273. Because this model assumes away *ex ante* competition among innovations to be included in the standard, its emphasis lies upon a comparison between *ex ante* contracting and *ex post* FRAND enforcement.

share of the surplus from standardization would generally provide stronger incentives to innovate.[9]

In response, implementers make three broad arguments against using a more lenient interpretation of FRAND to try and stimulate upstream innovation. First, there is no guarantee that higher SEP royalties lead to more innovation. Economic theory suggests that stronger patents can lead to more innovation, but not always. In settings where innovation is sequential and complementary, stronger patents can reduce aggregate innovation by impeding decentralized sharing of ideas.[10] Moreover, as a practical matter, a weaker interpretation of FRAND might simply lead firms to seek more patents for marginal ideas that have little *ex ante* value but can still be used to claim a share of the *ex post* surplus from standardization.[11]

Second, implementers note that many firms contribute to standards development without seeking to monetize their patents.[12] Their incentive to contribute may stem from a desire to grow the market for complementary goods and services, or from the non-pecuniary benefits of having proprietary technology incorporated into the standard. The existence of SSO contributors who do not monetize their SEPs indicates

[9]See, e.g., a letter from former Assistant Attorney General of the Department of Justice Makan Delrahim to IEEE to "supplement, update, and append" the February 2, 2015 Business Review Letter, September 10, 2020, available at https://www.justice.gov/atr/page/file/1315291/download; J. G. Sidak (2013) "The Meaning of FRAND, Part I: Royalties" *Journal of Competition Law & Economics*, 9(4): 931-1055; R. Epstein and K. Noroozi (2017) "Why Incentives for 'Patent Holdout' Threaten to Dismantle FRAND, and Why It Matters" *Berkeley Technology Law Journal*, 32: 1381-1432; D. Ginsburg, K. Wong-Ervin and J. Wright (2015) "The Troubling Use of Antitrust To Regulate FRAND Licensing" *CPI Antitrust Chronicle*, 10(1): 2-8.

[10]See J. Bessen and E. Maskin (2009) "Sequential innovation, patents, and imitation" *The RAND Journal of Economics*, 40(4): 611-635. Galasso and Schankerman (2013) "Patents and Cumulative Innovation" *The Quarterly Journal of Economics*, 130(1): 317-369, also provides some empirical support for the idea that patents can stymie cumulative innovation in "complex technology" sectors, such as computers and information technology.

[11]For example, see B. Kang and R. Bekkers (2015) "Just-in-time patents and the development of standards" *Research Policy* 44(10): 1948-61, and also C. Righi and T. Simcoe (2021) "Patenting Inventions or Inventing Patents? Strategic Continuation Practice at the USPTO" (Working paper).

[12]The literature on open-source software development also explores incentives to contribute to collaborative projects. For example, see, J. Lerner and M. Schankerman, *The Comingled Code*, MIT Press, 2010.

that licensing revenue is not always necessary to induce upstream innovation.

Finally, implementers argue that the *ex ante* incremental value definition of FRAND creates the same innovation incentives that exist outside the world of SEP licensing. In general, the owner of a valid and infringed patent can raise its price to the point where it equals the incremental value of the patented technology over the next best non-infringing alternative. Incorporating a patent into a standard can dramatically increase the costs of "design around" – creating opportunities for an unconstrained SEP holder to charge higher royalties. An *ex ante* incremental value definition of FRAND places implementers in roughly the same situation as non-SEP infringers, and the fact that we observe rapid innovation for many non-standardized technologies suggests that such a rule would not undermine the net incentives for innovation.

Ultimately, neither economic theory nor legal argument is sufficient to establish that a particular definition of FRAND strikes the optimal balance between promoting upstream innovation and downstream implementation. For that reason, several studies have sought to examine the empirical evidence.

As a starting point, there are now many papers and reports that characterize the IPR policies of various SSOs.[13] These studies are useful for illustrating the high level of diversity that exists in practice. For example, while FRAND is the most common form of licensing commitment, there are some SSOs that require SEP owners to offer royalty-free licenses, and others where firms commit to offer a license at a predetermined rate. There is also considerable variation across SSOs in the procedures for identifying patents that may be essential and the provisions governing a SEP holder's licensing commitment. The main conclusion that emerges from examining this heterogeneity in SSO IPR policies is that there is no consensus on a single "best"

[13]For example, see Lemley (cited above) and also R. Bekkers and A. Updegrove (2013), "A Study of IPR Policies and Practices of a Representative Group of Standards Setting Organizations Worldwide" available at SSRN: https://ssrn.com/abstract=2333445.

solution to the underlying problem. Moreover, to the extent that IPR policies are matched to the technical and economic idiosyncrasies of an individual SSO, it will be very difficult to draw any inference about the link between IPR polices and innovation through cross-sectional comparisons.

The main alternative to cross-sectional analysis is a within-SSO study that links IPR policy revisions to changes in participation and upstream innovation within a particular SSO. There are three well-known IPR policy revisions that could be used for this purpose. In 2003, the World Wide Web Consortium (W3C) switched from a FRAND to a Royalty Free licensing policy. In 2007, the VMEBus International Trade Association (VITA) adopted a policy of mandatory *ex ante* disclosure of maximum royalty rates. And finally, in 2015, the IEEE Standards Association revised its FRAND policy, placing explicit limitations on SEP owners' access to injunctive relief.

Jorge Contreras has estimated the impact of the 2007 VITA policy revision on several standardization outcomes.[14] A key provision of the revised policy held that SSO participants must disclose the material terms required to license any SEPs prior to adoption of a new VITA standard. Although it was controversial at the time, Contreras found no evidence of a change in the number of standards started or adopted at VITA, the length of time required to develop those standards, or their quality. While one prominent member did leave VITA, most of the members responding to Contreras' survey suggested that the revised policy improved the open-ness and transparency of its standards development process.

This paper seeks to measure the impact of the W3C and IEEE IPR policy revisions on innovation and SSO participation.[15] Although we are not aware of other quantitative evaluations of the 2003 W3C IPR policy change, Contreras provides a

[14] J. Contreras (2011), "An Empirical Study of the Effects of Ex Ante Licensing Disclosure Policies on the Development of Voluntary Technical Standards" NIST Working Paper GCR 11-934.

[15] We rely on public data, which is not available for VITA.

detailed discussion of the events surrounding its adoption and implementation and concludes that, "the RF policy at W3C has largely been a success."[16]

There have been several studies of the 2015 IEEE IPR Policy revisions, offering divergent narratives of its impact. Gupta and Effraimides emphasize that IEEE revisions led several SEP owners to submit "negative" disclosure letters – essentially refusing to make FRAND commitments under the new policy. They also find evidence of a slowdown in the 802.11 comment resolution process (a proxy for the speed of standards development), and in the number of new Project Authorization Requests (PARs).[17] On the other hand, a series of reports by IPlytics find that IEEE activity has increased along several dimensions since 2015.[18] In particular, they find an increase in PARs, technical contributions, members, published standards, and patent applications for technology classes linked to the 802.11 standard.

In the next section, we describe the W3C and IEEE policy revisions in greater detail, before turning to our data and research design.

3 IPR Policy Revisions

3.1 W3C

The World Wide Web consortium is an international community, founded in 1994, that develops and maintains standards for internet publishing. The most famous

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

[17] Gupta, Kirti and Effraimidis, Georgios (2018) "IEEE Patent Policy Revisions: An Empirical Examination of Impact" Available at SSRN: https://ssrn.com/abstract=3173799. We note that the modest 4.2% decline in 802.11 PARs reported by Gupta and Effraimides was not subjected to any test for statistical significance.

[18] The IPlytics reports, "Empirical study on patenting and standardization activities at IEEE" (2017), "IEEE's Empirical Record of Success and Innovation Following Patent Policy Updates" (2018), and "Empirical Analysis of Technical Contributions to IEEE 802 Standards" (2019) are available at https://www.iplytics.com/about/publications/.

W3C standards are Hypertext Transfer Protocol (HTTP) and Hypertext Markup Language (HTML), which comprise the core protocols used to transmit and render web pages. In addition to those critical standards, W3C develops and manages a host of other protocols, including XML, SOAP, and CSS, that extend web functionality and enable cross-platform communication.

W3C operated without a formal IPR policy from 1994 through 1999. However, the rapid growth of the internet brought increased contact with "hardware" industries (telecommunications, broadcast media and consumer electronics). That convergence, along with the rapidly increasing issuance of software patents, led to a growing number of cases where patents could potentially impede the development of Web standards. For example, during the late 1990s the W3C encountered delays over an Intermind patent related to the P3P standard, a Microsoft patent related to the CSS standard, and a patent related to the XLink standard owned by Sun. Although each of these episodes was resolved, they convinced W3C that a clear patent policy was needed to ensure the successful development and adoption of Web standards.[19]

In July 1999, W3C created the Patent Policy Working Group (PPWG).[20] On August 16, 2001, this group published an initial draft of a two-track policy that would allow each new WG to select between RAND and RF licensing modes at the time it was chartered. This draft received strong reactions from W3C members and the public. While reactions from W3C members were mixed, comments from the public were almost uniformly negative, with the developer community expressing a feeling of being "betrayed by what they believe to be a sudden shift in policy."[21] Bruce Perens,

[19] Supra note 16.

[20] Daniel J. Weitzner, "Standards, Patents and the Dynamics of Innovation on the World Wide Web" W3C, November 1, 2004, available at https://www.w3.org/2004/10/patents-standards-innovation.html.

[21] "Patent Policy Working Group Face-to-Face Meeting Summary" W3C, October 15-17, 2001, available at https://www.w3.org/2001/10/ppwg-cupertino-ftf-summary.html. A sample of the comments can be found in "www-patentpolicy-comment@w3.org from

a leader of the open-source community, suggested that developers would produce alternative Royalty-Free Web standards ("fork" the Web) if the draft patent policy was passed.[22]

The controversy surrounding the initial draft led W3C to undertake substantial revisions to the proposed policy. On February 26, 2002, November 14, 2002 and March 19, 2003, W3C published subsequent drafts providing that RF licensing should generally be required. Although some members remained opposed to its RF licensing provisions, the new W3C patent policy was finalized on May 20, 2003 and became operative on February 15, 2004 with the endorsement of W3C Director, Tim Berners-Lee.[23] The 2004 policy states that:

> "In order to promote the widest adoption of Web standards, W3C seeks to issue Recommendations that can be implemented on a Royalty-Free (RF) basis. Subject to the conditions of this policy, W3C will not approve a Recommendation if it is aware that Essential Claims exist which are not available on Royalty-Free terms."[24]

The policy does contain an exception that allows for patented technology to be used in W3C standards, but only after a Patent Advisory Group (PAG) comprised of all Working Group members and the W3C Chair determine that there are no

October 2001 by thread", W3C, available at https://lists.w3.org/Archives/Public/www-patentpolicy-comment/2001Oct/thread.html.

[22] "We'll fork the Web to keep it Free", The Register, October 3, 2001, available at https://www.theregister.com/2001/10/03/well_fork_the_web/.

[23] "Patent Policy Working Group History," W3C, available at https://www.w3.org/2001/ppwg/history. "W3C Patent Policy" W3C, May 20, 2003, available at https://www.w3.org/Consortium/Patent-Policy-20030520.html. On February 5, 2004, some administrative changes were made to the patent policy before it became operative. These changes include "updated links to the W3C Process Document and a change to one administrative detail (allowing the Team to use other mechanisms than email for disclosures)". "Director's Decision, W3C Patent Policy," W3C, available at https://www.w3.org/2003/05/12-director-patent-decision-public.html.

[24] "W3C Patent Policy," W3C, February 5, 2004, available at https://www.w3.org/Consortium/Patent-Policy-20040205/.

acceptable workarounds. During the first ten years of the RF policy, there were 12 PAGs formed, and in each case the issues were resolved without any serious disruption to the W3C standardization activity.[25]

Figure 1 shows how the number of unique authors, organizations and "contributions" to W3C evolved during the five years before and after the policy change (denoted by a vertical line in the figures).[26] All three outcomes exhibit an increasing trend between 1999 and 2003, while the new IPR policy was under development, and we do not observe any persistent decline after 2003, when it was adopted. It does appear that contributions declined in 2004, and that the growth in contributions leveled off after 2003. It is not clear, however, if this reflects the policy revision or other factors, such as a natural ebb in the W3C workflow driven by the life cycle of various standards. The next section describes our empirical strategy for addressing this inherent weakness of simple pre- versus post-policy comparisons.

3.2 IEEE

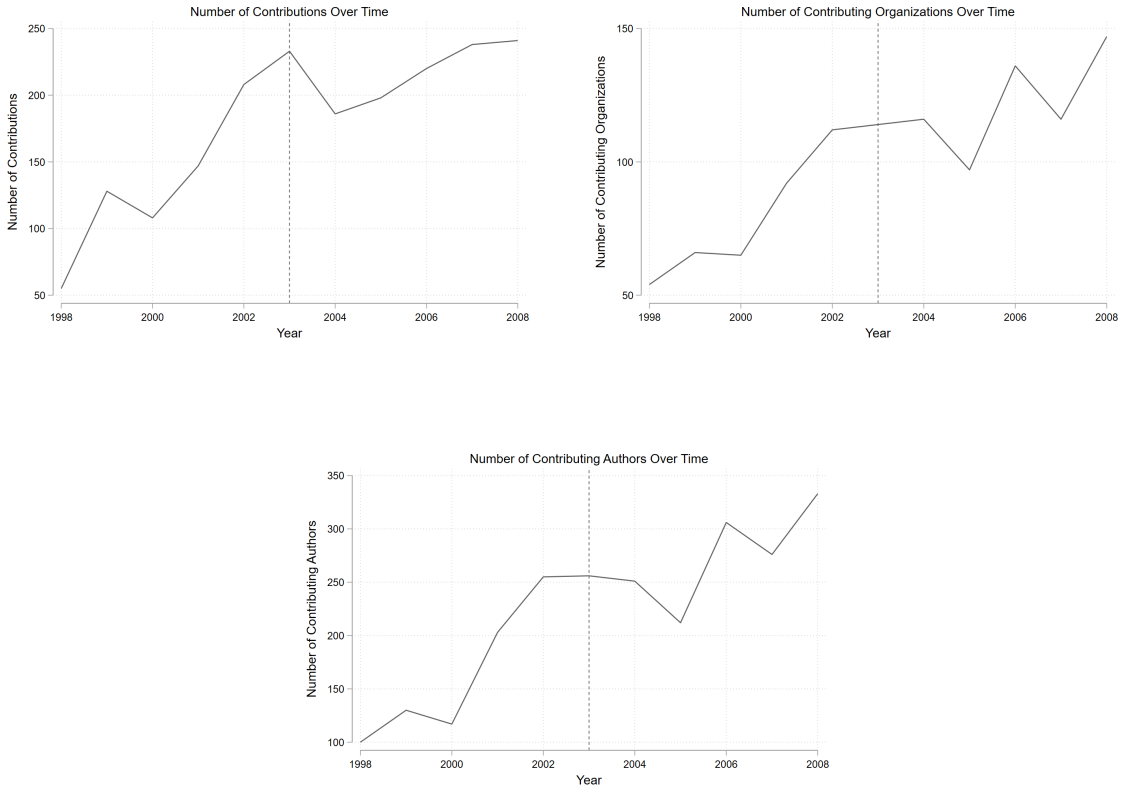
The IEEE-SA is a U.S. based global standard setting body that develops standards for a wide range of technologies. Our analysis will focus on IEEE's Local and Metropolitan Area Networking Standards Committee (LMSC or Project 802), which develops computer networking protocols. While LMSC's most famous standard is the 802.11 or "WiFi" wireless networking standard, other significant IEEE networking protocols include Ethernet (802.3), Zigbee (802.15.4) and Bluetooth (802.15.1).

Since at least the mid-1990s, the IEEE's IPR policy has sought to obtain RAND licensing assurances from potential SEP owners. The policy has been revised on

[25] Contreras, supra note 16, at page 879.

[26] All of the measures are described in more detail below. A contribution is defined as a new version of a standard (Technical Draft or Technical Report). All individual contributors without affiliations are grouped together as one "organization."

Figure 1: Participation at W3C before and after the Policy Revision



several occasions, including a 2007 update that added the option for prospective SEP owners to make an ex ante public commitment to their most restrictive licensing terms.[27]

In March 2013, the IEEE Patent Committee (PatCom) appointed an Ad Hoc committee to recommend potential updates to the IEEE-SA patent policy.[28] The discussions were motivated by a perception that ambiguities in the definition of RAND were contributing to widely divergent positions on reasonable rates between SEP owners and implementers. These views were reinforced by statements from antitrust agencies – including the DoJ, the FTC, and the European Commission – publicly lamenting the vague language in SSO's IPR policies and urging SSOs to clarify their policies.[29]

Between June 2013 and May 2014, IEEE-SA published for public comment four drafts of a revised IPR policy that sought to clarify the interpretation of the RAND commitment. There were four key elements of the new policy that focused on the scope of the licensing commitment and the interpretation of "reasonable" rates, terms, and conditions:[30]

[27] The 2007 update is described in a US Department of Justice Business Review letter: https://www.justice.gov/atr/response-institute-electrical-and-electronics-engineers-incs-request-business-review-letter.

[28] "IEEE Request for Business Review Letter," The United States Department of Justice, September 30, 2014, p. 13, available at https://www.justice.gov/sites/default/files/atr/legacy/2015/02/17/311483.pdf.

[29] See Renata Hesse, "Six 'Small' Proposals for SSOs Before Lunch: Remarks as Prepared for the ITU-T Patent Roundtable," The United States Department of Justice, October 10, 2012, available at https://www.justice.gov/atr/file/518951/download; Edith Ramirez, "Standard-Essential Patents and Licensing: An Antitrust Enforcement Perspective," The United States Federal Trade Commission, September 10, 2014, available at https://www.ftc.gov/system/files/documents/public_statements/582451/140915georgetownlaw.pdf; Joaquin Almunia, "Speech at the Competition Enforcement in the Knowledge Economy Conference at Fordham University," European Commission, September 20, 2012, available at https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_12_629.

[30] See "Draft IEEE Standards Board Bylaws: Draft 39 versus Current Policy," IEEE, available at https://grouper.ieee.org/groups/pp-dialog/drafts_comments/SBBylaws_100614_redline_current.pdf

1. **Reasonable Rate**: The update provides that reasonable royalty rates shall exclude any value attributable to including the patented technology in an IEEE standard. It also provides that three factors should be considered when determining such rates, though the analysis need not be limited to these factors:[31] (1) the value the patented functionality contributes to the smallest saleable Compliant Implementation; (2) the value contributed by all Essential Patent Claims for the same IEEE Standard practiced in that Compliant Implementation; (3) existing licenses covering use of the Essential Patent Claim, conditional on that such licenses were not obtained under the explicit or implicit threat of a Prohibitive Order (e.g., injunction or exclusion order), and are otherwise sufficiently comparable to the proposed license.

2. **Compliant Implementation**: The update defines a Compliant Implementation as "any product (e.g., component, sub-assembly, or end-product) or service that conforms to any mandatory or optional portion of a normative clause of an IEEE Standard", therefore entitling implementers at different levels of the supply chain to SEP owners' licensing assurances.

3. **Prohibitive Order**: The update provides that a submitter (or its successor) of a Letter of Assurance is not permitted to seek or enforce a Prohibitive Order unless an implementer fails to participate in an adjudication or fails to comply with the outcome of an adjudication before a first-level appellate review process, if sought, is completed.

4. **Reciprocal Licenses**: The update clarifies that a submitter (or its successor) of a Letter of Assurance is allowed to condition the licensing of its SEPs on the reciprocal licensing of the licensee's SEPs but is not allowed to condition the licensing of its SEPs on the licensing of the licensee's non-SEPs, or on the licensing of the licensor's non-SEPs. Put differently, the licensor is not allowed to bundle its non-SEPs with SEPs in the license to raise royalty rates above reasonable levels or use its SEPs as leverage to obtain a cross license under the licensee's non-SEPs.

During a public comment period, the IEEE received and considered over 600 comments on the proposal.[32] On February 2, 2015, the US Department of Justice issued a Business Review Letter stating that the revised policy "has the potential to

[31] IEEE proposes these factors as a framework for determining reasonable rates, but does not attempt to determine the royalty rate for any SEP. See Supra note 28, at 16.

[32] "Tutorial for 802 on 2015 IEEE-SA Patent Policy Update," IEEE, July 13, 2015, pp. 12-13, available at https://grouper.ieee.org/groups/802/802_tutorials/2015-07/802_Patent_Policy_Tutorial_Slides_13_July_2014.pdf.

benefit competition and consumers by facilitating licensing negotiations, mitigating hold up and royalty stacking, and promoting competition among technologies for inclusion in standards."[33] The IEEE Board of Directors approved the policy update on February 8, 2015 and the new policy became effective on March 15, 2015.

The revised policy drew strong opposition from a group of active SEP licensors. For example, after the revisions were approved Qualcomm stated that it "...will not make licensing commitments under the new policy; when Qualcomm has a choice of where to participate in standardization activity, Qualcomm will favor standard-setting organizations with neutral policies for intellectual property rights over the IEEE; and for future Qualcomm contributions to IEEE standards, Qualcomm will make alternative licensing commitments that will be decided on a case-by-case basis."[34] InterDigital submitted a similar statement, and in 2016 Nokia, InterDigital, Orange, and Ericsson began submitting "negative" Letters of Assurance indicating that they would not grant licenses according to the updated patent policy.[35] At the same time, the policy update was welcomed by a large number of participants including Cisco, Intel, Apple, Microsoft, Broadcom, and Dell.[36]

[33] "Response to Institute of Electrical and Electronics Engineers, Incorporated," The United States Department of Justice, February 2, 2015, available at https://www.justice.gov/atr/response-institute-electrical-and-electronics-engineers-incorporated.

[34] "Qualcomm Responds to Updated IEEE Standards-Related Patent Policy," *Evaluation Engineering*, February 11, 2015, available at https://www.evaluationengineering.com/industries/communications/wireless-5g-wlan-bluetooth-etc/article/13010984/qualcomm-responds-to-updated-ieee-standardsrelated-patent-policy.

[35] "Re: Licensing Assurances and IEEE's 2015 Patent Policy," InterDigital, March 24, 2015, available at http://wpuploads.interdigital.com.s3.amazonaws.com/uploads/2015/03/Letter-to-IEEE-SA-PatCom.pdf; Kirti Gupta and Georgios Effraimidis, "IEEE Patent Policy Revisions: An Empirical Examination of Impact," *The Antitrust Bulletin*, 2019, Vol. 64(2). An example of a negative LoA can be found at https://standards.ieee.org/content/dam/ieee-standards/standards/web/governance/patcom/loas/negative-loa-802_11ah-ericsson-27Sep2016.pdf.

[36] See "Why We Support IEEE's Patent Policy," *EETimes*, April 3, 2015, available at https://www.eetimes.com/why-we-support-ieees-patent-policy/; "Qualcomm, Apple, Huawei Clash over Patent Policy at Historic IEEE Committee Meeting," mlex, March 24, 2021, available at https://mlexmarketinsight.com/news-hub/editors-picks/area-of-expertise/antitrust/qualcomm-apple-huawei-clash-over-patent-policy-at-historic-ieee-committee-meeting.

Figure 2 shows participation at IEEE Project 802 before and after the patent policy update. The four panels show respectively: (1) the number of contributions to major IEEE 802 standards by year, where each technical document is treated as a contribution[37]; (2) the number of contributions to major 802 standards by year, where each revision of a technical document is treated as a contribution; (3) the number of groups publishing technical documents each year within the major 802 standards; (4) the number of unique organizations making technical contributions to 802.11 by year. For the first three outcomes, there is no obvious decline after 2015. Within 802.11, however, we do see a relatively sharp drop in the number of organizations making technical contributions in 2016. Again, it is unclear whether this reflects the impact of the new policy, or natural fluctuations in member activity and composition linked to other factors. The next section proposes an empirical strategy for isolating the impact of the revisions.

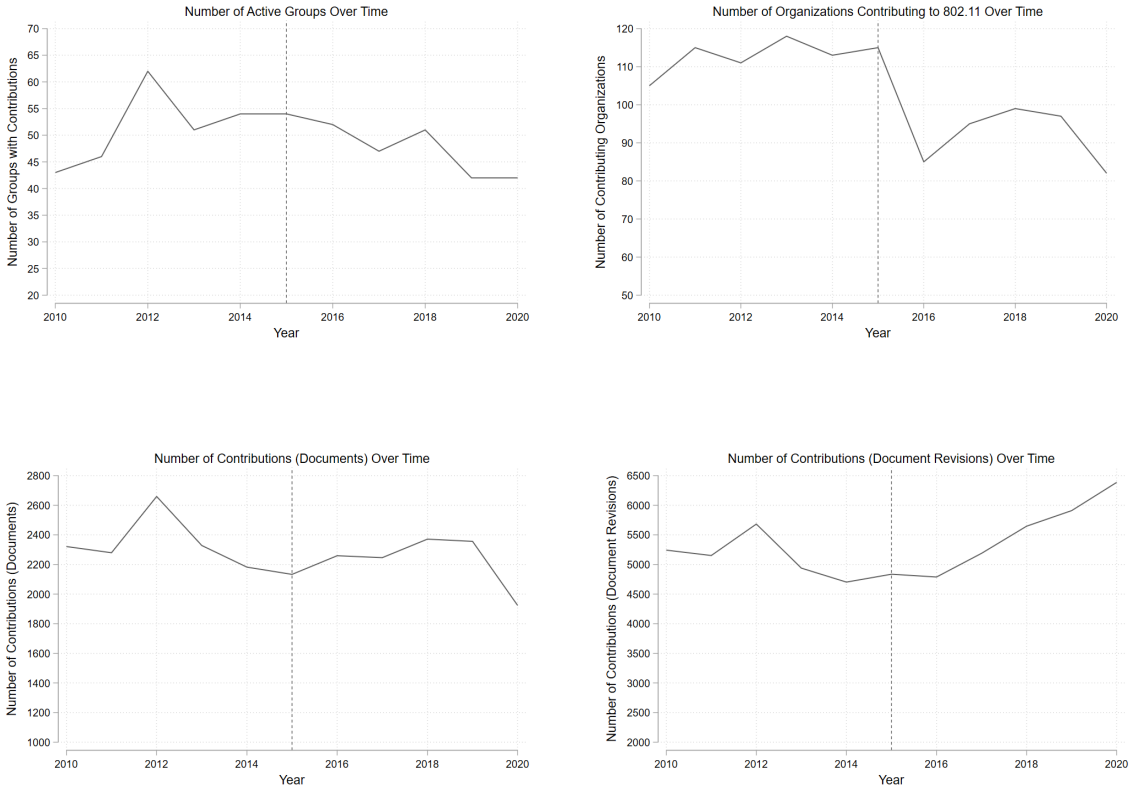
4 Data and Empirical Strategy

To measure the impacts of the W3C and IEEE policy changes, one might compare various measures of innovation and SSO participation before and after the adoption of a new IPR policy. The potential problem with that approach is that the impact of a revised IPR policy can be confounded with other changes that take place over the same period. For example, if the IPR policy updates coincide with a natural lull in standardization activity due to the technology development lifecycle, a simple pre vs. post comparison will conflate the two factors.

To address this concern, we use a difference-in-differences research design that rests

[37] These standards include 802.11 (WLAN WG), 802.15 (WPAN WG), 802.16 (Working Group on Broadband Wireless Access), 802.18 (Radio Regulatory Technical Advisory Group), 802.19 (Wireless Coexistence WG), 802.21 (Handover Services WG), 802.22 (WRAN WG). We exclude "administrative" contributions using a procedure described below.

Figure 2: Participation at IEEE before and after the Policy Revision



on two types of comparison: "before versus after" and "treatment versus control." We consider several definitions of the treatment group, but in every case it consists of "units" (e.g. firms, working groups, patent classes) that we expect to be more responsive to a change in IPR policy because they are more active in SEP licensing and patent monetization. For example, in a firm-level analysis we use a set of active SEP licensors who publicly objected to the IEEE policy revisions as the treatment group and compare their contributions to other IEEE participants that did not object to the new policy. In this research design, the change over time in control group outcomes provides an estimate of counter-factual changes (i.e., but-for the revised IPR policy) in the treatment group. Subtracting the before-after change in the control group from the before-after change in the treatment group yields an estimate of the causal impact of the IPR policy revisions on firms (units) in the treatment group.

To be more precise about this approach, suppose we have a sample of units (standards, working groups, firms, or patent classes) indexed by i, each observed for several time-periods indexed by t. For each unit, in each period, we observe an outcome, Y_{it}, that measures innovation or SSO participation. Our difference-in-differences estimates can be obtained from a regression model:

$$Y_{it} = \alpha + \beta_1 Post_t + \beta_2 Treated_i + \beta_3 Post_t \times Treated_i + \varepsilon_{it} \quad (1)$$

where $Post_t$ is an indicator variable equal to zero in periods before the IPR policy change and one in periods after the change; $Treated_i$ is indicator variable equal to zero for units in the control group and one for units in the treatment group; the α's and β's are parameters to be estimated; and ε_{it} is a residual term that captures changes in outcomes not explained by the model.

In practice, we estimate a more flexible version of the same model where the

variable $Treated_i$ is replaced by a set of unit-specific intercepts (denoted by α_i) that capture time-invariant idiosyncratic differences in the average outcome across all firms in the treatment and control groups. Similarly, we replace the variable $Post_t$ with a set of year-indicators (denoted by λ_t) that control for any changes over time that impact all units in the analysis. This leads to the widely used two-way fixed effects estimator:

$$Y_{it} = \alpha_i + \lambda_t + \beta_3 Post_t \times Treated_i + \varepsilon_{it} \tag{2}$$

where the key parameter, β_3, measures any impact of the W3C or IEEE patent policy updates on units in the treatment group.

We produce five sets of estimates, each based on a different unit of observation (i), treatment group, or outcome variable. In our first set of models, the unit of observation is an IEEE Working Group (WG) during the period from 2010 to 2020. Within the IEEE-SA process, a WG is a potentially large effort organized around a particular standard (e.g. 802.11 or 802.15).[38] We define the treated group as either the 802.11 WG or a set of "patent intensive" WG's that had relatively more patent disclosures during the pre-2012 time-period.[39] The outcome measure is based on a count of contributions (i.e. documents submitted to the working group) that we scraped from the IEEE website.[40]

According to IEEE, "Contributions may be different types of documents ranging from pure research to technical analysis, complete technical specifications and use cases." For each contribution, we collect data on the relevant Committee, WG, sub-

[38] Within a WG, work is further divided into various Task Groups (TGs, each requiring a PAR), Study Groups (SGs) and Interest groups (TIGs). The IEEE standards process is described at https://standards.ieee.org/develop/index.html.

[39] The patent intensive WGs are 802.11, 802.15, 802.16, 802.21 and 802.22. The control group consists of 802.18 and 802.19.

[40] The IEEE archives contributions to all 802 Working Groups at https://mentor.ieee.org/802/bp/StartPage.

group (i.e. TG, SG or TIG), publication date, author and author affiliation. We remove purely administrative Contributions by omitting those with a title that includes the term "minutes", "agenda", or "liaison." We consider two ways of counting these Contributions. First, we create a variable called *Documents* that counts the number of new Document Control Numbers (DCN) – each indicating a new contribution to the standard – submitted to an IEEE WG. Second, we create a variable called *Revisions* that counts both new DCNs and revisions of prior contributions that retain a prior DCN. We take a logarithmic transformation of both outcome variables because the counts are highly skewed and because it yields a simple interpretation of the estimated coefficients as a percentage change.

Our second set of models focus on the 802.11 WG between 2010 and 2020. The unit of analysis is an organization (typically a firm, but in some cases a University, government agency or non-profit). The treated group is comprised of four major contributors that monetize their SEPs and that publicly opposed the IEEE IPR policy revisions: Ericsson, InterDigital, Nokia and Qualcomm. The control group includes all other IEEE contributors. For the outcome, we continue to use contribution counts (i.e. Documents and Revisions).

Our third set of analyses focus on patenting in technology classes associated with the 802.11 specification between 2010 and 2018.[41] Using data from the USPTO PatentsView database, we identify the primary Cooperative Patent Classification (CPC) code of each patent declared to the IEEE 802.11 Committee, and take the CPC main group as our unit of analysis.[42] The outcome is a count of new US patent applications in a focal CPC main group i filed in year t. Instead of defining a discreet treatment group, the variable $Treated_i$ in this analysis measures the exposure of a

[41] We use a slightly shorter time window because of truncation in the patent data.

[42] The patent list was provided by IPlytics. One caveat associated with this approach is that we are not able to identify SEPs covered by "blanket" disclosures.

particular CPC main group to the 802.11 standard. Specifically, it is either a logged count of declared essential 802.11 patents in that CPC main group, or the share of all patents in the CPC main group that were declared essential to the 802.11 standard.

For the fourth set of analyses, we turn to data from the W3C during the period from 1998 to 2008. We obtained a list of all W3C Standards and Drafts from the W3C website. The complete revision history of these documents is available online.[43] For each revision of each standard we obtain information on the Working Group, publication date, maturity level, along with a complete list of authors or editors and their affiliations. For the first of our two W3C analyses, the unit is defined as an organization. The outcome is a count of W3C contributions, defined as the number of times that organization appeared on a new revision of any standard. For the W3C, it is difficult to identify a particular set of participants that were actively engaged in SEP licensing. Thus, we place all for-profit firms into the treated group, and use all non-profit organizations as the control sample – based on the assumption that non-profits are not seeking to monetize web-related SEPs.

For the final set of analyses, we take the W3C Working Group as the unit of analysis. The treated group consists of all WG's for which we could find a web page mentioning patent disclosures from the 2001-2002 time-period. The outcome is a count of Contributions to each WG.

[43]The W3C process is described at https://www.w3.org/2020/Process-20200915/.

5 Results

5.1 IEEE Contributions by Standard

Table 1 shows the results from our first set of analyses. In column (1), we take the 802.11 WG as the treated group and all other IEEE WG's as the control. The coefficient on the Post x 802.11 indicator variable shows that there was a statistically significant increase in contributions to the 802.11 WG after the IPR policy revisions, relative to the growth rate of other working groups. This result is inconsistent with the hypothesis that we should see a relative reduction in 802.11 WG activity, because it is the working group with the most IPR disclosures (and arguably the standard at the core of the controversy over IEEE's policy revisions).

Table 1: IEEE Contributions by Standard

	Dependent Variable: Log Number of Contributions			
	(1)	(2)	(3)	(4)
	Documents	Documents	Revisions	Revisions
802.11 × Post	0.98**		1.19**	
	(0.41)		(0.46)	
Patent Intensive × Post		-0.74		-1.01
		(0.60)		(0.67)
Year Fixed Effects	✓	✓	✓	✓
Standard Fixed Effects	✓	✓	✓	✓
Observations	77	77	77	77
R-squared	0.342	0.046	0.356	0.046
Mean of Dependent Variable	4.68	4.68	5.26	5.26

Notes: The dependent variable is log number of contributions at the standard-year level. Columns 1 and 2 treat the first version of each document (dcn) as a contribution. Columns 3 and 4 treat each document version (rev) as a contribution. The standards considered include 802.11, 802.15, 802.16, 802.18, 802.19, 802.21, 802.22. "Patent-intensive" standards include 802.11, 802.15, 802.16, 802.21, 802.22, which is determined by comparing the number of patent disclosure events for each standard during 1983-2011 normalized by the number of contributions to each standard before 2012. Administrative documents are excluded. Contributions during the 2010-2020 period are considered. Standard errors are robust to heterogeneity. *** p<0.01, ** p<0.05, * p<0.1.

In column (2) of Table 1, we redefine the treated group as a set of "patent intensive" WGs (including 802.11, but also 802.15, 802.16, 802.21 and 802.22) that had relatively more IPR disclosures. The results show that contributions to these WG's

did decline relative to less patent intensive WG's (802.18 and 802.19), although the effect is imprecisely measured and not statistically different from zero. The last two columns in Table 1 replicate the results in the first two columns using Revisions as the outcome measure.

Overall, the results in Table 1 do not support the hypothesis that revisions to the IEEE IPR policy led to decreased participation. In particular, contributions to the 802.11 WG increased significantly compared to other IEEE standards development efforts. And while there was a decline in contributions to patent intensive working groups (compared to those with fewer IPR disclosures), that decline is not statistically significant. The main caveat for these findings is that they are based on a relatively small sample of 77 WG-year observations, and a very coarse measure of IP intensity. Thus, our next set of results turn to more disaggregated data.

5.2 IEEE Contributions by Organization

Table 2 shows the results for a set of analysis where the unit of observation is the contributing organization (by year) and the treated group consists of four firms that strongly opposed the IEEE IPR policy revisions: Ericsson, InterDigital, Nokia and Qualcomm. The estimation sample contains the 35 organizations with the largest number of 802.11 contributions between 2010 and 2020, with all other organizations aggregated into a composite "Other" observation.[44]

The results in columns (1) and (2) show that contributions from the four "treated" firms – measured as Documents or Revisions respectively – increased relative to other 802.11 WG participants in the period after the IPR policy revisions. Once again, however, the increase is not significantly different from zero. In columns (3) and (4),

[44]The top 35 organizations collectively accounted for 87% of total 802.11 contributions in our sample.

we further disaggregate the data so that the unit of observation is an organization within a Task Group (TG) formed to work on specific projects subject to a PAR.[45] We include organization-TG fixed effects to control for variation in the overall importance of the different TGs. Once again, we find a statistically insignificant increase in contributions from the four treated firms.

Table 2: Contributions to IEEE 802.11 Standards by Contributing Organization

	Dependent Variable: Log Number of Contributions			
	(1) Documents	(2) Revisions	(3) Documents	(4) Revisions
Qualcomm/Ericsson/Nokia/InterDigital × Post	0.43	0.37	0.078	0.090
	(0.72)	(0.88)	(0.061)	(0.082)
Year Fixed Effects	✓	✓	✓	✓
Organization Fixed Effects	✓	✓		
Organization-Group Fixed Effects			✓	✓
Observations	396	396	21,384	21,384
R-squared	0.039	0.042	0.002	0.002
Mean of Dependent Variable	2.53	3.25	0.13	0.18

Notes: The dependent variable of Columns 1 and 2 is log number of contributions at the contributing organization-year level. The dependent variable of Columns 3 and 4 is log number of contributions at the contributing organization-group-year level. Columns 1 and 3 treat the first version of each document (dcn) as a contribution. Columns 2 and 4 treat each document version (rev) as a contribution. Administrative documents are excluded. Contributing organizations whose total numbers of revisions contributed during the 2010-2020 period rank below the 35th are grouped together into an "Other" group. Contributions during the 2010-2020 period are considered. Standard errors are clustered at the contributing organization level. *** p<0.01, ** p<0.05, * p<0.1.

It is important to note that most contributions from the treated firms made after the IEEE IPR policy revisions were subject to "negative" disclosure letters that committed only to RAND licensing under the terms of the pre-2015 policy. Nevertheless, the finding of a small and statistically insignificant increase in contributions from the most vocal opponents of the new policy is inconsistent with the hypothesis that a more restrictive policy leads to any substantial decline in SSO participation.

[45] We include a set of organization-TG fixed effects to control for variation in the magnitude of the task.

5.3 Patent Applications

Because contributions to an SSO are an admittedly noisy proxy for standards-related innovation, our third set of analyses use patent data as an alternative outcome measure. In these analyses, the unit of observation is a CPC group. The outcome is a logged count of all US patent applications that were filed in a given year and assigned the same primary CPC classification. The sample includes all CPC groups containing one or more declared essential 802.11 patent, and our measure of "treatment intensity" is either a logged count of 802.11 patents in that CPC group or the percentage of patents in the CPC group that were declared essential. We include year fixed effects in all models.

Table 3: Published US Patent Applications by CPC Main Group

	Dependent Variable: Log Applications			
	(1)	(2)	(3)	(4)
Log Number of Declared 802.11 Patents x Post	0.0041	0.0041		
	(0.013)	(0.013)		
Share of Declared 802.11 Patents x Post			-0.16	-0.16
			(0.18)	(0.18)
Year Fixed Effects	✓	✓	✓	✓
CPC Main Group Fixed Effects		✓		✓
Observations	3,087	3,087	3,087	3,087
R-squared	0.111	0.056	0.182	0.056
Mean of Dependent Variable	4.74	4.74	4.74	4.74

Notes: The dependent variable is log number of US patent applications at the CPC main group-year level. US patent applications filed during the 2010-2018 period are considered. The numbers of declared 802.11 patents by CPC main group are provided by IPlytics. "Share of declared 802.11 patents" is calculated for each CPC main group as the ratio between the number of declared 802.11 patents and the total number of US patent applications filed between 2010 and 2018. Only CPC main groups with at least one 802.11 declaration are included. "Log number of declared 802.11 patents" is included as an independent variable in Column 1, and "share of declared 802.11 patents" is included as an independent variable in Column 3. Standard errors are clustered at the CPC main group level. *** p<0.01, ** p<0.05, * p<0.1.

The results in column (1) of Table 3 show that doubling the number of 802.11 declared essential patents in a CPC group is associated with a statistically insignificant 0.4 percent increase in total patent applications after the IPR policy change. In other words, we find essentially no change in patenting activity for CPC classes

more closely related to 802.11 standardization, compared to less related CPC classes, following the IEEE policy revisions. Adding CPC group fixed effects in column (2) produces no change in this finding.

In columns (3) and (4) we use the share of 802.11 SEPs in a CPC class, rather than a count, as our measure of treatment exposure. The results indicate that a 1 percentage point increase in the 802.11 SEP share is associated with a 0.16 percent decline in patenting following the IPR policy revisions. Again, this result is not statistically significant at conventional levels.

Overall, the results in Table 3 provide no evidence of a decline in patenting within CPC classes linked to the 802.11 standard following the IEEE's 2015 IPR policy revisions. Thus, these results are inconsistent with the hypothesis that policy revisions that strengthen FRAND requirements lead to a decline in innovation.

5.4 W3C Contributions by Organization

Our final two sets of analyses focus on the W3C's adoption of a Royalty-Free IPR policy in 2003. Table 4 shows results for difference-in-differences models where the treated group is comprised of for-profit organizations, and the outcome is the number of W3C contributions. In columns (1) and (2), the unit of analysis is the contributing-organization year. The results in column (1), show a 10 percent decline in contributions from for-profit contributors after the adoption of the RF policy. This result is consistent with the hypothesis of a decline in participation from patenting firms and is statistically significant at the 10 percent level. If we focus on the 50 largest contributors, however, the results in column (2) show a 20 percent increase in contributions

from for-profit firms.

Table 4: Contributions to W3C Standards by Contributing Organization

	Dependent Variable: Log Number of Contributions			
	(1)	(2)	(3)	(4)
	All Orgs	Top-50 Orgs	All Orgs	Top-50 Orgs
For-Profit × Post	-0.098*	0.19	-0.0019	0.0069
	(0.054)	(0.26)	(0.0019)	(0.011)
Year Fixed Effects	✓	✓	✓	✓
Organization Fixed Effects	✓	✓		
Organization-Working Group Fixed Effects			✓	✓
Working Group Age Fixed Effects			✓	✓
Observations	3,784	550	179,550	26,250
R-squared	0.056	0.203	0.001	0.008
Mean of Dependent Variable	0.41	1.38	0.014	0.062

Notes: The dependent variable of Columns 1 and 2 is log number of contributions at the contributing organization-year level. The dependent variable of Columns 3 and 4 is log number of contributions at the contributing organization-working group-year level. Each version of a standard is considered a contribution. Columns 1 and 3 include all contributing organizations. Columns 2 and 4 only include contributing organizations whose total numbers of contributions during the 1998-2008 period rank in the top 50. Contributions during the 1998-2008 period are considered. Working group age is defined as the number of years between the year in which a contribution is first made in the working group and the year corresponding to the observation. Standard errors are clustered at the contributing organization level. *** p<0.01, ** p<0.05, * p<0.1.

In columns (3) and (4) we change the unit of analysis to the contributor-WG, producing a large increase in the overall sample size. We also add contributor-WG fixed effects to the specifications. The estimates in columns (3) and (4) show no evidence of a compositional shift from for-profit to non-profit contributors. Once again, we take the results in Table 4 as indicating that implementation of the W3C's royalty-free patent policy did not produce any substantial decline in participation from patenting firms.

5.5 W3C Contributions by Working Group

In the previous W3C analysis, our treated group was based on whether a contributor was a for-profit firm, which is a coarse proxy for firms seeking to monetize SEPs. As a final analysis, therefore, we consider an alternative definition of the treated group, based on whether we could find evidence of any pre-2003 patent disclosures within a

Working Group. The unit of observation for this analysis is the Working Group-year.

Table 5: Contributions to W3C Standards by Working Group

	Dependent Variable: Log Number of Contributions	
	(1) Standards	(2) Versions
Having Patent Disclosures × Post	0.23	0.33
	(0.21)	(0.30)
Year Fixed Effects	✓	✓
Working Group Fixed Effects	✓	✓
Observations	374	374
R-squared	0.183	0.154
Mean of Dependent Variable	0.90	1.15

Notes: The dependent variable is log number of contributions at the W3C working group-year level. Each version of a standard is considered a contribution. Multiple versions of the same standard within a year are treated as a single contribution in Column 1 and multiple contributions in Column 2. Working groups having patent disclosures are working groups for which we were able to find a patent disclosures web page around 2001-2002 containing mentions of disclosed patents. Working groups for which such web pages were not found or did not indicate the existence of disclosed patents are classified as not having patent disclosures. Contributions during the 1998-2008 period are considered. Only working groups that had any contributions in 2001-2002 are considered. Standard errors are clustered at the working group level. *** p<0.01, ** p<0.05, * p<0.1.

The results in Table 5 indicate that contributions to W3C Working Groups with pre-2003 patent disclosures increased relative to patent-free WG's after the adoption of the RF policy. The result holds whether contributions are measured as new documents or all versions but is not statistically significantly different from zero in either case.

Overall, the results of our W3C analyses in Tables 4 and 5 suggest that the switch from a *de facto* FRAND policy to a royalty-free IPR policy had no discernible impact on participation and the standards development work of that SSO.

6 Conclusions

This paper seeks to provide some empirical evidence on the link between IPR policies, innovation and SSO participation. Specifically, we study two well-known IPR policy revisions: a switch from FRAND to Royalty-Free licensing at the W3C in 2003, and

a revision of the IEEE's IPR policy in 2015. In each case, we estimate difference-in-difference regressions that compare outcomes before and after the policy-change for companies (or parts of the standard or SSO) that we expect to be differentially affected by the change in IPR policy.

Overall, we find little evidence that these policy changes caused a decline in participation by SEP licensors or reduced innovation in patent-intensive parts of the SSO. This pattern holds for both W3C and IEEE, across numerous measures of participation and innovation, and for a variety of different treatment and control group comparisons. We interpret these results as evidence that any link between IPR policies, innovation, and SSO participation is much weaker than purely theoretical arguments to the contrary often suggest.

Our analysis is subject to a number of important caveats. Whereas an ideal experiment might randomly allocate some firms or WG's to a new IPR policy, while leaving others to work under the previous policy, both of our "natural experiments" were applied to all participants in the relevant SSO. Thus, we were forced to construct a set of treatment and control groups based on prior expectations about who would be more adversely affected by a particular policy change. Our treatment and control groups provide only a coarse proxy for the variation in incentives that we would like to capture, and in the case of the IEEE, we have a relatively short window of post-policy revision data to exploit. Finally, it is important to emphasize that we mainly find null results. That is, while we cannot reject the hypothesis that the W3C and IEEE IPR policy revisions had no impact on innovation or SSO participation, we also cannot rule out modest impacts (whether positive or negative).

Nevertheless, we believe our empirical results are a potentially useful addition to the debates over SSO IPR policy reforms. In particular, these debates are often couched in terms of balancing the benefits of greater access and reduced ambiguity

around the meaning of FRAND against the cost of reduced upstream innovation and declining participation of SEP licensors in the process. As we wrote in the introduction, however, most of the debate about these costs and benefits has been grounded in theory. Our findings show that any impacts that the W3C and IEEE policy revisions had on SEP holder innovation and participation are too modest to be reliably measured using data on contributions, Working Group participation or patenting.