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The Technical Standardization Ecosystem and Institutional Decision Making: The Case of Intellectual Property Rights Policies

Justus Baron

Jorge L. Contreras

Martin Husovec

Pierre Larouche

Nikolaus Thumm

TILBURG UNIVERSITY

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By
Justus Baron, Jorge Contreras, Martin Husovec,
Pierre Larouche and Nikolaus Thumm

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THE TECHNICAL STANDARDIZATION ECOSYSTEM AND INSTITUTIONAL DECISION MAKING: THE CASE OF INTELLECTUAL PROPERTY RIGHTS POLICIES

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Justus Baron
Senior Research Associate
Northwestern University
Chicago, Illinois, USA

Jorge Contreras
Presidential Scholar and Professor of Law
University of Utah
Salt Lake City, Utah, USA

Martin Husovec
Assistant Professor
Tilburg University
Tilburg, Netherlands

Pierre Larouche
Professor of Law
University of Montreal
Montreal, Canada

Nikolaus Thumm
Senior Fellow
European Commission Joint Research Centre
Seville, Spain

Abstract

In this paper, we analyze decision making on Intellectual Property Rights (IPR) policies in the standardization ecosystem. While a large literature has studied IPR policies of Standard Developing Organizations (SDOs), we contribute a more rigorous analysis of how these IPR policies are shaped by the interdependencies between SDOs and between SDOs and a variety of stakeholders. While SDO stakeholders often have opposing policy preferences, they are tied together by non-generic complementarities and a joint interest in the overall performance of the standardization system, which are constitutive characteristics of an ecosystem. The standardization ecosystem is characterized by widely shared institutional norms, which – in the field of IPR – result in the preponderance of what we call a "Baseline Policy". SDOs' positions in the ecosystem

contributes to explain where in the ecosystem institutional innovations going beyond the Baseline Policy are more likely to arise. We analyze different mechanisms of transmission of such novel practices, such as emulation and precedent.

JEL Codes: L15, L31, O34, O36

This paper builds upon a European Commission JRC Science for Policy Report prepared by the authors, *Making the Rules: The Governance of Standard Development Organizations and their Policies on Intellectual Property Rights* (European Commission, 2019). This paper constitutes an important additional step analysing and conceptualizing the idea of a "standardization ecosystem".

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1. Introduction

Standardization plays a critical role in industrialized societies. Technology standards describe general rules and common features of products and services that allow for interoperability, facilitate comparison, and define minimum quality levels. Many such standards are developed by private firms and other non-governmental stakeholders under the auspices of Standard Development Organizations (SDOs). SDOs provide a stable venue for cooperation among industry stakeholders (many of which are competitors), and their governance policies define the rules according to which standards are developed and made available to users. As the large majority of SDOs are non-governmental, non-profit organizations,[1] the development of these rules is a complex process of industry self-regulation. Yet the specific processes of SDO governance are significantly shaped by the legal requirements applicable to different SDOs, their respective governance documents and traditions, and interaction with a variety of diverse stakeholders as well as other SDOs in a complex ecosystem.

SDOs interact with each other, as well with other related organizations, in a complex web of mutual dependencies. Standardization, particularly in the field of information and communication technologies (ICT) is characterized by a high degree of institutional fragmentation and competition. Several hundred (if not thousand) organizations develop standards for related and often overlapping technologies; and there is significant overlap between these SDOs in terms of organizational membership, and even participating individuals (Baron and Spulber, 2018, Baron, 2020). While each SDO is ultimately responsible for its own policy responses to governance

[1] See JRC (2019) for an overview of legal structure of some of the leading SDOs.

questions, the decisions of different SDOs are often responsive to the same exogenous influences and are influenced by each other. Despite their importance, these *interdependencies* have not been systematically studied. This article highlights how such interdependencies ultimately shape the entire standardization ecosystem.

To date, existing analyses have largely conceptualized standardization using the tools and methods of economic and legal research. Economists, on the one hand, have described the determination of SDO rules as a competitive process in which SDOs compete for members and contributors of essential technologies (Lerner and Tirole, 2006 & 2015; Chiao et al, 2007). Nevertheless, this "forum shopping" literature largely ignores the fact that firms and other stakeholders respond to SDO policy choices not only by participating in SDOs with rules that they favour, but also by helping to shape the rules of SDOs that they join. Furthermore, the forum shopping literature neglects the importance of hierarchical and cooperative relationships among different SDOs, and ignores the substantial switching costs that often make it impossible to respond to SDO policy choices by moving standardization activities to another venue. Legal scholars, on the other hand, have offered extensive analysis of the overarching legal requirements affecting SDOs and the regulatory models defining the interaction between public authorities and SDO activity (Schepel 2005).

However, none of these analyses accounts for the richness of the mostly non-hierarchical, non-contractual interdependencies between different SDOs and their policy choices. Since SDOs and their respective stakeholders are subject to the same regulatory requirements, they also share an interest in shaping the regulation of standardization. SDOs and their stakeholders work together toward promoting the common "culture" of standardization in the public and private sectors. These overarching institutional norms and traditions that are shared by individuals and organizations

participating in different SDOs have not been considered by existing analyses of SDO governance, even though historians have chronicled them.[2]

Indeed, stakeholders perceive the numerous individual SDOs as constitutive elements of what standardization practitioners increasingly call a "standardization ecosystem" (ANSI (2019), Biddle (2018), Teece and Linden (2017)). That ecosystem comprises, in addition to SDOs, the multiplicity of entities and individuals that participate in standardization, as well as their sometimes shared and sometimes divergent values, norms, goals, constraints, and interdependencies.

Management scholars have developed a more rigorous conceptualization of "ecosystems" in innovative industries. Jacobides et al. (2016) define "ecosystems" as "distinct forms of organizing economic activities that are linked by specific types of complementarities". In this article, we draw upon the insights of this management literature in order to explore how the conceptualization of a standardization ecosystem may shed light on SDO governance.

More specifically, we explore: (1) how different policy choices made by SDOs depend on their respective *positions* in the standardization ecosystem, (2) how policy responses *circulate* in the system, and (3) how these choices of individual SDOs in turn *shape* the overarching institutional norms and regulatory requirements that are generally applicable to all SDOs. We analyse all of these questions within the context of SDO policies on intellectual property rights (IPR) as one particularly salient and particularly controversial aspect of SDO policy-making.

In addition to its significance for standardization studies, our analysis also has the potential to inform the emerging and quickly growing literature on organizational ecosystems. The field of ICT standardization is a paradigmatic example of a set of multilateral relationships that cannot be

[2] Russell (2014) and Yates and Murphy (2019) offer historical accounts of the evolution of standardization traditions since the 19th century.

accounted for by other conceptualizations (such as competition or hierarchy) alone. In addition to demonstrating the potential of the ecosystems literature to structure the analysis of these complex institutional relationships, our analysis may help to sharpen the contribution that the ecosystems literature can make in analyzing the circulation of individual choices in an ecosystem. As a contribution to the literature on innovation ecosystems, our study sheds light on how the standardization ecosystem accommodates and supports incremental institutional innovations at the margins along with the progressive evolution of shared institutional norms at the core; thus providing both a flexible and a stable basis for rapid technological change.

2. The International Standardization Ecosystem

The international standardization ecosystem comprises a large number and great diversity of organizations and individuals, as well as their participants and stakeholders.[3] An SDO may act as a regulating actor in a technological platform ecosystem (see e.g. Ceccagnoli et al., 2012; West and Wood, 2014; Wareham et al., 2014). At the same time, SDOs are associations participating in the development and dissemination of rules for their respective fields, and they are themselves members of larger market and industry-wide ecosystems.

Beyond the well-understood relationships between firms participating in the development or implementation of a common standardized technology, ecosystems may involve groups of firms or agents related to each other through more diverse sets of interdependencies. Teece (2017) proposes that the "ecosystem represents the environment that the firm must monitor and react to".

[3] Updegrove (2019) catalogs more than 1,000 active consortia, trade associations and other SDOs operating in various fields.

A similarly general definition of ecosystems emphasizes the 'shared fate' or common interests of a group of agents or firms (Iansiti & Levien, 2004).

Ecosystems have to be distinguished from other informal sets of relationships between agents, such as those that characterize industries and professions. Groups of independent (and often competing) firms are often subject to common rules, including binding laws and regulations as well as informal norms and conventions. Firms in the same industry often share common interests in the development of such rules. Similarly, at the individual level, different individuals independently carrying out similar work often form part of more or less institutionalized professions and share common interests. While ecosystems usually involve heterogeneous actors occupying different and complementary roles in a modular production system, industries and professions are generally defined by the common characteristics of their members, which may exercise a similar role in different production systems.

The common interests of the members of an industry or profession are often represented by one or several industry associations. The traditional analysis of industry associations emphasizes their role as lobbyists on behalf of the common interests of their members. Greenwood et al. (2002) paint a more nuanced picture of their role, and describe the role of industry associations in the dissemination of institutional change within a field through the legitimation of new practices. There is a significant body of research on the diffusion of new practices in a field (Rogers 2003). Young (2009) identifies three broad classes of models of such diffusion processes: contagion, social influence, and social learning. Each process is characterized by a slow initial adoption, followed by an acceleration in the diffusion of the new practice, and an ulterior deceleration (S-shaped diffusion).

Many SDOs arose from industry or professional associations, and as such, they traditionally act on behalf of a set of industry stakeholders. Nevertheless, while many industry associations have a stable relationship with a well-defined set of relatively homogeneous actors, SDOs often develop standards that are used in different industries by heterogeneous actors with different and often opposed interests. This phenomenon has become increasingly apparent with the emergence of the Internet of Things (IoT), which is anticipated to use wireless communication standards developed within SDOs that arose from the computing and telecommunications industries in a wide array of industries from transportation to white goods to electrical power distribution. By developing common rules for these different actors and legitimizing innovative practices, SDOs can act as mediators of opposing interests among complementary constituents of an ecosystem.

3. Architecture of the Standardization Ecosystem

This Section summarizes the range of external constraints that shape SDO decision-making processes within the ecosystem, including legal regulations, hierarchical relationships with other SDOs, industry stakeholder demands, and competition with other SDOs.

a. Legal Constraints of the Standardization Ecosystem

Standardization lies at the intersection of private coordination and public regulation. Historically, SDOs in most Western countries arose out of efforts by private actors – engineers

and industry – to create fora for the standardization of different product components (ISO, 2007; Ruppert, 1956; Yates and Murphy, 2019).[4]

In the second half of the 20th century, it became increasingly common for standards developed by private SDOs to be used in governmental regulation. In that sense, "technical standard setting, though conducted largely through private organizations, possesses many attributes of a public function" (Contreras 2017). This public function of private standardization has led to an increased scrutiny of the processes of private SDOs. The public dimension of interoperability standards arises from their impact on trade and competition, as well as public procurement, industrial policy and innovation. Each of these external sets of rules and constraints continues to shape the standardization ecosystem.

International Trade law. At the international level, standardization organizations are subject to general constraints arising out of international trade law, and in particular the Agreement on Technical Barriers to Trade (TBT), which is part of the World Trade Organisation (WTO) Agreement. The TBT directs WTO members to use international standards to the extent possible when they need to impose technical regulations on traded goods (Article 2.4). The TBT also requires WTO members to comply with a Code of Good Practice in standardization activities and to take all reasonable measures to ensure that non-governmental SDOs within their jurisdiction adhere to and comply with it. It also directs standardization bodies not to discriminate among products from different WTO member countries.

[4] By contrast, in many Asian countries, including China, South Korea and Japan, as well as in Canada, the National Standards Bodies setting national industry standards and participating in international standards organizations such as ISO and IEC are government agencies (Ernst, *others*).

Direct Regulation of Standardization. In 1985, the EU adopted its "New Approach" to technical harmonisation and standards, which is now embodied in Regulation 1025/2012. The EU established a decentralized system, where EU legislation is limited to setting out the procedural and institutional framework and the essential requirements to be met by standardized products, while European standards are primarily created by European Standardization Organisations (ESOs: CEN-CENELEC and ETSI) with the participation of private stakeholders through their respective National Standards Bodies (NSBs). Regulation 1025/2012 imposes obligations upon the ESOs and NSBs with respect to governance, including transparency and the participation of consumer, environmental and social organizations, SMEs, and public authorities.

In contrast, there are few specific legal provisions targeting standardization or SDOs in the United States. Instead, the National Technology Transfer and Advancement Act of 1995, as supplemented by OMB Circular No. A-119 (2016), expresses a strong preference for the use of standards from private, non-governmental "voluntary consensus standards bodies" in regulation and government procurement. Circular A-119 provides a definition of 'voluntary consensus standards body', which generally has the attributes of openness, balance of interest, due process, an appeals process, and consensus decision making.

Competition and Antitrust Law. Because standards development through SDOs usually involves horizontal co-operation among competitors, competition and antitrust laws play an important role in shaping the practices and policies of SDOs. In both the European Union and United States, relevant legislation and case law have resulted in a set of guiding principles for SDOs that enable these competitors to develop compatible products while steering clear of antitrust and competition law violations (European Commission, 2019).

The Horizontal Guidelines issued by the European Commission[5] identify a number of safe harbour conditions for SDOs, including the observance of certain principles such as voluntary implementation, unrestricted participation, transparency, and a balanced IPR Policy. Similar principles are applicable in the U.S. In a series of cases in the 1980s,[6] the U.S. Supreme Court established that in order to avoid antitrust liability, SDOs should observe a certain level of transparency, openness and due process.

Accordingly, public policy towards standardization, in the developed world, has been largely self-regulatory and procedural: as long as legal and regulatory constraints on SDO procedures are respected and market constraints operate, public authorities will defer to SDO activities and decisions on substance. This represents a conscious policy choice in many countries (Contreras, 2017; Bremer, 2016; Büthe and Mattli, 2011).

b. Relationships among SDOs

In addition to legal requirements, SDOs are often constrained by their relationships with other SDOs. Many SDOs are bound by requirements issued by another SDO or other private organizations, or formal agreements to practice common policies to ensure smooth technical cooperation with other SDOs.

Vertical relationships.

[5] Guidelines on the applicability of Article 101 of the Treaty on the Functioning of the European Union to horizontal co-operation agreements.

[6] *American Society of Mechanical Engineers (ASME)* v. *Hydrolevel* 456 US 556 (1982) and *Allied Tube & Conduit* v. *Indian Head* 486 US 492 (1988).

A large number of SDOs form part of a hierarchical international system, which is coordinated under the auspices of the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and the International Telecommunications Union (ITU). These bodies are apex organizations for an extensive infrastructure which has its foundations at national level, as ISO and IEC membership consists in one NSB for each country (European Commission, 2019). The same NSBs often represent their countries in regional organizations, such as CEN and CENELEC in Europe. This global system is linked together via collaboration agreements between ISO, IEC and ITU at international level; as well as agreements between regional and international standardization organizations.[7] The NSBs also transpose the principles of the international system to the national level, as they often act as accreditation bodies or otherwise issue authoritative guidance that applies to sectoral SDOs in their respective countries.

The normative function of SDOs within their vertical structure often transposes and extends the legal requirements that are applicable to SDOs. ISO/IEC Guide 59:1994 affirms and substantially extends the abovementioned WTO provisions regarding standard development procedures. The updated ISO/IEC Guide 59:2019 adds provisions regarding appeals, as well as IPR Policy; and explicitly limits the scope of application of the Guide to NSBs. At the European level, CEN-CENELEC similarly issued guidelines that affirm and significantly extend the obligations set by Regulation 1025/2012 for the NSBs of EU Member States.[8]

In addition to being bound by these procedural guidelines, NSBs often also directly follow substantial policy choices made at a higher hierarchical level. For instance, NSBs and regional

[7] Such as the Frankfurt and Vienna agreements that formalize the relationships between CEN, CENELEC, ISO, and IEC

[8] CEN-CENELEC Internal Regulations Part 1D and CEN-CENELEC Guide 22:2018 define due process requirements (regarding transparency, openness, impartiality and consensus) and principles regarding effectiveness, coherence and viability that member SDOs are required to adopt.

organizations adopted the ISO/IEC/ITU Common Patent Policy. CEN-CENELEC's own patent policy, CEN-CENELEC Guide 8 is only "intended to complement, clarify and facilitate the implementation of the [ISO/IEC/ITU common] Patent Policy".

In the United States, ANSI makes the connection between the international standardization organizations and numerous private-driven US-based SDOs. ANSI administers the designation of privately-developed standards as 'American National Standards' (ANS). ANS designation is advantageous, both commercially and legally. In order to achieve this designation for their standards, SDOs must be ANSI-accredited. Accreditation occurs when ANSI is satisfied that an SDO meets ANSI's Essential Requirements, which are consistent with those of OMB Circular A-119. While there is no uniform review mechanism to assess whether SDOs meet the criteria of OMB Circular A-119, the review of an SDO's rules and processes for ANSI accreditation provides an institutionalized forum for assessing individual SDO practices against shared institutional norms.

A significant number of SDOs thus are subject to some form of vertical control, and their individual processes and policies are assessed against principles defined at a higher hierarchical level. These private instruments of vertical control often build on and extend the generally applicable legal provisions. As a consequence, the SDOs that are directly embedded in these vertical structures are subject to significantly more specific requirements regarding their processes of decision-making and the substance of their IPR policy.

Cooperative relationships

In addition to these hierarchical structures, some SDOs are bound by formal horizontal cooperative relationships with other SDOs. Seven SDOs (ARIB, ATIS, CCSA, ETSI, TTA, TTC, and TSDSI) develop mobile telecommunication standards together within the 3rd Generation Partnership Project (3GPP).[9] This close technical collaboration requires significant overlap in policy principles, such as IPR policies.[10] Technical collaboration between SDOs on standards is widespread, even though it is often less institutionalized than in the case of 3GPP.[11] In other instances, SDOs coordinate directly on policy aspects. ISO, IEC, and ITU follow a common patent policy, and IEEE-SA, IETF and W3C are all part of Open Stand, a group promoting a series of governance and standardization principles.

c. Relationship with stakeholders

Industry Stakeholders and other Members of the Ecosystem

SDOs are fundamentally shaped by their interactions with diverse stakeholder groups. Different types of stakeholders participate in SDOs. While private firms often receive the most attention in studies of SDO governance and dynamics, several other stakeholder groups, including government agencies, universities and public research institutes, interested individuals, and civil

[9] The same seven SDOs, plus TIA as an additional member, also collaborate within OneM2M on the development of machine-to-machine communication standards.

[10] Article 55 of the 3GPP Working Procedures formulates general requirements for the member SDOs' IPR policies.

[11] Baron and Spulber (2018) document that the average standard document in a large sample had 1.14 equivalent documents at other SDOs (i.e. each standard is on average accredited by more than two different SDOs).

society organizations, participate in standardization at SDOs. Participation in SDOs by these types of non-corporate stakeholders varies. Rules of the process can discourage participation by certain players so that minority, civil society and public policy interests are not well-represented (Werle and Iversen, 2006). In many cases, however, the ability of non-corporate stakeholders to participate in SDO activities is limited by practical constraints such as cost, resources and expertise, rather than restrictive policies.

As a result, a majority of SDO participants are private companies (Baron and Spulber, 2018), and the large majority of individuals participating in standards development are affiliated with private companies (Baron, 2020). Companies have a variety of motives for engaging in standards development. Originally, the impetus for standardization arose from large industrial firms such as Ford Motor Company and AT&T, as well as the U.S. military, each of which sought to diversify its sources of components by creating standardized specifications that could be satisfied by different suppliers. It became necessary to involve component suppliers and manufacturers in the standardization process as electrical and mechanical components increased in complexity, resulting in a mix of producers and users of standardized goods that persists today (Russell, 2014; Yates and Murphy, 2019). Because producers and users often have divergent commercial goals and requirements (e.g., users want high quality components at a low cost, and producers want to satisfy user requirements while remaining profitable), there has long been an inherent tension within SDOs as these two major stakeholder constituencies have sought to advance policies and positions favorable to their own commercial interests.

In the ICT sector, a divide has also arisen between firms that participate in standardization primarily to earn revenue from patented technologies that are incorporated into standards, and firms that primarily seek to earn revenue from the sale of products and services that implement the

resulting standards (i.e., "patent-centric" versus "product-centric" firms) (Contreras, 2013; European Commission, 2019). Of course, even this division is blurred, as many firms occupy roles as both developers and contributors of technology to standards, as well as implementers of standards in products that they manufacture and sell.[12] Moreover, shifting corporate strategies and market realignments have resulted in several large firms moving from one camp to the other in both directions.

But despite the vocal and sometimes adversarial rivalry between patent-centric and product-centric firms within SDO policy debates, it is clear that these rival firms can, and must, cooperate within the technical standardization sphere. Just as the large manufacturers and component suppliers of early twentieth century industrial standardization were required to cooperate in order to achieve mutual benefits, the patent-centric and product-centric players in today's ICT markets appear to be co-dependent with respect to the development of technical standards that will benefit the entire industry.

SDO policy making by stakeholders

While the development of technical standards is generally open to different stakeholder groups, decision-making on SDO governance processes, such as rules and policies, may follow different models. Some organizations, in particular consortia, are often viewed as direct tools of their members. Other organizations have a higher degree of organizational independence, which

[12] It is for this reason that we decline to adopt the terminology sometimes seen in SDO IPR policy debates of "innovators" versus "implementers". This terminology establishes the misleading sense that firms that implement standards in products do not themselves innovate or make technical contributions to those standards.

may give greater latitude to SDO leadership (such as the W3C director, or the IEEE-SA governance boards) to make committal policy choices on controversial matters. NSBs generally seek a wide national consensus on both policy and technical matters, even though – in contrast to standards – policy matters can be decided by vote in closed governance bodies. In addition to directly participating in SDO decision-making, stakeholders exert indirect influence, as SDOs must make decisions in view of potential stakeholder responses.

Competition Among SDOs

SDOs sometimes compete to develop different standards in the same technological field, resulting in .“standards wars” such as the well-known contests between videotape formats (VHS vs. Betamax) and high-definition DVDs (HD-DVD vs. Blu-ray). In the ICT sector, the IEEE 1394 (Fire Wire) standard failed to achieve market success in light of competition from the Universal Serial Bus (USB) standards developed by the USB Implementer Forum (USB-IF) (European Commission, 2019)).

Another form of competition occurs when the owners or “sponsors” of proprietary technologies choose between different SDOs as venues for the standardization of their technologies (a strategy called “forum shopping”, Lerner and Tirole, 2006&2015; Chiao et al., 2007). Such selections may be made either at the beginning of a standardization project, or during the project, if the technology sponsors become dissatisfied with progress at the original SDO (so-called “voting with their feet”). Yet it is not necessarily easy to move a standardization project from one SDO to another. In many cases, standards development may be tied to specific SDOs, and can only be migrated at a substantial cost. These switching costs include the cost of coordinating with other SDO members, as well as the loss of organizational and reputational

capital. Indeed, SDOs provide a framework for repeat interaction between their members (Larouche and Schuett, 2016). The value of repeat interaction and reputation are built over time and cannot be easily reproduced in different organizations. SDO members may thus face significant difficulties in migrating their standards development projects to a different organization when they are unhappy about a policy revision at a particular SDO (European Commission, 2019).

Alternatively, dissatisfied members of one SDO may continue to participate in the SDO, while using a separate forum to establish agreement or build support for a particular solution (a practice referred to as "stepping out of the room" (European Commission, 2019)). Once progress has been achieved, these stakeholders may gravitate back to the original SDO to seek endorsement of their work product. For instance, a group of firms formed the Enhanced Wireless Consortium (EWC), allegedly out of frustration with an impasse over the development and licensing of the IEEE 802.11n standard (DeLacey et al., 2006). Early Worldwide Web standards such as HTML were transitioned from IETF to the newly-formed W3C due to policy and cultural disagreements, while leaving protocols such as HTTP with IETF. Contreras (2016).

d. A Refined Model of the Standardization Ecosystem

The standardization ecosystem can be characterized by a three-layer model (e.g., European Commission, 2014). A *first* layer is constituted by formal, established SDOs, including the large international organizations (ISO, IEC, ITU) and the officially designated NSBs and regional standardization bodies. These organizations often have significant functions that are shielded from competitive pressure. At the same time, these specific functions and their position within this

formal hierarchy justifies that these organizations be under significantly increased legal and regulatory constraints. These SDOs are frequently also required to take a large variety of sometimes conflicting interests and constituencies into consideration.

In the *third* layer, are a large number of informal industry consortia that are created and dissolved every year. While these organizations do not face the formal institutional constraints of first layer SDOs, they must attract members, contributors and implementers. The policy choices of these organizations are thus significantly shaped and constrained by the interests of their most vocal and powerful stakeholders. Furthermore, these SDOs need to build confidence in their processes and policies. One way to do so is to seek accreditation by bodies such as ANSI, and in order to further that end, mirror the policies of large established SDOs or submit their standards and specifications to more formal SDOs for approval.

Between the formally established standardization bodies and the more informal and smaller consortia, there is a *second* layer constituted by several large and significant SDOs, such as IEEE, IETF and W3C. These organizations receive their authority not from a formal legal designation, but instead from their technical leadership, their installed base of standards and standardization projects, and their established membership. All of these features make it inconvenient and costly for participants to shift to a new organization. Given that the SDOs in this second layer are less directly subject to formal regulatory constraints than SDOs in the first layer, and more shielded from competitive pressures than SDOs in the third layer, this second layer is a natural locus of institutional innovation in the standardization ecosystem.

While there are some notable instances in which SDOs may exhibit attributes of more than one layer (a primary example being ETSI, which has many of the formal institutional characteristics of the first layer, while sometimes also acting as a member-driven organization akin

to SDOs in the second layer), this rough characterization helps to understand the interactions and relationships among SDOs in the standardization ecosystem.

4. SDO IPR Policy Development

Having analysed and refined an ecosystem conceptualization of technical standardization in the previous section, we examine the impact and influence of the standardization ecosystem on the development of SDO IPR policies.

a. The Debate Over SDO IPR Policies

Standards are often covered by patents held by the firms that participated in their development. In the ICT sector, more than a hundred different patent holders may sometimes claim that hundreds or thousands of patents are essential to the implementation of the standard.[13]

Since the mid-twentieth century, many SDOs, recognizing that patents held by individual firms could inhibit broad adoption of their standards, have adopted formal policies that seek to guaranty that patent holders will permit all market participants to incorporate the standardized technologies into their products (often referred to as "IPR policies") (Contreras, 2015b). Most SDO IPR policies share general principles, which we discuss below as constitutive elements of a 'Baseline Policy'. Nevertheless, over the last decades, several SDOs have considered and debated a variety of further obligations arising from licensing commitments made under their patent policies. Among the most contentious of these issues has been the terms and conditions of the licenses that a patent holder must offer to standard implementers while remaining consistent with

[13] See, e.g., Baron & Pohlmann, 2018, p.521, tbl. 7 (the 4G LTE standard is covered by 45,279 patents; the 3G UMTS standard is covered by 39,748 patents).

its commitment to grant licenses on a "fair, reasonable and nondiscriminatory" (FRAND) basis (see below). In this debate, product-centric SDO participants have typically sought to include terms in SDO IPR policies that would tend to constrain these licensing terms (including limitations on the level of royalties that may be charged, as well as other terms), and patent-centric participants have opposed such constraints, seeking instead to leave the determination of specific licensing terms to bilateral negotiations between patent holders and implementers.

A small number of large stakeholders on both sides commit significant resources to the pursuit of these policy goals (see e.g. Lemley and Simcoe, 2017, for a discussion of different firm strategies). Individuals that directly or indirectly represent these stakeholders participate in the governance bodies (in particular the committees specifically addressing IPR policy issues) of many SDOs. Discussions of IPR policy issues at different SDOs thus often involve the same set of highly motivated industry stakeholders, contributing to deepen the interdependencies between individual SDOs' policy discussions.

b. Impact of Ecosystem Features on IPR Policy Development

While there has been extensive analysis and debate in the literature concerning the development of SDO IPR policies, and how particular policy features may be responsive to (or captured by) particular stakeholder constituencies (e.g., Sidak (2015)), there has been little analysis to date of the impact of the overall standardization *ecosystem* on these critical policy decisions. In this Section, we analyse how the development of SDO IPR policies is shaped by the ecosystem – both in terms of the locus of institutional innovations and the channels of propagation of new practices through the ecosystem.

Baseline Policies

In view of the exogenous legal constraints discussed above, IPR policies typically include the following provisions: (1) an obligation to disclose patents essential to implementation of a standard, and/or (2) an obligation to license such patents on terms that are "fair, reasonable and non-discriminatory" (FRAND) (see Baron and Spulber, 2018; NAS, 2013; DOJ-FTC, 2007).[14] Generally, SDOs will only standardize the patented technology if such a commitment is given. The precise royalty rates and other terms required by FRAND commitments are seldom specified in SDO policies.

It was mentioned earlier that, in general, SDO regulation follows a procedural approach, which defers to SDOs for the technical substance of standardization. With respect to IPR policies however, competition law enforcement guidelines, public procurement rules, and standardization-specific regulations consistently refer back to key provisions of SDO IPR policies, namely the requirements to disclose potential SEPs and commit to licensing on FRAND terms. While these requirements are not legally mandated, they are considered indicative of SDOs' compliance with legal and regulatory obligations (sometimes referred to as a "safe harbour"). Accordingly, the vast majority of SDOs implement one or both of these provisions in their IPR policies, which constitute the core elements of what we have termed a "Baseline Policy" (European Commission, 2019).

In most cases, Baseline Policy requirements are intentionally stated in general terms. Many SDOs implement these general requirements without additional detail, leaving the determination

[14] Such FRAND terms may be royalty-free or royalty-bearing.

of precise contours of patent licensing transactions to negotiation among members.[15] An important SDO IPR policy that closely follows the Baseline Policy, without adding additional detail, is the ISO/IEC/ITU patent policy. This policy serves as a template for the IPR policies for hundreds of SDOs that are members of ISO or IEC or follow the policies of a national SDO that is member of ISO and/or IEC. Likewise, the large majority (more than 90%) of ANSI-accredited SDOs simply adopt the ANSI patent policy verbatim or with only cosmetic alterations (Contreras (2015a, p.42 n.72)). Other SDOs, such as ETSI, have elaborate IPR policies with detailed provisions but do not add significant substantive obligations beyond those specified by the Baseline Policy.

There are thus hundreds of SDOs around the world that have very similar IPR policies conforming to this baseline. Adoption of these key provisions by large numbers of large and well-known SDOs further reinforces their status as widely shared institutional norms.

Baseline-Plus Policies

In contrast to SDOs adopting Baseline IPR policies, some SDOs have chosen to create or revise their IPR policies in ways that go beyond the Baseline. For example, some SDO polices require commitments to license SEPs on terms and conditions that are more specific or less restrictive than FRAND. In particular, SDOs such as W3C and API, and consortia responsible for standards including Bluetooth, HDMI and USB, require licensing of SEPs on royalty-free basis. Other SDOs allow individual working groups to decide whether they wish to impose royalty-free licensing obligations on their participants (e.g. ECMA and OASIS), or impose additional

[15] In many cases, particularly outside of the ICT sector, patents are simply not important enough to the standardization work of the SDO to merit significant debate or discussion. For this reason, these SDOs may adopt the Baseline Policy simply as an expediency.

obligations on participants (e.g. VITA's requirement for patent holders to announce their maximum royalty rate in advance). We refer to all of these as "Baseline-Plus Policies". One prominent example of a Baseline-Plus Policy is that of IEEE-SA, which defines the parameters for SEP licensing more specifically than the Baseline Policy and prohibits the owner of a SEP from seeking an injunction to prevent the use of a standardized technology under certain circumstances. The IEEE-SA policy amendments that introduced these provisions in 2015 were controversial and led to significant opposition by several IEEE-SA participants, generally in the patent-centric camp.

Generally, few SDOs formulate Baseline-Plus policies (European Commission, 2019). SDOs wishing to go beyond Baseline Policies may have to expend both financial resources (legal fees), staff time (diverted from standardization work) and social capital (member goodwill).

The Standardization Ecosystem and Baseline-Plus Policies

The standardization ecosystem itself appears to have a significant impact on the willingness and ability of SDOs to adopt Baseline-Plus policies. First, Baseline-Plus policies are rare among the most formal SDOs (the first layer). These SDOs serve as focal organizations for a number of national or sectoral standardization bodies and often have public functions conferred on them by governmental authorities. Moreover, many of these organizations are subject to vertical constraints resulting from their place in the organizational hierarchy. Their policies are characterized by a significant degree of stability and generality.

At the same time, some SDOs in the third layer also stick very close to the Baseline policy, possibly because this is the least controversial and resource-intensive path for a small and resource-

constrained organization, and also because these groups may wish to avoid internal disputes that might deter the recruitment or retention of members.

SDOs that are able to enact significant and contentious Baseline-Plus policies must be relatively free from constraints within the standardization ecosystem. This is primarily the case of SDOs in the second layer. The vertical constraints applicable to these organizations are often quite permissive and accommodate a broad range of IPR policy choices. For example, even the contentious IEEE-SA IPR policy change in 2015 was approved by ANSI as conforming with its Essential Requirements and was the subject of a favourable Business Review Letter from the DOJ. At the same time, significant switching costs and other factors allow these SDOs to introduce policies that are opposed by significant segments of their constituencies without facing immediate competitive responses by stakeholders.

These two dimensions of organizational autonomy are intertwined. Some organizations can eschew endorsement from ANSI and other oversight bodies if they already possess sufficient legitimacy and credibility in the eyes of their stakeholders. This is the case with IETF and W3C. These organizations are relatively free of constraints precisely because they face relatively little competitive pressure. On the other hand, third layer SDOs that would generally be free to determine their own policies within broad confines established by general legal principles may voluntarily decide to adopt or copy important policy provisions from established SDOs to build confidence in their governance.

Thus, the ability of SDOs to adopt controversial IPR policies appears to be related to the degree of flexibility and independence that they possess within the standardization ecosystem. In addition, the position of an SDO within the standardization ecosystem determines whether and

through which channels new practices that it adopts will spread to other SDOs, and impact overarching institutional norms.

c. Circulation of policy innovations within the ecosystem

An important aspect of the standardization ecosystem is the manner in which it facilitates the circulation and dissemination of policy changes made by other SDOs. It is in the nature of the SDO ecosystem that SDOs reach differentiated solutions for their specific context, market realities and members. Nevertheless, SDOs still pay attention to what other SDOs are doing – whether because of competitive pressures or collaborative requirements – and the set of stakeholders overlaps from one SDO to another. Thus, policy changes at one SDO will be noticed by others and may influence policy-related actions of other SDOs.

The mechanisms by which IPR policy changes circulate from one SDO to another are not well understood. Sometimes, debates surrounding contested policy changes become controversial because stakeholders may fear that the policy course chosen by one SDO will become 'contagious' and spread to other SDOs within the ecosystem. This creates a fear that a precedent is being set for other SDOs. When the policy change made by the first SDO is presented as a mere 'clarification' or 'interpretation' of widespread concepts, as opposed to a modification intended to address the specific context of a given SDO, that fear is amplified.

Naturally, not all SDO policy decisions have the potential to become 'contagious'. Some policy changes address perceived idiosyncratic problems or needs of a specific organization. However, SDO policy changes often address general topics that could also apply to other SDOs. Such changes often arise in a context of a broader public discussion during which various

stakeholders (including SDO participants and public agencies) debate perceived problems with existing IPR policies and possible policy options, or even expressly call upon SDOs to take specific actions. In these instances, debates over an individual SDO's policies are often inseparable from the broader context of self-regulation of the standardization ecosystem.

In the following part, we will study several examples of individual changes to SDO IPR policies in order to analyze the specific mechanisms of transmission of such individual IPR policy innovations in the standardization ecosystem.

Uncontested IPR policy changes – the case of SEP transfers

FRAND commitments are given by firms owning relevant patents. Once their ownership changes, the question arises whether such commitments still bind their new owners (see NRC (2013)). Competition authorities in Europe and the U.S. identified the lack of transferability of such commitments as a serious concern and brought enforcement actions when such commitments were not honored. In addition, these authorities encouraged SDOs to amend their patent policies to clarify that FRAND obligations bind third parties acquiring encumbered SEPs (NRC 2013; Kühn et al., 2013; Hesse 2012).

Such policy clarifications can offer guidance to other SDOs regarding the meaning of obligations or provisions included in their policies. That is, even if SDO-A has not made a policy change, the clarification made by SDO-B to a similar provision in SDO-B's IPR policy can inform both the leadership and members of SDO-A regarding the interpretation of SDO-A's policy. Thus, as a result of various SDO policy changes, in addition to court decisions and antitrust proceedings, SDO patent licensing commitments are now *generally* viewed by many as binding upon a party

purchasing a FRAND-encumbered SEP. Policy changes such as these, if they become broadly recognized as desirable, can shift norms and expectations, thereby encouraging other SDOs to adopt similar clarifications. Baron and Spulber (2018) document that over time, an increasing number of SDOs adopted policy provisions relating to the binding nature of FRAND commitments. As such policy spreads, it might even become part of the Baseline Policy.

This circulation process is an example of how SDO IPR policy changes (supported by court decisions and competition enforcement) can spread quickly when the solution adopted is not contested and is favoured by most stakeholders.

Contested IPR policy changes

In the case of the 2015 IEEE-SA patent policy change, industry experts on both sides agree that the particularly heated debate was in part attributable to the fact that many believed that the policy change could produce effects going well beyond IEEE.[16] The policy change occurred in a context in which some observers and stakeholders publicly stated that existing FRAND licensing obligations were insufficiently defined in SDO policies and various policymakers explicitly invited SDOs to clarify the licensing obligations arising out of their policies (see, e.g., Hesse 2012; Kühn et al, 2013). Furthermore, several of the new or revised provisions of the IEEE-SA policy reflected pending court decisions or antitrust investigations (e.g., IEEE-SA's reference to the "smallest saleable compliant implementation" as a possible starting point for FRAND determinations

[16] *See* Intellectual Asset Management, May 16, http://www.iam-media.com/Blog/Detail.aspx?g=e8f72d6e-a3f8-45d8-882f-3ebdd3a1d69e (an IEEE participant arguing that "the furore around the IEEE policy has much to do with the policy itself but more to do with the concerns that some companies have about contagion" or K. Mallinson, "Tide turns in US and EU agencies' policies on SEP licensing", IP Finance, December 2017. http://www.ip.finance/2017/12/tide-turns-in-us-and-eu-agencies.html (about setting global standards).

mirrors an evidentiary rule cited by the U.S. Court of Appeals for the Federal Circuit for the calculation of royalty rates on the basis of the "smallest saleable patent practicing unit" or SSPPU).[17] These modifications thus had a potential of affecting established institutional norms.

Some of the new or modified provisions of the IEEE-SA's 2015 policy have the character of explicit policy changes (e.g., a qualified waiver of the use of injunctive relief), whereas others are formulated as more specific interpretations or clarifications of the obligations arising out of provisions previously included in the policy (e.g., definitions of general terms such as "reasonable rates" or "compliant implementation"). As the previous policy closely followed the language of the ANSI Essential Requirements, similarly worded provisions exist in the patent policies of a large number of other SDOs, amplifying the potential for IEEE-SA's interpretations to reverberate to other SDOs.

In contrast to the contested policy changes at IEEE-SA, in 2016 CEN and CENELEC released a white paper that purported to interpret the meaning of "FRAND" under CEN's policy (CEN/CENELEC, 2016). Though this document can be read more broadly as guidance on the meaning of FRAND in general, it does not constitute a formal amendment of CEN's policy. Thus, though the CEN/CENELEC white paper generated significant interest and participation by stakeholders in its development, it did not result in the same degree of industry-wide turmoil as the 2015 IEEE-SA amendments.

These examples illustrate how SDO policy changes and interpretations have the potential to inform the interpretation of concepts and terms shared by the policies of other SDOs, or even generally accepted legal principles. Yet because of the contested nature of the changes, it is

[17] Ericsson Inc. v. D-Link Systems Inc., 773 F.3d 1201 (Fed. Cir. 2014).

important to understand how these policy changes can circulate amongst SDOs within the ecosystem. In this respect, we identify two analytical avenues: (1) horizontal circulation amongst SDOs via some form of emulation mechanism, and (2) hierarchical circulation through the intervention of an authoritative institution, via a precedential mechanism.

Horizontal circulation – Experiment and emulation

Adopting new SDO policies can have experimental value. SDOs can adopt policies that are discussed e.g. in academic research or abstract policy discussions, but are not yet widely practiced. Over time, SDOs can draw upon the experience of other SDOs with policy options in order to improve the quality of their own governance. This corresponds to models of social learning (Peyton Young, 2009), where more actors adopt a new practice after seeing it successfully implemented.

The benefits of 'social learning' among SDOs suggests that the standardization ecosystem lends itself to *experimentation*: SDO stakeholders may consciously choose to implement a new policy within one SDO (or its working groups), so that the effects of the policy innovation may inform policy debates in other SDOs. ECMA e.g. introduced a royalty-free patent policy in 2013 that was explicitly described as "experimental". Under this policy, ECMA may designate specific task groups of one of its technical committees as royalty-free groups. Experimentation with IPR policies in this specific sense is rare. Among other things, it requires that the decision makers at the SDO implementing the experimental policy internalize the benefits of the information that is generated through the experiment. This may e.g. be the case if decision making at an SDO is controlled by stakeholders with significant activities and interests in a larger number of SDOs.

More commonly, “experimentation” resides in the overarching regulatory approach to SDO policy making, rather than in the decision making at individual SDOs. While individual SDOs and their stakeholders may pursue idiosyncratic goals when adopting new policies, regulators (including public authorities and private organizations with a normative function in the ecosystem) may take into account the experimental value of such innovations and therefore adopt a permissive approach to the adoption of policies that differ from established norms. This approach corresponds to what has been defined as ‘experimentalist governance’ (Sabel, 2008; Weiser, 2007), including more policy-centred models such as legal emulation (Larouche, 2013).

For instance, when W3C adopted a royalty-free licensing policy, some stakeholders, who argued that the policy change would produce significant adverse effects on innovation, vehemently opposed the change (Contreras 2016). Yet after the change, other SDOs also adopted royalty-free policies. In 2005, for example, OASIS allowed its newly created working groups to select a royalty-free licensing mode, and in 2009 introduced a third, patent non-assertion mode. When in 2011, the American Petroleum Institute (API) adopted a royalty-free licensing policy, opponents challenged API’s ANSI-accreditation. In a letter in support of API, two ANSI members argued that the “widespread adoption of policies with default [royalty-free] licensing rules, including by groups responsible for prevalent standards such as the HTML standard [W3C]” showed that “there is demonstrably no merit to the argument that such policies have discouraged or will discourage innovation”. Hence, “ANSI should do nothing to discourage experimentation with different IPR policies and models by accredited standards developers”. Ultimately ANSI ruled that the API policy remained compliant with the ANSI Essential Requirements.

The adoption of other royalty-free patent policies and the reference to W3C in the discussion suggest that the early move by W3C constituted a model for similar policy changes at other SDOs.

Nevertheless, policies with default royalty-free licensing rules did not spread widely across all SDOs, but mostly remained confined to SDOs with a similar technological focus on web-based technologies (OASIS) and to smaller technology-specific consortia (e.g., USB, Bluetooth, HDMI), thus generally remaining more limited in scope.

A different outcome can be observed with respect to SDO IPR policies requiring ex ante disclosure of most restrictive licensing terms and conditions (i.e., maximum royalty rates). In 2006, VITA adopted a policy making such ex ante disclosures compulsory. VITA's policy change was strongly opposed by some stakeholders, who predicted significant adverse effects of the new policy. Contreras (2013) analyzed the consequences of this policy change and found no conclusive evidence for such adverse effects. Nevertheless, VITA's example was not followed by other significant SDOs, and IEEE and ETSI, which had been considering such policy changes, elected instead to allow ex ante disclosures on a voluntary basis rather than making them mandatory. The experimental value of VITA"s policy innovation may have been limited by the fact that VITA is a comparatively small SDO with a limited number of SEPs. Furthermore, there is limited overlap in membership between VITA and other SDOs where SEPs play a more prominent role. Stakeholders in these SDOs may thus have limited exposure to VITA's policy in practice.

The preceding examples reveal the essence of this horizontal circulation mechanism: even if a policy change enacted at one SDO may potentially be relevant to the policies of other SDOs, decisions made at one SDO do not set a formal precedent for other SDOs. Debates over similar policy issues taking place at different SDOs may result in different outcomes for a variety of reasons. SDOs may operate in different technological fields, and some IPR policy options may be perceived as better suited to some technological fields than to others (e.g. RF licensing obligations may be considered better suited to web-based standards, which are characterized by lower up-front

investments and a more dispersed user base than e.g. telecommunications standards). Furthermore, in spite of sometimes significant overlap, membership typically differs from one SDO to the other. In addition, the governance models of SDOs differ significantly, and some SDOs require significantly larger degrees of support to adopt a proposed modification of their policies than others. Given that each SDO evolves within its own context, and stakeholder expectations may vary from one SDO to the other, it should not be surprising that contested IPR policy changes may not circulate so easily.

As a consequence, outside of cases where public authorities intervene to reduce diversity, the SDO ecosystem could very well settle on an equilibrium where many different interpretations and implementations of a single general pronouncement have currency amongst SDOs. That is, if SDO-A creates a definition of FRAND that includes features such as SSPPU valuation, and SDO-B creates a definition that expressly rejects SSPPU valuation, there is a potential for confusion and hence inefficiency within the ecosystem. While unfortunate, this divergence and inconsistency already exists in numerous areas relating to the interpretation of SDO IPR policies as a result of conflicting judicial decisions around the world and within the same jurisdictions (see Contreras, 2019).

Hierarchical circulation – Precedent

A more constraining model for the circulation of IPR policy changes amongst SDOs would require the participation of a hierarchically superior institution that could bind SDOs following a precedential model. Under that model, a pronouncement by that institution would turn the IPR policy change of one SDO into a precedent which the others are bound to heed. Two institutions could be seen to play such a precedent-setting role in the development of IPR policies, namely

agencies and courts applying competition law, as well as ANSI interpreting its Essential Requirements.

As discussed above, competition and antitrust law have a major influence on both SDO governance and on the Baseline Policy. That influence has been felt through the decisions of enforcement agencies and courts. Since these decisions are based on generally-applicable law that affects all economic actors across the board, the reasoning of authorities or courts in applying competition or antitrust law to a case involving one SDO is *prima facie* applicable to other SDOs as well, unless that first case can be distinguished.

These authorities can become involved in the development of SDO IPR Policies in several ways. In particular, authorities can initiate reviews of policies, either *sua sponte* or at the request of one or more stakeholders. Perhaps the most direct means for engaging antitrust authorities in a policy change is by requesting a Business Review Letter (BRL) from the US Department of Justice, with the hope that such letter will not only provide an assurance that the DoJ does not currently intend to bring an antitrust enforcement action with respect to a proposed policy change, but also to confer some legitimacy on the change and possibly give it some precedential value.

Given its position within the U.S. standardization ecosystem, ANSI is uniquely placed to give precedential value to IPR policy changes made by its accredited SDOs by assessing whether an SDO's policies comply with the ANSI Essential Requirements. ANSI rulings on the meaning of its Essential Requirements and on the conformity of a specific IPR policy with them have precedential value across the entirety of ANSI-accredited SDOs. For example, as VITA, API and IEEE-SA are all ANSI-accredited SDOs, their amended IPR policies were examined by ANSI to ensure that they continued to comply with the Essential Requirements after policy changes were made. ANSI determined in each of these cases that the amended policies were in compliance with

its Essential Requirements, though some stakeholders opposed this conclusion. In the case of API, ANSI referred to the re-accreditation of OASIS as a precedent that default royalty-free licensing policies can be compliant with the ANSI Essential Requirements.[18]

Neither of the sets of institutional actors discussed in this Section confers formal precedential authority on an individual SDO's policy language, however. As we have seen, competition law leaves substantial margin to SDOs as to how they comply with basic legal requirements, barring antitrust authorities from selecting individual SDO policies as precedents that other SDOs are compelled to follow. Furthermore, consistency across time and jurisdictions may be lacking. As for ANSI, it appears better placed on substance (being a body specializing in standardization with requisite IPR expertise), but it is not a public authority and lacks the precedential weight of a governmental authority. Nevertheless, the formality of ANSI's process, its expert competence and the broad recognition of its authority lend legitimacy to policy pronouncements made by ANSI, giving them an inherent precedential value.

While review of individual SDO policy innovations by antitrust authorities (e.g. through a BRL) or ANSI does not constitute a formal precedent, it may constitute what Greenwood et al. (2002) term 'theorization' of a new practice: the review process clearly identifies and defines the new practice, while attesting to its legitimacy and conformance with overarching institutional norms.

[18] Another such example involved ANSI's review of a policy decision by X9, and ANSI-accredited SDO. As with the royalty-free debates, some ANSI members feared that ANSI's decision regarding X9 would have precedential effect on other SDOs (see European Commission, 2019).

5. Conclusion

The fabric of the standardization ecosystem consists of a dense web of formal and informal institutional ties among different SDOs, between SDOs and their industry stakeholders, and between private SDOs and public authorities. While different SDOs develop standards for different technologies and/or different industries independently of one another, the decisions made by individual SDOs are subject to common rules, and significantly influence other SDOs. The various interdependencies among SDOs in the standardization ecosystem help to explain where in the ecosystem institutional innovations arise, and how they are transmitted from one SDO to another.

Our research demonstrates the usefulness of the ecosystem conceptualization for the analysis of institutional innovation in self-regulating industries. Other, simpler models can account for only parts of the observed dynamics. For instance, standardization could be analysed as a 'field', comprised by a variety of different SDOs playing similar roles in different industries. Traditional models for the propagation of new practices in a field, such as contagion and social learning (Peyton Young, 2009), are relevant for the analysis of the diffusion of new IPR policies among SDOs. Similar to Greenwood et al. (2002), we also identify instances in which a private accreditation body for SDOs (ANSI) can act as a regulator within the field, and contribute to the theorization and legitimization of novel practices developed by individual SDOs. These processes bear many similarities to the spread of legal and administrative innovations among states in a federal legal system.

Nevertheless, these models miss essential aspects of the process of institutional change in SDOs. In particular, SDOs are not monolithic decision makers. Rather, industry stakeholders often participate directly in the governance bodies where relevant policy decisions are made. SDOs involve these stakeholders in their governance because SDOs rely on the contributions of these

stakeholders for standard development and financial support. Different stakeholders play different roles in the standardization process and provide complementary value to it. Successful SDOs strike a balance between the policy expectations of these different stakeholder groups; and this balance is reflected in both individual SDOs' IPR policies and the overall policy mix in the SDO ecosystem.

Furthermore, the same set of stakeholders participate in the standard development activities and governance of different SDOs. At the individual level, SDO IPR policy options are debated within a circumscribed group of specialized experts who participate in the governance bodies of various SDOs. The overlap between the individuals and organizations participating in the decision making of various SDOs has important implications. Stakeholders may use the processes of one SDO to influence policy outcomes at other SDOs. We have identified instances in which individual SDO policy changes may serve as experiments, or set relevant (though informal) precedents. Furthermore, the limited set of experts and organizations involved in a variety of SDOs internalizes the external effects that one SDO's policy changes may exert on other SDOs. Debates over individual SDO policy changes therefore often take place in consideration of the common interest of stakeholders in preserving the health of the ecosystem.

These attributes – active participation by a diverse set of actors tied together by non-generic complementarities and a sense of community or awareness of the joint interest in preserving the system's capacity to support technological innovation – are defining characteristics of an ecosystem. Framing the observed interdependencies within the ecosystem conceptualization allows for a better understanding of these characteristics, and may contribute to the development of a coherent regulatory approach to SDO's policy making on IPR.

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List of acronyms

3GPP	Third Generation Partnership Project. A consortium of seven SSOs in the field of mobile telecommunication, including ETSI.
AFNOR	Association française de normalization
ANSI	American National Standards Institute
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical standardization
DIN	Deutsches Institut für Normung
DoJ	United States Department of Justice (generally referring to Antitrust Division herein)
ESO	European Standardisation Organisations (CEN, CENELEC, ETSI)
ETSI	European Telecommunication Standards Institute
FRAND	Fair, Reasonable and Non-Discriminatory. Also Reasonable and Non-Discriminatory (RAND). Concept describes the licensing terms to be offered by the owner of an SEP to standard implementers.
FTC	United States Federal Trade Commission
IEC	International Electrotechnical Committee
ICT	Information and Communication Technologies
IEEE	Institute of Electrical and Electronics Engineers. The IEEE Standards Association (IEEE SA), which is part of IEEE, is an important SDO best known for developing the IEEE 802.11 standard.
IETF	Internet Engineering Task Force
ISO	International Organisation for Standardization
ITU	International Telecommunications Union

LTE	Long-Term Evolution. Standard for 4th generation high-speed wireless communication for mobile phones and data terminals developed by 3GPP
NSB	National Standards Bodies, such as AFNOR and DIN
NGO	Non-governmental organisations.
OASIS	Organization for the Advancement of Structured Information Standards
OMB	Office of Management and Budget (OMB), part of the Executive Office of the President of the United States
SEP	Standards-essential patent. A patent that is essential to the implementation of a standard. Various definitions exist regarding the scope and nature of essentiality.
SDO	Standards Development Organization.
TBT	Agreement on Technical Barriers to Trade, commonly referred to as the TBT Agreement, is an international treaty administered by the WTO.
TSDSI	Telecommunications Standards Development Society, India
VITA	VMEbus International Trade Association
WTO	World Trade Organization
W3C	World Wide Web Consortium