Governing the Anti-commons:
The Institutional Logic of Standard Setting Organizations

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Abstract

Shared technology platforms are often governed by standard setting organizations (SSOs), where interested parties seek a consensus solution to problems of technical coordination and platform provision. Economists have modeled SSOs as certification agents, bargaining forums, collective licensing arrangements and R&D consortia. This paper integrates these diverse perspectives by adapting Elinor Ostrom's framework for analyzing collective self-governance of shared natural resources to the problem of managing shared technology platforms. There is an inherent symmetry between the natural resource commons problem (over-consumption) and the technology platform anti-commons problem (over-exclusion), leading to clear parallels in institutional design. Ostrom's eight principles for governing common pool resources illuminate several common SSO practices, and provide useful guidance for resolving ongoing debates over SSO intellectual property rules and procedures.

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Introduction

Compatibility standards define the architecture of shared technology platforms, and help ensure that independently designed products work together well. There are several ways to organize the supply of standards, including "standards wars" characterized by decentralized technology adoption, or through the efforts of a dominant platform leader.[1] This paper considers the design and performance of voluntary consensus standard setting organizations (SSOs), the institutions that supply standards for many of the most important modern technology platforms, including the Internet and the cellular tele-communications infrastructure.

SSOs are multi-faceted institutions, and there is no standard economic model of how they work. Various authors have described SSOs as certification agents (Lerner and Tirole 2006), venues for bargaining (Simcoe 2012; Farrell and Simcoe 2012a), catalysts for collective licensing (Lemley 2002; Shapiro 2001), or consortia for joint R&D (Cabral and Salant 2008). This paper integrates these diverse perspectives by treating SSOs as institutions for the collective self-governance of shared technology platforms, drawing heavily on the work of Elinor Ostrom (1990), who examined the parallel problem of developing local institutions to govern a shared natural resource.

The lessons from Ostrom's research are not directly applicable to SSOs because compatibility standards and natural resources are fundamentally different. Broadly speaking, standards are non-rival goods characterized by positive consumption externalities, while natural resources can be depleted and are prone to over-use. Nevertheless, Ostrom's framework for institutional analysis is a natural fit for studying SSOs. In both settings, independent actors benefit from access to a shared resource, and confront similar problems of institutional design, such as overcoming free riding in the supply of a public good; monitoring and enforcing rules for access (or exclusion); and crafting credible commitments that prevent short-run opportunistic behavior.

This paper begins by describing the inherent symmetry between the "commons problem" of natural resource over-use, and the "anti-commons problem" that can arise when many parties have the ability to exclude others from practicing a shared technology standard (Heller and Eisenberg 1998; Buchanon and Yoon 2000). Once this symmetry is recognized, many features of SSOs, such as their membership rules, internal organization, compliance testing and certification activities, and intellectual property policies are seen to have natural counterparts in the common-pool resource (CPR) institutions studied by Ostrom.

[1] Simcoe and Farrell (2012b) suggest that there are four main ways to achieve compatibility: decentralized standards wars, platform leadership by a dominant player (e.g. a monopoly supplier, large customer or the government), standard-setting organizations, and converters (or multi-homing). For a review of the economics of standards wars, see Besen and Farell (1994). The economics of platform leadership are described in Rysman (2009), as well as by Gawer and Cusumano (2007) and Evans and Schmalensee (2008).

After highlighting the symmetry between commons and anti-commons, and describing the substantial organizational heterogeneity among SSOs, this paper considers the link between SSO organization and performance. Ostrom developed a set of eight "design principles" for CPR self-governance by studying a group of long-lived natural resources. Four of her principles are related to resource provision, and translate easily to the governance of shared technology platforms. Four others are related to managing platform access, and must be modified to account for the difference between commons and anti-commons. Broadly speaking, SSOs conform to Ostrom's design rules, with the possible exception of vague intellectual property policies, which are linked to several ongoing legal disputes.

The paper concludes by discussing the problem of institutional change. Over the last twenty years, traditional standards developing organizations have declined in importance relative to informal consortia. Incumbent SSOs have responded to this shift by streamlining established processes and finding ways to collaborate with consortia. Looking forward, it is possible to discern a similar pattern of adaptation within and between organizations in the area of SSO intellectual property policies.

Governing the Anti-Commons

In his famous formulation of the commons problem, Garrett Hardin (1968) describes a group of farmers who collectively over-graze a common pasture, leading to the collapse of their shared natural resource. The collapse occurs because each farmer seeks the private benefits from grazing their own animals on the commons, but does not internalize the full cost of their action upon the underlying resource. The commons problem is a widely used metaphor for what Ostrom (1990) calls a Common Pool Resource (CPR): a self-replenishing resource, such as an irrigation district or inland fishery, that exhibits negative consumption externalities, either because of congestion effects or because the shared resource becomes depleted with over-use.

Since Coase (1960), the standard economic prescription for averting Hardin's tragedy is to create a system of property rights. While Coase's central insight is powerful, it begs the questions of how property rights should be defined, measured, awarded and enforced. The key contribution of Ostrom's research is to highlight the wide variety of institutional arrangements that CPR users have created to solve these collective action problems on their own. Using detailed case studies from a wide range of settings, Ostrom and her colleagues show how enduring systems of CPR self-governance typically adapt the design of property rights institutions to account for features of the local environment.

Can Ostrom's analytical framework be used to study the problem of governing shared technology platforms? If so, the first step is to note the fundamental difference between commons and anti-commons. Unlike CPRs, technology platforms typically exhibit positive consumption externalities, or network effects. Thus, as more users or complements are added to a shared system, the marginal benefits produced by the next user grow larger.[2] As a result, the central threat to a technology platform is not over-use, but over-exclusion. Heller and Eisenberg (1998) coined the term anti-commons to describe the situation where many parties have rights to exclude others from a shared non-rival resource. If each rights-holder charges the individually optimal price (taking others' decisions as fixed), and does not internalize the overall reduction in demand, the shared resource will be under-utilized.[3] Specific examples of the anti-commons problem include the ICT "patent thicket" described by Shapiro (2001) and the creation of proprietary extensions or "forks" that prevent inter-operability of complements between rival systems.

While there is a clear difference between the commons and anti-commons problems, this does not render Ostrom's approach to institutional analysis irrelevant for studying technology platforms. In both settings, actors must devise rules and procedures that prevent rent dissipation, by restricting access to CPRs or preventing exclusion from technology platforms. Moreover, the inherent symmetry between commons and anti-commons often simplifies the task of translation. For example, Ostrom describes the task of regulating access to a CPR as an appropriation problem. Technology platforms face the analogous coordination problem of convincing users to adopt common standards. Similarly, the "appropriator" who plays a central role in Ostrom's analysis becomes an "implementer" when speaking of new technical standards.

Adapting Ostrom's analytical framework to study technology platforms is not as simple as flipping the "sign" attached to rules for accessing a shared resource, since access rules interact with incentives to provide the underlying public good. In her work, Ostrom recognized this inter-dependency, and she divided the overall problem of CPR self-governance into two parts: appropriation problems and provision problems. Where appropriation (and coordination) problems are concerned with access rules that allocate the benefits from using a shared resource, provision problems are related to building, maintaining or restoring the shared resource over time.

The remainder of this section provides a variety of examples that illustrate how SSOs solve the related problems of coordination and platform provision. To be clear, I use the term SSO broadly to encompass any multilateral organization that governs some key piece of a shared technology platform. Thus, while standards

[2] Katz and Shapiro (1985) and Farell and Saloner (1988) develop early models of increasing returns in platform adoption. Liebowitz (1994) highlights the distinction between network externalities and network effects, and argues that even if network effects are pervasive, platform users may still realize the preponderance of potential gains from coordination.

[3] Cournot (1838) first noted that complementary monopolies under-produce relative to both the static optimum (i.e. when the access price is zero), and a single monopoly rights-holder.

practitioners sometimes adopt a narrower definition, the SSOs in this paper can include open-source software communities and certain kinds of collective licensing organizations, as described below.

Coordination Problems

The basic coordination problem faced by an SSO is to convince independent implementers to adopt common standards for product design. When network effects are strong, a simple endorsement may suffice. Economic models of "cheap talk" capture the idea that such endorsements can become self-fulfilling prophecies, since implementers have strong incentives to coordinate when the mutual benefits inter-operability are large. Lerner and Tirole (2006) develop a theory of forum shopping by technology sponsors seeking SSO endorsement for their own technology. Rysman and Simcoe (2008) study the impact of SSO endorsements on patent citations, and find evidence of both selection effects (SSOs incorporate better-than-average patents into standards), and an increase in citations following the endorsement.

Of course, not all endorsements lead to implementation. For example, in the Lerner and Tirole model, technology sponsors face a trade-off between choosing a friendly SSO that is likely to accept their technology, and a legitimate organization whose endorsement will influence prospective implementers. In practice, the factors that may lend credibility to an SSO endorsement include the presence of key firms, historical success, and the nature of the process for achieving consensus.

Small consortia focused on a single standard often derive legitimacy from the participation of key firms that can individually make a sizable contribution to a standards' installed base. For example, the original sponsors of the Universal Serial Bus (USB) connector standard included Compaq, Intel, IBM and Microsoft. The founding members of the Bluetooth Special Interest Group (SIG) were Ericsson, Intel, IBM Nokia, and Toshiba. Both technologies have achieved widespread adoption, partly because it was clear from the outset that they would have support from significant implementers.

Another group of SSOs have achieved credibility based on their past success. For example, both the Internet Engineering Task Force (IETF) and World Wide Web Consortium (W3C) emerged from quasi-academic settings, and now manage large parts of the Internet infrastructure. In both cases, the rapid growth of the platform drew in significant commercial participants, as opposed to the presence of those firms driving adoption of the key standards.[4]

Finally, many accredited standards developing organizations (SDOs) derive legitimacy from their emphasis on consensus governance. For example, the

[4] For histories, see Russell (2006) or Simcoe (2012) on the IETF, and Berners-Lee and Fischetti (1999) on the W3C.

American National Standards Institute (ANSI) will only accredit SSOs as developers of American National Standards if they are characterized by "open participation, a balance of interests, due process, a formal appeals process, and consensus decision-making… defined as general agreement, but not necessarily unanimity, [with] a process for attempting to resolve objections by interested parties." (ANSI 2013) In principle, prospective implementers can expect standards emerging from the SDO consensus decision-making process to have broad support and reasonable quality.

In addition to making *ex ante* endorsements that harness implementers' collective incentives to achieve inter-operability, many SSOs work to ensure that firms adhere to their standards through *ex post* compliance testing and certification.

When network effects are strong, compliance testing alone may be sufficient. For example, many large SSOs sponsor "plug fests" where independent vendors come together and test their products in a common operating environment. Likewise, smaller consortia are often associated with a facility such as the University of New Hampshire Inter-operability Lab, which provides a vendor neutral infrastructure for inter-operability testing.[5] In these settings, participants typically provide their own test suites that check whether products conform to each of the mandatory features of a new standard.

When network effects are weaker, certification programs may complement compliance testing by providing an additional incentive to comply with standards – particularly for standards with well-known consumer brands. Some certification programs are run by the SSO that creates the underlying technical standards, such as Bluetooth SIG, while others are administered by a separate "promoter" organization, such as the Wi-Fi Alliance.

In some cases, SSOs will link certification programs to a licensing regime that either promotes broad platform access, or preserves key participants rights to extract a stream of rents. For example, certified Bluetooth implementers must enter a royalty-free cross-license with all other Bluetooth adopters, thereby creating a *de facto* royalty-free patent pool. The HDMI consortium requires all implementers to take a royalty-bearing license, but offers a substantial discount (from $0.15 to $0.05 per unit) to implementers that use their logo on product and promotional materials.[6]
The Java programming language provides an interesting example of a certification program linked to a complex licensing regime. Sun Microsystems (now Oracle) certifies third-party implementations of the Java language, and licenses the underlying source code, as well as the language specification itself, on different terms to commercial and open-source software developers. One goal

[5] A description of the UNH Inter-operability lab, and a list of affiliated standards consortia can be found at https://www.iol.unh.edu/
[6] HDMI licensing terms are available online at http://www.hdmi.org/manufacturer/terms.aspx

of the certification program is to preserve inter-operability by limiting other firms' ability to "fork" or hijack the Java standard. For example, Bresnahan (2002) describes how Microsoft worked to "embrace and extend" Java by linking it to proprietary Active/X technologies that were tightly integrated with Windows and Microsoft Office.[7] At the same time, Oracle's commercial license is clearly an effort to capture rents by restricting platform access for specific types of users.

A final approach that SSOs may take to encourage broad coordination on a shared technology platform is to reduce the cost of implementation. One simple form of cost reduction is to make access to specifications inexpensive. For example, many SDOs historically funded their operations by selling copies of standards. However, the SSOs that govern key technology platforms, such as the European telecommunications Standards Institute (ETSI) and the IETF, increasingly fund operations from conference and membership fees, and make their technical specifications freely available.

Providing reference implementations that illustrate how to incorporate standardized functionality into new products may also lower the costs of coordination. Thus, many SSOs use different publication "tracks" to distinguish between the normative standards that receive a formal SSO endorsement, and various types of complementary information, such as test suites and reference implementations. For example, the IETF has a standards-track and nonstandards-track publication process. ETSI distinguishes between a normative Technical Specification (TS) and a more informative Technical Report (TR).

Provision Problems: Creating Standards

In Ostrom's framework, CPRs face the "supply side" provision problem of constructing and maintaining a shared resource. The parallel problem for SSOs involves selecting new standards and upgrading old ones. In both settings, rules for shared resource provision must strike a balance between free-rider problems and rent-seeking behavior.

Free riding is a potential problem in the supply of any public good, and economists have long recognized the issue in the context of standards development. For example, Weiss and Sirbu (1990) study free-rider problems in the development of the 10BaseT Ethernet standard. By matching product catalogs to meeting rosters, they found that only 71 out of 245 implementers participated in technical committee meetings, with even fewer making meaningful contributions.

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[7] More recently, Oracle has alleged that Google's Android operating system successfully forked the Java developer community by copying the structure of Java's application programming interfaces, but producing code that will not run on other Java compatible devices (see the "Opening Brief and Addendum" filed by Oracle America, Inc. in *Oracle of America, Inc. vs. Google, Inc.*, U.S. Court of Appeals for the Federal Circuit, Case No. 2013-1021.)

One solution to free rider problems in SSO participation is to rely on large firms, since they internalize more benefits from improving the overall platform. Some of the largest contributors to IT standardization are companies like IBM, Intel and Cisco who benefit directly from increased demand for products that implement new standards, and indirectly through the increased supply of complements. Even for these firms, however, the costs of standardization can be large. For example, Hewlett Packard and Sun Microsystems each belonged to more than 150 SSOs in 2003, and IBM reportedly spent $500 million on standards-related activities in 2005.[8]

A second solution to free rider problems is to harness participants' interest in having their own technology adopted as an industry standard. The benefits from inserting proprietary technology into a shared standard can include faster product development lead times, avoiding redesign costs, compatibility with proprietary complements, smoother migration of an existing installed base, and royalties from licensing standard essential patents (SEPs).[9] Unfortunately, these private benefits of SSO participation are often tied to specific choices about technology and access rules. Firms' preferences often vary depending whether their proprietary complements are micro-processors, routers, operating systems or advertisements. Thus, Farrell and Simcoe (2012a) model standard setting as a rent-seeking game where participants hold out for selection of their preferred technology.

In practice, SSOs use several organizational tools to balance the costs of free riding and rent seeking. One approach is to limit initial participation to a small number of firms whose interests are well aligned. For example, the founding members of the USB, Bluetooth and HDMI consortia were a relatively small set of firms that agreed on both technical specifications and licensing terms prior to releasing the initial specification. As described above, this works well if the initial "club" contains large or influential firms, since a less open process may reduce the legitimacy that comes from due process and broad participation.

Consortia that limit initial participation in standards development sometimes take their specification to an SDO for certification at a later date. This hybrid approach may limit free riding and rent seeking in the early stages of standards development, while preserving the benefits of a more formal consensus process at later stages. Recent studies by Leiponen (2008) and Meniere and Pohlmann (2012) suggest that "pre-standardization" within small consortia has become quite common in some technology sectors. On the other hand, a proliferation of

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8 See "Major Standards Players Tell How They Evaluate SSOs" (Andrew Updegrove, Consortium Standards Bulletin, http://www.consortiuminfo.org/bulletins/pdf/jun03/survey.pdf), and Chiao, Lerner and Tirole (2007) citing Forbes magazine.

9 These private benefits of participation are often overlooked by those who argue that "de-valuing" SEPs might cause a broad decline in SSO participation (e.g. Brief of Amicus Curiae Qualcomm, Inc. in support of reversal in *Apple Inc. vs. Motorola, Inc.* U.S. Court of Appeals for the Federal Circuit, Case No. 2012-1548.). In fact, several SSOs, W3C and VITA, have switched to royalty-free licensing or *ex ante* disclosure without experiencing a collapse in participation (Contreras 2011).

consortia may lead to parallel efforts, and potentially protracted stalemates in the final push for a common standard. Large SSOs with many technical committees often try to strike a balance between promoting experimentation and facilitating the development of competing standards by convening a governing board that must approves all new working groups.[10]

Government intervention offers a final solution to problems of free-riding and rent-seeking in standards provision. For example, Farrell and Shapiro (1992) describe how, after years of delay, the FCC intervened to choose a specific standard for digital television transmission. More recently, the National Institute for Standards and Technology (NIST) initiated the Smart Grid Inter-operability Panel (SGIP) to identify a suite of protocols that would enable a “smart” electrical infrastructure. In general, government intervention in private standard setting may be productive when there are large gains from coordination and little scope for innovation or uncertainty about the merits of competing alternatives. However, government intervention in highly technical standard-setting processes can pose problems including lack of expertise, regulatory capture, and lock-in to the government-supported standard.

Provision Problems: Regulating Access

In Ostrom’s framework, demand side provision problems involve “regulating withdrawal rates so they do not adversely effect the resource itself.” The parallel problem for shared technology platforms is to regulate efforts to exclude potential implementers or limit compatibility. SSOs solve these provision problems by facilitating credible commitments, and organizing efforts to monitor and sanction those who behave opportunistically.

Credible Commitments: SSOs facilitate two types of credible commitments. First, they provide a mechanism for firms to delegate control over key interface technologies, which might otherwise be manipulated to exclude competitors. Secondly, they provide a formal process for securing commitments to license essential patents on reasonable and nondiscriminatory (RAND) terms.

By ceding control of their technology to an SSO, firms may commit to *ex post* competition, since they can no longer exclude future rivals by denying or degrading the benefits of inter-operability. Farrell and Gallini (1988) show how this can increase long-run profits, even for a monopolist, if *ex post* competition solves a hold-up problem that would otherwise depress end-user demand, or encourages entry by suppliers of complementary goods.[11]

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[10] At the IETF this group is called that Internet Engineering Steering Group, while the IEEE has the Standards Board (SASB).
[11] In this regard, SSOs are just one type of commitment device. Gawer and Henderson (2007) provide a detailed case study of how Intel uses aspects of organizational design to make similar commitments.

In practice, the credibility of any commitment to *ex post* competition depends upon a firm's role in the governing the SSO that will manage the shared technology. Thus, efforts to secure SDO certification for consortia standards are sometimes controversial. For example, Microsoft issued a formal complaint when Sun submitted the Java specification to the International Organization for Standardization (ISO) to have it certified as a Publicly Available Specification (PAS), partly because of the way in which Sun proposed to retain control of Java trademarks and licensing.[12] Several years later, observers complained that Microsoft abused the same process to obtain ISO certification of its Open Office XML formats.

SSOs can also facilitate credible commitments to license patents that would be infringed by any compliant implementation of a standard. There is a large legal and economic literature on SSO intellectual property policies that describes how the details of SEP licensing commitments vary across SSOs (e.g. Lemley 2002; Farrell et al 2007; Simcoe 2012b; Bekkers and Updegrove 2012). Some consortia, such as W3C and Bluetooth SIG, require all implementers to grant a royalty-free license to any firm that will grant a reciprocal license to their own SEPs. Other consortia, such as HDMI and the HDBaseT Alliance have a "Promoter/Adopter" model where the founding promoter-members offer a royalty-bearing license with specific terms and conditions, and any adopters who take that license commit to a royalty-free grant-back of heir own SEPs. Some SSOs, such as IEEE and VITA, encourage or require individual members to disclose specific license terms and conditions prior to endorsing a standard. However, the most common form of licensing commitment, and the minimum required by most SSOs, is a promise to license SEPs on "(fair) reasonable and non-discriminatory" (FRAND or RAND) terms and conditions, perhaps subject to reciprocity on the part of the licensee.

While the precise meaning of FRAND is hotly disputed, the consensus view of economists is that these commitments are meant to encourage implementation by preventing *ex post* hold-up (i.e. royalties that reflect the costs of switching to alternative technologies after a standard is widely adopted) and mitigating royalty stacking when there are multiple SEP holders.[13,14] Compared to the specific *ex*

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[12] For example, see the document "Microsoft Comments to the US Technical Advisory Group JTC 1" at ftp://ftp.microsoft.com/developr/drg/JTC1/finaljt2.htm.

[13] Many SSO intellectual property policies have explicit language indicating that the goal of these policies is to promote adoption. For example, see the ISO/IEC/ITU Common Patent policy, which states that "a patent embodied fully or partly in a Recommendation… must be accessible to everybody without undue constraints. To meet this requirement in general is the sole objective [of the policy]." (http://www.iec.ch/members_experts/tools/patents/patent_policy.htm)

[14] In the ongoing smart-phone patent disputes, licensors typically take the position that FRAND commitments only require them to grant a license to any willing licensee, while prospective licensees argue that FRAND implies a waiver of the right to seek injunctive relief and a commitment to terms and conditions that reflect the ex ante incremental value of patented technology compared to alternatives available at the time of standardization, and taking account of the entire "thicket" associated with a particular standard or product. For an overview of this debate, see Swanson and

ante commitments described above, FRAND commitments provide SEP holders with flexibility to craft detailed licensing terms and conditions *ex post*, often in the context of a broad portfolio cross-license that covers both essential and non-essential patents. On the other hand, by failing to articulate a clear FRAND standard, SSOs may invite hold-up and litigation. Simcoe, Graham and Feldman (2009) found that patents declared to SSOs as potential SEPS were 5 to 7 times more likely to be litigated than a randomly matched sample of same-age patents from similar firms and technology classes.

The licensing commitments required by many SSOs are similar to certain aspects of open-source licensing (Lerner and Tirole 2002). In particular, many SSOs and most open-source communities will only license an implementer that is willing to license to their own essential patents (or copyrights). However, there are also several differences between the SSO and open-source approach. First, as described above, many SSOs allow a price above zero.[15] Second, reciprocity in the SSO context need not be symmetric. For example, in Promoter-Adopter consortia, implementers typically sign a royalty-bearing license that includes payments to the Promoters as well as a royalty-free grant-back. Finally, while many open-source licenses require a royalty-free commitment to all future implementers, the reciprocity and grant-back conditions allowed by many SSOs can be bilateral.[16]

Monitoring and Enforcement: To enhance the credibility of the contractual commitments described above, many SSOs support efforts to monitor and sanction opportunistic behavior. However, sanctions are often more difficult for shared technology platforms than CPRs. Where restricting access to a CPR is a natural form of punishment that mitigates the underlying problem of over-consumption, excluding users from a shared technology platform is costly, since it reduces the size of the addressable installed base.[17]

SSOs' compliance testing and certification activities are one example of monitoring and enforcement. As described above, these programs may help prevent forking, or selective implementation of only the functionality that benefits a particular vendor. The sanctions used by most certification programs are based on denying access to trademarks and logos, such as Bluetooth or Wi-Fi, and are therefore particularly effective in settings where consumers value those brands.

Baumol (2005), Farrell et al (2007), Layne-Farrar et al (2007), Miller (2007), and the U.S. Federal Trade Commission (2011).

[15] While a number of open source advocates claim that non-zero prices lead to fundamental incompatibilities between FRAND and GPL, Kesan (2011) suggests that the majority of open-source licenses can accommodate implementation of standards covered by FRAND commitments.

[16] Some firms have tried to unilaterally strengthen the commitment to third parties in the SSO process by making their own licensing commitments conditional on a GPL-like reciprocal grant-back that extends to all prospective implementers. (e.g. see Google's IPR declaration to IETF at https://datatracker.ietf.org/ipr/1649/).

[17] Much of the angst over Microsoft's alleged efforts to "embrace and extend "various web standards reflects the fact that excluding them from the underlying platform is simply not practical.

SSOs also monitor and enforce platform-access rules through their intellectual property policies. Rules requiring SSO participants to disclose potential SEPs before a specification is finalized and endorsed provide on type of centralized monitoring. The details of these disclosure policies vary across SSOs. For example, the IETF requires disclosure of specific patents unless the owner is willing to make a royalty-free licensing commitment. At the IEEE, disclosures need not list specific patents, but do trigger an obligation to provide at least a FRAND licensing commitment.

Disclosure polices are supported by two types of enforcement. First, if patents are disclosed but the owner is unwilling to provide a licensing commitment, most SSOs will attempt to work around the patent or withdraw the standard. This can be a potent threat *ex ante*, since many SEPs may have little value but for their inclusion in a standard. But threatening to withdraw an SSO endorsement may have little influence *ex post*, when a standard is widely adopted, since by then implementation costs are sunk and switching to an alternative technology is not a viable option. Thus, antitrust authorities provide a second layer of enforcement for IP disclosure rules. Specifically, the U.S. Federal Trade Commission has brought action against several firms for failing to disclose patents to an SSO and then seeking a royalty-bearing license from implementers.[18]

In contrast to the centralized monitoring and enforcement of disclosure rules, many SSOs rely on decentralized monitoring and enforcement of licensing commitments. For SSOs that do not require a commitment to specific terms and conditions *ex ante*, centralized monitoring and enforcement of licensing commitments would pose a number of practical challenges. First, many bilateral license agreements cover a broad range of technologies, making it hard to apportion the value of any deal to a particular set of SEPs. Second, most license agreements are confidential, so it is hard to observe the prevailing price for a bundle of SEPs. Finally, SSOs may be reluctant to intervene in disputes between members, or incur any antitrust risk that could arise from facilitating discussions about licensing terms.

Unfortunately, decentralized monitoring and enforcement of SSO licensing commitments also has several drawbacks. First, decentralization may lead to under-provision of enforcement. An individual licensee will have weak incentives to challenge SEP-holders’ proposed rates if the benefits of a victory in court also accrue to competitors. And the problem is compounded if proposed royalties can easily be passed one to consumers. Second, while decentralized monitoring works well for relatively symmetric firms – since that leads to a bilateral threat of hold-up – SEPs are increasingly owned by vertically dis-integrated inventors and other non-practicing entities who are not concerned with the threat of an injunction against their own products. Finally, decentralized monitoring relies on

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[18] See Dell Computer Corp., 121 F.T.C. 616 (1996); Union Oil Co. of Cal., FTC Docket No. 9305, and Rambus, Inc., FTC Docket No. 9302.

courts or regulators to adjudicate disputes and enforce sanctions. While this may work well if commitments are clearly specified, litigation can be uncertain, costly and time-consuming activity if SSOs provide little guidance about the overarching objectives or intended consequences of FRAND commitments.

To summarize the argument thus far, CPRs and shared technology platforms face the symmetric problems of commons and anti-commons. Thus, where CPRs regulate access to prevent over-consumption, SSOs encourage coordination and work to prevent over-exclusion. Nevertheless, both settings feature institutions for collective self-governance that face similar problems of free-riding and rent-seeking in resource provision, facilitating credible commitments, and designing rules for monitoring and enforcing sanctions against opportunistic platform users. Moreover, just as Ostrom found considerable variation in the design of local institutions for governing CPRs, we can observe substantial heterogeneity in the rules, procedures and internal organization of SSOs.

Design Principles for Digital Platforms

While Ostrom cautioned against one-size-fits-all policy prescriptions for CPRs, she also found that long-enduring institutions for CPR self-governance conformed to a set of eight "design principles." This section of the paper adapts these best practices for shared technology platforms, and asks whether the current ICT standardization infrastructure conforms to those rules.

Table 1 presents Ostrom's original design principles, along with a set of platform design rules that account for the distinction between commons and anti-commons. The original principles are divided into two groups. The first four rules address problems of participation and organization design, and translate easily from CPRs to SSOs. The second group deals with problems of access, exclusion, monitoring and enforcement, and must be modified to address the distinction between commons and anti-commons.

Table 1

General Principle	*Ostrom's CPR Design Rule*	*Design Rule for Shared Technology Platforms*
	Organization and Provision	
Local Adaptation	*Appropriation rules restricting time, place, technology and/or quantity of resource units are related to local conditions and to provision rules requiring labor, material and/or money.*	*Rules restricting implementation (e.g. through compliance testing or access prices) are related to the "local" industry environment, and to provision of underlying technology or a proprietary installed base.*
Collective Choice	*Most individuals affected by the operational rules can participate in modifying the operational rules.*	*Implementers affected by operational rules can participate in modifying them.*

Legitimacy	*The rights of appropriator to devise their own institutions are not challenged by external government authorities.*	*SSOs can design their own organizations and are generally not challenged by external government authorities.*
Nested Hierarchies	*Appropriation, provision, monitoring enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.*	*Implementation, standard setting, compliance testing, certification, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.*
Monitoring and Enforcement		
Clear Boundaries	*Individuals who have rights to withdraw resource units from the CPR must be clearly defined, as must the boundaries of the CPR itself.*	*Rights to exclude implementers from using a standard are clearly defined, as are the boundaries of the standard itself.*
Accountable Monitoring	*Monitors, who actively monitor CPR conditions and appropriator behavior, are accountable to the appropriators or are the appropriators.*	*Monitors who actively audit implementation and exclusion from shared technology platforms are accountable to implementers and platform users.*
Graduated Sanctions	*Appropriators who violate operational rules are likely to be assessed graduated sanctions by other appropriators, by officials accountable to those appropriators, or by both.*	*Implementers and technology contributors who violate rules regarding compatibility or exclusion are likely to be assessed graduated sanctions by SSOs, implementers or platform users.*
Conflict Resolution	*Appropriators and their officials have rapid access to low cost local arenas to resolve conflicts.*	*Implementers and users have access to low-cost local arenas to resolve conflicts.*

Local Adaptation

As described above, there is substantial heterogeneity in the organization of SSOs. Some consortia are little more than licensing commitments linked to a particular technology, while organizations like ISO set global standards for a wide range of industries and technologies. Between those extremes are SSOs that govern significant platforms, such as the IETF and ETSI, and others that focus on a single standard or small market niche. They may have different membership rules, decision-making processes, and intellectual property policies. Some SSOs run branding and certification programs and others focus purely on technical specification development.

The optimistic view of this heterogeneity is that it reflects experimentation and evolution (Cargill 2001), or perhaps “healthy standards competition” (Greenstein 2009). Ongoing experimentation can often produce a good fit between the rules platform governance and salient characteristics of the local environment. On the other hand, it is not obvious that “free entry” and competition between SSOs will produce efficient governance. For instance, the proliferation of SSOs increases the potential for forum shopping, as emphasized by Lerner and Tirole (2006).

For the most part, U.S. public policy adheres to the idea we should avoid a "one size fits all" policy towards SSOs. For example, while regulations like OMB A-119 (governing the use of voluntary standards in public procurement) may contain language favoring accredited SDOs, there is normally a provision to allow for consortia or even proprietary standards in cases where relying on SDO specifications would be "impractical."

Collective Choice

Participation rights vary across SSOs. In general, SSOs face a trade-off between ensuring broad participation to enhance the legitimacy of their final recommendation, and restricting decision-rights in order to prevent rent-seeking and provide strong incentives for platform provision. Thus, accredited SDOs adhere to strong due process and balance of interest rules that allow any interested party to have a say in the process, while many smaller consortia limit the voting and participation rights of non-founding or non-paying members.

Nevertheless, as a general rule, SSOs are controlled by their members. While large or successful SSOs may be slow to change, their operational rules do evolve over time. For example, within the last ten years there have been substantial changes in the intellectual property policies of the W3C, IEEE, VITA and OASIS. Most of these changes are proposed by a rules committee and approved by the voting members of the SSO in a process that is broadly consistent with Ostrom's design principle of collective choice. Moreover, when a firm feels dis-enfranchised by existing SSOs, it is often possible to create a rival institution and compete with the standards of the incumbent platform provider.[19]

Legitimacy

While a government may occasionally intervene to select a particular standard, as in the case of digital broadcasting, regulators rarely challenge SSO legitimacy. As a form of horizontal cooperation, SSOs sometimes elicit antitrust scrutiny.[20] However, the U.S. SDO Advancement Act of 2004 provides that SSO activities will be evaluated under a rule of reason standard, and exempts registered SDOs from treble damages in antirust lawsuits. The European Unions Horizontal Cooperation Guidelines also suggest that SSOs will be typically viewed as pro-competitive forms of colaboration.

Nested Hierarchies

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[19] Lerner and Tirole (2007) assume free-entry in their model of the SSO industry.

[20] For example, the American Society of Mechanical Engineers was found guilty of antitrust violations following a private lawsuit when a committee chairman was found to be acting in the interests of his employer. See *American Society of Mechanical Engineers v. Hydrolevel Corporation*, 456 U.S. Supreme Court 556 (1982).

Within and between SSOs, there is often a clear hierarchy in terms of the collaborative relationship between various organizations. At the bottom of this hierarchy is the technical working group. Large SSOs may have hundreds of individual committees or working groups in operation at any one time. The next layer is the SSO itself. For accredited SDOs, the next layer is the regional standards organization such as ANSI, or an international equivalent, such as BSI in Great Britain or DIN in Germany. The top layer in this system are the "Big I" international SDOs: ISO, IEC and ITU.

While standards consortia exist outside the multi-layer accredited SDO model, they can use alternative paths to have their specifications become international standards. For example, some standards go through ISO's PAS process. Other consortia, such as Bluetooth SIG contribute their technology to an SDO.[21] Finally, many SSOs also have close (if not hierarchical) links with complementary institutions such as promoter groups and patent pools.

Clear Boundaries

Ostrom found that it was important to have clear rules and definitions regarding who was allowed extract a given amount of resource from a CPR, at what time and place, and to have a clearly defined boundary for the CPR itself. These clear boundaries facilitate a level of "contractual specificity" that simplifies the problems of monitoring, enforcement and dispute resolution. Because standards are non-rival, shared technology platforms are less concerned with defining who has rights to adopt a standard. But it is important for SSOs to provide clear rules regarding the rights to exclude, lest forking or a thicket of license-seekers lead to under-use of the platform.

Compliance testing and certification help to clarify the technical boundaries of a platform and ensure individual implementers provide reciprocal compatibility benefits to other platform users. Some intellectual property policies also provide clearly defined rights to exclude – particularly those consortia that use up-front licensing as a condition of platform access. However, SSOs that rely on FRAND commitments without articulating a clear set of principles for adjudicating disputes arguably provide unclear boundaries.[22]

While clarifying the intent of FRAND commitments would do much to clarify the boundaries of shared technology platforms, it is not a perfect solution to the larger challenge of ensuring access. For example, firms that do not participate in SSOs are not bound by licensing commitments, and SEPs are just one part of

[21] Bluetooth is also known as IEEE 802.15 because that is the IEEE wireless personal area networking committee that standardizes Bluetooth technology.

[22] Many SSOs would argue that FRAND policies also provide clear boundaries, since they are based on the principle that no one has a right to exclude implementers. However, from an economic standpoint access fees are a form of exclusion, since some user is always at the margin.

the broader patent thicket (albeit an important one). Thus, providing clear boundaries may sometimes require SSOs to collaborate with other private institutions, such as patent pools, or with policy-makers in antitrust agencies, courts and the patent office.

Accountable Monitoring

The compliance testing and certification programs run by many SSOs are one form of monitoring by agents who are directly accountable to the community of implementers. Plug-fests and inter-operability labs provide an alternative type of monitoring. While the plug-fests and other forms of decentralized inter-operability testing rarely carry sanctions, SSOs can often harness participants' self-interest to achieve compatibility.

SSOs also use patent disclosure rules as a monitoring device that is backstopped by both internal and external sanctions. Monitoring of licensing commitments, on the other hand, is typically left to implementers. FRAND licensing commitments present a particularly difficult problem, since centralized monitoring is often impractical, and individual licensees may have weak incentives to bargain fiercely if "nondiscriminatory" licensing implies that competitors will face similar royalties. One step towards a more effective regime of decentralized monitoring and court enforcement would be for SSOs to clarify the specific intent of FRAND commitments.

Graduated Sanctions

In the CPRs studied by Ostrom, appropriators often used a variety of low cost sanctions to bring those who violated rules back into line with community norms. She contrasted the gradual escalation found in many CPRs with the "trigger strategies" used in many repeated-game models. While SSOs use a variety of sanctions with different levels of severity, it is hard to find examples of the graduated sanctions that seem common in CPR settings, perhaps because SSOs are more reluctant to withdraw access than CPR-governing institutions.

One form of sanction used by SSOs is to de-certify a product, or deny access to the logos and trademarks associated with a well-known consumer brand. Another type of sanction is exclusion from an SSO.[23] In principle, some SSOs will withdraw their endorsement of a standard if a SEP-holder will not commit to FRAND licensing, though it seems rare in practice. Finally, in cases where firms fail to disclose SEPs and then seek a royalty-bearing license, antitrust agencies may intervene on behalf of implementers.

Conflict Resolution

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[23] For example, following a new technical contribution, the W3C patent policy allows firms a short time-window to make royalty-free licensing commitments or withdraw from the relevant technical committee.

Technical committee meetings, plug-fests and interoperability labs provide low cost forums for SSO participants to resolve conflicts over technical issues, compliance and forking. However, conflicts over intellectual property often go to court, and the resulting litigation may be costly and time-consuming. While some observers have proposed that SSOs could ask members to commit to an alternative dispute resolution process in the event of a licensing dispute, this practice remains unusual.[24]

Institutional Change

While SSOs largely conform to the design principles described above, one exception may be in providing intellectual property rules that establish clear platform boundaries. This section briefly describes what one of the most significant changes in ICT standard-setting in the last two decades – the emergence and growth of the consortium model – and asks what lessons it might hold for the ongoing debates over intellectual property policies.

As shared platforms increasingly displaced monopoly platform leadership (e.g. Bresnahan and Greenstein 1999), a number of observers began to voice concerns that established SDOs were struggling with the demands of ICT standardization. For example, David and Shurmer (1996) and Cargill (2001, 2002) described the challenges that ICT standard setting posed for incumbent organizations as of the early 1990s. First, SDOs had little experience with "anticipatory" standardization, and their ponderous procedures were often poorly adapted to the rapidly changing ICT landscape. Second, increased stakes could exacerbate rent-seeking, particularly in SDOs where consensus meant complete unanimity. Third, technological converge may blur distinctions between industries and sectors that delineated the existing division of labor among SDOs. Finally, changes in industry structure, such as the increasing vertical dis-integration of innovation and production, might upset established political arrangements within SDOs and technical committees. For all of these reasons, many observers suggested that SDOs could be displaced by a more nimble and narrowly focused set of standards consortia

There has undoubtedly been a surge in the number of consortia since the early 1990s, with organizations such as the IETF, W3C and OASIS emerging to govern very significant information parts of the ICT infrastructure.[25] Recent research also supports the idea that increased economic stakes will produce coordination delays in technical decision making (Simcoe 2012), and that vertical disintegration poses challenges for traditional cross-licensing models with respect to SEPs (Simcoe, Graham and Feldman 2009). However, the ongoing relevance of institutions such as ETSI, IEEE and ISO/IEC suggest that any

[24] For example, see Kuhn, Scott-Morton and Shelanski (2013).
[25] Farrell and Simcoe (2012b) also report a steady growth in the number of new consortia formed, base on analysis of the list of SSOs maintained by Updegrove at www.consortiuminfo.org.

reports of the demise of the traditional SDO were premature.

Starting in the 1990s, SDOs responded to the challenges of ICT standard setting in a variety of ways. Some organizations streamlined their administrative processes.[26] Others, including ISO/IEC, CEN and CENELEC relaxed the definition of consensus from unanimity to a two-thirds supermajority. Many SDOs found ways to work together with consortia. One example of collaboration is the ISO PAS process described above. Another example is the creation of 3GPP, a joint venture that combines six regional telecommunication SDOs, and a host of smaller consortia that participate as "Market Representation Partners."[27]

What lessons does the evolution of SDOs hold for current debates over SSO intellectual property polices? First, "free entry" into standard setting provides an important source of pressure for change. Just as the emergence of consortia pushed traditional SDOs to re-think many of their rules and procedures, we might expect the intellectual property polices of new consortia to serve as a model for reform at existing SSOs. There may already be sigs of such a shift. For example, ISO recently announced that it will conduct a formal review of its intellectual property policy, and the IEEE is examining the idea of working more closely with patent pools.[28]

A second lesson is that change is unlikely to produce a uniform policy. Although securing credible licensing commitments is a general problem, the members, markets and technologies of different SSOs will seek different solutions. While an increasing number of consortia specify license terms and conditions *ex ante*, this approach may not suit larger SSOs that wish to preserve flexibility to take different approaches for different standards, and have a strong desire to stay out of member conflicts.

A third prediction is that solutions may emerge through cooperative arrangements among different institutions. In some cases, consortia may develop explicit *ex ante* licensing arrangements (such as the Bluetooth pool) in advance of submitting a specification to an existing SDO. Another possibility is that SSOs may become more closely involved in *ex post* collective licensing efforts, such as patent pools. For example, DVB administers a collective license, and IEEE has set up an exploratory effort to establish pools for some of its standards.

Finally, some observers have suggested that there is increased need for a layer of institutions that can integrate the work of multiple SSOs for specific

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[26] For example, the 1999 IEC Annual Report claimed that 20 percent of standards were developed in less than three years, "in direct response to industry requests that we speed up the standardization process." (By comparison, the 1991 Annual Report indicated a mean development time of 87 months (page 6)).

[27] A list of 3GPP partners is available at http://www.3gpp.org/The-Partners. Of course there is still an occasional turf battle between an SDO and closely related consortium. For example, Besen and Sadowsky (forthcoming) describe a recent conflict between ITU and IETF over Internet governance.

[28] The announcements can be viewed at http://standards.ieee.org/news/2012/802pat.html

applications. Examples include the Smart Grid Interoperability Panel (SGIP) and the OneBlu patent pool, which incorporates patents for a variety of hardware, software and media standards used in players of CD, DVD and Blu-ray discs.[29]

Conclusions

Compatibility standards define the architecture of shared technology platforms that are often governed by a broad community of users. The resulting collective action problem resembles self-governance for natural resources. This paper extends Elinor Ostrom's framework for analyzing self-governing CPRs to the parallel problem of creating standards for technical inter-operability. This approach to leads to a more encompassing view of SSOs that accounts for the various perspectives advanced within economics, including SSO as certifier, as bargaining forum, as catalyst for collective licensing, and as forum for cooperative R&D.

Both SSOs and CPRs exhibit substantial heterogeneity, often reflecting variation in their natural, industrial or technological environment. Consequently, Ostrom advocates for a nuanced approach to public policy that resists any one-size-fits-all approach to regulating CPRs. The same lesson applies to SSOs, and is consistent with the general stance taken by U.S. innovation policy.

At the same time, applying Ostrom's eight design principles to shared technology platforms suggests that many SSOs could go further to define clear boundaries and mechanisms for monitoring and enforcing licensing commitments. Potential solutions to the SEP-licensing problem include greater reliance on explicit *ex ante* terms and conditions (as with many consortia), greater efforts to facilitate *ex post* collective licensing (as with patent pools), and articulating a clear set of principles for interpreting FRAND commitments in the event they must be enforced. There are already signs that evolutionary pressures may be pushing SSOs to experiment with and adopt several of these alternative approaches.

[29] Additional information on these programs is available at http://www.nist.gov/smartgrid/ and http://www.one-blue.com/

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