The Rules of Standard Setting Organizations:

An Empirical Analysis

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This paper empirically explores standard-setting organizations' policy choices. Consistent with Lerner-Tirole (2006), we find (a) a negative relationship between the extent to which an SSO is oriented to technology sponsors and the concession level required of sponsors and (b) a positive correlation between the sponsor-friendliness of the selected SSO and the quality of the standard. We also develop and test two extensions of the earlier model: the presence of provisions mandating royalty-free licensing is negatively associated with disclosure requirements, and the relationship between concessions and user friendliness is weaker when there is only a limited number of SSOs.

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1. Introduction

The economic importance of technological standards has grown tremendously over the past two decades. The growing recognition of the importance of the standardization process has been attributed in large part to the growth of the information technology and communications industries, for which standards are critical. At the same time, there has been substantial flux among these organizations: for instance, over the past 15 years, consortia and informal standard-setting bodies have in many cases supplanted formal national and international standard development organizations (Cargill (2002)).

Because commercial stakes attached to standards and patents have become so important, the adoption of technical approaches covered by specific patents, the requirement of backwards compatibility with earlier technologies, and the relative emphasis on cost and performance have all been highly contentious issues. Unsurprisingly, the financial resources devoted by firms to standardization and patenting has increased sharply.[1] And as discussed in more detail below, firms' strategic behavior in standards-setting organizations has frequently been the subject of litigation in recent years.

Despite their growing role, standard-setting organizations (SSOs) have attracted remarkably little empirical attention from economists. This paper seeks to address this gap by investigating the relationship between these organizations' characteristics and their policies governing the disclosure and licensing of intellectual property such as patent awards.

Lerner and Tirole (2006) analyze forum shopping by technology sponsors. The basic idea is that the sponsor of an attractive technology can afford to make few concessions (such as royalty-free licensing) to prospective users and to choose an SSO that is relatively friendly to his cause. The model thus predicts a negative relationship between the extent to which an SSO is oriented to technology sponsors and the concession level required of sponsors, as well as a positive association between the sponsor-friendliness of the selected SSO and the quality of the standard.

We extend this model in two ways. First, introducing disclosure policies, we show that a higher licensing price should be associated with more disclosure. Second, we show that in settings where there are only a limited number of SSOs, the relationship between concessions and user-friendliness may not hold: Sponsor-friendly SSOs may demand substantial concessions in order to attract weak standards; by contrast, user-friendly SSOs may make weak demands so as to appeal to sponsors with stronger technologies. This suggests that the relationship between concessions and user friendliness is likely to be weaker when there are fewer SSOs.

[1] Jaffe and Lerner (2004) document that patent filings and litigation have increased approximately three-fold in the past two decades. IBM's standard-development efforts are estimated to have totaled one half-billion dollars in 2005 (http://www.forbes.com/2005/09/26/ibm-software-investments-cz_qh_0926ibm.html (accessed March 30, 2006).

To test these predictions, we built the first database of SSOs. Combining information from the SSOs' web sites, records of standard-setting bodies, and information collected from surveys and interviews, we compiled a database of nearly 60 bodies.

Our results are largely consistent with theoretical predictions:

- First, we find a negative relationship between the SSOs' orientation towards sponsors and the strength of the concessions they demand. This significant negative relationship continues to hold even when we control for industry effects.
- Second, the data reveal a statistically significant association between sponsor-friendliness and the maturity of the technological sub-field in which the standard is located, which we suggest should be a proxy for attractiveness.
- Third, we find that the presence of a provision mandating royalty-free licensing is negatively associated with the presence of a disclosure requirement, while weaker "reasonable-and-non-discriminatory (RAND)" licensing requirements are strongly associated with such a provision.
- Finally, when we divide the SSOs into those with above and below the median number of other SSOs in their technological sub-field, we find that the relationship between user friendliness and concessions is considerably tighter among SSOs located in classes with many other organizations.

The plan of this paper is as follows. Section 2 discusses strategic interactions between firms during standardization. The related literature is reviewed in Section 3. Section 4 presents the theoretical framework. The data are discussed in Section 5. Section 6 presents the empirical analysis. The final section concludes the paper.

2. Strategic Interactions and Standard-Setting Bodies

Coordination through standardization frequently has substantial economic benefits. These include larger markets with greater economies of scale and the greater ability to sell complementary goods. Standards can emerge in a variety of ways. First, *de facto* standards emerge as firms offer competing, incompatible technologies and consumers gravitate to a particular technical solution: e.g., the emergence of the Microsoft operating system. Second, some *de jure* standards are selected by government agencies, as was done, for instance, by the United States in the context of high-definition television (Farrell and Shapiro (1992)). While government standard setting is a fascinating topic in its own right, the very different institutional environment and incentives suggest that it should be analyzed separately. Throughout this paper, therefore, we will focus on the *de jure* standardization process through SSOs organized by private parties.

The complexity of the decision-making process and the impact of standards design on firm profitability can make the standardization process intensely competitive:

- Standards are frequently formed at an early stage of a technology's evolution. In many cases, there are a variety of promising alternatives among which the standard-setting body must choose. These alternatives' relative virtues may still be uncertain.

- Being included or excluded from an important standard can have a substantial impact on a firm. For instance, having one's intellectual property deemed essential to a new standard can help insure a steady stream of licensing revenue in future years. A standard that demands backwards compatibility can insure ongoing revenues for a legacy product for many years.

As a result, established and new firms alike are willing to devote substantial effort to the standardization process. Standard-setting bodies have established a variety of rules to help adjudicate this process. Industry observers often distinguish between traditional standards development organizations, which often are open to all willing participants and have detailed, often cumbersome procedures for adopting new standards, and special interest groups, which are often small, invitation-only bodies which can move rapidly to a consensus. Despite the frequently ponderous pace at which traditional standards-development organizations move, they often perceived to provide a more effective "stamp of approval" than special interest groups dominated by technology sponsors. Looking more generally across standard-setting bodies, it is clear that these organizations fall along a spectrum, with some bodies being more oriented towards technology sponsors and others that reflect more the perspectives and concerns of end users.

Because there are typically multiple technological approaches to the same problem, standard-setting groups frequently find themselves in competition, whether with other standard-setting bodies or even with other standard-setting efforts within the same organization. To be sure, these bodies are to a certain extent differentiated, for instance, by end-user orientation, the standardization process followed, and the geographic composition of the membership. But often SSOs face the difficult choice of whether to endorse a standard developed by a different standard-setting body, or instead to proceed with the development of a standard of their own.

A natural question is the extent to which the rules of standard-setting bodies are enforceable. If the commitments that firms make in the standard setting process were not binding, the value of these commitments would be minimal. Three bodies of law are potentially relevant.[2] The first of these is contract law. SSOs often do not require members to sign detailed contracts stipulating their obligations relating to intellectual property. Either the firms are asked to sign general statements agreeing to conform to the organization's rules, or else do not need to sign any statement whatsoever. (Formal policies were quite rare as recently as the early 1990s (Updegrove (2006)).) Furthermore in these agreements, critical phrases—such as "reasonable" and "non-discriminatory"—are typically undefined. As a result of these considerations, contract law is not always the mechanism chosen to enforce SSO's rules.

Fortunately for the workings of SSOs, there are two alternatives. Two doctrines in patent law are particularly relevant. "Equitable estoppel" covers situations where a patent holder leads another party to believe that it will not enforce a patent against him through

[2]This review of legal doctrine is based on Cowie and Lavelle (2002), Lemley (2002) and Mueller (2002).

misleading actions. This doctrine has been used to invalidate suits in instances when SSO members failed to disclose relevant patent holdings. Another doctrine, termed by Lemley (2002) "implied license," covers situations when a firm discloses its patent holdings but then fails to comply with the restrictions on licensing to which it concurred. Once again, the firm's ability to extract substantial damages from other SSO members may be limited.

As a second alternative, the members of the SSO can assert two torts against an SSO member who behaves in an opportunistic manner. Members can claim that the failure to disclose relevant intellectual property is a violation of the anti-monopolization provisions of the Sherman Antitrust Act. Alternatively, they can claim that the failure to comply by the provisions of the SSO is a form of fraud, or misrepresentation.

Most of the cases to date involving technology-based SSOs have revolved around disclosure issues.[3] One much-discussed case involved Dell Computer's patent covering the "VL-Bus" standard (a bus is a mechanism to transfer instructions between a computer's central processing unit and its peripherals). Dell, a leading manufacturer of personal computers, was a member of the Video Electronic Standards Association (VESA), which also included virtually all other major U.S. computer manufacturers. In the early 1990s, the body began considering a design for computer bus architecture that would enable faster graphics displays. VESA approved the VL-Bus standard, which was primarily employed in the 486 family of IBM and "IBM clone" personal computers, in 1992. As part of the approval process, representatives of member companies certified that they knew of no intellectual property that the standard would violate.

Not until after 1.4 million personal computers were sold employing the VL-Bus standard, the FTC alleged, did Dell begin contacting VESA members, and indicating that they were violating a patent that it had obtained in 1991. The FTC claimed that the standard-setting body could have readily adopted an alternative design, had they known of Dell's patents. Dell settled the FTC complaint in November 1995, agreeing not to enforce its patent against manufacturers employing the VL-Bus architecture. The firm also agreed not to enforce any other technology that it had failed to disclose to standard-setting organizations.[4]

Similarly, Rambus had sued three manufacturers of dynamic random access memory (DRAM) semiconductors of violating its patents covering its Sync-DRAM (SDRAM) technology. These manufacturers—Hyundai Electronics Industries, Infineon Technologies, and Micron Technology—counter-claimed, charging the firm with having engaged in fraud and violating the Sherman Act. In particular, they asserted that the company had failed to disclose its patent applications to the standard-setting body in which it was an active member. Rambus had participated in the Joint Electron Device

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[3]There has, however, been at least one recent case involving the interpretation of an SSO's rules regarding licensing of intellectual property (*Broadcom Corp. v. Qualcomm, Inc*., Civil Action no. 05-3350 (MLC), D.N.J., 2005).

[4]http://www.ftc.gov/opa/1995/9511/dell.htm.

Engineering Council (JEDEC) standard-setting body from 1992 to one month after the Dell consent decree was finalized in mid-1996 (when it stepped down). During this period, it only disclosed one patent filing to the group. Rambus' critical SDRAM patent, which had been filed in 1990, was not disclosed to the standard-setting body. Indeed, internal company e-mails referred to the firm's intention not to disclose this filing to the JEDEC group despite its apparent relevance. Furthermore, executives discussed strategies to demand that other manufacturers undertake licenses once the standard had become established. While the initial trial found that Rambus has indeed committed fraud, the Court of Appeals for the Federal Circuit concluded in *Rambus v. Infineon* that Rambus's obligation to disclose pending patent applications under the JEDEC SSO's policy was very narrow, essentially limited to applications for patents that a party wishing to comply with the standard would *necessarily* infringe in order to comply.[5] Since the trial record established clearly that Rambus explicitly modified the language of its patent claims to *try* to cover devices with features that were revealed to Rambus in JEDEC meetings, there can be no doubt that Rambus violated the intent and spirit of the JEDEC policy. In effect, the appeals court did not dispute that Rambus *tried* to commit fraud, but ruled that it did not succeed.

3. Related Literature

Despite the copious research on standards, it is striking how little work has addressed the question of how these organizations are or should be organized. Many of the papers (e.g., Farrell and Saloner (1985)) focus on *de facto* standard setting, where there is no role for an SSO. Alternatively, a number of works, both in economics and political science, have focused on settings where government bodies adjudicate between the desires of different parties about possible standards (e.g., Farrell and Shapiro (1992)).[6] In addition, several papers have considered which settings (e.g., the extent of buyer and seller concentration and product differentiation) are suited to the establishment of standards (for instance, Hemenway (1975)).

The economics literature on SSOs has largely focused on their role as a forum where competitors can resolve conflicts. In Farrell and Saloner (1988), two firms can choose between two incompatible technologies. They can do so by repeatedly talking with each other (when meeting at the SSO), through product market competition (*de facto* standard setting in the marketplace), or through a hybrid between the two approaches. The SSO in their model is a place where the two parties can negotiate, but has no institutional features (e.g., rules governing decision-making or requiring concessions from sponsors). Nor would there be a need for more than one SSO in this setting, since the features of the SSO do not matter. The authors show that the committee process is more likely to arrive at a

[5]*Rambus, Inc. vs. Infineon Technologies AG, et al.*, United States Court of Appeals for the Federal Circuit, 01-1449, -1583, -1604, -1641, 02-1174, -1192 (January 29, 2003).

[6]Besen and Saloner (1989) discuss non-governmental SSOs, but they focus their more analytic discussions—whether entailing the development of new theory or narratives that attempt to relate institutional features to theory—on *de facto* standard-setting activity.

high-value consensus than product market competition, but that it usually takes longer. The hybrid approach is likely to dominate both alternatives.

Farrell (1996) models the standard-setting process as a "war of attrition" between sponsors of two competing standards. Each sponsor, ceteris paribus, prefers her standard to be selected and has private information about its quality. Farrell shows that the higher-quality technology is ultimately selected, but that the delay is a function of vested interests. Reducing vested interests (e.g., by adopting rules that limit the utilization of intellectual property used in standards) reduces delay. Bulow and Klemperer (1999) present, among other innovations, a generalized model in which multiple firms compete to get several technologies included into a standard.

Simcoe (2003) similarly depicts the standard-setting process as a "war of attrition" between multiple parties, each with their own proposed standard. He then corroborates the model using standards considered by the Internet Engineering Task Force. Rysman and Simcoe (2005) stress the importance of SSOs by showing that SSO patents are cited far more frequently than a set of control patents, and that SSO patents receive citations for a much longer period of time. Furthermore, they find a significant correlation between citation and the disclosure of a patent to an SSO, which may imply a marginal impact of disclosure.

Aside from this work, however, empirical work on SSOs has been dominated by case studies. Most relevant to this work is Lehr's (1996) documentation of the intense jockeying between firms in projects at two standard-setting bodies. Sirbu and Zwimpfer (1985) present a case study of X.25, which standardized "packet switching" over public networks. Besen and Johnson (1986) describe seven cases where SSOs reached consensus on broadcast standards. Weiss and Sirbu (1990) examine eleven choices between proposed standards made by standard-setting bodies. An older two-part study (1978 and 1983) by the U.S. Federal Trade Commission also provides numerous examples.

4. The Theory

4.1 Concessions and user friendliness

As in Lerner and Tirole (2006), we explore a setting where the owner of an idea or property must convince potential users of its value. In the bare-bones version of the model, the utility of the users of the technology is $U = a + b + c$, where:

- a is common knowledge and measures the strength of the proposed standard.
- b is unknown to both technology sponsor and users and reflects unobserved quality to users.
- c is the extent of concessions made to users: e.g., requirements to license intellectual property critical to the standard.

We assume that users adopt the standard only if U appears to be positive. That is, we normalize at 0 the users' utility either from adoption of a competing standard or from the *status quo*. The attractiveness parameter a reflects, among other things, the intensity of competition with rival technologies; a technology facing strong competition from alternative potential standards is, ceteris paribus, characterized by a low a. The sponsor's profit, π, is a decreasing and (weakly) concave function of c: $\pi'(c) < 0$ and $\pi''(c) \leq 0$.

The SSO chosen by the sponsor learns b and decides whether to endorse the technology. The SSO's objective function is a weighted average of user and sponsor benefits, $U + \alpha\pi$. Thus, the weighting factor, α, is (the opposite of) user-friendliness. For the moment, we assume free entry for SSOs, so there is a continuum of SSOs with different levels of user-friendliness.

Let $F(b)$ denote the cumulative distribution function. We assume that F has the standard monotone hazard rate property: $f/[1-F]$ is increasing. This property in turn implies that $m(b) \equiv E\left[\tilde{b} \mid \tilde{b} \geq b\right]$ grows with b at a rate lower than 1. Furthermore:

$$m'(b) \equiv \frac{f(b)}{1-F(b)}\left[m(b)-b\right]$$

Timing. We consider the following three-stage game:

(1) The sponsor chooses an SSO, that is α, and a concession c.
(2) The SSO learns b (more generally, it could learn a signal of b), and then chooses whether to recommend the standard.
(3) Users decide whether to adopt the standard.

Formally, the concession c is chosen by the sponsor. However it can be shown that c could alternatively be selected by the SSO, that is, under free SSO entry there is no dissonance between the sponsor and the selected SSO with regards to the choice of concession.[7]

The SSO with type α endorses the standard if and only if

$$[a+b+c]+\alpha[\pi(c)] \geq 0.$$

The standard is therefore adopted by the users following an endorsement by the SSO if and only if:

$$a + E\left[b \middle| b \geq -(a+c+\alpha\pi(c))\right] + c \geq 0. \quad (1)$$

[7]It can further be shown that nothing would change if c were chosen after the SSO endorses the standard and before the users adopt the technology (see Lerner-Tirole 2006).

The sponsor then solves

$$\max_{\{\alpha,c\}}[1-F(-(a+c+\alpha\pi(c)))]\pi(c)$$

subject to (1).

Proposition 1 *(Lerner-Tirole 2006) (i) The weaker the proposed standard, the more extensive the concession and the more credible the SSO selected by the sponsor: concession c^* decreases and sponsor friendliness α^* increases with a. (ii) When concessions are (minus the level of) royalties, i.e., $\pi = \pi_0 + p$ and $c = -p$, the optimal α is smaller than or equal to 1. It is equal to 1 when the optimal royalty p is strictly positive, i.e., when the attractiveness parameter exceeds some threshold.*

Intuitively, the sponsor of an attractive technology can afford both making few concessions and choosing a friendly SSO (part (i)). When concessions take the form of a low royalty, but the optimal royalty is strictly positive, the SSO is optimally balanced ($\alpha = 1$) since the sponsor captures and thus internalizes user welfare. When the optimal royalty is a corner solution at the royalty-free level, then $\alpha \le 1$ as the sponsor makes up for the infeasible negative royalty through a more user-friendly SSO (part (ii)).

4.2 Determinants of disclosure

One aspect that was not considered in the earlier paper is disclosure of information in the standard-setting process. In our interviews, firms highlighted several costs associated with the disclosure of even already-issued patents. In particular, they argued that due to the number and complexity of patent portfolios, rivals frequently could not determine "the needle in the haystack": that is, which patents were relevant to a given standardization effort.[8] By highlighting the relevant patents or applications, in many cases firms felt they were disclosing to competitors valuable information about the applicability of their patent portfolios and their future technological strategies more generally. Second, early disclosure of plans may invalidate the ability to get future awards. Third, the undisclosed intellectual property may have multiple uses, only one of which is relevant to the standard. A disclosure can spur efforts to invent around the technology and thereby either lead to a sacrifice in profits in unrelated markets, or else boost the attractiveness of a competing standard. In such cases, the sponsor would like to retain secrecy—or at least ambiguity—of the applicability of its patent portfolio.

Some SSOs demand that sponsors commit to revealing awards and/or applications shortly before the standard is endorsed. Others do not require disclosure, although there is an understanding that undisclosed patents that are later deemed relevant to the standard will

[8]As an illustration of the disclosure effect, press releases by firms announcing patents that have already been issued have strongly positive reactions (Erturk, et al., 2006). In addition, U.S. legal rules mandating trebled damages for willful infringement lead firms to discourage their engineers from even examining the patent portfolios of their competitors.

be subject to the same pricing principles as the ones that are currently examined by the SSO: for example, a royalty-free agreement will as well cover undisclosed, essential patents in the future. While in our sample, the same pricing regime (for instance, royalty-free or reasonable-and-non-discriminatory) applies to both disclosed and undisclosed patents, it is not a priori obvious why this is the case. In particular a sponsor who does not wish to disclose patent applications, wants to collect royalties on examined patents, and yet would like to reassure users as to the possibility of a hold-up, could offer RAND on patents disclosed in advance of the adoption of a standard, and a royalty-free treatment for undisclosed patents that are subsequently deemed essential.[9]

Intuitively, disclosure involves a trade-off between reassuring users and not wasting intellectual property. On the one hand, the absence of disclosure raises the concern that users, once they have invested in the technology, will be held up by the sponsor as a missing piece of intellectual property is needed for the most effective implementation of the technology. On the other hand, in the absence of hold-up concerns of the users, the sponsor would prefer not to disclose applications or technological strategies more generally.

In order to investigate the relationship between disclosure policies, pricing and user-friendliness, let us study the following extension of the basic model. The sponsor has two pieces of intellectual property:

- the existing, disclosed patent (or set of patents), that forms the basis for the standard;
- an "add-on" potential patent, that is subject to an application to the patent office or is merely in the pipeline. There is no uncertainty about whether the patent on this add-on will be granted (nothing changes if the patent will be granted with probability less than 1).

There are two states of nature, i.e., two types of sponsors: "good" (probability ρ) and "bad" (probability $1-\rho$). In either case, the add-on patent adds value H to the standard. What differs is the baseline value. For the good type, the add-on really adds to the value of the existing technology: the attractiveness parameter increases from a to $a+H$. By contrast, for the bad type, the add-on is a missing piece in the initial standard. In its absence, the proposed standard has attractiveness $a-H$ only, and what the add-on does is to restore this attractiveness parameter to its full-implementation value a. Thus, H is a measure of the potential for hold-up.

The modified timing goes as follows:

[9]Indeed, such a "mixed regime" has been proposed under the name of "penalty default" by Lemley (2002). The European Telecommunications Standards Institute had proposed in 1993 that all essential intellectual property rights of a participant not disclosed within 180 days of the inception of a standard-setting project would be subject to automatic licensing. This requirement was abandoned in 1995 after pressure from information technology firms (for a detailed discussion, see Dolmans (2002)).

(i) The sponsor applies to an SSO with parameter α and disclosure policy specifying whether patent applications are to be disclosed (D) or not (ND) upon acceptance. It also specifies prices, $p \geq 0$ for the basic technology and $q \in [0, H]$ for the add-on (whether the latter is disclosed or not).

(ii) The SSO observes b, and under disclosure, the state of nature; it then chooses to endorse the technology or not. If the technology is endorsed and under a disclosure agreement (D), the sponsor must disclose the add-on.

(iii) The users choose whether to adopt the technology and, if so, pay price p.

(iv) The sponsor receives a patent for the add-on, which is then deemed essential by the SSO (if it has not been disclosed earlier) and charges price q to the users.

The good type incurs disclosure cost $d > 0$ in unrelated markets, say, when the add-on is disclosed (the disclosure cost for the bad type is irrelevant as long as it is strictly positive, since the bad type then never has an incentive to disclose). Disclosure of the add-on reveals whether the add-on is a true improvement or else just implementation-enabling.

A couple of important points are in order. First, the sponsor cannot do better than choosing to contract on whether to disclose and on prices (the contract is an optimal one). Because the value added by the add-on patent is the same, H, in both states of nature, it is not possible to elicit from users information about the state of nature. Second, we implicitly assume that the sponsor cannot disclose to the SSO confidentially, i.e., that the disclosure is subject to leakages. Otherwise, disclosure would always be a dominant strategy for the good type (and costless for the bad type). It would just not be perceived as costly and would be a non-issue.[10]

The game is a signaling game. As will become clear from the expressions of profits, the good and bad types have the same preferences over prices p and q. Thus, we assume that the SSO and the users infer nothing about the state of nature from the choice of p and q. By contrast, preferences differ as to the disclosure decision, which therefore will convey information to the SSO and the users. Second, we will show that the signaling game always has a Pareto-dominant equilibrium; we will accordingly focus on this equilibrium for comparative statics purposes.

(a) *Disclosure*

[10]The reader may wonder how the SSO can decide to endorse the standard before seeing the add-on in case the policy is one of disclosure. This, however, is not an issue. Because only the good type may in equilibrium disclose, the SSO can presume that the basic technology has value a and accept conditionally on checking that this is indeed correct. Mathematically, and following the treatment below, it endorses the standard if and only if

$$[(a+H)+b-(p+q)]+\alpha[\pi_0+(p+q)] \geq 0,$$

and commits not to endorse the technology if the basic value is $a-H$ rather than the claimed level of a.

As we noted, only the good type can benefit from disclosure. Letting b^* denote the SSO's cut-off, and $\left(p^D + q^D\right)$ the proposed prices, users adopt the technology if and only if:

$$(a+H)+m(b^*)-\left(p^D+q^D\right)\geq 0.$$

Letting $P^D \equiv p^D + q^D \geq 0$, the sponsor's expected profit is

$$[1-F(b^*)][\pi_0 + P^D - d],$$

accounting for the fact that the disclosure cost d is incurred only in case of endorsement, as is the case in practice. (Note, too, that such conditional acceptance maximizes the SSO's appeal, as it avoids wasteful disclosure when the standard is turned down, that is, when $b < b^*$.)

And so the good type's profit under disclosure is:

$$\pi^D(d,a) = \max_{\left\{b^* \middle| b^* \geq m^{-1}(-(a+H))\right\}} \left\{[1-F(b^*)][\pi_0 + (a+H) + m(b^*) - d]\right\},$$

where the set restriction refers to the constraint that the price P^D be non-negative.[11]

(b) *Nondisclosure*

Let $\hat{\rho}$ ($0 \leq \hat{\rho} \leq \rho$) denote the SSO's and the users' posterior probability of the sponsor being of the good type when there is no disclosure. Letting $P^{ND} \equiv p^{ND} + q^{ND}$, and $\hat{b}$ denote the SSO's cut-off, users adopt the standard if and only if:

$$(a+\hat{\rho}H)+m(\hat{b})-P^{ND}\geq 0.$$

The sponsor's expected profit in the absence of disclosure is type-independent and equal to:

$$\pi^{ND}(\hat{\rho},a) = \max_{\left\{\hat{b} \middle| \hat{b} \geq m^{-1}(-(a+\hat{\rho}H))\right\}} \left\{[1-F(\hat{b})][\pi_0 + (a+\hat{\rho}H) + m(\hat{b})]\right\}.$$

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[11]If at the optimum $P^D > 0$, then there is an indeterminacy as to the respective levels of p^D and q^D (as long as $p^D + q^D = P^D$ and $q^D \leq H$). If there were a cost of developing the add-on, arbitrarily small in expectation, but with wide support, the optimal contract would backload payments through a two-part tariff with $q^D = \min\left\{P^D, H\right\}$, so as to provide the sponsor with maximal incentives to develop the add-on. The indeterminacy would be removed.

A *separating* equilibrium exists if and only if

$$\pi^D(d,a) \geq \pi^{ND}(0,a).$$

A *pooling* equilibrium exists if and only if

$$\pi^{ND}(\rho,a) \geq \pi^D(d,a).$$

Finally, a *semi-separating* equilibrium exists if there exists $\hat{\rho} \in (0,\rho)$ such that

$$\pi^D(d,a) = \pi^{ND}(\hat{\rho},a).$$

Lemma 1 *(i) If multiple equilibria co-exist, both types of sponsor are better off in the one with the least amount of disclosure (the maximal amount of pooling). Furthermore, either the separating equilibrium exists and is unique, or the Pareto-dominant equilibrium is the pooling equilibrium.*

(ii) [Focusing on the Pareto-dominant equilibrium in case of multiplicity], there exists $d^* > 0$ such that separation obtains for $d < d^*$ and pooling for $d \geq d^*$.

Proof: (i) π^D is belief-free. By contrast, the two types' (common) payoff in the absence of disclosure is increasing in $\hat{\rho}$. And so both prefer $\hat{\rho}$ to be equal to ρ. More formally, either $\pi^D(d,a) > \pi^{ND}(\rho,a)$ and then the equilibrium is unique and separating. Or $\pi^D(d,a) \leq \pi^{ND}(\rho,a)$ and then the pooling equilibrium exists and dominates any other equilibrium.

(ii) This results from the fact that π^D is decreasing in d, while π^{ND} does not depend on d. ■

From now on, we will select the Pareto-dominant pooling equilibrium when it exists (when it does not, the separating equilibrium is the only equilibrium anyway).

Proposition 2 (*within equilibrium: disclosure positively correlated with* (α,P))

In (a separating) equilibrium, disclosure is associated with a) higher prices and b) lower user-friendliness of the selected SSO.

Note that we focus on separating equilibria. There is no variation if pooling obtains. Intuitively, disclosure demonstrates the absence of hold up and thereby makes the technology more attractive. Proposition 2 therefore is akin to Proposition 1 (the proofs of Propositions 2 through 4 can be found in the Appendix).

The next proposition shows that disclosure is akin to a concession in that more attractive standards are less likely to require disclosure.

Proposition 3 ***(disclosure is less likely for an attractive standard)***

When the technology becomes less attractive (a falls), the range of disclosure costs for which disclosure occurs in equilibrium expands (d^* grows).

4.3 Positioning with limited SSO competition

The analysis so far has made the extreme assumption that there is free entry into the SSO market and delivered a number of sharp implications, including the negative relationship between sponsor-friendliness and concessions.

A finding that α and c co-vary negatively, though, might be attributed to the possibility that there is a limited number of SSOs for a given technology field and that user-friendly SSOs just demand more concessions. To assess the validity of this alternative theory, it is important to distinguish two types of SSO policies: ex ante rules and ex post discretionary actions. User-friendly SSOs will naturally ex post demand more concessions.[12] On the other hand, our empirical analysis focuses on the ex ante rules that govern applications to the SSO. As we now show, it is much less obvious that a more-user-friendly SSO with market power will choose tougher rules.

To illustrate this, we look at the case in which a fixed set of SSOs select concessions in order to attract a sponsor with known characteristic a (and therefore preferred SSO $\alpha^*(a)$). For expositional simplicity, we ignore disclosure decisions and return to the basic framework of Section 4.1.

Our notion of competition can be interpreted as one among either for-profit SSOs that maximize revenue or not-for-profit SSOs that try to attract business; in either case, the SSO chooses c so as to solve

$$(I) \qquad \max U(\alpha) = [1 - F(b)]\pi(c)$$

subject to

$$a + m(b) + c \geq 0$$

[12]Whether they will indeed be successful in their attempt at "technology morphing" is another matter. To the extent that they delay approval, they may signal bad news to the users and so compromise the very acceptance of the standard by users even with increased concessions: see Lerner-Tirole (2006).

and

$$a + b + c + \alpha\pi(c) = 0.$$

[A not-for-profit certifier tries to attract the sponsor's business; a for-profit one charges $\mathrm{P}(\alpha) = \max \left\{ U(\alpha) - \max_{\alpha' \neq \alpha} U(\alpha'), 0 \right\}$; in either case, the certifier wants to maximize $U(\alpha)$.]

Proposition 4 shows that over a range of parameters, the concession is then *increasing* with sponsor-friendliness. It therefore precludes any general conclusion as to the negative co-variation between α and c. Sponsor-friendly SSOs are ex post lenient (with regard to their choice of *b**) and so must impose strong concessions (high *c*) in order to persuade consumers to adopt technologies that have weak appeal, and thereby attract such technologies. User-friendly SSOs must demand low concessions in order to be attractive to sponsors of technologies with strong appeal.

Proposition 4 ***(SSO positioning under imperfect SSO competition)***

Consider the competition between a given set of SSOs for a sponsor whose technology has appeal parameter a *and preferred SSO is thus* $\alpha^* \equiv \alpha^*(a)$. *There exists* $\underline{\alpha} < \alpha^*$ *such that for* $\alpha \geq \underline{\alpha}$ *, the concession c made by SSO* α *is increasing with* α. *That is, the sponsor must make fewer concessions when applying to the more user-friendly SSO.*

5. The sample

Before testing the theory, we describe the construction of our sample. Our empirical approach was to develop as comprehensive a sample of SSOs as possible. To do this, we compiled data ourselves and also searched the Internet for information about these organizations and their policies.

To identify the SSOs we would employ in our study, we employed "snowball sampling", a popular form of non-probability sampling. Krathwohl (1997, p. 173) notes that "snowball sampling is used to discover the members of a group of individuals not otherwise easily identified by starting with someone in the know and asking for referrals to other knowledgeable individuals." We first started off with the list in Lemley (2002). Lemley limited his population to groups that (a) disclosed their intellectual property policies in on-line documents or after direct contacts and (b) included Sun Microsystems as a member or an observer in the late 1990s. His judgment (p. 1903, and footnote 45) is that this method is representative of industries that he termed as "telecommunications and computer networking industries," in which the most contentious IP issues arise. From this paper, we discovered a reference to another list at consortiuminfo.org. We employed all SSOs listed at consortiuminfo.org that related to information technology and communications technologies and disclosed their intellectual property policies in on-line documents or after direct contacts, including those that Lemley did not use (apparently because his second criteria was not satisfied). We also used a variety of other lists, including www.cenorm.be/isss/Consortiua/Surveyshort.htm, www.diffuse.org/fora.html, www.webstart.com/cc.standards.html,[13] and www.marinade.ltd.uk/content/standard.html. These additional lists had diminishing returns, and we stopped when we could not identify any additional lists which had any standards that met our criteria.

We then coded the characteristics of the organizations based on the data collected from publicly available sources such as bylaws, charters, and websites of these bodies, as well as the authors' survey, emails, and telephone interviews.[14] Our final dataset is both from publicly available sources such as bylaws, charters, and websites of these bodies, as well as the authors' survey, emails, and telephone interviews. In some cases, observations needed to be dropped after we could not obtain consistent answers to our questions.

Our sample encompassed technologies related to the information technology, telecommunications, and electronics industries. More specifically, in the *ISO Catalogue*, each ISO standard is listed under a technological sub-field such as "computer graphics," which is in turn under a technological field such as "information technology and office machines." All but one of the SSOs in our sample fell into three technological fields (field number in parentheses): (31) Electronics; (33) Telecommunications, audio and video engineering; and (35) Information technology and office machines. In fact, 80% of the sample (47 out of 59) fall *exclusively* in these fields.

Although non-probability sampling is very common due to its convenience, it poses a number of concerns. First, there is no clear-cut way to tell how representative in the statistical sense the sample is. Since there are relatively very few empirical works on SSOs and there is no comprehensive list containing all such organizations, however, we could not find a better alternative.

To answer the question about whether our sample is big or small relative to the total, we provide here some references for comparison:

1. http://www.cmpcmm.com/standards.html lists 141 entries of both standards and SSOs. A significant portion of which are standards, not SSOs.
2. consortiuminfo.org lists 26 national, 10 international, and 11 regional SSOs.
3. ILI standards database, which covers over 600,000 worldwide standards across many different technologies, claims to include over 250 major standards issuing authorities, from the U.S., Europe, Japan, Australia, and major international bodies.[15]
4. PERINORM covers over 500,000 worldwide standards. It includes 21 national institutes.[16]

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[13] The link is now changed to http://www.cmpcmm.com/standards.html.

[14]We created a survey website in June 2003. It is available at http://cess.nyu.edu/hfc/sso. We thank ISO for allowing us to base our survey on the ISO classification. The databases we used included those of Gale and ILI Infobase.

[15] http://englibrary.blogspot.com/2006/03/ili-standards-infobase.html.

[16] See http://www.cssinfo.com/perinorm.html, and http://www.bsi-global.com/Business_Information/Publications/perinorm.xalter.

A second concern is our inability to observe SSOs that had failed prior to the data collection effort. All the SSOs in our sample were still in existence at the time of the data-collection effort, because those are the organizations that we could still collect data on their policies. (Failed SSOs typically do not maintain a website that allows one to learn their policies or key contacts.) A problem with such bias is that there could possibly be some characteristics of those organizations that could explain why they failed or had a short life which are not captured in our sample.

Related to the sample bias question is the question of the independence of data. If, for instance, U.S. SSOs overwhelmingly followed the template developed by the American National Standards Institute—the body that, among other activities, accredits standards developers and represents the United States in the International Organization for Standardization—the statistical significance of our findings might be overstated. In fact, intellectual property policies of SSOs are very diverse. For instance, Lemley (2002, p. 1904) writes: “What is most striking about the data is the significant variation in policies among the different SSOs.” This claim is illustrated in Table 1: along the dimensions summarized here (a subset of the intellectual property policies of SSOs), there are only two organizations (namely, DVB and IrDA) that have the same policies as ANSI.

Table 1 provides an initial overview of the sample. It lists the names of the organizations, their websites, and some additional information:

- Whether the organization has a policy covering patents.
- The rules regarding the licensing of patents by the SSO. In particular, we highlight whether the SSO requires sponsors to commit to license this intellectual property on RAND terms, on a royalty-free basis, and two less-common variants: provisions that the sponsors assign their intellectual property to the SSO and that the SSO can compel licensing of the sponsors’ patents.
- Whether sponsors must commit to abide by a formal dispute-resolution process.
- Whether there are requirements to disclose relevant patents (and in some cases, applications) before the selection of the standard.

It should be acknowledged that the uncertainty and pending litigation alluded to above implies that our characterization of SSO’s licensing rules is likely to face an errors-in-variables problem. While the formal licensing policies can be observed, the extent to which these rules are enforceable remains in question. The *Rambus* decision discussed above and several others have engendered doubts about the enforceability of SSOs’ rules about intellectual property.

6. The analysis

We next present the analysis. First, we discuss the proxies that we have developed for c, the measure of concessions demanded by the SSO, and α, the orientation of the SSO to sponsors relative to users. We then explore their relationship. We also consider the relationships between α, disclosure requirements, and the maturity of the technology.

6.1 The relationship between user-friendliness and concessions

Table 2 summarizes the elements of the two indexes. The first seeks to capture α, the extent to which the SSO is oriented to users or sponsors:

- *The nature of the organization.* Special interest groups (SIGs) are frequently observed to have a greater orientation to sponsors than other organizations. The membership of these groups is frequently confined to intellectual property rights holders.[17] Moreover, SIGs' mandates frequently also include the marketing of these standards rather than just a dispassionate endorsement. The contrast is sharpest between SIGs and standards development organizations (SDOs) like the Institute of Electrical and Electronics Engineers. An SIG has a narrower interest than an SDO. Also, the specifications of an SIG are more likely to come from a single member, while SDOs build standards based on the contributions of various members.[18]
- *The nature of the membership.* Some SSOs have individual members, while others are confined to corporations. (Yet others involve additional parties, such as academic institutions and government agencies.[19]) We regard SSOs with all-corporate membership as higher-α organizations.[20]
- *The nature of the voting rules.*[21] In interviews with a number of practitioners, the importance of voting rules was highlighted. The SSOs that required standards to

[17]In an illustrative e-mail, one informant writes that, "the working groups of our organization are comprised of members from many of the large industry leaders—therefore many of the companies that have an interest in IP protection are already stakeholders."

[18]It should be noted that there is also a third class of organization. Fora, inasmuch as the organizations are involved in the standard-setting process, are frequently seen as a middle ground. As a platform for the exchange of information, members of fora facilitate, accelerate, and promote the general interoperability of products in an industry. Fora work with other SSOs to develop standards and improve the usability of standards by preparing implementation guidelines as recommendations to members on the usage of a standard. While these organizations often seek to make use of existing standards whenever possible, they may also create their own standards or specifications. Fora thus can be seen as both complements to and substitutes for other SSOs.

[19]More than half of the organizations (57%) consist of corporations only. 8% consist of both individuals and corporations, and 25% consist of corporations and others. One organization consists of all three types of members. Almost all organizations (92%) have corporate members.

[20]Our results continue to hold when we include organizations whose members are exclusively governmental bodies (which might be prone to pressure from national corporations) with the all-corporate firms.

[21]The major sources of information here are the charters and bylaws on the websites of the organizations, and the survey. Sometimes, there is no specific decision process pertaining to standard setting. In that case, we assumed that the publicly available decision process, which pertains to general decisions, encompasses standard setting decisions also. If the organizations answered the voting rule question in our survey, the answers were used to compile the data. Otherwise, we compiled the data ourselves by reading the charters and bylaws of these organizations; we created a summary for each of these organizations. The summaries are archived at http://cess.nyu.edu/hfc/sso/decisionprocess.zip.

be approved by consensus or with a super-majority were seen as being much less prone to endorse a standard than those that use majority voting.[22]

- *The age of the organization.* Numerous observers (e.g., Cargill and Bolin (2004)) have observed that the standard-setting process has become increasingly politicized over time. These observers have attributed this trend to the growing involvement of lawyers and business development personnel in an activity that had been previously dominated by engineers. (See Simcoe (2003) for empirical support of this claim.) While many established organizations have adjusted their rules to accommodate the interests of the sponsors, these changes have frequently been slow. Discussions suggest that rules have been slanted in a more pro-sponsor direction most dramatically in the more recently established SSOs. (These newer organizations have lacked the institutional traditions that have served to slow the pace of change in older groups.[23]) We expect SSOs established after the median date in the sample (1995) to have a higher α.

It is difficult to assign a relative importance to these four elements. We thus simply—in an admittedly imperfect approximation—sum these four dummies, and create an α score between zero and four. In diagnostic regressions below, we also look at each element separately.

We similarly create an index of c, the number of concessions offered by the sponsor. We focus on the two elements identified as most critical in our discussions, the commitments regarding licensing and the allocation of residual decision-making rights:[24]

- *Licensing restrictions.*[25] In a number of SSOs, firms must commit to license key intellectual property needed to implement the standard to those who request it. These commitments typically take two forms: the firm commits to license the patents either on a royalty-free basis, or on RAND terms. While ambiguities

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[22] 34% and 27% of organizations use majority voting rules and super-majority to approve standards, respectively. 13% of organizations use consensus. There is no information for the remaining 25% of organizations.

[23] All of the organizations adopting the consensus rule are significantly older than the majority of organizations. Note that nearly half of the organizations in our sample were founded between 1996 and 2002, and 73% of them are less than 15 years old.

[24] Organizations vary in the extent to which they disclosed historical information. While some organizations carefully archive earlier policy documents, in many cases only contemporaneous policies are available. Thus, when coding these policies, we simply focused on the policies that were in place in October 2002. We ignored proposed alterations to these policies when available in draft form, focusing instead on policies actually in place.

[25] Organizations typically define (a) the rules (e.g., RAND licensing requirements) governing the intellectual property, and (b) the range of covered intellectual property. Almost all organizations (96%) include patents among the intellectual property policies covered under their rules. About half of the organizations (45%) have policies governing trademarks, 77% copyrights, and 39% other types of intellectual property rights.

surround exactly how binding a RAND licensing commitment is, most observers see it as a serious commitment, though clearly not as restrictive as a promise to provide royalty-free license (see Lemley (2002)). We include two dummies: one that takes on the value one if the firm must commit to provide royalty-free licenses, and one that takes on the value one if they must commit to either RAND or royalty-free licenses.[26] We include compulsory licensing and patent assignment requirements as equivalent to royalty-free licensing for the purposes of this analysis.[27]

- *Residual decision rights.* In many SSOs, there is no clear road map to resolving disputes. In others, however, the firms must commit to bringing their disputes before an adjudicary body of the SSO.[28]

Again, we create an index of concessions, which ranges from zero to two.

The final two measures reported in Table 2 relate to the extent of disclosure in the SSO. As highlighted in Section 4.2, the predictions here will be somewhat different from those for other concessions because of the adverse selection effect. We report whether the sponsors were required to disclose either patent awards or applications prior to the adoption of a standard.

Table 2 reports the results of this analysis. While not all cross-tabulations between the proxies for α and c are statistically significant, the basic pattern is clear: in every case, the level of concessions, c, is higher for those with a lower proxy for α, that is, a greater orientation towards users. When we add together the α dummies in the final two columns, we see in each case the difference is significant at the five-percent confidence level. For instance, for SSOs that require royalty-free licenses, the α score is 0.6; for the others, it is 1.6. For SSOs requiring binding dispute resolution, the α score is 0.4; for the others, it is again 1.6.

The results regarding the disclosure requirements are much less clear-cut. Only one of the ten cross-tabulations is significant, and that only at the ten-percent confidence level. The summed α scores are also not significantly different from each other.

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[26]It is worth highlighting that many crucial details are often not stipulated in these contracts. The case *Intel v. VIA Technologies* (174 F.Supp. 2d 1038 (N.D. Cal. 2001)), for instance, revolved around the question of whether the licensing commitment entered into as part of a standard covered just the basic features of the standard or else also included various extensions. Some of the loopholes that firms have successfully exploited are cataloged in Feldman, et al. (2000) and Kipnis (2000).

[27]The majority (63%) of organizations use RAND in their patent licensing rules. Only 9% of organizations use royalty-free rules. Even fewer organizations use assignment (2%) and compulsory rules (2%). We also repeat the analysis with a third dummy that takes on the value one for those SSOs that require patent assignment (which might be seen as particularly taxing). The results are little changed.

[28]Our data show that only 9% of organizations have a dispute resolution mechanism. It should be noted that in some cases, separate provisions govern copyright licensing, but we have not recorded these.

In Table 3, we look at the correlations between the α and c proxies. There is a strong negative correlation between the scores, -0.53, which is highly statistically significant: that is, more user-friendly SSOs offer more concessions. We also examine the correlation between these two scores and the individual elements of the other index. These correlations are each statistically significant, at least at the ten-percent confidence level. Once again, no significant relationship between the disclosure policies and the α score appears.

We next turn to regression analyses. In Table 4, we seek to explain the extent of concessions offered by an SSO, given its level of user-friendliness. (This assumption of the exogeneity of α is plausible if we assume free entry. As the tabulations of the frequency of other SSOs in the technological sub-fields of our sample discussed below reveal, this assumption does not appear unreasonable. If it did not hold, we should probably regard this as more representative of correlation than causation.) In each case, we estimate first a basic specification, and then with (unreported) dummy variables that control for the technologies covered by the SSO. (We determine these first by checking the ILI Infobase, which classifies the standards published by the SSOs according to the ISO technological fields—a scheme used in the International Organization for Standardization's *ISO Catalogue*.[29] For SSOs not included in the database, we ask the organizations to respond to our survey, filling out the number of standards they published in each field and sub-field. For non-responding SSOs, we make our own classification, based on information from the mission statements or elsewhere on the organizations' websites.) We employ ordered logit regressions throughout, reflecting the fact that while we expect that an organization with a c score of 2 is more restrictive than that with a score of 1, it is difficult to say exactly how much more restrictive it is.

The table reveals again that there is a strong relationship between c and α, even after we add industry controls. When we examine the individual elements of α, we see that while all the coefficients are negative, the two consistently significant indicators are if the standards body is an SIG and if all the members are corporations.

When we look at the determinants of the three individual components of the c score in Table 5, we see that the α score is consistently negative in each. Moreover, each coefficient is statistically significant at least at the five-percent confidence level. When we look at the two disclosure measures, we find that not only is the α coefficient statistically insignificant, but it takes on a different sign.

6.2 Additional analyses

In this section, we look at three additional predictions of our model. These relate to the relationships between disclosure requirements and licensing price, the impact of limited competition between SSOs, and the consequences of the differing maturity of standards.

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[29]This is available on-line at http://www.iso.org/iso/en/CatalogueListPage.CatalogueList (accessed October 10, 2004). See also "How are ISO Standards Developed?", http://www.iso.org/iso/en/stdsdevelopment/whowhenhow/how.html (accessed August 21, 2004).

First, as was discussed in Section 4 above, we also hypothesize a relationship between disclosure and price. In particular, Proposition 2 suggested that within an equilibrium, a higher licensing price was associated with more disclosure.

In Table 6, we look at the two most commonly encountered terms relating to licensing fees and their relationship with the disclosure provisions. We find that the presence of a provision mandating royalty-free licensing is negatively associated with the presence of a disclosure requirement, while RAND licensing is strongly associated with such a requirement. The pattern goes the same way in both the analysis of the disclosure of patent awards and applications, but it is much stronger in the former case.

The pattern of more disclosure being associated with higher licensing rates in Table 6 is broadly consistent with the theoretical predictions above. The fact that the relationship is stronger for patent awards is also consistent with our predictions. Lemma 1 states that if the disclosure cost is high, then it is more likely that there will be pooling with no disclosure, making the relationship overall weaker. Since it is plausible to assume that the disclosure cost is higher for patent applications than for awards, this pattern is also expected.

Second, as noted above, an alternative hypothesis for the relationship between c and α is that the patterns are due to market power. It may be that some SSOs have few competitors. As a result, they may be able to demand more concessions from sponsors, while having a much more user-orientated approach. As shown in Section 4.3, this argument, while initially plausible, does not bear up under scrutiny. As Proposition 4 showed, when there are a limited number of SSOs, it is by no means clear that the relationship between α and c will still hold.

We address this issue in two ways. First, we rerun the regressions in Table 4, simply adding a proxy for the market power of each SSO. The proxy we employ is the density of other SSOs in the same technological sub-field(s) as a given SSO.[30] If the sponsor can turn to many other SSOs, then it is unlikely that the SSO can impose these types of requirements. We determine this measure again through the ILI Infobase, using the classification scheme in the International Organization for Standardization's *ISO Catalogue*.[31] In general, the density of SSOs is quite high. The mean SSO has 13.9 other SSOs in its sub-field (with a median of 13.5).

We check to see whether once this control is added, the relationship between α and c still holds. Then, we compare the goodness-of-fit in regressions when SSOs do and do not have considerable competition.

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[30]For instance, if an organization is active in sub-fields A and B, and there are 3 and 4 active organizations in A and B, respectively, then the market power index for this organization is (3 + 4)*1/2.

[31]Of course, the sponsor may have the option to create a new SSO, a possibility that our measure can only imperfectly capture.

Table 7 presents the results of the analysis. In the first four regressions, we examine the impact of adding the measure of SSO density in the technological sub-field. We find the measure has little impact: across all four regressions (and numerous unreported ones), it is not statistically or economically significant. As before, there is a strong negative association between c and α.

We then compare the goodness-of-fit in regressions using SSOs that did and did not have market power. We divide the SSOs into those where there was above and below the median number of other SSOs in their technological sub-fields. In the reported regressions (and in numerous unreported ones), the goodness-of-fit is higher when we use SSOs located in sub-fields with many other organizations: the absolute t-statistics of the independent variables of interest are larger, the χ^2-statistics are more statistically significant, and the log likelihoods are smaller. This is particularly striking in the last pair of regressions reported in Table 7. When using those SSOs with above-median density, three of four c-score elements are statistically significant; when using those below the median density, none are. This pattern is consistent with the predictions of Proposition 4.

The final analysis in Table 8 examines the relationship between the maturity of the standards in the technology where the SSO is operating and the α measure. We believe that the best indicator of opportunity is not the maturity of the project per se, but rather the collective state of projects in that particular technological sub-field. Over time, many of the substantial technological uncertainties about standards in a sub-field are likely to be resolved, increasing its attractiveness. If a field is less developed, it would be more difficult for technical committees to come up with standard proposals or drafts that take into account all technological implications, thus lengthening the approval time of standards in the field. Alternatively, there may be a higher option value to sponsors from delaying their decision to participate, as suggested in Farhi, et al. (2005). We thus use the maturity level of standards in a technological field as a proxy for the standard's attractiveness to users.

We compute the maturity of the technological sub-field(s) in which each standard operates as follows. Following the procedure outlined above, we assign each organization to one or more sub-fields as delineated in the *ISO Catalogue*. We then construct the maturity level for each of the sub-fields by summing up the maturity ranks of all other standards in the sub-field and dividing the sum by the number of standards in each sub-field. We use the ISO's rating of maturity, which indicates the maturity of that standard on a scale of 0 ("preliminary stage") to 99 (standard withdrawn after being implemented). We compute the average maturity of the standards in that category. If there are no standards in a sub-field, it receives the least mature rank. If an organization spans across fields or sub-fields, we compute a simple average of the maturity levels for all relevant fields or sub-fields.[32]

[32] In principle, we could have calculated a weighted average but since we do not have information for the number of standards of most of the organizations, we have not pursued this approach.

Table 8 reports that there appears to be a positive correlation between maturity and α. The first panel indicates that SSOs operating in sub-fields where standards are above the median maturity tend to have a significantly higher α. The second panel presents an ordered logit regression, with the α score of the SSO as the dependent variable. Once again, a higher maturity score is significantly associated with a higher α, consistent with the theoretical predictions delineated above.

7. Conclusion

Standard-setting organizations have received surprisingly little empirical scrutiny, despite their economic importance and dynamism. This paper seeks to address this omission, empirically examining a cross-section sample of nearly 60 SSOs.

From Lerner-Tirole (2006), we expected a negative relationship between the extent to which an SSO is oriented to technology sponsors and the concession level required of sponsors. In this paper, we indeed find a significant negative relationship, even when we control for industry effects. We also expected the sponsor-friendliness of the selected SSO to be positively associated with the quality of a standard. The data reveal a statistically significant association between sponsor-friendliness and the maturity of a technological sub-field in which the standard is located, which we suggest should be a proxy for attractiveness.

Our theoretical analysis of disclosure requirements predicts that a higher licensing price should be associated with more disclosure. Empirically, we find that the presence of a provision mandating royalty-free licensing is negatively associated with the presence of a disclosure requirement, while weaker "reasonable" licensing provisions are strongly associated with such a requirement. Second, we show that in settings where there are only a limited number of SSOs, the relationship between concessions and user-friendliness may not hold. When we divide our sample of SSOs into those where there were above and below the median number of other SSOs in their technological sub-field, we find that the relationship between user-friendliness and concessions is considerably tighter among SSOs located in classes with many other SSOs.

This work leaves a number of questions unexplored. One of the most intriguing of these has to do with the *dynamics* of certification. Lerner-Tirole (2006) and the extensions discussed here present a static model in which a one-time decision is made. In the real world, SSOs and sponsors may employ more complex strategies: for instance, a sponsor may reapply to an SSO after its initial application is rejected. (Farhi, et al. (2006) presents a theoretical look at these issues.) Understanding the dynamics of the certification process represents an important empirical challenge.

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Appendix 1: Proof of Proposition 2

Compare the two programs

$$\pi^{D}(d,a)=\max_{\{b^*|b^*\geq m^{-1}(-(a+H))\}}\{[1-F(b^*)][\pi_0+(a+H)+m(b^*)-d]\},$$

and

$$\pi^{ND}(0,a)=\max_{\{\hat{b}|\hat{b}\geq m^{-1}(-a)\}}\{[1-F(\hat{b})][\pi_0+a+m(\hat{b})]\}.$$

a) Let us first demonstrate that disclosure is associated with a higher price in a separating equilibrium. Let us assume a contrario that $P^{ND} > P^{D}$. This inequality can arise only if $P^{ND} > 0$. Because $P^{ND} > 0$, then $\alpha^{ND} = 1$ and so the cut-off $\hat{b}$ is the efficient cut-off. By contrast, $\alpha^{D} \leq 1$ (with equality if $P^{D} > 0$) and so the cut-off b^* is either efficient or socially too high. Thus we have: $b^* \geq \hat{b}$. And so

$$P^{D}-P^{ND}=[a+H+m(b^*)]-[a+m(\hat{b})]>0.$$

b) Let us show that $\alpha^{D} \geq \alpha^{ND}$. This is clearly the case when $P^{D} > 0$, as then $\alpha^{D} = 1$ and $\alpha^{ND} \leq 1$. So, assume that $P^{D} = P^{ND} = 0$. Using the users' and the SSO's indifference equations, one then gets:

$$a+H+m(b^*)=a+m(\hat{b})=0$$

and

$$(a+H)+b^*+\alpha^{D}[\pi_0-d]=a+\hat{b}+\alpha^{ND}\pi_0=0$$

implying that

$$(\alpha^{D}-\alpha^{ND})\pi_0=[m(b^*)-b^*]-[m(\hat{b})-\hat{b}]+\alpha^{D}d\ ,$$

which together with $m' < 1$ and $b^* < \hat{b}$ yields $\alpha^{D} > \alpha^{ND}$. ■

Appendix 2: Proof of Proposition 3

Recall that d^* is given by

$$\pi^{D}(d^*,a)=\pi^{ND}(\rho,a).$$

Let P^D and P^{ND} denote the prices under disclosure, and non-disclosure and pooling, respectively (beware that P^{ND} is not the same as in Proposition 2, as we are now looking at pooling rather than separating). The same proof as for Proposition 2 shows that $P^D \geq P^{ND}$.

Suppose, first, that $P^D = P^{ND} = 0$. Then, for $d = d^*$,

$$\left[1 - F\left(m^{-1}(-a - H)\right)\right]\left(\pi_0 - d^*\right) = \left[1 - F\left(m^{-1}(-a - \rho H)\right)\right]\pi_0$$

and so

$$\frac{\partial\left(\pi^{ND} - \pi^D\right)}{\partial a} = \frac{1 - F\left(\hat{b}\right)}{m\left(\hat{b}\right) - \hat{b}}\pi_0 - \frac{1 - F\left(b^*\right)}{m\left(b^*\right) - b^*}(\pi_0 - d^*)$$

$$= [1 - F(\hat{b})]\pi_0\left[\frac{1}{m(\hat{b}) - \hat{b}} - \frac{1}{m(b^*) - b^*}\right]$$

(using the fact that $m' = \frac{f}{1-F}(m - b)$). Because $\left[m(b) - b\right]$ is decreasing and $\hat{b} > b^*$,

$$\frac{\partial\left(\pi^{ND} - \pi^D\right)}{\partial a} > 0.$$

Thus, there is disclosure for a smaller set of disclosure costs as a increases.

Suppose, next, that $P^D \geq P^{ND} > 0$. Then $\pi^D = \pi^{ND}$ requires that $d^* = (1 - \rho)H$ and $\hat{b} = b^*$. Furthermore,

$$\frac{\partial\left(\pi^{ND} - \pi^D\right)}{\partial a} = \left[1 - F\left(\hat{b}\right)\right] - \left[1 - F\left(b^*\right)\right] = 0.$$

Finally, assume that $P^D > P^{ND} = 0$. Then

$$\frac{\partial(\pi^{ND} - \pi^D)}{\partial a} \propto \left[1 - F\left(\hat{b}\right)\right]\left[\frac{\pi_0 - d^* + P^D}{m\left(\hat{b}\right) - \hat{b}} - 1\right].$$

But using the efficiency condition,

$$\pi_0 - d^* + P^D = m\left(b^*\right) - b^*.$$

Finally, $m' < 1$ and $b^* < \hat{b}$ implies that $\frac{\partial\left(\pi^{ND} - \pi^D\right)}{\partial a} > 0.$ ■

Appendix 3: Proof of Proposition 4

Proof: Consider a sponsor of a technology with known attractiveness a. Let α^* denotes his "ideal SSO," and (b^*, c^*) denote the corresponding cut-off and concession level:

$$\begin{cases} a + m(b^*) + c^* = 0 \\ a + b^* + c^* + \alpha^* \pi(c^*) = 0 \\ 1 + \alpha^* \pi'(c^*) = 0. \end{cases}$$

An SSO with type $\alpha \neq \alpha^*$ attempts to offer as high a surplus $[1 - F(b)]\pi(c)$ as it can. If $\alpha > \alpha^*$, the SSO lacks credibility in the eyes of users and must make a high concession to gain sufficient credibility:

$$c > c^*.$$

To see this, suppose, to the contrary, that $c \leq c^*$. Then letting b denote the cut-off for (c, α):

$$a + b + c + \alpha\pi(c) = 0$$

and

$$a + m(b) + c \geq 0$$

if the standard is to be adopted by users. And so

$$m(b) - b \geq \alpha\pi(c) > \alpha^* \pi(c^*) = m(b^*) - b^*,$$

which, together with $m' < 1$, yields $b < b^*$. But then

$$a + m(b) + c < a + m(b^*) + c^* = 0,$$

and so the standard is not adopted by users after all. Note also that for $\alpha > \alpha^*$, the two constraints in program (I) must be binding; otherwise, the first-order condition would yield:

$$\frac{\pi'}{\pi} + \frac{f}{1 - F}(1 + \alpha\pi') = 0. \quad (4)$$

But $\alpha > \alpha^*$, $c > c^*$, $\pi'' < 0$ and $1 + \alpha^* \pi'(c^*) = 0$ imply that the left-hand side of (4) is strictly negative.

Similarly for $\alpha < \alpha^*$, but "not too small", the two constraints in program (I) must be binding. For α close to α^*, (4) would yield c far below c^*, which by continuity cannot be the solution.[33]

Now, when the two constraints are binding,

$$a + m^{-1}(-a - c) + c + \alpha\pi(c) = 0,$$

and so

$$\frac{dc}{d\alpha} = \frac{\pi}{\frac{1}{m'} - (1 + \alpha\pi')}.$$

Now $1 + \alpha\pi' < 0$ for $\alpha > \alpha^*$, and $(1 + \alpha\pi')$ small for α smaller than, but in neighborhood of, α^*. Hence $\frac{dc}{d\alpha} > 0$. ■

[33] To show that the highest gross sponsor payoff cannot decrease discontinuously as α decreases, suppose that SSO α offers concession *c* so that the standard is adopted if recommended by the SSO (if not, then obviously the payoff cannot decrease as it is equal to 0):

$$a + m(b) + c \geq 0$$

$$a + b + \alpha\pi(c) = 0.$$

Now consider SSO (α - $d\alpha$) with $d\alpha > 0$. It is easy to see that for concession *c+dc* the cutoff is *b+db* with

$$db = \pi(c)d\alpha - \alpha\pi'(c)dc,$$

and that the users still adopt as long as

$$dc \geq -\frac{\pi(c)m'(b)d\alpha}{1 - \alpha\pi'(c)m'(c)}.$$

Table 1 Sample Overview

Standard Development Organization	Address	Patents Covered by Organization Policy	External Patent Licensing Rules				Dispute Resolution Mechanism	Disclosure Requirements
			RAND	*Royalty Free*	*Assignment*	*Compulsory*		
ANSI	www.ansi.org	Y	Y	N	N	N	Y	Y
ATM Forum	www.atmforum.com	Y	N	N	N	N	N	Y
BCDF	www.bcdforum.org	Y	Y	N	N	N	N	Y
BioAPI	www.bioapi.org	Y	Y	Y	N	N	N	Y
BPMI	www.bpmi.org	Y	N	N	N	N	N	N
BSI	www.bsi-global.com	Y	N	N	N	Y	Y	N
CEN	www.cenorm.be	Y	Y	N	N	N	N	Y
CPExchange	www.cpexchange.org	Y	N	N	Y	N	N	N
DCMI	dublincore.org	N	N	N	N	N	N	N
DMTF	www.dmtf.org	Y	Y	N	N	N	N	Y
DVB	www.dvb.org	Y	Y	N	N	N	Y	Y
ECMA	www.ecma.ch	Y	Y	N	N	N	N	Y
ECTF	www.ectf.org	Y	Y	N	N	N	N	Y
EDIFICE	www.edifice.org	NA	NA	NA	NA	NA	NA	NA
ETIS	www.etis.org	Y	Y	N	N	N	N	Y
ETSI	www.etsi.org	Y	M	N	N	N	Y	Y
Frame Relay Forum	www.frforum.com	Y	Y	N	N	N	N	Y
GEA	www.gigabit-ethernet.org	Y	Y	N	N	N	N	Y
Home Plug	www.homeplug.org	Y	Y	N	N	N	M	N
Home PNA	www.homepna.org	Y	Y	N	N	N	N	Y
HomeRF	www.homerf.org	Y	Y	N	N	N	N	N
I2O	www.i2osig.org	Y	N	Y	N	N	N	N
IEEE	www.ieee.org	Y	Y	N	N	N	N	Y
IETF	www.ietf.org	Y	Y	N	N	N	N	Y
IMTC	www.imtc.org	Y	N	N	N	N	N	Y
Internet Home Alliance	www.internethomealliance.com	Y	N	N	N	N	N	N
IrDA	www.irda.org	Y	Y	N	N	N	Y	Y
ISO	www.iso.ch	Y	Y	N	N	N	N	Y
ITU-T	www.itu.int/ITU-T	Y	Y	N	N	N	N	Y
MEF	www.metroethernetforum.org	Y	Y	N	N	N	N	Y
MSF	www.msforum.org	Y	Y	N	N	N	N	Y
MWIF	www.mwif.org	Y	N	N	N	N	N	Y
NMF (Telemanagement Forum)	www.nmf.org	Y	Y	N	N	N	N	Y
NPF	www.npforum.org	Y	Y	N	N	N	N	Y
NSIF	www.atis.org/atis/sif/sifhom.htm	Y	Y	N	N	N	N	Y
OASIS	www.oasis-open.org	Y	N	N	N	N	N	N
OGC	www.opengis.org	Y	Y	N	N	N	M	Y
OIF	www.oiforum.com	Y	Y	N	N	N	N	Y
OMA	www.openmobilealliance.org	Y	Y	N	N	N	N	Y
OMG	www.omg.org	Y	Y	N	N	N	N	Y
Open Group	www.opengroup.org	Y	Y	N	N	N	N	Y
OSDL	www.osdl.org	N	N	N	N	N	N	N
OSGi	www.osgi.org	Y	Y	N	N	N	N	Y
PCCA	www.pcca.org	Y	N	N	N	N	N	Y
PCI SIG	www.pcisig.com	Y	Y	N	N	N	N	Y
RDMA	www.rdmaconsortium.org	Y	Y	N	N	N	N	Y
RosettaNet	www.rosettanet.org	Y	N	Y	N	N	N	N
SDMI	www.sdmi.org	Y	N	N	N	N	N	Y
SNIA	www.snia.org	Y	Y	N	N	N	N	Y
STA	www.scsita.org	Y	N	N	N	N	N	Y
TIA	www.tiaonline.org/standards	Y	Y	N	N	N	N	Y
UPNP	www.upnp.org	Y	Y	N	N	N	N	Y
W3C	www.w3.org	Y	N	Y	N	N	N	Y
WAP Forum	www.wapforum.org	Y	Y	N	N	N	N	Y
WfMC	www.wfmc.org	Y	N	Y	N	N	N	Y
Wired for Management	developer.intel.com/ial/wfm/wfmspecs.htm	Y	N	Y	N	N	N	N
X.org	www.x.org	NA	NA	NA	NA	NA	NA	NA
XIWT	www.xiwt.org	Y	N	N	N	N	N	Y
XML.org	www.oasis-open.org	Y	N	N	N	N	N	N

Y= Yes; N= No; M- Maybe; NA= Not Available.

Table 2 Chi-Squared and t-Test Analyses of the Relationship Between α and c Score Elements, as well as Disclosure Measures

	ALPHA SCORE ELEMENT (HIGHER ALPHA CHOICE IS THE LEFT COLUMN)										ALPHA SCORE (0 TO 4)	
	Is this an SIG (SIGs and SSOs only)?		Is this an SIG (all)?		All members corporate?		Decisions made by majority rule?		Younger organization?		If element is…	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
c Score Elements												
Royalty free licensing?	10%	14%	10%	13%	0%	24%***	5%	16%	7%	17%	0.6	1.6**
Royalty free or RAND licensing?	40%	83%***	40%	80%***	59%	87%**	65%	77%	69%	77%	1.3	2.1***
Binding dispute resolution?	0%	15%	0%	11%	8%	10%	0%	14%	0%	18%**	0.4	1.6**
Disclosure Measures												
Is patent disclosure required?	60%	80%	60%	81%	75%	79%	79%	76%	68%	86%*	1.4	1.9
Is application disclosure required?	20%	26%	20%	24%	26%	21%	32%	19%	8%	30%	1.5	1.5

*** denotes significant at the 1% confidence level; **, 5%; *, 10%.

Table 3 Correlation Analysis between Alpha and c Scores and their Elements, as well as Disclosure Measures

	Alpha score (0 to 4)		Is this an SIG?		All members corporate?		Decisions made by majority rule?		Younger organization?	
	Coefficient	p-Value	Coefficient	p-Value	Coefficient	p-Value	Coefficient	p-Value	Coefficient	p-Value
c Score (0 to 3)	-0.53	0.000	-0.32	0.018	-0.43	0.001	-0.25	0.071	-0.27	0.050
Royalty free licensing?	-0.31	0.017								
Royalty free or RAND licensing?	-0.36	0.005								
Binding dispute resolution?	-0.31	0.023								
Is patent award disclosure required?	-0.18	0.190								
Is patent application disclosure required?	0.01	0.987								

Table 4 Ordered Logit Regression Analysis of c Score, with α Score and its Elements as Explanatory Variables

	Dependent Variable: c Score			
α score	-1.13	-1.36		
	[0.30]***	[0.35]***		
Is this an SIG?			-1.85	-2.04
			[0.81]**	[0.83]**
Are all members corporate?			-1.71	-1.79
			[0.67]**	[0.70]***
Decisions made by majority rule?			-0.74	-0.92
			[0.62]	[0.64]
Younger organization?			-0.66	-1.09
			[0.60]	[0.65]*
Dummies for technology included?	N	Y	N	Y
Chi-Squared Statistic	17.41	23.89	19.99	25.73
p-Value	0.000	0.000	0.000	0.000
Log Likelihood	-47.67	-44.43	-46.38	-43.51
Number of Observations	55	55	55	55

t-Statistics in brackets.

*** denotes significant at the 1% confidence level; **, 5%; *, 10%.

Table 5 Logit Regression Analysis of Elements of c Score and Disclosure Elements, with α Score as Explanatory Variable

	Dependent Variable									
	Royalty-free licensing?		Royalty-free or RAND licensing?		Binding dispute resolution?		Is patent disclosure required?		Is application disclosure required?	
α score	-1.15	-1.19	-0.82	-0.97	-1.43	-2.10	-0.39	-0.29	0.01	0.17
	[0.53]**	[0.56]**	[0.32]***	[0.36]***	[0.72]**	[1.03]**	[0.29]	[0.30]	[0.29]	[0.32]
Dummies for technology included?	N	Y	N	Y	N	Y	N	Y	N	Y
Chi-Squared Statistic	6.51	9.49	7.85	9.88	6.32	11.05	1.77	6.41	0.00	3.25
p-Value	0.011	0.024	0.005	0.020	0.012	0.026	0.183	0.093	0.966	0.355
Log Likelihood	-17.98	-15.20	-30.56	-27.52	-13.59	-11.22	-29.72	-27.40	-30.07	-28.45
Number of Observations	57	48	57	53	55	55	57	57	55	55

t-Statistics in brackets.

*** denotes significant at the 1% confidence level; **, 5%; *, 10%.

Table 6 Chi-Squared Analyses of c Score Elements Regarding Price and Disclosure Measures

	Is award disclosure required?		Is application disclosure required?	
	Yes	**No**	**Yes**	**No**
Royalty-free licensing?	5%	38%***	0%	17%
RAND licensing?	77%	15%**	85%	57%*

*** denotes significant at the 1% confidence level; **, 5%; *, 10%.

Table 7 Ordered Logit Regression Analysis of c Score, with Market Power Proxy

	Dependent Variable: c Score							
	Using Entire Sample				Dividing Sample into Above and Below Median SSO Density			
					Above	Below	Above	Below
α score	-1.12	-1.35			-1.55	-1.32		
	[0.30]***	[0.35]***			[0.56]***	[0.54]**		
Is this an SIG?			-1.84	-2.08			-2.15	-35.79
			[0.81]**	[0.83]**			[1.11]*	[229.07]
Are all members corporate?			-1.74	-1.83			-2.38	-1.64
			[0.68]***	[0.71]***			[1.13]**	[1.12]
Decisions made by majority rule?			-0.69	-0.82			-0.37	-1.45
			[0.62]	[0.66]			[0.99]	[1.23]
Younger organization?			-0.61	-1.05			-2.09	-0.60
			[0.61]	[0.65]			[1.07]*	[0.94]
Density of other SSOs	-0.02	-0.01	-0.04	-0.04				
	[0.06]	[0.07]	[0.06]	[0.07]				
Dummies for technology included?	N	Y	N	Y	Y	Y	Y	Y
Chi-Squared Statistic	17.53	23.95	20.36	26.07	13.56	9.84	15.69	12.91
p-Value	0.000	0.000	0.001	0.001	0.001	0.043	0.008	0.074
Log Likelihood	-47.61	-44.41	-46.20	-43.35	-18.91	-24.04	-17.85	-22.51
Number of Observations	55	55	55	55	29	26	29	26

t-Statistics in brackets.

*** denotes significant at the 1% confidence level; **, 5%; *, 10%.

Table 8 t-Test and Ordered Logit Regression Analysis of α Score, with Maturity Proxy as Explanatory Variable

α if mature	1.7
α if not mature	1.1
t-Statistic	1.92
p-Value	0.060
	Dependent Variable: α Score
Mature technology	-1.00
	[0.54]*
Chi-Squared Statistic	3.45
p-Value	0.063
Log Likelihood	-81.88
Number of Observations	58

t-Statistics in brackets.

*** denotes significant at the 1% confidence level; **, 5%; *, 10%.