The Economic Realities of Open Standards:

Black, White and Many Shades of Gray

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Abstract

Open standards have long been popular among buyers of goods and services in the information technology sector. Self-interested buyers and sellers, however, have had incentives to overstate (or understate) the openness of various standards. This paper rejects the simplified view that there is a single model of an open standard, as well as the assumption that a fully open solution is always an optimal (or even a feasible) outcome. The author analyzes various economic and technological forces that make standards more or less open and how these economic forces are affected by the policy choices available to firms, standards setting organizations, and regulators. The author uses this analysis to suggest objective measures for standards openness and a typology of common bundles of standards rights; he also notes the practical limits to open standards.

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1. Open Standards: Ideals vs. Reality

> The concept of "open systems" has become an icon to conveniently express all that is good about computing. It … has always been held up as the ideal to which computing should subscribe (Cargill 1994, p. 3).

As Cargill indicates, "open" for compatibility standards has been promoted as a universally good thing—right up there with motherhood and apple pie. For many corporate and individual users of information technologies, open standards are the *ne plus ultra* for external technologies.[1] In contrast, for many information technology (IT) vendors, nirvana is having their proprietary standard win a standards battle, which creates switching costs and other lock-ins, thereby providing an ongoing stream of rents to pay shareholders, employees, and of course executive bonuses (e.g., Morris and Ferguson 1993, Shapiro and Varian 1999).

Here, I argue that the many attempts to promote open standards have been at best naïve. Contrasted to these utopian ideals, real world standards are rarely fully open or fully closed: unlike the "Western" movies of 50 years ago, when it comes to standards openness there are no black hats and white hats — only shades of gray. At worst, these unrealizable ideals are economically destructive: producers must be paid somehow, and the cost of developing a standard—and of producing the technology precursors and eventual implementations—must be either directly or indirectly born by the eventual beneficiaries. Thus, economic realism about open standards is a prerequisite to any discussion of open standards, whether firms strategies or public policy.

1.1 The Case for Open Standards

If you ask most buyers today what they prefer about open standards, their answer implies that they believe than open standards assures that multiple vendors will provide competing implementations of

[1] For example, a partnership of European standardization bodies have defined an open standard as one "developed and/or affirmed in a transparent process open to all relevant players…; either free of IPR concerns, or licensable on a (fair), reasonable and non-discriminatory ((F)RAND) basis; driven by stakeholders, and … publicly available" (ICTSB, 2005: 10).

that standard, which therefore reduces (or eliminates) the risk of proprietary rent-seeking. More sophisticated users are also aware of the positive feedback mechanism of the adoption of network goods, and they thus hope to share in reduced costs through economies of scale or at least avoid joining (as David 1987 refers to them) the ranks of "angry orphans."

The presumption, then, is that open standards lead to wider knowledge about a technology and more competition, which in turn, provide wider variety and lower prices for implementations of the standards and the associated complementary products. Meanwhile, lower prices are expected to produce a positive feedback loop, thereby further increasing demand. In Figure 1, I summarize a general causal model integrating the implicit arguments advanced by advocates of open standards — adapted from the West (2005) analysis of similar implicit arguments advocated for Apple Computer.

Beginning with the Open Systems movement of the 1980s, organizational buyers and government regulators have adopted policies formalizing a bias towards open standards, as when the U.S. Government's procurement requirements sustained the POSIX (Portable Operating Systems Interface for UNIX) codification, which was sponsored by the Institute of Electrical and Electronics Engineers (IEEE). At times, the enthusiasm for open standards (particularly among technical users) has approached the fervor of a social movement, as with the "Live Free or Die: UNIX" license plates (Raymond 2003). This ideology of choice and user freedom led directly to the Free Software and Open Source social movements (West and Dedrick 2005).

1.2 Do We Know *Open* When We See It?

What is an open standard?[2] Some have argued that Open Source software is the ultimate form of an open standard because implementations are provided freely for all to use (West 2003). Others have argued (at

[2] For some standardization experts, the question of an open standard is much simpler, because they claim the word *standard* can only be used for specifications developed (or directly sanctioned) by government agencies or quasi-official bodies such as ANSI, the ISO or ITU. Consistent with the economics literature, this paper uses the broader definition of *standard* to encompass that which provides technical interoperability and comparability, no matter what its origins.

least privately) that Open Source software is merely a single implementation produced by a closed group, without the process fairness of a formal standards development organization (SDO).

One way to define *open standard* would be through inductive theory creation from a series of commonly accepted exemplars. After all, such inductive theory creation is a widely accepted approach in the social sciences and is particularly suitable for reconciling contradictory or paradoxical evidence (Eisenhardt 1989). Therefore, I list four of the best-known IT standards that have been cited by at least some advocates as examples of open standards (Table 1), and provide a short history of each standard below:

- *"Wintel" personal computers.* In the 1980s, the IBM PC was hailed as a revolutionary open computing standard—in contrast to the vertically integrated mainframe computer and rival PC standards (Grindley 1995; Grove 1996; West 2005). While competition at the system level was high, it became clear during the 1990s that competition at the processor and operating system level was low, leading to high profits for Microsoft and Intel, and various user attempts to reduce their proprietary rents (Kraemer and Dedrick 1998; West and Dedrick 2001).
- *GSM phones.*[3] The most popular second-generation mobile phone standard was created using formal de jure standardization processes and was fully sanctioned as a government standard (e.g., Haug 2002). Yet, key goals of the standard were to generate patent royalties for participants (estimated at $15 per handset), and thus keep out foreign manufacturers (Iversen 1999; Bekkers 2002; Loomis 2005). Unlike elsewhere, in Europe governments protected GSM from competition through explicit regulations (West 2002).
- *The Open Group.* This group is the steward of the Open Systems movement, promoting UNIX as a multivendor portable operating system. It has rigorous procedures for process fairness and compliance certification, but its high fees limit participation in its standardization efforts to the largest of vendor and user organizations.

- *The Internet Engineering Task Force (IETF).* In contrast to the Open Group, the IETF had no membership fees, open discussions through online mailing lists, and freely distributed standards. Nevertheless, the IETF was supported by high fees for participation in its face-to-face meetings (Gross 2004). Also, some of its most successful standards (e.g., SMTP, or Simple Mail Transfer Protocol; TCP/IP, or Transfer Control Protocol/Internet Protocol) were achieved in the organization's early days, when it was an invitation-only group of contractors working for the U.S. Department of Defense.

These examples highlight at least two problems with the conventional open versus closed dichotomy. First, a specific producer, user, or policymaker might think, "I know an open standard when I see it," but a consistent classification across all stakeholders seems unlikely.[4] Perhaps in some areas of public policy, an intersubjective definition administered by a small number of privileged individuals is an acceptable solution, but it is problematic in establishing consistent policies for the operation of a complex economy.

Second, just as Gabel (1987) identified multiple dimensions of compatibility, these examples suggest that openness is represented by more than a single dimension. Previous researchers (von Burg 2001, p. 34; West 2003) have identified multiple intermediate levels of openness between the most proprietary and most open examples of standards.

If different stakeholders have heterogeneous importance ratings for these dimensions and there is perceptual error in rating each standard along a continuum, then attempts to identify the most open standard can easily produce divergent ratings across a range of stakeholders. Thus, we need a more rigorous and consistent way of identifying standard openness. At the same time, we should acknowledge that different stakeholders assign different priorities to the various dimensions of openness, and some stakeholders (e.g., vendors) do not prefer the most open alternative for some of these dimensions.

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3 GSM originally stood for *Group Spécial Mobile,* but seeking to shed its Francophone roots while keeping the now-famous acronym, was later changed to Global System for Mobile Communications (Bekkers, 2002: 273).

4 In a 1964 Supreme Court opinion, Justice Potter Stewart declined to enact an objective standard for pornography not protected by free speech, famously observing, "perhaps I could never succeed in intelligibly doing so. But I know it when I see it" (*Jacobelis v. Ohio,* 378 U.S. 184).

In the following section, I focus on the role of standards in the IT sector, examine the various economic and technological forces that make standards more or less open, describe the competing interests inherent in open standardization, and introduce a process model for understanding standards adoption. Next, in Section 3, using the process model as a foundation, I examine the multiple dimensions of standards openness and discuss what attributes of standards and of the policies used in their creation that can increase or decrease their openness. Then, in Section 4, I examine what the practical limits to openness are in privately funded innovation and standardization? Finally, in Section 5, I offer conclusions and directions for further research.

2. COMPETING INTERESTS IN OPEN STANDARDIZATION

2.1 Role of Standards in the IT Sector

Product compatibility standards have been an essential prerequisite for much of the IT sector, which includes computing, software, networking, and telecommunications products. These IT products derive much or all of their utility from the interoperability obtained by implementing compatibility standards. There may be symmetric interoperability between two competing products implementing the same standards, as when one telephone modem, fax machine, or e-mail program talks to another. Or, there may be asymmetric interoperablility across a well-defined interface among two or more classes of products—such as between a computer platform and its applications or a cell phone and its radio base station.

Technical interoperability has economic consequences. Rohlfs (1974) first identified the symmetric case, which we now refer to as a *direct network effect,* where increasing adoption by other users of a given standard increases the utility of that standard to the focal user. Asymmetric compatibility corresponds to what Katz and Shapiro (1985, p. 424) call "hardware-software paradigm" and what Teece (1986, p. 289) terms "specialized complementary assets," where the most popular standard attracts a larger supply of complementary products, which in turn increases the attractiveness of the standard. This positive feedback model provides "demand side economies of scale" (Katz and Shapiro 1985; Rohlfs

2001). At the same time, user investments in these specialized assets create switching costs, such that users tend to keep the same standard once procured (Greenstein 1993, 1997).

A final factor in the economics of standards competition is the up-front research and development (R&D) necessary to create both the standard and its implementation. Where such R&D costs are high, they combine with network effects and switching costs to create a barrier to potential competitors through increased returns to scale; thus, the most popular standard tends to gain increasing advantage over second-tier rivals (Arthur 1996; Bresnahan and Greenstein 1999). While vendors usually worry about placing second in a standards contest, the "winning" standard in a product category that is never widely adopted may also face dire financial consequences (Grindley 1995).[5]

Given these factors, IT vendors want their respective proprietary standards adopted to provide an ongoing stream of rents. And consequently, IT buyers seek out less proprietary alternatives, as with the UNIX-based open systems.

2.2 Where Do Standards Come From

Various typologies have classified standards as de jure versus de facto on the basis of whether standards are officially sanctioned by the weight of law.[6] Nevertheless, there is a wide array of possible standards setting organizations (SSOs)[7] ranging from a government agency to a single firm serving its own proprietary interests.[8]

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[5] This is a necessarily cursory summary of more than 20 years of economic research on the impacts of standards, including research on network effects, switching costs, and their impacts on interfirm competition. For more detailed reviews, see, for example, Shapiro and Varian (1999), West (2000), Sheremata (2004) and Suarez (2004). For discussions of the limits of the network effects theories, see Liebowitz and Margolis (1999) and West (2005).

[6] This bifurcation greatly simplifies prior taxonomies, such as those of Paul David (see David 1987; David and Greenstein 1990; David and Steinmueller 1994). The subsequent discussion of openness skirts the details of these taxonomies, and the reader is referred to the original work for a more complete treatment.

[7] The comparatively recent SSO acronym does not have a formal definition, but in some usages it refers to multivendor organizations—both officially sanctioned and private consortia—and thus implicitly it excludes the case of a single proprietary firm. Here it is used to refer to any organization that creates a compatibility standard.

[8] Other types of SSOs also include an officially accredited SDO (e.g., the ISO); trade or professional associations to which quasi-official authority has been delegated (e.g., the IEEE); trade or professional associations broadly open to all comers (e.g., Consumer Electronics Association); and ad hoc consortia, usually with invitation-only membership, organized to produce a particular group of standards (e.g., the DVD Forum).

Usually, an SSO defines its scope as translating a particular technology into a completed specification; however, the technical and economic benefits of a standard are delivered by its implementations. Many SSOs thus recognize the role of implementations as a prerequisite to finalizing specifics, as with the Internet Engineering Task Force's (IETF) criterion for "rough consensus and running code" (West and Dedrick 2001). Because of the importance of complementary products, even single-firm standards sponsors often seek feedback from complement providers through large-scale beta pre-release distributions.

This process of creating a specification from a technology, one or more implementations of that specification, complementary products (or complements), and the eventual adoption and use of these products is illustrated by Figure 2. The inputs to the standardization process are given in Table 2.

2.3 Stakeholders in Standardization

The outcome of standardization depends on the SSO's leaders, both in setting its formal policies (if any) and in key early decisions. But who decides who leads? Who is affected by these decisions? There are five classes of potential stakeholders in the standards outcome: (1) technology providers, (2) incumbent vendors, (3) vendor challengers, (4) complement providers, and (5) users.

Technology providers are firms that provide the technology incorporated into the standard, and the outcome of the standard effects how they receive returns on the resources they used for the R&D of their technology. In many cases, these firms are also implementing the eventual standard.

Of the pool of potential implementers, market-leading vendors—or incumbent vendors—often seek to use their market power to win acceptance of their own standards, whether they are created within the firm or by a friendly SSO. In either case, the goals are to control direction of the standard implementation and earn a stream of proprietary rents (Morris and Ferguson 1993; Moschella 1997; Shapiro and Varian 1999; West and Dedrick 2000; Gawer and Cusumano 2002).

Many open standards are created by groups of firms united in competing against a proprietary standard to avoid being shut out of the market (Grindley 1995, p. 31). Such standards alliances by vendor challengers often reflect their individual weak market power vis-à-vis the industry leader's. As a leading expert on standards consortia explained, “There was a greater threat of someone getting a monopoly than [there was] the likelihood of themselves getting a monopoly”; the vendor challengers join open standards consortia because “you’re not so much gaining an advantage as denying someone else from gaining a proprietary advantage” (Updegrove 2004).

For example, vendors in the X/OPEN group sought to win adoption from customers to weaken IBM’s market power (Gabel 1987). Conversely, market leaders feel less need to be open, as when IBM (unsuccessfully) sought to promote its Token Ring LAN standard against the IEEE-sanctioned Ethernet standard (von Burg 2001).

Whether makers of recorded music (Grindley 1995) or videogames (Gallagher and Park 2002), complement providers want one thing: A large market for their respectively complementary products. Like the vendors, they want a high level of adoption, but unlike vendors, they rarely care about the price, and thus generally prefer lower-price, higher-volume implementations of standards. For example, during Apple’s brief experiment of licensing Macintosh PC clones , some of the most virulent support for the clones came from the Macintosh trade press and independent software vendors, that would enjoy a larger market if the clone makers increased system sales even slightly. Apple cared whether its profits from licensing clones matched those lost from direct sales, but the complementors did not (West 2005).

Finally, users care about the degree to which the standards implementations deliver the promised interoperability. As was previously noted, many also care about the degree to which open specification (or spec-creation process) enables competition between vendors, as well as care about the risk of being orphaned by an abandoned standard. Despite their intended role as the eventual consumer of the standards, users are largely under-represented in IT standardization, which is mostly dominated by IT vendors (Jakobs, Procter, and Williams 2001; de Vries, Verheul, and Willemse 2003). Many user organizations are happy to leave the details of standardization to their suppliers (Jakobs, Procter, and Williams 1996; Isaak forthcoming). Nevertheless, monopsony buyers have often played a disproportionate role in determining standards outcomes, as with the influence of government telephone monopolies in Japan and various European countries in setting telecommunications standards (Lyytinen and Fomin 2002), or the role of U.S. cable television operators in forcing the standardization of cable modems (Eisenmann 2004). At the other extreme, highly knowledgeable individual engineers (sometimes referred to as the "geek crowd") loosely organized via the Internet now have a significant influence on standardization policies, particularly as they relate to open source software.

2.4 Cooperative Versus Competing Interests

Vendors, complement providers, and even users may make investments that are specialized to a given standard (Teece 1986). If the standard proves unsuccessful (usually represented by a lack of adoption), that investment proves wasted. Thus, all three stakeholder groups share a common interest in seeing the standard widely adopted.

When it comes to proprietary standards, leading vendors and users have conflicting goals. The leading vendors obviously want their own version adopted as the standard—as with, for example, IBM winning mainframes or Qualcomm winning U.S. cell phone adoption. If this does not occur, they would nevertheless prefer that an open standard be adopted than have a rival's proprietary version be adopted. The vendor's worst case scenario would be to spend resources creating a proprietary standard and then be required to switch to a rival's, such as Sony did with the VHS video recorder standard (Grindley 1995). A stylized version of this payoff matrix is shown in Table 3.

Even when facing little or no competition, leading vendors face conflicting goals between sales volume and sales per customer, which West (2003, p. 1259) identifies as

> … the essential tension of *de facto* standards creation: that between appropriability and adoption. To recoup the costs of developing a platform, its sponsor must be able to appropriate for itself some portion of the economic benefits of that platform. But to obtain any returns at all, the sponsor must get the platform adopted, which requires sharing the economic returns with buyers and other members of the value chain.

Meanwhile, the vendor challengers might seek to establish an open standard if their own proprietary standard has little chance of adoption.

3. *DIMENSIONS OF STANDARDS OPENNESS*

Standards have multiple potential dimensions of openness. The practice of standardization thus far suggests that these dimensions are not fully orthogonal, in that openness in some dimensions is correlated to that in others. Still, it is possible imagine several mutually exclusive and comprehensive systems for mapping the space of standards openness. Here, I organize the classification on the basis of the process model in Figure 2.

3.1 Specification Rights

The specification creation process converts the basic technology into a set of rules for interoperability between one or more class of goods. The process can range from simple to extremely complex—from a single-firm proprietary standard, where decisions are made within the boundaries of the firm to a collaboratively developed standard that almost always includes firms creating implementations (vendors), but may also include other stakeholders such as users, complementors, or suppliers of component technologies. For collaborative standards, there will be variance within groups on the basis of differing needs and prior investments. For example, among those standardizing UNIX, only a small number of vendors and users cared about its use in real-time systems such as aircraft (Isaak forthcoming). Therefore, it matters which stakeholders get a voice and how disagreements are resolved.

Thus, whose interests are served by a specification depends on two factors: The first is what access do outsiders have in the decision process, or who participates—which O'Mahony and West (2005) term "permeability." The second is how the decisions are made by those who do participate.

3.1.1 Who Participates?

There are four scenarios under which stakeholders can participate in standards creation or sponsorship.

1. Fixed group (no new members): New entrants are not allowed to participate in the standardization effort, as with most single-firm proprietary standards and most standards fora. In other cases, new firms can join but cannot obtain the same rights as the founding members, as with Intel's USB (universal serial bus) standardization (Mackie-Mason and Netz, this volume).

2. Members with qualifications (country club): Commonly found with standards consortia, here existing members decide which firms can become new members, typically using some combination of objective and subjectively interpreted criteria. The X/Open consortium fit this pattern (Isaak forthcoming).

3. Nondiscretionary membership (fitness club): Upon filing a form (and, in most cases, paying dues) nearly all firms can become members. Many trade associations (such as the Telecommunications Industry Association, arbiter of U.S. cell phone standards) use this process.

4. Nonmember organizations (town meeting): There is no membership required to participate, such as the IETF, which prides itself on its openness to participation.[9]

Within these four scenarios, there may be differing levels of accessibility. Qualifications can be interpreted strictly or loosely; the membership dues or participation costs can be a few thousand dollars (allowing small companies to participate), hundreds of thousands of dollars (excluding all but the largest of firms) or proportional to firm size (allowing small firms but maximizing revenues from large firms). There may also be indirect barriers: If a large organization pays to have dozens of engineers become knowledgeable and actively involved, then it may be difficult for competitors to have similar influence without a comparable investment in cash and/or labor.

3.1.2 Specification Process

Different SSOs can vary considerably in the openness of the process used to create a specification. Among the most important issues are how decisions are made: For example, a requirement for consensus or a supermajority tends to increase the influence of a small number of participants or, conversely, reduce the ability of a single powerful vendor to dominate the process.

Meanwhile, SDOs are usually held as exemplars of process openness (e.g., Krechmer forthcoming). Yet, such openness costs time and money; during the 1980s, this proved a disadvantage for formal SDOs, leading to the rise of standards consortia (ConsortiumInfo.org 2005). Such consortia can improve speed and time to market through decreased permeability—either by who may join or by how much influence smaller firms have, or both. Led by a handful of dominant industry firms, a small consortium with less due process can more quickly complete a specification and begin implementation.[10]

Openness has been a key attribute of both many studies of formal standardization practices (e.g., Cargill 1989; David and Shurmer 1996; Jakobs 2000; Egyedi 2003; Krechmer forthcoming) and case studies in telecommunications and open systems standardization (e.g. Bekkers 2001; Isaak forthcoming). The often-studied formal process of openness, however, does not completely predict the actual level of openness. In one of the few studies of the level of openness, Egyedi (2003, p.34) concludes that "dominant rhetoric underestimates the openness of most industry consortia and overestimates the democratic process in formal standards committees."

3.1.3 Goals of Participation

The decision process and the barriers to participation—whether direct or indirect—have a major impact on whose goals are served in standardization. These goals might include the following:

1. Matching existing implementations. One concern is to make standards consistent with existing investments—particularly when standardization is used to codify and harmonize existing implementations. In such post hoc standardization, users and complementors want new standards upwardly compatible with the standards they have already adopted. Vendors want the formal standard to closely match their existing de facto implementations: Sometimes this is achieved through a superset of existing participants, as with POSIX (Isaak forthcoming). In other cases, it is by "splitting the difference"

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[9] "The IETF is not a membership organization …The IETF is a large open international community…open to any interested individual. The actual technical work of the IETF is done in its working groups. To become a participant in the IETF, one merely becomes active in one or more working groups by asking to be added to the WG's mailing list" (IETF 2004).

[10] A membership-only standardization body could be either a standards "consortium" or a "forum", with the former considerably more open than the latter (Updegrove, 2005). As current research has not distinguished between the two, for simplicity's sake I generally use the term "consortium" to refer to both in this article.

between two incompatible approaches, as with V.90 standardization of 56K modems (Gandal, Gantman, and Genesove this volume).

2. Patent royalties. Vendors seek to steer standards to "read on" their patent portfolio, so that they can use the patents raise the cost to competitors (perhaps to prohibitive levels). Getting patents included in the standards is a crucial part of business models of nonintegrated firms that supply technology but not implementations, and thus depend on patent royalties for revenues, as with Rambus and the RDRAM standards.[11]

3. Alignment of technology. Beyond patents, potential implementers have varied technological expertise, and thus seek to influence the standard in a direction that will give them a (often transient) competitive advantage in implementation. Such tensions are rarely documented outside the SSO; a rare exception is Bekkers' (2001) account of the French and German goals in GSM standardization.

4. Pace of standardization. Participants may wish to control the rate of change in the standard. Proprietary systems and component vendors—whether IBM, DEC (Digital Equipment Corporation), Sun, Intel, or Microsoft—have always used dynamic standards as a source of competitive advantage: The more the standard changes, the harder it is to maintain commercially viable competing implementations, and thus single-firm de facto standards naturally favor a higher rate of change. Isaak (forthcoming) notes that, conversely, successful incumbent vendors often use procedural efforts to slow formal post hoc standardization, which can reduce switching costs and commoditize their respective proprietary implementations.

In addition to trying to change the specification, stakeholders also participate to learn about the nascent standard. The benefits may be transitory, but the value of having early access to an unreleased standard is often enough to attract firms to pay the membership fees that support the standardization effort (Updegrove 2003a). Yet, encouraging firms to pay for such access directly conflicts with providing transparency to nonparticipants. Krechmer (forthcoming) argues that a key measure of openness is the general availability of the specification documents, particularly for work in progress. For some SSOs, this openness first happens during a public comment period — before the standard is formally ratified, but after standards creators have enjoyed early access.

3.2 Implementation and Complementing Rights

Specification for a standard will not provide interoperability until an implementation is made available to end users. Vendors involved in creating the standard create offer their own individual (or shared) implementations. In some cases, the SSO encourages others also to implement the standard, while in others, competing implementations are not supported or are even actively discouraged. For example, in the open source community multiple implementations are disparaged as "forking".

For symmetric standards, interoperability is directly between implementations, while asymmetric standards require interoperability between implementations and complements. Such complements may be developed by vertically integrated implementers or third-party suppliers of complements. In some cases, customers may be their own complementors, as when management information systems departments create in-house software packages that work with a given platform standard.

3.2.1 Using the Specification

Key to implementing or complementing a standard is the availability of a complete specification. This is typically the major focus of a formal SDO, which seeks to create an open, fully documented specification. The policies of consortia vary considerably, with some also publishing formal specifications and others delaying or preventing access by nonmember firms. Specifications for creating complements for a standard are generally a proper subset of those necessary for implementing that same standard, allowing a monopoly (or oligopoly) standards creator to encourage complements without providing enough information for rival implementations.

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[11] The Rambus case is controversial because of questions as to whether its patent claims were finalized before or after the standard was written. Tansey, Neal, and Carroll (2005) offer an unusual perspective, presenting many of Rambus' actions as a rational response to implementer efforts to reduce or eliminate intellectual property (IP) royalties.

Owners of de facto standards often use a combination of trade secret and copyright law to deter rival implementations, as well as to exclude unlicensed complements. Such methods also help the owners collect royalties on complements. Nevertheless, statutory and case law in many developed countries have allowed reverse engineering to achieve compatibility to circumvent such barriers—with complements granted more latitude than competing implementations (West 1995).

3.2.2 Incomplete Specification and Disclosure

Standards differ in their complexity. The specifications for most modern complex systems are incomplete, and divergent interpretations (in implementations and/or complements) reduce actual compatibility until the interpretations are reconciled. For example, omissions from the initial GSM mobile phone standard meant that complementary products from competing vendors could not interoperate for years.

Incomplete specifications may reflect delays in specification, knowledge gaps between specification writers and the actual implementers, or merely the inherent limitation of describing on paper the full behavior of a complex system. Thus, for many software standards (such as UNIX or Linux) it is accepted that the source code for the implementation is more complete and accurate than any written specification — as acknowledged in modern software engineering practices (e.g., Reeves 1992). Hence, source code was incorporated in software engineering practices, such as agile programming and extreme methods (Fowler 2005). In particular, the availability of source code for a reference implementation reduces ambiguity and increases interoperability and openness; a notable example is how the Internet was enabled by the freely available Berkeley UNIX implementation of TCP/IP, which formed the basis for most open and proprietary implementations of the protocol.

Some omissions may be intentional, however. Proprietary firms with high market share may also add nonpublic interfaces to their implementation to provide preferential access to only some providers of complements. For example, a vertically integrated software vendor may seek to link sales of one layer of the software "stack" to another. When the vendor holds monopoly power in one layer, such linking is potentially a violation of national competition laws. This was one of the allegations covered by the 1995 consent degree resolving the first *United States v. Microsoft* case (Sheremata 1997). Thus, Krechmer (forthcoming) argues that complete documentation is an essential requirement for an open standard.

Even with full documentation, there are still opportunities for sponsors to gain advantage via tacit information gleaned through the creation of a standard. For example, Sun Microsystems developed and disseminated numerous industry de facto standards that were made available to customers, complementors, and competitors. Yet, much as with a fully proprietary standard such as IBM's MVS operating system or Microsoft Windows, Sun's control and knowledge of the technology gave it the quickest access to specifications and thus a time advantage in creating implementations. Finally, Sun benefited from a pool of tacit knowledge built up through learning by doing (Garud and Kumaraswamy 1993, p 360).

3.3 Usage Rights

Some rights to implementations are inherent in any standard created to support commercially distributed products. Typically, when a customer purchases a product, he or she purchases the rights to use the standard incorporated in the product and its complements. Many key rights—such as price, terms, or term of usage—are specified by the implementer. In these cases, the openness of the standard itself (e.g., its creation process or formal specification) is germane only to the degree that limited competition might force buyers to accept a single usage model.

Many standards, however, indirectly or directly constrain the rights of buyers to utilize implementations. For example, for many information goods, digital rights management (DRM) limits what users can do with their purchases (Samuelson 2003). In this case, complementors (leading media companies) refuse to provide their information goods for use with a standard unless the standard enforces certain use restrictions. So, from a user perspective, a music file encoded with a file format and DRM system such as Apple's FairPlay or Microsoft's Windows Media is less open than with a file encoded with the (royalty-bearing) MP3 standard which imposes no such usage restrictions.

3.4 Must Open Be Free?

3.4.1 Patents, Royalties, and Open Standards

Some aspects of a standard can raise costs at any phase of the process. The key emerging cost issue has been the increasing impact of patents and patent royalties (cf. Simcoe this volume and forthcoming), primarily due to the success of royalty-based business models for standards such as MP3 and GSM. Other factors have included the case law approval of software patents in the United States, and patent reforms that have made patents easier to enforce without increasing the rigor of the screening process (Graham and Mowery 2003; Updegrove 2003b). Although the royalties are paid in later phases, the impact of IP rights (IPR) on a standard is largely determined by the IPR policies used to create the standard. These policies constrain the ability of sponsors and other interested parties to profit from the incorporation of their own IPR in a standard.

One possible SSO approach to IP, which risks blocking efforts by patent holders, is sheer denial, that is, ignore potential patent issues when writing the standard and let the marketplace sort it out during the implementation phase. A more aggressive approach is mandatory disclosure, that is, requiring standardization participants to disclose any possibly related IP during the specification process. Even this latter policy has limitations: First, in a large corporation, the standardization representative may not be aware of the company's entire IP portfolio. Second, (as with other SSO policies) the provisions are not binding on firms that choose not to participate in the SSO effort.

The two most commonly used royalty approaches for standards-related patents are reasonable and nondiscriminatory (RAND) and royalty free. While the RAND approach can be royalty free, in practice it allows a specific subset of standards sponsors (the patent-holders) to create an exclusive club whose members (through cross-licensing) generally have a superior cost structure to nonmembers. Some (e.g., Krechmer forthcoming) consider RAND to be the minimum acceptable policy for effective open standardization. Meanwhile, the royalty-free approach is approach is strongly preferred by Open Source developers (and others) who consider such that patent royalties—no matter how nondiscriminatory—are not open enough (Festa 2002).

Actual IPR costs go beyond mere policies. Firms within the SSO may seek in good faith to minimize IPR costs, or they may cooperate in creating a patent pool that avoids royalties for participants but increases costs for nonparticipants.

3.4.2 Who Pays?

With free standards, there is a real question of where the resources and incentives will come from (1) to create the technology eventually incorporated in a standard (such as a compression algorithm), (2) to include participants in the standardization activity, and (3) to pay for the operation of the SSO itself. Fully proprietary standards such as those from IBM or Microsoft have been cross-subsidized by a vertically integrated standards creator and implementer. Yet, such cross-subsidies then potentially limit innovation to such vertically integrated firms by excluding potential sources of external technology and innovation (West forthcoming).

Absent such cross-subsidies, revenue models have included four direct methods to offset costs:

1. Access to Specification. Charging for access to a standard (no matter how nominal) tends to hinder diffusion of the standard and its associated knowledge (Rada and Berg 1995). Specifications may be free from proprietary firms that can assure themselves of revenues from selling an implementation, while nonproprietary SSOs that depend on standardization revenues are more likely to sell their specifications. Outside the IT sphere, important policy questions have been raised about the government mandated regulations (such as building codes) that require access to commercially sold standards.

2. Rival Implementations. The patent portfolio of the GSM mobile phone standard was intentionally designed to keep out competitors, such that more than twenty years after deployment of the first GSM system, foreign firms decided acquiring the patent portfolio of one of the original GSM sponsors was an attractive way to enter the European market (Ramstad and Pringle 2004).

3. Complementors. While video game console makers such as Nintendo encourage third parties to make complementary products (software), a fundamental basis of their business model is that they charge royalties on all third-party products shipped (Gallagher and Park 2002).

4. Customers. The MPEG-4 video compression standard was the first audio-visual standard that not only charged royalty fees on encoding and decoding tools (complements), but also sought a royalty for commercial content distributed in the MPEG-4 format (Bier 2002).

In addition to these four direct methods, SSOs potentially institute indirect methods to offset costs. Barriers to rival implementations—including incomplete standardization or withholding of key information from nonparticipants—will increase implementation costs for those nonparticipating firms choosing to implement the standard. Both direct and indirect costs tend to raise user prices, reduce variety of implementations and complements, and reduce adoption of the standard.

4. DISTINGUISHING OPENNESS IN PRACTICE

4.1 Common Bundles of Openness

Firms face a fundamental dilemma in their standardization investment: They need a standard to be open enough to attract adoption but closed enough to be able to appropriate a return on that investment (West 2003). After several decades worth of experience, there is a range of business models for standards, which fit Gawer and Cusumano's (2002) definition of "open but not open" platforms: Noted below are three basic approaches to these models:

1. Open to complementors. In this basic computer industry model—later adopted by the videogame industry—the systems vendor controls platform standards but seeks third-party software vendors to provide essential complements. There are various business models for sponsors gaining direct or indirect revenues from complements, such as the differences between PCs and videogame consoles in the relationship between the implementer and complementors (Takahashi 2002).

2. Open to the club. Some standards consortia in computers, communications, and consumer electronics pools the interests of members to gain an advantage over outsiders in terms of tacit knowledge, time to market, or IPR licensing costs.[12] Insiders and outsiders are often separated by a large admission fee, which also provides essential resources.

3. Open as a public good. Some combination of industry and public representatives create a standard that will be shared by all, without discrimination; producers use these infrastructure standards as a basis for their own products.

Other levers are available for opening standards. It is assumed that some variables (price of specifications) have less impact than others (IPR royalties), but absent empirical proof, these present opportunities for further experimentation in the practice of standardization.

In particular, openness of shared implementations offer a new range of possibilities for using open standardization as a means for organizing innovation. The most widespread use of such shared implementations can be found in Open Source software, where West and Gallagher (forthcoming) identify four basic business models, three of which roughly correspond to the three models listed above. In the fourth ("spinout") model, a firm abdicates control and transforms a once private implementation into a public good, in hopes of attracting donated innovations and fueling adoption of the standard.

4.2 Forces to Increase or Decrease Openness

Will a standard become more or less open over time? It is difficult a priori to predict the net effect of the competing forces. There are differing forces at work: Specifically, over time a firm's control over a standard weakens, which increases competition and thus openness. Meanwhile, supply and demand-side economies of scale strengthen the importance of that standard, which thus weakens the threat of competing standards.

4.2.1 Increasing Openness

One of the key benefits to being the proprietary sponsor(s) of a platform is gaining transitory competitive advantage over potential rivals, which might be via competing implementations or through providing

[12] Updegrove (2005) argues that only a few consortia fit this characterization, and, in fact, most SSOs of this nature are organized as a standards "forum" rather than "consortium."

complementary assets. This is particularly true for computing platforms—processors, operating systems, and middleware—for which vendors continue to add new interfaces to extend their proprietary standard.

Yet, for other types of standards, innovation is episodic: Major changes to cell phone standards have historically happened only once a decade (West 2002); for videogame platforms, once every five years (Gallagher and Park 2002).[13] Thus, for hardware and communications standards, a key goal is to temporarily suspend technological progress for some component of the system in the name of compatibility (cf. Bresnahan and Greenstein, 1999). That way, technical interoperability will be assured because products sold over time will interoperate, despite improvements in available technology such as provided through Moore's Law.

Ultimately, for standards for which innovation is episodic, implementations tend to become commoditized as tacit knowledge becomes widely dispersed. As such, the competitive advantage of the standard's original specification declines, barriers to entry and imitation decline—resulting in increased competition and openness to implementers. For example, though IBM invented the IBM PC standard, rivals learned how to clone cruical ROM (read-only memory) software, and by 1995 IBM held less than 10% of the global PC market (West and Dedrick 2000). Similarly, while Matsushita dominated the VHS standard in the mid-1980s, by 2001 Samsung claimed the top global share in VCR (video cassette recorder) production (Cusumano, Mylonadis, and Rosenbloom 1992; *Korea Times* 2001).

Finally, in some cases formal IPR becomes obsolete—either because it is invented around, or because the patent term has expired. RCA once held the patent for the 45 rpm record and other key audio technologies, but the patents eventually expired. From 1979 to 1996, the UNIX standard was covered by a patent on Dennis Ritchie's setuid access permission solution (U.S. Patent 4,135,240), but the patent expired just as Linux was beginning to become widely adopted.

[13] In this regard, videogame platforms are more like consumer electronics and less like computing platforms.

4.2.2 Decreasing Openness

Other factors tend to decrease openness of a standard by increasing the power of the standards owner relative to implementers, complementors, and users. One common factor increasing the proprietary control of a leading standard is that rivals weaken or disappear through the positive feedback spiral forcing "that which loses advantage to lose further advantage" (Arthur 1996, p. 100). So, as a once-equal platform contest becomes more unequal, these positive feedback loops mean that the winning platform attracts a wider variety of third-party complements, as has happened in successive generations of videogame consoles (Gallagher and Park 2002; Takahashi 2002).

A related consequence is that an aggressive early battle for complements can dissipate. In other words, the standards victor need not fight for complementors because they will naturally gravitate to the most popular standard. In 1990, Microsoft worked hard to convince independent software vendors (ISVs) not only to invest to upgrade MS-DOS applications, but also to prioritize specializing user interface applications for Windows 3.0 ahead of OS/2 and Macintosh; by 1998, all three alternatives to Windows were declining and major ISVs of necessity made Windows their top priority—decreasing their leverage with Microsoft.

Finally, users often make their own investments in a technological innovation, described as "user innovation" (von Hippel 1988) or "co-invention" (Bresnahan and Greenstein 1996); a common example of this kind of investment among organizational users of information systems has been internal software development (e.g., Baba, Takai, and Mizula 1996). If user innovation is specialized to the given standard, then the users' switching costs are raised (Greenstein 1993, 1997). These switching costs may reflect direct economic investments, or "merely" the inconvenience of consumer frustration in the face of obsolete user skills (West, 2000). Either type of costs reduces the ability of users to bargain credibly with standards creators or implementers regarding switching to a rival standard.

5. *MAKING SENSE OF OPEN STANDARDS*

5.1 Realities: The Many Shades of Gray

The goal of this paper has been to dissect an oversimplified and perhaps dangerously naïve view of open standards. Standards have often been characterized as either open or proprietary, but in fact there are many gradations in between. So-called open and closed standards are similar in many ways, such as in the rights for providing complements to or using implementations of the standard. In both cases, those involved in creating a specification gain tacit knowledge that is not available to outsiders.

As with anything else in life, there is no free lunch in IT standardization. The costs to creating standards and firms' responses to them can make standards more or less open. Firms creating a standard hope to gain a payoff through some subsequent competitive advantage, such as creating barriers to imitators. These barriers either directly or indirectly reduce the openness of a standard; and firms will be willing to create open standards only if their business model allows for cross-subsidy of standards creation. In fact, Updegrove (2003a) notes that attempts to make SSOs more open can destroy the revenue model that allows the organization to operate.

Standards have multiple dimensions of openness, with many standards relatively open on one dimension and relatively closed on another. If these dimensions are organized around the phases of standardization—specification, implementation, complements, and use—then different stakeholders will have different priorities, perceptions, and preferences regarding standards openness, depending on what their interest in the standard is. Some of the stakeholder interests will be aligned: Most if not all stakeholders will want to see the standard widely adopted and used. Other stakeholder interests will be divergent, if not contradictory. Users will want many commoditized implementations, while vendors may want a small number of differentiated implementations.

Finally, openness is not a static construct, but instead—as with any artifact of a complex interdependent sociotechnical system—a dynamic one. Some changes tend toward dissipating proprietary advantage and increasing commoditization, particularly for static standards such as those fixed in hardware, where once scarce tacit knowledge of a standard becomes more widely diffused over time through labor mobility, reverse engineering, or rivalrous R&D. The changes in openness may also be structural. The UNIX-related POSIX standards process became less open, as the initial efforts of firms and individuals were supplanted by select members of a vendor consortium (Isaak forthcoming). Conversely, the initial consortium to create an Open Source ecosystem around the Eclipse tools for Java was originally tightly controlled by IBM, but has since delegated control to a wider group of firms (West and Gallagher forthcoming).

5.2 Implications for Policymakers

Openness has direct policy implications. Key aspects of U.S. (and in some cases E.U.) antitrust lawsuits against IBM, AT&T, Microsoft, Intel and Rambus, among others, have turned on the openness of standards (e.g., Sheremata 1997; Gilbert and Katz 2001). Public policymakers must define which are the relevant stakeholders in any determination of openness, as reflected in the quasi-experiment of recent antirust cases related to Microsoft Windows. In the European Union, where rival implementers are relevant to competition policy, regulators forced Microsoft to disclose server application program interfaces (APIs) to enable competing and complementary interoperability; no such order was made in the United States, where injunctive relief must be justified entirely on the basis of user welfare.

The list of relevant stakeholders and their requirements also varies by context, in terms of producers, buyers, and the prevailing business models. For a national telecommunications standard, a monopoly standard is the norm, while a monopoly (or small oligopoly) of service providers is expected but a single hardware vendor would be unacceptable. For videogame consoles, a single hardware provider is an outcome of the business model, as is a requirement that software vendors pay to access the standards' IPRs to support the platform. Hence, competition and buyer choice are provided by competing de facto standards resolved through the marketplace.

Some standardization policy has been defined in terms of the organization form used in standards creation, that is, an accredited SDO such as the ISO. Meanwhile, empirical researchers have shown that some closed standardization fora use processes that are as open as a formal SDO (Egyedi 2003), while nominally public SDOs can be used by participants to close barriers against rivals (Bekkers, Duysters, and Verspagen 2002). Thus, a key implication of this paper is that a require for an "open standard" should be defined by the degrees of openness across multiple dimensions rather than the organizational form or even (solely) by the standardization process used. Table 4 offers possible examples of such dimensions; Krechmer (forthcoming) offers a partially overlapping typology from a different perspective.

For those involved in multivendor standardization efforts, particularly important is the increasing cost of patent royalties for standards implementations. During the 1980s and early 1990s, a handful of companies created successful business models from designing their IPR into nominally open standards such as GSM, CD-ROM, and MP3. This has prompted hundreds of companies to seek their own patent annuities, raising the IPR costs of succeeding standards. Simcoe (this volume) demonstrates that even the prospect of such bonanzas threatens to grind standardization processes to a halt.

From a policy standpoint, such excesses will self-correct if there is competition between standards; for example, leading W-CDMA cell phone makers sought a cap to patent royalties to reduce the IPR cost disadvantages relative to the rival cdma2000 (West, forthcoming). But the increasing assertion of IPR in standards will force regulators to trade off IPR as an incentive for innovation against other policy goals, as happened in the *Rambus v. Infineon* cases (Tansey, Neal, and Carroll 2005).

But favoring standards competition as a market corrective would go against government policy to explicitly pick a winning open standard—as with U.S. procurement of POSIX systems or European mandates for GSM. If the goal is to promote competition through support of multivendor standards, what is a multivendor standard? Is UNIX (with multiple semi-compatible implementations running on proprietary hardware) more competitive than the Wintel standard (with a single processor and operating system supplier but multiple competing systems vendors) (West 2003). And should goals of openness override other goals of cost or performance; Isaak (forthcoming) notes that despite direct Federal support for UNIX standardization, government procurement eventually bowed to the efficiencies of high-volume commodity PCs that swamped the UNIX-compliant (but low-volume) workstations and minicomputers.

5.3 Further Research

Putting aside the simplistic bifurcation between open and proprietary classifications of standards provides a wealth of new research opportunities regarding the antecedents, processes, and consequences of compatibility standards. One opportunity would be to map the variability of openness across technologies, standards, and standardization fora to refine classification of the openness dimensions (or develop new ones) and create repeatable (inter-rater reliable) measures of openness. A parallel example can be seen in Open Source software, where, in considering seventeen Open Source projects, O'Mahony and West (2005) identify three dimensions and measure twelve "design parameters" available for increasing the openness of the projects to other participants. From this, they identify two kinds of openness—transparency and permeability—and conclude that it is much easier for profit-seeking sponsors to provide outsiders with visibility than with some authority over control of the project.[14]

Research could examine the interrelationships between these dimensions and parameters. In practice, there is an assumption that degrees of openness are correlated, but should distinguish between those that are causal, from a common antecedent or merely correlational? Are there inverse relationships between specific parameter pairs or is there merely a general constraint to generate revenue somehow? Research should also consider how standardization business models are changing over time, such as how the rise of the Internet increased the expectation of free downloadable standards and reduced the attractiveness of printed (and sold) paper copies.

It is assumed that more-open standards create fewer barriers to imitation and entry. But are some parameters for closing more anti-competitive than others? How do policymakers distinguish between the inherent advantages that accrue to standards creators from anti-competitive behavior creating an illegal cartel? Since some degree of coordination among standards creators (e.g., patent pools) is both exclusionary and reduces implementation transaction costs, where should regulators draw the line? What

[14] Krechmer (forthcoming) recommends his own list of 10 openness criteria, and offers suggestions on how to classify different levels for each. However, his measures are truncated because they omit degrees of "closed"-ness.

can be done to encourage forum shopping (e.g., on IP policy or specification openness) that serves user needs rather than vendor needs?

Such studies should also consider the gap in our knowledge of actual (rather than formal) standardization openness. For example, industry veterans talk about how large companies at the hub of business ecosystems mobilize smaller dependent companies to manipulate open standards voting in their own favor, but such manipulations have not been studied.

Conversely, much of the normative advice to firms is about seeking to control proprietary standards (e.g., Morris and Ferguson 1993; Gawer and Cusumano 2002). If even an Intel or a Microsoft cannot unilaterally impose industry standards without alliances with other firms, how much should new proprietary standards sponsors open up enough to win allies, complements, and adoption, without eliminating all proprietary advantage?

More than just a technical specification, a standard defines the interrelationship of products (and thus value propositions and business models) between firms within an ecosystem. Iansiti and Levien (2004) argue that even without formal market power, firms can create durable value and competitive advantage if they can define a unique role in enabling the ecosystem's overall health. Sponsors of standards often have such latitude, particularly if direct rivals can be excluded from the specification process. Elsewhere in this volume, Mackie-Mason and Netz show how Intel has used such exclusion to create two successful multivendor PC industry standards open enough to attract complementors and thus win adoption, but proprietary enough to assure Intel competitive advantage over rival implementations.

Measuring such effects will be problematic, particularly because by its very nature data is most readily available for only a truncated sample of openness. A few researchers (such as Rosenkopf, Metiu, and George 2001; Simcoe this volume) have shown how to compile data from those SSOs that have a comparatively high level of specification openness. Studying the increasing number of private, members-only standards consortia depends on to what degree these consortia (to use the classification of O'Mahony and West 2005) provide transparency if not permeability. Rarer still are studies of how standards are created within a single firm, such as the process for resolving the trade-offs of creating or capturing value in standards identified by West (2003). Occasionally, regulators themselves obtain the essential data through litigation discovery process; those rare opportunities have informed our understanding of standards policy (e.g., Fisher, McGowan, and Greenwood 1983) and could potentially fill in some of the gaps in our understanding of open standards.

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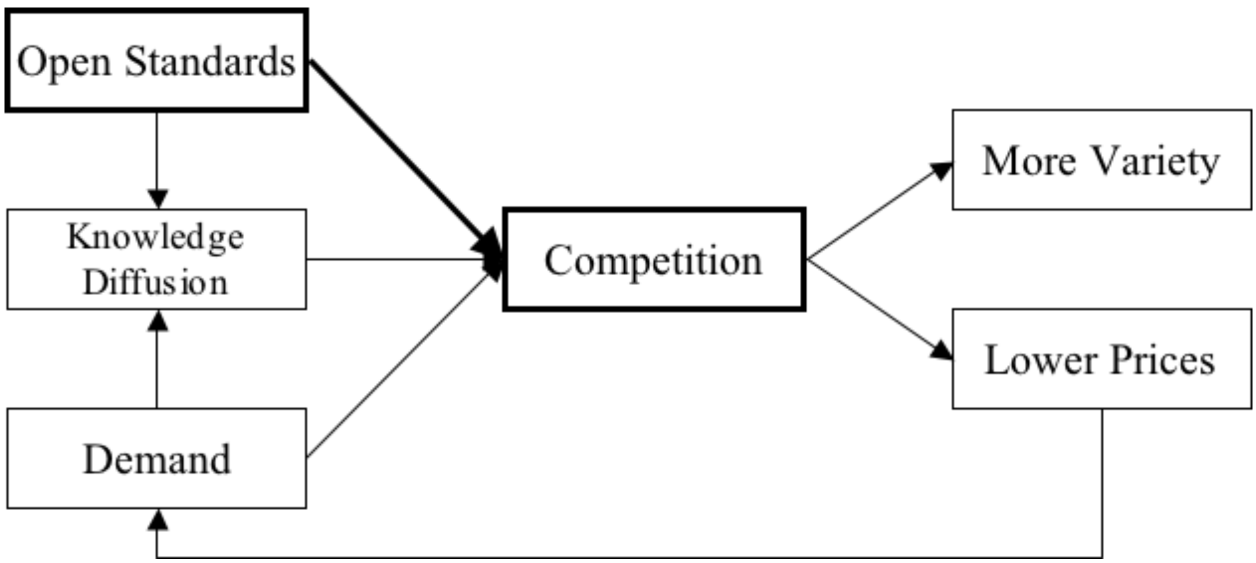
FIGURES AND TABLES

Figure 1: Causal Model of Open Standards



Source: Adapted from West (2005)

Figure 2: Process Model for Stakeholders in Creation and Adoption of Standards

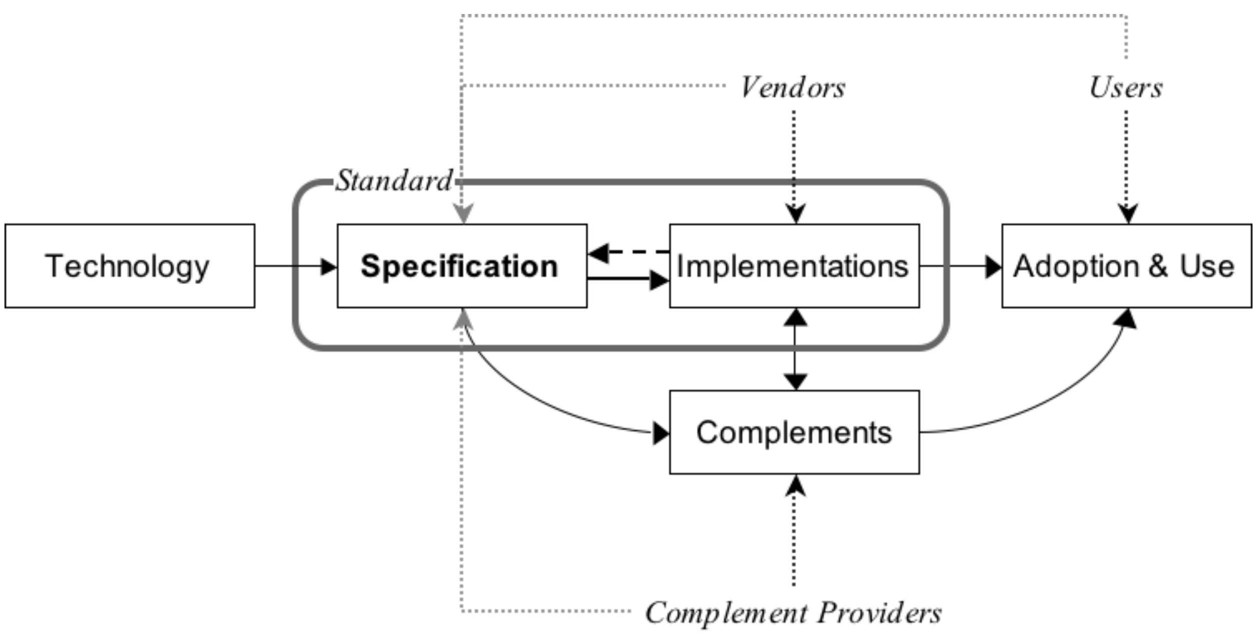


Table 1: Previously Cited Exemplars for Open Standards

Standard	Industry	Sponsor	Open Attributes	Closed Attributes
"Wintel" (i.e., Windows + Intel)	PCs	Two proprietary component suppliers	Multiple systems vendors Low switching costs between systems More open than proprietary mainframe, rival PC standards	Operating system, microprocessor quasi-monopolies Proprietary rents paid to both suppliers
GSM	Mobile phones	Government-sanctioned SDO	Built on formal standardization best practices True multivendor standard Widespread adoption—world market leader	Excluded all but two non-European firms Patent royalties on all implementations Key Goal: Keep Japan out of European market
Open Group	Workstations	Trade association	Clear process fairness Mission is to be vendor-neutral Objective conformance mechanisms	Membership is $5,000-$500,000 per year
IETF	Internet	Virtual Internet association	No membership requirements Specifications distributed free on Internet	Key standards written by closed group of U.S. Government contractors Fees to participate in standards meetings

Table 2: Inputs and Outputs in Four Phases of Standards Creation and Use

Phase	Input	Participant	Policy	Output
Specification	Technology Market demands Participant goals	*any*	Standardization process	Standard specification
Implementation	Specification Existing capabilities Business model	Producer	IP law IP licenses	Product Pricing Use policies
Complement	Specification Implementations	Complementor	Acccess to standard	Complementary product
Use	Implementations Complements	User	Product licenses	Use benefits

Table 3: Hypothetical Vendor Payoff Matrix for Joining Versus Fighting Standards coalitions

Winning Standard Is …	Ours	Competitor's
Completely open	+1	-1
Multivendor proprietary	+2 to +5†	-11
Single vendor proprietary	+10	-11

† Maximum payoff if only one competitor is in the coalition

Table 4: Dimensions of Standards Openness

Phase	Stage	Category	Dimension of Openness	Open State	Closed State
Creation	policy	access	Access to standardization process	Anyone can participate	Only founding firm(s) can participate
Creation	policy	competition	Control of standardization process	All participants have a vote	Decisions are made arbitrarily by sponsor(s)
Implementation	policy	cost	Cost of standard specification	Free	Expensive
Implementation	policy	access	Access to standard to implement	Any firm can make an implementation	Only sponsor(s) can implement standard
Implementation	policy	access	Access to standard to complement	Any firm can make complements	Complements limited to vertically integrated sponsor(s)
Implementation	policy	cost	Free use of standard IPR	IPR is licensed royalty free	IPR separates firms into "haves" and "have nots"
Implementation	outcome	cost	Ratio of IPR cost to implementation costs	IPR costs are negligible	Implementation costs are dominated by IPR royalties
Implementation	policy	cost, access	Shared reference implementation	A reference implementation reduces implementation costs	Everyone implements from scratch
Implementation	outcome	competition	Competing implementations	Low barriers make implementations a commodity	Only one implementation exists
Implementation, Use	policy	competition, cost, access,	Free complete implementation	A shared implementation is available for all to use	Everyone builds their own implementation
Use	policy	access	Access to standard to use	Users have full rights to use the standard	Use is restricted to specific firms
Use	policy	access	Access to standard to use	Users can user the standard for any purpose	Certain types of uses are not allowed (e.g. rival implementations)
Use	policy	cost	Access to standard to use	No further payment is required to use an implementation	Additional payments must be made to standards or IPR owner to use the implementation