Introduction

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TECHNOLOGICAL standards are a cornerstone of the modern information economy. These standards affect firm strategy, market performance and, by extension, economic growth. While there is general agreement that swift movement to superior technological standards is a worthwhile goal, there is much less agreement on how an economy can attain those goals in specific instances. Sometimes there are even debates about whether appropriate standards arose in past episodes – for example, academics still dispute whether Betamax was a technically superior video cassette recorder (VCR) to VHS. Answers are not transparent because a variety of market and nonmarket processes determines the evolution of standards. By default, decentralized market mechanisms, private firms, and standards development organizations shape the development and diffusion of standards.

In addition, when government actors step in to sponsor a new standard or move the market between standards, as they occasionally do, debates about the interaction of competing market and technical factors are not merely academic, nor are the answers transparent. Government actors can make choices about competing specifications for a standard and often have the power to mandate compliance with the standard. Moreover, rarely are these decisions reversed, and when they are, the events are noted for their rarity. For example, the Federal Communication Commission's decision to alter its prior choice over the color television standard a few years later prevented the country from employing technology that all experts regarded as obsolete. It was clearly the right decision in retrospect, and it raises the troubling question about how many poor choices have been made but not reversed because the mistake was less obvious to decision makers than to the technology insiders.

General agreement about appropriate public policy toward government standard setting does not exist. The most basic questions remain

unaddressed. For example, when should policymakers move markets between standards? And when is a government policy favoring compatibility superior to one that fosters – or at least accedes to – competition between incompatible systems?

Despite considerable attention from economic theory, many of these questions remain open. Historically, most research has appropriately attempted to answer questions regarding market competition between competing standards.[1] And, if the reader will allow a bold and sweeping assessment about the received wisdom in the field, despite the existing substantial body of work informed policy values two types of studies that are not yet abundant: (1) empirical studies of standardization that compare and contrast outcomes with and without government intervention and (2) studies identifying the key theoretical trade-offs between the vast variety of mechanisms for determining standards, such as government-based, market-oriented, and the many quasi-market and nonmarket processes.[2]

With that in mind, on May 13 and 14, 2004, the Federal Reserve Bank of Chicago and Northwestern University cosponsored a conference entitled "Standards and Public Policy." The conference brought together roughly forty experts in public policy on standards, including economists from academia, the Federal Reserve System, and industry. We have compiled twelve papers from the conference presentations. Readers will note our emphasis: The volume contains papers focusing on applied questions at the nexus of the pragmatic and puzzling. The goal was to move beyond well-examined settings to less familiar ground.

In this introduction, we briefly place the chapters that follow in context. The early chapters are empirical studies of actual standards competition. Middle chapters focus on committees and standards organizations, while the last section of the book examines governmental approaches to standards policy. We cannot claim that this collection is comprehensive. Indeed, we must admit that certain issues remain nearly as murky as before: Our concluding chapter is a self-admittedly tortuous attempt to go beyond "it depends" in the policy debate, by an

[1] We do this literature a disservice by referring to it so casually, but we do so in the interest of brevity.

[2] The earlier collections by Besen and Johnson (1986), Gabel (1987, 1991), and Grindley (1995) are exceptions.

expert who has contributed at least as much as any other researcher in the field. Nonetheless, the consensus of our conference attendees is that (at least) this type of discussion moves our understanding forward, even if ultimate answers are hard to find. We hope our readers reach the same conclusion.

1 The economics of standards competition

There are a host of prominent historical cases involving duels between competing standards. The VHS/Betamax duel in the VCR markets is a well-known case. There are many others, such as GSM (Global System for Mobile Communications) versus CDMA (Code-Division Multiple Access) and TDMA (Time Division Multiple Access) in cell phones, IBM (International Business Machines) versus DEC (Digital Equipment Corporation) in minicomputers, Microsoft Word versus Word Perfect in word processing, and US Robotics versus Rockwell in 56 K modems. Standards wars also commonly arise as subplots to related larger product market duels. For example, various banks may belong to incompatible ATM (automatic teller machine) networks, and United Airlines and American Airlines sponsor competing airline reservation systems.

What happens in one of these classic standards wars has been the subject of much study.[3] A primary concern is whether the market can settle on an inefficient standard or optimal speed of adoption. This has been at issue in many of the historical episodes mentioned. As an example, consider the decision faced by adopters of a new communication standard such as the fax machine. If no consumers have fax machines, then no one consumer will want to adopt the first fax machine, because a fax machine has no stand-alone value if it cannot communicate with other machines. Thus, adoption by none seems a plausible outcome – though most prefer a situation in which many

[3] Rather than attempting to be exhaustive in our references, we refer the reader to surveys that highlight the main points of the literature. David and Greenstein (1990) is a comprehensive survey of the literature on standards. See Stango (2004) for a more narrowly focused recent discussion of standards wars. Besen and Farrell (1994) and Katz and Shapiro (1994) are excellent pieces covering the economics of compatibility and standards wars. Gandal (2002) provides a more recent survey of some public policy issues related to compatibility and standardization.

consumers adopt. This is a potentially serious policy concern, especially when society as a whole is worse off with adoption by none instead of by many.[4]

Another related concern is the possibility that the market can exhibit lock-in, or what Farrell and Saloner (1985) call *excess inertia*, namely, the propensity to become trapped on an inferior standard. The intuition Farrell and Saloner describe is a situation in which "[adopters] are fence-sitters, happy to jump on the bandwagon [of the new standard] if it gets rolling but insufficiently keen to set it rolling themselves."

Based on this theoretical insight, there is at least a weak consensus in the literature that market-based movement between standards may be suboptimal. "Suboptimal relative to what alternative?" is a reasonable question to ask in response. Networks may not develop at all if most participants are lukewarm about a new standard due to technical uncertainty, even though all would collectively benefit from it. Alternatively, bandwagons may gather speed remarkably quickly once a network becomes large enough to justify investments by potential adopters – indeed, suggesting that markets may, in fact, move between standards too quickly in some circumstances. The lack of any or even partial communication between or among all the potentially affected decision makers can exacerbate such bandwagons.

Despite abundant theoretical thinking on these issues, there have been only a few empirical studies of the economic determinants of standards. These studies are enabled by the appearance of data allowing researchers to examine standards issues by using econometric techniques.[5] These studies have focused on understanding the mechanisms behind market events, not their welfare outcomes. Dranove and Gandal (2003), for example, study application entry in the DVD/DivX (digital video disc/digital video express) war. DVD and DivX were two competing technical formats, and one quickly failed in the marketplace. Dranove and Gandal find that the "preannouncement" of

[4] In fact, in this particular case, it was also a concern that contemporaries did worry about. The technical specifications that became embedded in the fax machine underwent several revisions (without widespread use) before finally becoming widely adopted. See the detailed account in Schmidt and Werle (1998).

[5] This discussion omits mention of the growing empirical literature that focuses on establishing the existence of either direct or indirect network effects, rather than on standards per se (see, e.g., Rohlfs [2001] or Farrell and Klemperer [in press] for a discussion of this literature).

the DivX standard affected the adoption of DVD technology, though they do not attempt to assess whether this outcome was efficient. Gandal et al. (1999) show that the diffusion of the new DOS (disc operating system) standard was affected by the availability of complementary software, but similarly do not attempt to ascertain whether the transition was efficient.

Another example of this line of research is a recent paper by Ohashi (2003), which estimates the importance of network effects in the VHS/Betamax standards battle.[6] An interesting result of Ohashi's analysis is that while it appears that consumers valued the VHS standard early in the battle, he estimates that it would have been possible for Betamax to capture the market if it had used its first-mover advantage to build an installed base through low pricing. Again, this analysis focuses on understanding the results from market mechanisms and process, an understanding that would inform policy choices without presuming what type of actions are optimal.

In this same vein, this volume contains three contributions to the literature dealing with competition between standards. Chapter 1, by Timothy F. Bresnahan, Stanford University, and Pai-Ling Yin, Harvard Business School, adds to our knowledge of empirical circumstances shaping the determination of de facto standards. The authors study both economic and technical forces affecting the diffusion of Web browsers, focusing on why Netscape Navigator eventually lost its lead as a de facto standard to Microsoft Internet Explorer. They draw on the theory of standard setting, especially on the positive economics predictions about market outcomes, such as a tendency to tip and a tendency toward inertia. The basic insights of standard setting theory are borne out in the browser war. They introduce new considerations in their analysis of market conditions, such as the rate of growth of demand and the distribution system. This leads to a complete positive theory of standard setting and a complete theory for explaining the otherwise surprising reversal.

[6] This paper is part of a larger recent literature using structural techniques to estimate the importance of network effects. Rysman (2003) is an early paper examining network effects in the Yellow Pages market. Nair et al. (2003) estimate the magnitude of indirect network effects between Personal Digital Assistants (PDAs) and PDA software. Knittel and Stango (2004) estimate the strength of network effects in ATM markets.

Chapter 2, by Richard Langlois, University of Connecticut, examines institutional structure as a competitive force in standards wars. He looks at the US cluster tool industry, which manufactures the equipment used to produce semiconductors. Competition for these tools is divided between a large vertically integrated firm, Applied Materials, which uses its own proprietary specifications, and a fringe of more specialized competitors. The fringe has responded to the competition from Applied Materials by creating a common set of technical interface standards.

Rather than calling this a standards battle, Langlois notes that it is better thought of as a battle of alternative development paths: The closed systemic approach of Applied Materials versus the open modular system of the competitive fringe. He analyzes the trade-off between the benefits of system innovation and internal economies of scale and scope on the one hand and the benefits of modular innovation and external economies of standardization on the other. While this case provides an interesting example of an industry where diverse approaches to standardization may coexist, the industry is starting to undergo change. Langlois observes that the industry may see a transformation to a more common structure, where several larger firms adhere to common standards and become broadly compatible systems integrators that outsource manufacturing to specialized suppliers of subsystems.

Chapter 3, by Joel West, San Jose State University, looks at the meaning of open standards in market competition. West defines a standard as open if the "rights to the standard [are] made available to economic actors other than sponsors." He indicates that this transfer can occur if rights are waived or conceded, licensed to other organizations, or are not protected by force of law, such as a patent. He points out that while open product compatibility standards are often viewed as socially optimal, the reality is that not all open standards are really open. His paper illuminates the different aspects for openness and their implications for adoption, competition, and public policy.

West argues that it is important to determine who has access to the standard, including customers, complementors, and competitors. Next, it is necessary to decipher what rights are made available to those who have access to the standard, such as creating the specification, using the specification, and using an implementation. Overall,

access to the standard can be limited through membership requirements on the creator side or use rights on the user side. West suggests that policymakers could address the deficiencies in openness in several ways, including direct regulation, procurement, intellectual property law, and competition policy.

These three chapters deal with different aspects of standards competition. Indeed, they all focus on problems that are highly relevant to the business and user communities, which raise questions about the choices faced by market participants. Such research and exploration is a promising development, as it moves the conversation toward applied issues that policymakers must grapple with in actual circumstances.

2 Standards organizations and firm strategy

Although standardization often occurs through competition, nonmarket processes may also shape outcomes. These processes take a variety of forms. Confronted with an incipient or active standards war, firms may behave cooperatively to settle things through joint ventures, consortia or other alliances. For example, banks have formed shared ATM networks (e.g., Star, Plus, and Cirrus) as joint ventures to internalize the network benefit associated with allowing customers access to any banks' ATM machines, as well as to create a sponsor for the standard. They may also develop standards through explicit industry consensus, usually mediated within a formalized industry process. These formal de jure standards can emerge from a specialized industry standards body, or ratification by a standard setting organization (SSO) such as the American National Standards Institute, or ANSI.[7]

The SSOs play many useful roles in solving network coordination problems, especially those related to lack of communication. They can serve as forums for affected parties to educate each other or settle disputes. Clearly, these groups are most likely to succeed when market participants mutually desire interoperability, need to establish a mechanism for communication, and need a mechanism to develop or

[7] An organization that handles standards in the United States, ANSI is a subgroup of the ISO (International Standards Organization), which is an umbrella group containing a host of standards bodies.

choose from one of many technical alternatives. For example, this was the role taken by grocers groups in the development of bar codes for retail products. It is also the role taken by the International Telecommunication Union (ITU) in the development and upgrading of interoperability standards for fax machines and related products that use similar protocols.

Unfortunately, standards organizations are not a perfect solution to coordination problems. They can easily fall prey to some of the same structural impediments that plague standards wars. The development of UNIX standards in the 1980s illustrates these weaknesses. Many firms perceived strategic alliances as tools to further their own economic interests and block unfavorable outcomes. As a result, two different consortia, Open Software Foundation and Unix International, originally sponsored two different UNIX standards; and industry participants lined up behind one or another on the basis of economic self-interest. In the early 1990s, the market was confused yet again as different consortia (and firms) sponsored slightly different forms of UNIX. Only the surprising emergence and widespread adoption of Linux in the latter part of the 1990s moved the situation closer to unification around a single technical specification, reducing costs to the building of complementary tools and applications, as well as reducing the costs of maintenance across installation for system integrators and other information technology consultants.

It is no secret that the specifications underlying most standards are at least partially determined in these nonmarket settings. That raises issues associated with the alliances and standards organizations that foster cooperation among firms. Such cooperation can yield procompetitive benefits, but it also can run afoul of antitrust law. There is tension between the benefits accruing from cooperation and the antitrust issues involved with such cooperative behavior. The recent antitrust cases against Mastercard and Visa illustrate the importance of this issue.[8] The inability to overcome the disagreements in the current high-definition–DVD/Blu-ray standards war illustrates the issues when cooperation does not emerge.

There have been several economic studies of nonmarket nongovernmental processes. For example, in his 1996 work, Farrell studies the performance of standard setting bodies, focusing on the trade-offs

[8] See Evans (2003) for a discussion of these issues.

between the delays inherent in achieving consensus and the benefits of avoiding a costly standards war. His key notion is of *vested interests*, which are asymmetries between the payoffs of the "winner" and "loser" after a standard has been adopted (the winner is that whose proposed standard is adopted). These vested interests cause delay and impede consensus. Strategies to reduce vested interests, such as licensing, can therefore improve outcomes. In other work, Farrell (1989, 1995) also discusses a similar point in a less formal way, suggesting that weakening intellectual property protection can help markets settle on standards more quickly.[9]

This book contains several studies of the activities inside SSOs. In Chapter 4 of this volume, Shane Greenstein, Northwestern University, and Marc Rysman, Boston University, focus on the early 56K-modem market to highlight the coordination costs of resolving a standards war. The standards war in the 56K-modem market involved two very similar network technologies. The ITU was apparently helpful in resolving the conflict, by establishing a focal point for the industry. Nevertheless, the development of focal points carries costs – in this case, those of membership, meeting, submission, and negotiation associated with the standard setting process. This combination of explicit and implicit costs can add further complications to reaching an effective consensus. The voting environment also has implications for the resolution process. The ITU uses a consensus voting system. Since all firms in the market are members, each can delay the process if its own concerns are not met. The authors conclude that the ITU acted in a way that produced net benefits. In their view, it is unlikely that the alternatives of regulation or the market would have overcome the social costs of coordination any more easily.

Chapter 5, by Charles Steinfield, Michigan State University; Rolf Wigand, University of Arkansas; M. Lynne Markus, Bentley College; and Gabe Minton, Mortgage Bankers Association of America, is a rich study of vertical information systems standards in the US mortgage industry. These standards may address product identification, data definitions, standardized business documents, and/or business process sequences. The case study identifies three important processes in this

[9] The primary focus of his discussion – particularly in the 1989 article – is on compatibility and whether markets achieve efficient levels of adoption rather than on markets' choice between competing standards, but the intuition applies.

environment: (1) the way that the standardization process is structured to facilitate participation and consensus, (2) the approaches used to promote adoption of open standards, and (3) the steps taken to ensure the ongoing maintenance and integrity of the standard. The results emphasize the importance of

- company and individual incentives,
- using formal and informal governance mechanisms to minimize conflict and reach consensus,
- inclusive and proactive policies regarding membership,
- a limited scope of standardization activities,
- explicit intellectual property rights policy, and
- trying to institutionalize the entire standardization process into a formal structure.

Chapter 6, by Neil Gandal, Tel Aviv University, Michigan State University; Nataly Gantman, Tel Aviv University; and David Genesove, Hebrew University, focuses on how firms interact in standards organizations to influence their product market, in this case the modem market. Gandal, Gantman, and Genesove explain that network effects are inherent in the modem market because Internet users and Internet Service Providers benefit as more people adopt compatible technology; furthermore, interoperability is crucial for the seamless transmission of data.

While over 200 companies in this market attended standardization meetings from 1990 to 1999 and around the same number received patents from 1976 to 1999, only 45 firms did both. Firms receiving at least one modem patent were more likely to have attended at least one standardization meeting during these time periods; furthermore, large firms are more likely to attend standardization meetings. These results suggest that large firms are behaving strategically; they may in fact be over-attending meetings. While the results show that attendance at meetings and thus getting patents is beneficial, for smaller firms the benefits may not translate into greater market share.

The chapters above again illustrate areas where theory meets the activities of market-based actors. The SSOs can be valuable institutions (as evinced by their ubiquity). Moreover, their existence induces a real possibility for strategic behavior, some of which contributes to outcomes that benefit both users and producers and some of which does not. More work in this area would certainly improve policy.