Technology Standards

by

Jeffrey A. Hart
Professor
Department of Political Science
Indiana University
Bloomington, IN 47405

Paper prepared for the International Communication Compendium Panel at the annual meeting of the International Studies Association, San Francisco, California, March 25-29, 2008. It was revised for the International Studies Compendium Project on June 10, 2009. Please do not cite or quote without the permission of the author.

Abstract: Technology standards are important because of their role in reducing uncertainty for both producers and consumers and thus in creating the necessary conditions for market growth. Much has been written about the economics of standards. This paper focuses on the politics of standards, especially in the area of information and computer technologies (ICTs). The rise of international competition over ICT platforms and architectures has given standards a new prominence in international politics. The specific cases of the Internet (TCP/IP) standards, along with those for cellular phones, digital television (DTV), and high-definition video recorders will be examined here.

Introduction

A technical standard is a norm or requirement usually established in a formal document that sets uniform engineering or technical criteria ("Standard"). Three types of technical standards are reference, minimum quality, and compatibility standards. A reference standard is "a material, device, or instrument whose assigned value is known relative to national standards or nationally accepted measurement systems (United States Nuclear Regulatory Commission)." For example, all countries have an agency that sets measurement standards for time, distance, weight, etc. In the United States, the agency currently responsible for this service is the National Institute for Standards and Technology (NIST). NIST is the successor to the Bureau of Weights and Standards in the Department of Commerce that was itself established under the Constitution in 1789. Reference standards have been around for centuries to assure, for example, that a coin has the right amount of gold or silver and a scale that says that a cut of beef weighs a pound is properly calibrated. Markets need reference standards to reduce uncertainty about the metallic content of money and about measurable quantities of goods (Kindleberger 1983; Spruyt 1994).

A minimum quality standard sets criteria for quality permitting sellers to certify a good or as service as meeting (or not) those criteria. An example of this is an average fuel-efficiency standard for automobiles. A law requiring that all automobiles of a certain type must meet a given fuel-efficiency standard establishes a minimum standard for gas mileage below which the average vehicle cannot legally go. Consumers may find this useful, especially when the price of gasoline is rising.

Compatibility standards set criteria for how a device works with other devices. An example of a compatibility standard is the size of batteries that go into electronic devices. If a device requires an AA size battery with 1.5 volts, then both producers and consumers can be sure that pretty much any AA battery they purchase will work with that device. For components like batteries, the compatibility standard usually includes the physical dimensions as well so that product designers can be certain that all batteries in that category will fit into the designated space. From here on, the terms "compatibility standards" and "technology standards" will be used interchangeably.

Compatibility standards can also be about "interfaces" such as connectors or ways of interacting with devices. One popular interface standard in personal computers is the universal serial bus (USB) connector that works to connect any two devices that support the USB standard. Another interface standard that most people are familiar with is the RJ-11 connector used to connect a telephone to a telephone jack. Interfaces are not always physical. Computers use graphical user interfaces (GUIs), such as the icons on a Windows desktop, to make it easier for consumers to go from computer to computer without having to learn a new GUI.

An important historical example of a compatibility standard is the gauge size of railroad tracks. Two national railroads with different gauge tracks are incompatible in a particular way. At the border of the two countries with a common border but different track sizes it will be impossible for the trains of one country to continue on into the neighboring country, so passengers and cargo will have to be unloaded, carried across the border, and reloaded on the other side to proceed. Making track sizes incompatible was sometimes justified during periods of international political instability as necessary for protecting against foreign invasions. However, when countries wished to promote free movement of goods and services, or data, across borders, they tended to move to compatible systems (Friedlander 1995; Shapiro and Varian 1999: 208-210).

In the area of international network infrastructures, such as the global airline network, it may be useful to have compatibility standards so that participants do not have to learn new procedures as they move across borders. For this reason, all pilots and traffic controllers around the world are required by the International Civil Aviation Organization to use English for communication purposes and a standard list of terms and commands to ease mutual understanding. This is generally justified as promoting not just economic efficiency but also passenger safety (Forster and King 1995; Zacher 1996; Golich 1989).

Economists analyze standard setting in technology from two perspectives. First, they examine the relationship between the development of technology standards and the smooth operation of markets. A general assertion is that standards reduce transaction costs for everyone and therefore are collective goods (Kindleberger 1983: 378). More recently economists have focused on networks and how standards help consumers and producers benefit from network economies. When the existence of standards permits rapid growth in the user base of a particular technology, economists hypothesize that users are likely to benefit more rapidly from what they call network economies (Katz and Shapiro 1985; Katz and Shapiro 1994; Gandal 2002).

Secondly, economists focus on the strategic interactions among actors (generally firms and governments of nation-states) in standard setting using game theory as their guide to analysis. Actors may benefit disproportionately from the adoption of one standard rather than another, but all actors lose if no standard emerges. Thus, standard setting is analyzed as a game of coordination (Abbott and Snidal 2001; Mattli and Buethe 2003: 9-10).

Economists have also considered the possibility that standards can be used strategically for the advantage of a subset of actors. There may even be "standards wars" – prolonged conflicts over which standards to adopt and preserve (Shapiro and Varian 1999). In addition, the setting of standards creates a Principal-Agent relationship between the actors affected by standards and those charged with creating and enforcing the standards (Mattli and Büthe 2005).

Political scientists and international relations (IR) scholars have also adopted these approaches. They go beyond them, however, to talk about standards as part of an overall governance system or regime, especially in international affairs. IR scholars, in particular, have studied this in connection with theories of governance and regime change (Abbott and Snidal 2001; Spruyt 2001; Mattli and Büthe 2003; Mattli and Büthe 2005).

How Technology Standards are Established

There are three main ways for standards to be established:

1. market competition,
2. private standard-setting organization, and
3. governmental imposition (David and Greenstein 1990: 3).

Market Competition

Standards that emerge from market competition may do so in a variety of ways. First, there may be a dominant firm that imposes its preferred standard on everyone else. An example is the Microsoft Windows operating system that Microsoft basically imposed on users of PC-compatible computers (David and Greenstein 1990). Another contemporary example is the format used for music that is played only on Apple iPod devices and sold only on iTunes (Dedrick, Kramer, and Linden 2008). This sort of imposed standard is generally not very popular, even though it reduces uncertainty in the marketplace, especially when the imposed standard is used as a barrier to entry on the part of potential competitors.

There may be a competition among a small number of major firms that results in multiple standards. For example, in the early days of the VCR, two major standards competed with one another: BetaMax (backed by Sony and Philips) and VHS (backed by everyone else). The fact that VHS eventually triumphed is seen as evidence for the general undesirability of competing standards, especially to the degree that having multiple standards creates uncertainty for consumers and hence retards market growth. The fact that VHS was technologically inferior to BetaMax shows that the winners of standards competition are not always based on the most advanced technologies. Nevertheless, consumers may benefit from the competition between the multiple standards in the market as the final adoption of the VHS standard in the marketplace probably reflected consumer preferences (in this case, preference for the system that provided lower cost players with sufficiently high quality video images).

Another example of private standards competitions is the more recent competition between HD-DVD and BluRay players of high definition videos. Just as in the BetaMax/VHS competition, the market was held back initially because of consumer uncertainty; the victory of BluRay recently did not, as in the case of VHS, indicate that it was the superior technology but rather that both producers and consumers thought that it was the only viable choice in the long run. Toshiba, the backer of HD-DVD, had run out of money and was generating financial losses after aggressively promoting its standard.

Finally, there may be no agreement on standards because a number of important market actors believe the setting of standards is not in their interest. An underlying reason for this is that the technology is changing rapidly and neither producers nor consumers are willing to pay the costs of freezing the technology in order to reduce market uncertainty via standards. Often a different sort of standardization occurs during periods of rapid technological change that focuses on interfaces or what has come to be called “interoperability” (Lynch 1993).

Private Standard-Setting Organizations

Standards may also emerge without the intervention of governments if private actors negotiate standards in private (and hence voluntary) standard setting organizations (SSOs). An example of this in the United States is the American National Standards Institute or ANSI. The members of ANSI are individuals, private firms, government agencies, universities, and other standards organizations. Membership is voluntary. Full membership dues for private firms depend on the size of annual revenues, up to a maximum of $26,000 annually. The mission of ANSI is to "… enhance both the global competitiveness of U.S. business and the U.S. quality of life by promoting and facilitating voluntary consensus standards and conformity assessment systems, and safeguarding their integrity" (ANSI 2009). ANSI works with international private standards organizations such as the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC).

The study of national and international non-governmental SSOs has recently become an active area of research in both economics and political science. The privatization of the telecommunications agencies of major industrialized nations reduced the role of intergovernmental organizations in the setting of telecommunications standards and increased the important of SSOs (Genschel and Werle 1993). Standards for the Internet were set largely in nongovernmental bodies, mainly the Internet Engineering Task Force (IETF), although national governments and international intergovernmental organizations intervened from time to time (Simcoe 2007).

In recent years, a controversy has developed among legal scholars around the policies of SSOs regarding intellectual property rights. Some SSOs require their members to license patents associated with standards at royalty rates that are reasonable and nondiscriminatory (RAND); but others do not. When patent holders charge unreasonably high royalties, that is called a "patent holdup." If done for a number of associated patents, it is called "royalty stacking" (Anton and Yao 1995; Lemley 2007; Lemley and Shapiro 2007; Sidak 2007). Patent holdups and royalty stacking can have the effect of delaying the growth of new markets simply for the purpose of extracting payments from those who are inconvenienced.

Government-Imposed Standards

Finally, governments may impose standards on market players, although they might do so only after consulting them and/or after considerable lobbying by private actors with a stake in the outcome of governmental decisions. In the United States, a variety of agencies may be involved in standard setting activities. Below I will talk about the role of the Federal Communications Commission (FCC) in the setting of standards for digital television, but other agencies are frequently involved. The Department of Defense, for example, establishes minimum quality standards for its contractors under the military specification (MILSPEC) system. The Environmental Protection Agency (EPA) establishes air and water quality standards; the Department of Education establishes standards for education under the No Child Left Behind laws; and so forth. Sometimes public agencies combine government-mandated standards, often referred to as "command-and-control" standards, with voluntary standards in order to achieve goals that would not otherwise be attainable (Kollman and Prakash 2001).

National, Regional, and International Standards

Standards may be set at national, regional, or international levels. The European Union has a strong preference for regional standards, because of the desire to have a single European market (Crane 1979; Frenkel 1990; Tate 2001; Austin and Milner 2001; Egan 2001; Nicolaïdis and Egan 2001). The creation of NAFTA has resulted in some pressure for harmonization at least in standards across the members.

Incompatibilities can still crop up on either a national or regional basis. When they do, they may be part of a larger program of protecting national or regional firms and other stakeholders.

The ability of a particular nation-state to influence regional or international standards is one of the criteria used in assessing national power and prestige. Thus, the U.S. dominance in the setting of computer standards is perceived to be both an indicator and a result of U.S. economic power (Kim and Hart 2002). European successes in challenging U.S. technology standards in, for example, TV broadcasting or cellular phones, are cited as evidence of Europe's increasing power and independence from U.S. influence (Lembke 2003). The Japanese government's initial success in getting its standard for high definition television adopted as an international standard was seen as a sign of growing Japanese economic power (Hart 2004).

Incompatible standards may be used primarily to protect national or regional interests, as was the case in the European adoption of PAL and SECAM standards for television broadcasting and equipment (Crane 1979; Besen and Johnson 1986). This incompatibility, of course, imposes a cost in that the incompatibility may limit exports of goods, services and technology to other regions. Europe opted not to do this with its second-generation cellular phone standard, GSM, and with its rejection of Europe-only standards for networks and the World Wide Web (Lembke 2003).

Who Owns the Standard?

Some standards are proprietary, that is owned, and others are not. Some standards are promulgated by public agencies, others by private firms or private standards bodies. Then there is the possibility for mixed ownership, for example, when a standard is set for technologies developed by a research consortium that has both private and public participants. Many research consortia combine private and public sources of funding. Consortia often create pools of intellectual property rights and permit members to license the technologies underlying a new standard on a more favorable basis than non-members.

It is possible for a proprietary standard to be openly available to all via licensing of the underlying technologies. There may be a simple application, certification, or fee system so that actors adopting the standard can advertise their compliance with the standard, even if they did not participate in the creation of the underlying technologies. Thus, even if your firm was not involved in creating the U.S. digital television standard (ATSC) you can still produce products that are ATSC compliant and advertise them as such. Similarly, you can license the technology underlying the DVD standard even though you did not participate in developing the standard or the technologies behind it.

The logic of technology platforms is closely related to the above. A technology platform is a set of technologies and standards that must be understood and mastered by a firm before it can compete fully in markets related to the platform. Competition in high technology markets often boils down to competition over creating new platforms. Some scholars call this "architectural" competition, because the large players are competing to define the architecture, the overall design, for a new technology platform (Kim and Hart 2002; Ernst 2005).

An example of a technology platform is the PC-compatible computer. Another is the MP3 player or the iPod with its attendant technologies, services, add-ons, etc (Dedrick, Kramer, and Linden 2008).

Just as there is certain amount of prestige and profit attached to being able to influence a stand-alone international standard, there is considerably more prestige and profit connected with the ability to influence technology platforms (Kim and Hart 2002).

Consider a non-ICT example: the hybrid automobile or hydrogen-fueled motor vehicles. Japanese firms got out ahead of the pack with hybrid technologies and thereby defined the hybrid technology platform. General Motors tried to do the same with hydrogen-fueled vehicles with financial support from the U.S. government. Unfortunately for GM and the US, the timing was wrong. The move to hydrogen fuel was a larger and more difficult than the move to hybrids. Hydrogen vehicles required an entirely new distribution network for fuels. So the initiative for developing fuel-efficient vehicles which had already shifted to Japan and East Asia remained there with the development of hybrids.

Globalization and the Global Production Networks

Standards have risen in importance not just because of prestige and profit potential, but also because of the move toward a globalized world economy. The reduction in tariff and non-tariff barriers made possible by the GATT/WTO trade regime, the removal of capital controls and progressive liberalization of global capital flows, and the end of the Cold War have resulted in a more open world economy. In the globalizing world economy, firms attempt to locate parts of their value chain activities wherever the costs are low and the quality is high. So most firms have call centers and R&D centers in India, electronics manufacturing in China or elsewhere in East Asia, and engineers from the developing world working in "body shops" both at home and in foreign subsidiaries at lower wages than engineers from the industrialized world (Ernst 2005).

The elongation of value chains that is part and parcel of contemporary globalization would be difficult in the absence of technology standards. Tom Friedman is correct to attribute great importance to technological innovations like the Internet and open-source software as "flatteners" permitting people previously not able to participate in the global economy (because of difficulty of coordinating economic activities over large geographic distances) to do so (Friedman 2005).

The International Politics of Specific Technology Standards Competitions

In this section of the paper, I would like to turn to an examination of some specific recent technology standards competitions as illustrative of some of the general points above. The ones I have chosen to include here are:

- high definition television (HDTV) and digital television (DTV)
- ISDN and the Internet
- cellular telephones
- high-definition video recorders

HDTV and DTV

HDTV and DTV standards were developed and promulgated from the early 1980s on. The first country to do so was Japan. Japan's analog HDTV standard, Hi-Vision, was at first embraced in the United States, especially by the film industry, but later rejected in favor of a digital approach. The Europeans decided to adopt their own analog HDTV standard, HD-MAC, in the late 1980s. Shortly after the US adopted the digital approach in 1993, the Europeans abandoned HD-MAC and moved to adopt their own, incompatible standard for digital television, DVB. The Japanese stuck with Hi-Vision for too long before switching to their own incompatible digital television standard, ISBN. Thus, in the case of HDTV and DTV, no international standards consensus emerged. Instead, the result was three incompatible regional standards (Hart 2004).

ISDN and the Internet

Network standards competitions in the 1980s resulted in a variety of proprietary standards put forward by large mainframe computer firms like IBM, Siemens, and NCR, and efforts by the European Union to create a European standard under the ISDN banner and the so-called Open System Integration (OSI) model of networking. All the proprietary network approaches were blown away by the huge and rapid success of the Internet and its TCP/IP family of standards. The victory of TCP/IP over ISDN/OSI took Europe by surprise but the region adapted quickly and made a relatively smooth transition. The Internet standards, unlike the DTV standards, became global standards (Hart 2004). Incompatible standards were not able to compete.

The Internet standards were, for the most part, not proprietary. There were few barriers to adoption in the form of intellectual property or licensing fees. In addition, although there were initially problems with security and authentication (important for e-commerce) connected with the Internet, the users were happy with the lightness and interoperability of the system in comparison with its proprietary alternatives (Genschel 1997; Weber 2004; Drezner 2007).

Cellular Telephones

There have been three generations of cellular telephone technology since the 1980s. The first generation was analog, the second was digital, and third was digital with Internet-like data services. Early innovators like Motorola and Ericsson dominated the first generation. Later entrants like Nokia, Samsung, and Qualcomm became influential in standard setting by the second. The US opted for an anarchic system of competing standards in both the first and second generations, while limiting competition somewhat in the third. Europe successfully promoted a unified European standard, GSM, in the second generation, but has not been able to follow that with a major success in the third. Despite incompatible standards across firms and regions, the market for cellular phones has grown rapidly, especially in the developing world where land-line telephone services are mainly provided still by monopoly providers.

Third generation cellular phones are becoming the preferred access point for those who can afford them to the Internet, so there is considerable controversy and contestation over next-generation Internet 2.0 services like social networking and interactive mobile video (Funk 2002; Lembke 2003; Funk 2009).

High-Definition Video Recorders

With the rapid increase in demand for HDTV receivers, following the deployment of DTV services, there was a standards competition between two incompatible high-definition video playback systems: HD-DVD and BluRay. HD-DVD was the child of Toshiba and its allies; BluRay was championed by Sony and Philips and their allies. Consumers, unable to figure out which of the two standards would prevail, delayed their purchases. Prices remained high. When a few companies made dual-standard players available the price was too high to win over consumers. Eventually Toshiba threw in the towel, and BluRay emerged victorious.

What is a notable difference between this case and the others is the lack of governmental intervention. Neither the European Union nor the U.S. government had much at stake and the Japanese government probably did not want to favor one Japanese firm over another. Everyone is relieved now that the competition is over, however, especially the U.S. film industry because it preferred the BluRay system's copy protection and digital rights management (DRM) features.

Summary and Conclusions

Technology standards have always been important in the world economy, but they are becoming more so in the electronic age. Firms compete with one another for the prestige of establishing a new standard and especially technology platforms or architectures, and governments (including regional regimes like the EU and NAFTA) try to get standards adopted internationally that result in more local jobs and income. This is increasingly difficult as the world economy becomes more global, but that does not stop the various players from trying. The economics of standards is important, but a full understanding of technology standards requires a combination of economic and political perspectives.

The challenge for IR scholars will be to add to the overall discourse on technology standards by using their competitive advantage in studying national and international political dynamics. Unlike economists, IR scholars are not centrally concerned with the efficient operation of markets. They will continue to focus on issues that are important to their own discipline, such as the international struggle for power and the evolution of international regimes and institutions. They should join the sociologists in examining the role of nongovernmental actors in standard setting, because the idea of some sociologists that the emergence of some sort of global civil society is occurring is worth investigating (Loya and Boli 1999). They should follow the economists in their studies of the potential abuses of intellectual property rights associated with standards, particularly in the area of patent holdups and royalty stacking, because such practices may be associated with power-seeking behavior on the part of both multinational corporations and national governments. The interdisciplinary work on global production networks and architectural competition has important implications for the evolution of international politics. IR scholars and political scientists should continue to contribute to the research on open standards and the new model of engineering and competition that is associated with the open source software movement. In short, the study of technology standards must become an important part of the overall agenda of IR research.

References

Abbott, Kenneth W. and Duncan Snidal (2001) International "Standards" and International Governance. *Journal of European Public Policy* 8(3), 345–370.

American National Standards Institute (2009) "About ANSI," http://www.ansi.org/about_ansi/overview/overview.aspx?menuid=1.

Anton, James and Dennis Yao, (1995) "Standard-Setting Consortia, Antitrust, and High-Technology Industries," *Antitrust Law Journal* 64, 247-265.

Austin, Marc and Helen Milner (2001) Strategies of European Standardization. *Journal of European Public Policy* 8(3), 411–431.

Benoliel, Daniel (2004) Technological Standards, Inc.: Rethinking Cyberspace Regulatory Epistemology. 92, 1069-1116.

Besen, Stanley M. and Joseph Farrell (1994) Choosing How to Compete: Strategies and Tactics in Standardization. *Journal of Economic Perspectives* 8 (2), 117-131.

Besen, Stanley M. and Leland Johnson (1986) *Compatibility Standards, Competition, and Innovation in the Broadcasting Industry*. RAND Corporation Report (R-3453-NSF).

Brunsson, Nils and Bengt Jacobsson, eds. (2000) *A World of Standards.* New York: Oxford University Press.

Crane, Rhonda (1979) *The Politics of International Standards*. Norwood, NJ: Ablex Publishing.

David, Paul A. and Shane Greenstein (1990) The Economics of Compatibility Standards: An Introduction to Recent Research. *Economics of Innovation and New Technology* 1, 3-41.

David, Paul A. and Julie Ann Bunn (1988) The Economics of Gateway Technologies and Network Evolution: Lessons from Electricity Supply History. *Information Economics and Policy* 3, 165-202.

Dedrick, Jason, Kenneth L. Kramer, and Greg Linden (2008) Who Profits from Innovation in Global Value Chains? A Study of the iPod and Notebook PCs. Paper presented at the annual meeting of the Industry Studies Association, Boston, Mass.

Drezner, Daniel W. (2007) *All Politics in Global: Explaining International Regulatory Regimes*. Princeton, N.J.: Princeton University Press.

Egan, Michelle (2001) *Constructing a European Market: Standards, Regulation, and Governance*. New York: Oxford University Press.

Ernst, Dieter (2005) The New Mobility of Knowledge: Digital Information Systems and Global Flagship Networks. In Robert Latham and Saskia Sassen, eds., *Digital Formations: IT and New Architectures in the Global Realm*. Princeton, N.J.: Princeton University Press.

Farrell, Joseph and Garth Saloner (1985) Standardization, Compatibility, and Innovation. *RAND Journal of Economics* 16, 70-83.

Farrell, Joseph and Garth Saloner (1986) Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation. *American Economic Review* 76 (December), 940–955.

Farrell, Joseph and Carl Shapiro (1992) Standard Setting in High-Definition Television. *Brookings Papers: Microeconomics* 1-93.

Fearon, James (1998) Bargaining, Enforcement, and International Cooperation. *International Organization* 52, 269-306.

Forster, Paul W. and John Leslie King (1995) Information Infrastructure Standards in Heterogeneous Sectors: Lessons from the Worldwide Air Cargo Community. In Brian Kahin and Janet Abbate, eds., *Standards Policy for Information Infrastructure*. Cambridge, Mass.: MIT Press, 148-177.

Frenkel, Karen A. (1990) The Politics of Standards and the EC. *Communications of the ACM* 33, 41-51.

Friedlander, Amy (1995) *Emerging Infrastructure: The Growth of Railroads*. Reston, VA: Corporation for National Research Initiatives.

Friedman, Thomas L. (2005) *The World is Flat: A Brief History of the 21st Century*. New York: Farrar, Giroux, and Strauss.

Funk, Jeffrey (2002) *Competition Between and Within Standards: The Case of Mobile Phones*. London: Palgrave.

Funk, Jeffrey (2009) The Co-Evolution of Technology and Methods of Standard Setting: The Case of the Mobile Phone Industry. *Journal of Evolutionary Economics* 19, 73-93.

Gandal, Neil (2002) Compatibility, Standardization, & Network Effects: Some Policy Implications. *Oxford Review of Economic Policy* 18, 80-91.

Genschel, Philipp (1997) How Fragmentation Can Improve Coordination: Setting Standards in International Telecommunications. *Organization Studies* 18, 603-622.

Genschel, Philipp and Raymund Werle (1993) From National Hierarchies to International Standardization: Modal Changes in the Governance of Telecommunications. *Journal of Public Policy* 13(3) 203-225.

Golich, Vicki (1989) *The Political Economy of International Air Safety: Design for Disaster?* London: Macmillan.

Hart, Jeffrey A. (2004) *Technology, Television, and Competition.* New York: Cambridge University Press.

Jacobson, Harold (1979) *Networks of Interdependence*. New York: Alfred Knopf.

Katz, Michael L. and Carl Shapiro (1985) Network Externalities, Competition, and Compatibility. *American Economic Review* 75, 424–440.

Katz, Michael L. and Carl Shapiro (1994) Systems Competition and Network Effects. *Journal of Economic Perspectives* 8 (Spring) 93-115.

Kim, Sangbae and Jeffrey A. Hart (2002) "The Global Political Economy of Wintelism: A New Mode of Power and Governance in the Global Computer Industry," in James N. Rosenau and J.P. Singh (eds.), *Information Technologies and Global Politics: The Changing Scope of Power and Governance*. Albany, N.Y.: SUNY Press.

Kindleberger, Charles (1983) Standards as Public, Collective and Private Goods. *Kyklos* 36, 377-396.

Kollman, Kelly and Aseem Prakash (2001) "Green by Choice? Cross-National Variations in Firms' Responses to EMS-Based Environmental Regimes," *World Politics* 53 (April), 399-430.

Lembke, Johan (2003) *Competition for Technological Leadership: EU Policy for High Technology*. Burlington, Vt.: Edward Elgar.

Lemley, Mark A. (2002) Intellectual Property Rights and Standard-Setting Organizations. *California Law Review* 90, 1889-1980.

Lemley, Mark A. (2007) Ten Things to Do About Patent Holdup of Standards (And One *Not* To). *Boston College Law Review* 48, 149-168.

Lemley, Mark A. and Carl Shapiro (2007) Patent Holdup and Royalty Stacking. *Texas Law Review* 85, 1999-2041.

Loya, Thomas and John Boli (1999) "Standardization in the World Polity," in John Boli and George Thomas, eds., *Constructing World Culture: International Nongovernmental Organizations since 1875.* Stanford, Calif.: Stanford University Press.

Lynch, Clifford (1993) "Interoperability: The Standards Challenge for the 1990s," *Wilson Library Bulletin*, (March), 38-42.

Mattli, Walter (2003) "Public and Private Governance in Setting International Standards," in Miles Kahler and David Lake, eds., *Governance in a Global Economy: From Litigation to Arbitration* Princeton, N.J.: Princeton University Press.

Mattli, Walter and Tim Büthe (2003) Setting International Standards: Technological Rationality or Primacy of Power? *World Politics* 56 (October), 1-42.

Mattli, Walter and Tim Büthe (2005) Global Private Governance: Lessons form a National Model of Setting Standards in Accounting. *Law and Contemporary Problems* 68, 225-262.

Nicolaïdis, Kalypso and Michelle Egan (2001) Transnational Market Governance and Regional Policy Externality: Why Recognize Foreign Standards? *Journal of European Public Policy* 8(3), 454–473.

Shapiro, Carl and Hal R. Varian (1999) The Art of Standard Wars. *California Management Review* 4, 8–32.

Shapiro, Carl and Hal R. Varian (1999) *Information Rules: A Strategic Guide to the Network Economy*. Boston, Mass.: Harvard Business School Press.

Sidak, J. Gregory (2007) Patent Holdup and Oligopsonistic Collusion in Standard-Setting Organizations. *Journal of Competition Law and Economics* 5, 123-188.

Simcoe, Timothy (2007) Delay and de jure Standardization: Exploring the Slowdown in Internet Standards Development. In Shane Greenstein and Victor Stango, eds. *Standards and Public Policy*. New York: Cambridge University Press.

Spruyt, Hendrik (1994) *The Sovereign State and its Competitors: An Analysis of Systems Change*. Princeton: Princeton University Press.

Spruyt, Hendrik (2001) "The Supply and Demand of Governance in Standard-Setting: Insights from the Past," *Journal of European Public Policy* 8(3), 371–391.

Tate, Jay (2001) National Varieties of Standardization. Peter Hall and David Soskice, eds., *Varieties of Capitalism: The Institutional Foundations of Comparative Advantage*. Oxford: Oxford University Press.

Weber, Steven (2004) *The Success of Open Source*. Cambridge, Mass.: Harvard University Press.

Yates, JoAnne and Craig Murphy (2006) From Setting National Standards to Coordinating International Standards: The Formation of the ISO. *Business and Economic History Online* 4, 1-29. http://www.thebhc.org/publications/BEHonline/2006/yatesandmurphy.pdf.

Zacher, Mark W. with Brent A. Sutton (1996) *Governing Global Networks: International Regimes for Transportation and Communications*. New York: Cambridge University Press.

Online Resources

American National Standards Institute, http://www.ansi.org/.

European Telecommunications Standards Institute, http://www.etsi.org/.

International Electrotechnical Commission, http://www.iec.ch/.

International Organization for Standardization (ISO), http://www.iso.org/iso/home.htm.

National Institute for Standards and Technology, http://www.nist.gov/index.html.

"Standard," *Wikipedia*, http://en.wikipedia.org/wiki/Standard.

United States Nuclear Regulatory Commission, "Paragraph 74.4 Definitions," http://www.nrc.gov/reading-rm/doc-collections/cfr/part074/part074-0004.html.