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Compatibility, Standardization, & Network Effects: Some Policy Implications

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Abstract

Given the dramatic growth of the Internet and information technology industries in general, and the importance of interconnection in these networks, the economics of compatibility and standardization has become mainstream economics. In this paper, I examine several key policy aspects of standard setting in industries with network effects.

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I. Introduction

A network effect exists if consumption benefits depend positively on the total number of consumers who purchase compatible products. If the network effect is direct, as in a physical network, increases in the number of consumers on the same network raises the consumption benefits for everyone on the network. The most common examples are communication networks such as telephone and email networks.

A similar network effect can arise when individuals consume a system that consists of a "hardware" good and complementary software products. In such a "hardware/software" system, the consumption benefits of the hardware good are increasing in the variety of compatible software. A virtual (or indirect) network effect arises because increases in the number of users of compatible hardware increases the demand for compatible software and hence the supply of software varieties. The increase in the availability of different software varieties increases the benefit of all consumers who adopt compatible hardware. The consumers who purchase hardware/software systems thus constitute a virtual network.

Classic examples of markets where virtual network effects arise are consumer electronics, such as videocassette recorders and tapes, CD players and compact discs, computer operating systems and applications programs, and television sets and programming. Virtual network effects also arise in credit card networks (the credit card is the hardware and the software is the number of merchants that accept the credit card) and ATM bank networks (the bankcard is the hardware and the software is the number of ATM terminals from which money can be withdrawn).

In this paper, I examine several key policy aspects of standard setting, both in cases with direct (physical) network effects and in cases with virtual network effects. For the most part, the policy recommendations in settings with direct network effects apply to settings with indirect networks effects. In the case of virtual networks there may be additional considerations, which are discussed in detail. The goal is not to

provide a detailed survey, but rather to focus on key issues that have important policy implications.[1]

The last two decades have witnessed a proliferation of high-tech consumer electronic products that exhibit network effects. In such industries questions of compatibility and standardization are important. (In this context a standard refers to set of technical specifications that enable compatibility among products.) Because of the network effects that are inherent in such industries, successful diffusion of these products is often contingent on a single product winning a battle of market standards or firms achieving compatibility among competing standards.

To summarize, in markets with networks effects, the benefit to consumers from joining a network depends on the number of other consumers who join the network. This has several implications for competition in network markets.

- Expectations of consumers regarding the expected future size of a network are critical in determining the adoption of network products. Thus consumer expectations that one technology will become a standard may indeed lead to that technology becoming the standard. Expectations depend in part on installed base. Hence history matters.

- Competition in network markets is likely to lead to standardization on a single technology. In other words, the long-term co-existence of competing incompatible standards is unlikely. This is because a small initial advantage will likely influence consumer expectations about the adoption of a particular standard. This in turn will lead to more consumers adopting the standard. Because the value of the product increases in the number of adopters, the value of the network increases to future adopters. Often consumer expectations are self-fulfilling and an early lead can be transformed into an advantage that is difficult to overcome.

[1] David and Greenstein (1990) provide a comprehensive survey of earlier work, while Farrell and Klemperer (2002) provide a detailed survey of more recent work. Gilbert (1992), Katz and Shapiro (1994), Gandal (1995), and Matutes and Regibeau (1996) provide selective reviews of the literature.

- There is a coordination problem if joining a network involves a sunk investment for consumers.[2] If a network does not grow sufficiently or is abandoned, consumers will be stranded on an "orphan" technology. In such a case, expected network benefits will not be realized. For this reason, consumers may be unwilling to join a network. This problem is especially severe in the case of virtual networks, since the successful diffusion of such products depends on the availability of complementary products. For example, the success of a computer operating system depends on how many software applications can be run on it. If application software firms do not expect consumers to join the network, they will be reluctant to invest the sunk costs necessary to develop software. This is often referred to as a "chicken and egg" problem. Similar statements apply to video-game base-units and video games, HDTV and television programming, CD-players and compact discs, and so on.

The paper proceeds as follows. Section II briefly surveys the relevant theoretical framework on network effects and standards. Section III discusses key policy issues that have been examined in the literature. I review the relevant literature in the context of examining these policy issues. Section IV briefly concludes.

II. Theoretical Framework: Modeling Issues

The typical utility function employed in settings with direct network effects is of the form

$$U_{ij} = a_i + N_j^b, \quad 0<b\leq 1, \qquad (1)$$

where U_{ij} is the utility to consumer i from network j. This utility depends on the standalone benefit (a_i), which can differ among consumers. The second term represents the network benefit (or network effect), where N_j is the expected size of the network and "b" represents the strength of the network effect. The restriction $0<b\leq 1$ insures that the marginal benefit of an additional user on the network is positive, but

[2] The discussion here draws from Church and Ware (1998).

decreasing or constant in the size of the network. Although this framework seems quite simple, the fact that N_j, the expected size of the network, is endogenous introduces complications that make it difficult to analytically solve all but the simplest models.

The typical utility function in the setting with virtual network effects is

$$U_{ij} = c_i + M_j^d,\ 0<d\leq 1, \qquad (2)$$

where the utility to consumer i depends on the standalone benefit (c_i) and the number of compatible software varieties available for hardware j (M_j). In this setting there is not a direct network effect, since utility does not depend directly on the number of consumers who join the network. The number of compatible software varieties, however, does depend on and is increasing in the number of consumers who adopt hardware technology j. In other words, $M_j = f(N_j)$, $M_j'(N_j)>0$, so the reduced form (or equilibrium) utility from (2) does increase in the number of consumers that join the network. The modeling complexity is even greater in settings with virtual network effects because there is an extra level of agents (software firms, as well as hardware firms and consumers) and both the number of software varieties and the number of consumers on each network are potentially endogenous.[3]

There are two basic approaches to handling expectations.[4] In the fulfilled expectations approach, attention is restricted to equilibria in which consumers' expectations are indeed correct. Although it can be argued that this is the most satisfactory approach, it leads to models that are quite difficult to solve analytically; this severely limits the complexity of the model. An alternative approach is to assume that consumers have myopic expectations, that is, consumer utility is based only on the network size at the time of purchase. This assumption makes it easier to analytically solve the model and hence allows the models to be more sophisticated. The tradeoff is that myopic expectations are less satisfactory from a modeling standpoint. Since these two assumptions are polar opposites, it makes it difficult to

[3] I examine compatibility decisions in the presence of network effects. Some authors have examined compatibility decisions in the absence of direct or indirect network effects. See Matutes and Regibeau (1988) and Economides (1989).

compare results across settings, unless the results are robust to both of these extreme cases.

Additionally, timing issues may matter. This is especially true in the case in which there are virtual network effects. In such cases, there is interdependence between the hardware adoption decisions of consumers and the supply decision of software manufacturers. Do consumers purchase hardware before software firms choose the hardware technology for which to write software, or do software firms first choose which technology to supply software for. This is the chicken and egg problem. The theoretical literature typically assumes either that consumers first purchase software or that software firms first choose their preferred network.[5]

III. Key Policy Issues: What We Know and What We Don't Know

The general modeling framework discussed above has been used to address many issues. In this section I focus on key policy issues and summarize the relevant literature.

(i) Is Compatibility Desirable? The Tradeoff Between Standardization and Variety

Arthur (1983) and David (1985) identified the phenomenon of "locking in" to a standard in settings with direct network effects. They focused on unsponsored technologies, i.e., they did not examine the consequences of oligopolistic competition in industries with network effects. The seminal theoretical contributions on direct network effects in oligopoly markets are a series of papers by Farrell and Saloner (1985,1986a,1986b) and Katz and Shapiro (1985,1986) that examine the social and private incentives to achieve compatibility, that is the tradeoff between compatibility

[4] This discussion is based on Matutes and Regibeau (1996).
[5] In reality, the process probably involves some "give and take," that is, some software firms choose to make their software available for a particular technology, then some consumers make purchases, etc. Gandal, Kende, and Rob (2000) develop a theoretical model and use it to estimate the feedback from hardware to software and vice versa in the CD industry.

and standardization.[6] Chou and Shy (1990) and Church and Gandal (1992) examined similar questions in settings with virtual network effects.[7]

This literature has identified two important welfare results in the static tradeoff between "standardization" (all consumers adopt compatible products) and "variety" (several incompatible products have positive market shares).

- Market forces often result in suboptimal standardization, that is, left alone the market may fail to achieve standardization when standardization is socially desirable. This result is robust to both physical networks and virtual networks. For the physical networks case, see Farrell and Saloner (1986a). For the virtual network case, see Chou and Shy (1990) and Church and Gandal (1992). The latter paper shows that suboptimal standardization is most likely to occur when consumers place a relatively high value on software variety.
- Even if the market settles on a standard, the standard may be inferior, that is, social welfare would have been higher had an alternative standard been chosen.[8] This result is also robust to both physical networks and virtual networks.

(ii) How Should Standards be Set?

Assuming that standardization is desirable, how is it best achieved? Some policy makers have interpreted the results about (i) suboptimal standardization and (ii) the adoption of an inefficient technology to mean that regulators should play an active role in setting standards. Others have urged regulators not to intervene despite the presence of network effects.[9]

[6] Some of these papers also examined whether network markets tend to exhibit excess inertia (lock-in to inefficient old technologies) or excess momentum (inefficient adoption of new technologies).
[7] Markovich (2001) examines the tradeoff between standardization and variety in a dynamic setting using numerical methods. In her model, both software firms and consumers are strategic. She computes Markov-perfect Nash equilibria using numerical methods to solve a dynamic model that has no analytical solution.
[8] To see this, suppose that all consumers have adopted an "inferior" standard. No individual consumer has a unilateral incentive to switch because with strong network effects, the value of being part of the network dominates the intrinsic value of the product. Yet all consumers would have been better off if they had jointly chosen the superior standard.
[9] Leibowitz and Margolis (1994) criticize the literature on network effects in part because they believe it does not tell us whether effects identified by the theoretical literature (such as the failure to achieve

Broadly speaking, there are three ways that standards get set in practice: (I) De facto standards, i.e., standards set primarily by market. These standards are often proprietary.[10] (II) Voluntary industry agreements, where standards are often jointly developed. These standards are typically open standards, that is, they are not proprietary.[11] (III) Standards imposed by National Standards Bodies (NSBs), or agreed upon by regional or international standards development organizations (SDOs).[12]

Market Competition

Advantages to market competition include more technological competition and greater price competition (at least early on) among competing incompatible standards.[13] There are disadvantages to standards competition as well. There is typically a period of uncertainty when standardization is left to market forces; competition among incompatible standards may leave some early adopters stranded with abandoned incompatible equipment. Even if a standard is adopted, it may be

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compatibility) are privately or socially important. They argue that until the literature is able to estimate such effects in a meaningful fashion, the public policy debates are premature. A small empirical has begun to empirically examine technological adoption of products with network effects. The early work has primarily focused on providing empirical evidence of virtual network effects by showing that the value of the hardware depends on the variety of (compatible) complementary software. See Greenstein (1993), Gandal (1994), Saloner and Shepard (1995), Gandal, Greenstein, and Salant (1998).

[10] The PC operating system industry provides an example. Due to a bandwagon effects and the availability of a large amount of Windows compatible applications software, Microsoft has succeeded in setting standards in the PC operating systems industry.

[11] The DVD (digital video disc) industry provides an example of a jointly developed standard. Throughout the 1990s, video hardware and software manufacturers sought a digital format to replace videocassettes. In order to avoid another Beta/VHS format war, hardware manufacturers led by Sony, Toshiba, and Panasonic, and movie studios, led by Warner and Columbia (a division of Sony), worked together to establish a single standard. The result was the non-proprietary or "open" DVD standard.

[12] Examples of SDOs include the International Telecommunications Union (ITU), the oldest international standards body in the world, and the International Electrotechnical Commission (IEC). Given the importance of compatibility among international phone networks, the standards set by the ITU are done so by international consensus.

[13] Katz and Shapiro (1986) analyze a setting with two incompatible technologies and they investigate whether the market, by adopting only one of the competing technologies establishes a de facto standard. One technology has a cost advantage in the first period and the other technology has a cost advantage in the second period. Their model illustrates that the combination of network effects and incompatible products leads to intense price competition in early periods. Firms are willing to heavily discount their prices in early periods in order to build up an installed base advantage since this is attractive to later consumers.

inferior.[14] In some cases, uncertainty generated by competition between incompatible standards might lead to the failure of all technologies.[15]

An ex post proprietary standard also has its pros and cons. The static market power conferred upon the winner of a standards competition may lead to a slow rate of adoption due to high prices as well as a slowdown in the pace of technological change. On the other hand, control of a standard by a single entity reduces coordination problems and uncertainty and may help bandwagon effects get off the ground.

Standard Setting Organizations (SSOs)

The small theoretical literature finds that standards committees have desirable properties. Farrell and Saloner (1988) examine the incentives for firms to achieve coordination via standardization committees and compare committees to (i) to a pure market process in which there is no communication among firms and firms can make unilateral standardization choices and (ii) a hybrid committee/market process in which firms meet in committees and yet can also make unilateral standardization decisions.[16] They find that committees can better set standards in the sense that committees are more likely than market processes to achieve coordination, i.e., standardization. They identify a tradeoff here as well: the committee process will typically take longer than if standardization choices were left to the market. Perhaps, not surprisingly, the hybrid process outperforms the other two mechanisms.

[14] Katz and Shapiro (1986) show that the "second" technology is adopted for many parameter values for which it is socially optimal to adopt the first technology. This result is known as excess momentum. The market "bias" against the first technology is essentially a commitment issue. This is because the firm with the second technology (the lower marginal cost in the second period) can price below marginal cost in the first period, while the firm with the first technology cannot commit to price below marginal cost in the second period.

[15] Audio Quadraphonic sound provides an example. In the early 1970s, this technology promised concert-like music at home. Two competing incompatible technologies were introduced by Columbia and JVC/RCA. Despite the fact that RCA and Columbia were the dominant firms in record production and both held rights to lots of key titles, consumer concerns about being orphaned led to slow sales growth for both systems. By the mid-1970s, both technologies had failed. See Postrel (1990) for more details. This idea has been modelled by Kretschmer (2001).

[16] They use a simple model in which two firms prefer their own incompatible standard to that of a rival, but also prefer standardization to incompatibility.

Despite the increasing importance of standard setting organizations (SSO), there is little systematic research on the topic. The study of the interplay between market competition and standard setting organizations seems like a very fruitful area for future research.

Mandated Standards

Another alternative to market mediated standards is the setting of standards by regulators. A benefit from mandated standards is that *in theory* they can be set quickly.[17] Also, mandated standards insure coordination on a single technology.

A disadvantage of mandated standards is that there is less price and technological competition. Additionally, due to asymmetric information, firms typically know more about both costs and potential technological progress than regulators. This makes it difficult for regulators to set standards. Another problem is rent-seeking behavior induced by the prospect of mandated standards. Finally, setting a standard too early often implies deciding without relevant information that would be gained by waiting. In the case of HDTV in Japan, the government mandated a standard at an early stage. Most industry experts believe that the delay in adopting a standard and the competition among competing standards led to the U.S. receiving a higher quality HDTV system.[18]

(iii) Competition/Antitrust Policy in Settings with Network Effects

Network considerations affect all aspects of antitrust/competition policy. Here I examine a few key areas:

Innovation and Network Effects

Many high-tech consumer electronic products exhibit strong network effects. These industries also exhibit tremendous rates of innovation. Hence antitrust policies in

[17] See Cabral (2000) for further discussion. In practice, mandated standards are not necessarily set quickly because it may not be in the interest of the relevant firms to set a standard quickly.
[18] See Farrell and Shapiro (1992).

network industries must take account the strength of network efforts as well as the importance (and pace) of innovation.[19]

There is a small literature on the interaction between compatibility choices and technological progress/product introduction. The key question examined by the literature is how compatibility or its absence affects the rate of technological progress or the time when products are introduced. Although little in general can be said about the relationship between compatibility and product introduction/R&D, some progress has been made as the work surveyed below shows.[20] In particular, two general results that seem quite robust are (i) compatibility results in the optimal timing of product introduction and (ii) incompatibility speeds up product introduction.

Katz and Shapiro (1992) is a dynamic model with fulfilled expectations. In order to make it tractable, they consider a setting in which one of two competing products has been introduced and the second firm must decide (i) when to introduce its product, and (ii) whether to make its product compatible with the initial product. They show that the firm introducing the new technology is biased against compatibility.

Regibeau and Rockett (1996) similarly assume that the rate of technological progress is exogenous. Like Katz and Shapiro (1992), they endogenize both the compatibility decision and the product introduction date. Unlike Katz and Shapiro (1992), neither of the two competitors has introduced a product. In order to make the model tractable, they assume that consumers have myopic expectations about the firms' installed bases. This allows them to analyze a more complex introduction game. They find that compatibility speeds up the introduction of the first product, but increases the delay before the second product is introduced. They also find that when firms can credibly commit themselves to a standard in the early development stage, they agree to produce compatible products.

Kristiansen (1998) allows for endogenous product introduction rates and endogenous technical progress, but in a restrictive model in which firms can choose to introduce

[19] See Church and Ware (2001) for more discussion.
[20] This is in part because settings with endogenous compatibility choices and endogenous product introduction dates are difficult to solve analytically even if technological change is exogenous.

their technology in either period two or period three. In period 1, the firms develop their technology. It is assumed that the R&D cost of introducing the technology in period 2 is higher than the R&D cost of introducing the technology in period 3.[21] The model assumes that the technologies are incompatible. He finds that network effects lead to the technologies being introduced too early.

An interesting point in Kristiansen (1998) is that government intervention to set a standard at the beginning of the third stage can actually exacerbate the inefficient early introduction of products.[22] Hence if a regulator cannot impose a standard ex-ante (due to lack of information, etc.), government intervention ex-post will not lead to an improvement relative to the market.[23]

Integration and Foreclosure in Markets with Virtual Network Effects

One classic anecdote illustrating the critical role that complementary products play in the adoption of systems is the failure of the Betamax videocassette recorder (VCR) technology. The Betamax technology was apparently—"on its own"--- as good as the competing incompatible VHS technology.[24] Nonetheless, by 1981, VHS held a 66-percent share of the VCR installed base. When pre-recorded videocassettes became important in the early 1980s, rental stores preferred to carry VHS tapes because of their installed-base advantage. The dearth of Betamax tapes "tipped" the market to VHS, which became the de facto standard in 1988.

In the case of Betamax vs. VHS, neither of the two "hardware" technologies controlled the market for software (the movies). Such control has raised antitrust issues. The concern is that hardware control of software will foreclose other hardware providers.

[21] Kristiansen (1998) assumes rational expectations; despite this assumption he is able to solve the model because of the limit on the number of periods of R&D competition.
[22] This assumes that the policy is known in advance.
[23] This is reminiscent of Farrell and Saloner (1992). They examine the incentives for ex-post standardization in the context of converters and show that converters can give rise to suboptimal incentives to produce ex ante compatible products.
[24] Park (1997) cites a *1982 Consumer Reports* publication that tested various VCR models. The report concluded that there was no significant difference in the characteristics or qualities of the two platforms.

Church and Gandal (1996) assess the effect of hardware control of software provision in system markets. They show that when an incumbent can commit to an installed base of software, the incumbent can create strategic entry barriers that prevent an efficient entrant from entering the market. Bresnahan (1999) arrives at a similar conclusion. These models suggest that network effects can enable a monopolist to create strategic entry barriers.

Church and Gandal (2000) theoretically examine the possibility of such foreclosure in system markets where a system is composed of a hardware good & complementary software and the value of the system depends on the availability of software. Foreclosure occurs when a hardware firm merges with a software firm and the integrated firm makes its software incompatible with a rival technology or system. They find that foreclosure can be an equilibrium outcome where both the merger and compatibility decisions are part of a multistage game that permits the foreclosed hardware firm to play a number of counter-strategies. Further, they find that foreclosure can be an effective strategy to monopolize the hardware market.

Hence the antitrust concern about such foreclosure seems well founded. In practice antitrust authorities often require arrangements to insure access to the software of merged (hardware/software) entity. An example is the U.S. Federal Trade Commission's (FTC's) 1995 consent decree with Silicon Graphics, Inc. (SGI) which allowed SGI to acquire two of the three leading graphic entertainment software companies.[25] One of the reasons behind the FTC's challenge was that competing manufacturers of workstations would be foreclosed from two important independent providers of graphic software. One of the provisions of the consent agreement is that SGI make the two major entertainment graphics software programs it acquired from Alias Research compatible with the hardware workstations of a competitor.

Antitrust Policy Towards Standard Setting Organizations

Industry cooperation typically takes the form of a private consortium where the firms come together and reach an agreement on a standard. The theoretical literature

[25] The final consent decree is summarized at http://www.ftc.gov/opa/1995/9511/sil2g.htm.

suggests that standard setting organizations are more likely to lead to standardization than a market mediated processes. This suggests that standard setting organizations can play a useful role in achieving compatibility.

But such horizontal agreements among competitors raise antirust issues. Legal scholars are concerned that SSOs have the potential to manipulate standards committees. These consortia will likely have to obtain exemptions from antitrust authorities as they did in the case of DVD.[26]

Other 'antitrust issues' raised by private consortia are the exchange of information on costs, bias in the choice of the standard, and refusal to license the necessary technology to non-members. What should be the antitrust policy towards standard setting via committee? Lemley and McGowan (1998) suggest that an appropriate antitrust policy might be to allow standard setting consortia, but guarantee that all firms have access to the standard setting process.[27]

Merger Policy

Network effects affect merger policy because of issues related to compatibility & interoperability. The merger between America Online (AOL) and Time Warner provides a good overview of the issues.[28] The AOL/Time Warner merger, which was announced in January 2000, represented the largest proposed merger of all time.

One of the main concerns of the two relevant regulatory agencies, The Federal Trade Commission (FTC) and the Federal Communications Commission (FCC), was interoperability or compatibility between AOLs instant messaging service and the instant messaging services of competitors.[29] This concern arises from the presence of network effects. Although AOL offered basic (text-based) instant messaging service

[26] See Merges (1998).
[27] Even if everyone is welcome around the table, effective 'participation' depends on the decision rules of the SSO. If the decision rule requires unanimity then expanding participation might have a cost in terms of the speed of decision-making. See Lemley (2001) for a first look at these issues.
[28] This discussion in this section draws liberally from Faulhaber (2001).
[29] AOL had a very large installed base of subscribers when other firms (including Yahoo & Microsoft) began offering competing instant messaging services. In order to benefit from network effects, AOL's rivals designed their systems to be compatible with AOL's instant messaging service. AOL blocked the interconnection, citing safety, privacy, and security concerns. See Faulhaber (2001).

before the proposed merger, emerging instant messaging services such as voice over IP, the exchange of pictures, and streaming video require broadband capabilities. AOL gained significant broadband capabilities with its acquisition of Time-Warner. Hence, the FCC imposed the condition that AOL must offer interoperability with other providers of advanced instant messenger services before it is allowed to offer advanced instant messaging services itself.

While this decision came out of a merger case, the decision to require interoperability has antitrust implications for other settings with network effects. Should Internet backbone providers for example, be required to interconnect with other backbone providers? There clearly are strong network effects in this case as well. Currently there is no such policy and interconnection relies on private agreements.[30]

Requiring Backward Compatibility

Regulators occasionally require that a new technology be backward compatible. In 1997 for example, the FCC set down the guidelines for the new digital high definition television (HDTV) standard. Regular NTSC televisions will be able to view new broadcasts with a "down-converter" box, which will provide a somewhat improved image. New HDTVs will be able to watch old NTSC programs if they have a second (analog) tuner built-in.[31] This is similar to the strategy employed by the FCC in the early 1950s when a backward compatible prototype was chosen.[32]

Backward compatibility has benefits as well as costs. Benefits associated with backward compatibility are that old consumers are not stranded and that providing backward compatibility (and the associated software variety) will hasten adoption of the new technology. An additional benefit is that compatibility leads to the optimal rate of technological progress in many settings.[33] There are costs as well. It is claimed that backward compatibility requires additional development costs and hence

[30] Cremer, Rey, and Tirole (2000) examine a dominant Internet backbone provider's incentives to 'degrade' the quality of its connection with rival backbone providers.

[31] See "HDTV: How the Picture Looks Now," *Business Week*, May 26, 1997, and "Should you Roll Out the Welcome Mat for HDTV?" *The New York Times*, April 27, 1997.
[32] See Farrell and Shapiro (1992) for more on the role of standard setting in HDTV.
[33] See Matutes and Regibeau (1996).

slows down innovation. To the best of my knowledge, there is no thorough theoretical analysis of these issues.[34]

Gandal, Kende, & Rob (2000) developed a structural model and use it to estimate the feedback from hardware to software and vice versa in the CD industry. The advantage of the structural methodology is that enables researchers to conduct counterfactuals. Gandal, Kende, and Rob (2000) show that if it had been possible to make CD players compatible with LPs, compatibility could have accelerated the adoption process by more than a year. While such a counterfactual is purely a "thought experiment" for CD players, it has public policy relevance for other systems regarding the benefits of backward compatibility.[35]

(iv) Intellectual Property Rights in the Presence of Network Effects

Many economists and legal scholars have argued that intellectual property rights should be interpreted narrowly in settings with network effects.[36] This is because in the presence of network effects, copyright and other forms of intellectual property protection may confer monopoly power without any significant innovation. In many cases, consumers highly value the benefits from compatibility, rather than the differences in the other characteristics of the products. Thus the presence of network effects may turn the initial choices of small groups of users into de facto standards.

Copyright (and other forms of intellectual property protection) may also create entry barriers if intellectual property protection also extends to the interface aspects of network products. Many economists and legal scholars have argued that intellectual property rights should be limited in a way that facilitates compatibility or interoperability between competing products in markets with network effects. This might mean limited intellectual protection for the interface aspects of network

[34] See Choi (1994) for monopoly incentives to makes successive versions of products incompatible. See also Fudenberg and Tirole (1998) for monopoly pricing of upgrades.
[35] Rysman (2001) also uses a structural model to perform counterfactuals in the market for "Yellow Pages."
[36] Indeed, several economists authored an amicus brief on the issue that was submitted to the U.S. Supreme Court. The brief can be found online at http://elsa.berkeley.edu/~woroch/amicus.pdf.

products. [37] Lemley and McGowan (1998) suggest that limited copyright protection for interfaces would apply in cases when a firm improves an interface.[38]

The Council of European Communities Directive #91/250 (May 1991) on the legal protection of computer programs is in the same spirit. It authorizes the reproduction of copyrighted code under circumstances when "reproduction of the code and translation of its form...are indispensable to obtain the necessary information to achieve the interoperability of an independently created program with other programs…[The objective] is to make it possible to connect all components of a computer system, including those of different manufacturers, so that they can work together."[39]

(v) International Policy Issues in Setting with Network Effects

Despite the fact that many industries characterized by "network effects" (personal computers, telecommunications, consumer electronics products) are global, the literature on network effects has almost exclusively focused on closed economies.[40] The analysis of compatibility standards differs between closed-economy and open-economy contexts for several reasons. The most important difference from a policy standpoint is that the analysis of closed economies ignores any gains that might come from international coordination of standards. When there are network effects the benefits from standardization increase in the size of the network, regardless of whether the consumers are foreign or domestic.

Individual governments do not typically take into account the gains from the international coordination of standards policies. Broadcast television is an example. The National Television Standards Committee (NTSC) system was developed in the U.S. in 1954. The Sequential Couleur Avec Memoire (SECAM) system and the Phase Alternate Lines (PAL) system were developed in the early 1960s, SECAM in

[37] See Menell (1998) and Lemley and McGowan (1998).
[38] Hence in the case of the Borland spreadsheet and the Lotus interface, Borland would have been allowed to employ the Lotus interface since Borland's innovation improved the operation of the interface. On the other hand, in the case in which a firm simply imitates an interface, there would be full copyright protection for the original interface.
[39] See http://europa.eu.int/eur-lex/en/lif/dat/1991/en_391L0250.html.
[40] Exceptions include Gandal and Shy (2001) and Barrett and Yang (2001).

France and PAL in West Germany. All three standards are incompatible. The U.S. and Japan adopted NTSC, while the PAL system was adopted by most countries in Western Europe (except France). France and Eastern European countries adopted SECAM. This fragmentation likely slowed the development of a global market for television receivers. In order to sell television sets in France, foreign manufacturers had to adapt (convert) the receivers to the SECAM standard. Because of the incompatibility problems in television broadcasting, videocassettes produced for PAL cannot be played on NTSC television receivers (and vise-a-versa).

One solution that might internalize network effects across borders is a shift from national to regional or international standards committees. David and Shurmer (1996) provide qualitative evidence that such a shift has been taking place, especially in the case of information & communications technologies. They attribute this shift to advances in information & communications technologies and the importance of technical compatibility within products (such as computer operating systems & applications software and consumer electronics products) that employ these new technologies. According to the authors, "the information & communications technologies impact upon the standardization regime has been profound (David and Shurmer (1996), p. 797)."

IV. Conclusion

Network effects are prevalent in many markets, especially high-tech and information technology markets. This paper has provided a brief overview of some key policy issues. "Network economics" was at one time considered a rather esoteric field of research and examining the "tradeoff between the private and social incentives to achieve compatibility" seemed like a fairly abstract research topic. Given the dramatic growth of the Internet and information technology industries in general, and the importance of interconnection in these networks, the economics of compatibility and standardization has become mainstream economics. Hopefully the broader interest in the topic will help shed light on the many unanswered policy issues in this field.

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