Invisible Hands Versus Invisible Advisors: Coordination Mechanisms in Economic Networks

Shane M. Greenstein

Columbia Institute for Tele-Information
Graduate School of Business
809 Uris Hall
New York, New York 10027
(212) 854 4222

Abstract

The article discusses the efficacy of relying on market mechanisms to guide growth of economic networks, with special reference to information technology markets. Many insights into the efficacy of relying on market mechanisms are not consistent with one another, nor do they all transparently synthesize into a single policy vision. Thus, extending this literature appropriately should have some value. A secondary purpose of this essay is to identify important issues that remain unaddressed.

I. Introduction

The traditional model of the telecommunications network operated by a single paternal regulated firm ceased to be relevant in the United States some time ago. No single organization today internalizes the majority of design decisions, upgrading and maintenance problems associated with telecommunications networks. The network employed by the typical user blends some amount of communications technologies and computing technologies from scores of different public and private firms. Some information technologies, like a local area network in an office, are physically small and technically simple. Other information technologies, such as the public phone networks, cover large geographic areas and employ expensive and technically complex equipment.

It is an oversimplification, though not far off the mark, to observe that the locus of decision making regarding telecommunications networks has changed in the last three decades. Important network development decisions have increasingly moved out of the administrative offices of AT&T and into the offices of firms who answer to decentralized market-based mechanisms. It is also not far off the mark to observe that this change did not occur as a result of any single policy vision. Rather, it was the result of many technical, economic and legal factors. Indeed, it is the absence of a single guiding policy vision that raises concerns about the efficacy of the mechanisms guiding network development and growth today.

The primary purpose of this essay is to summarize the main insights made by economists about the costs and benefits of relying on market-based mechanisms for decentralized network development. Economists have been concerned about these issues in the rather recent literature on network economics and standardization. This literature contains many useful insights, but not all of them are consistent with one another, nor do they all transparently synthesize into a single policy vision. Thus, extending this literature appropriately should

have some value. A secondary purpose of this essay is to identify important issues that remain unaddressed.

The key to this literature is an economist's definition of a network. An economic network is composed of all buyers and suppliers who have economic incentive to care about a system's technical features (e.g, Wade [1992]). The term "economic network" is often confusing to those who view a telecommunications network as nothing more than just its physical linkages and its electronic signals. To an economist there is more to an economic network than just the physical equipment extant today, because economic relationships extend beyond physical boundaries of equipment. For example, many buyers and sellers of the same information technology may not buy equipment or services from the exact same supplier, but they may be a subset of the same economic network if they use compatible equipment.

An "economic network" is centered around a standard, which means that a component may serve as a sub-system within a larger arrangement of components. In the simplest case, standards can define the physical fit of two components. Familiar examples are modular phone jacks on telephone lines and handsets, and compatible telephone switches. More complex are the standards that determine electronic communication channels. The need for these standards is obvious, since successfully filtering, transmitting and translating voices across telecommunication networks requires precise engineering. Similar needs arise in the design of circuitry between computers, their operating system and computer application programs. Most of the interesting questions concern how these standards get designed and adopted.

Unfettered market processes may produce standards as a <u>de facto</u> result of either a "sponsored" or an "unsponsored" market process (David and Greenstein [1989a]). In a sponsored process, one or more entities, suppliers, or cooperative ventures, creates inducements for other economic decision-makers to adopt a particular set of technical specifications (e.g., pre-diversiture AT&T-sponsored telecommunication

standards). An unsponsored process has no identified originator with a proprietary interest, yet follows well-documented specifications (e.g., the QWERTY keyboard). Voluntary industry self-regulation may also play a role when economic networks arise out of the deliberations of voluntary standards-writing organizations (e.g., ANSI). Of course, standards may also be mandated by government bodies (e.g, FCC).

There is no compelling reason for government organizations to become involved in the development of every standard. They often do so because important public policy issues are at stake. They often do not do so because exogenous forces, such as dramatic technical change, outstrip the ability of any administrative process to guide events and it may be easier to leave decisions to market participants. The question of when it is best to rely on a market process instead of an government decision making is an open and active topic of debate, since it usually swings on trade-offs between imperfect market processes and imperfect government intervention.[1]

This article will focus on one part of this debate: understanding the efficacy of relying on decentralized market-based decision making processes and private organizations -- i.e. with minimal government intervention. Following the existing literature, this discussion emphasizes understanding the incentives of the organization who designs standards for an economic network. This article will first evaluate insights about market-based mechanisms and administrative processes and synthesize them. The final part of the paper will suggest that the standard view of network growth and development needs to be extended to bridge the distance between the concerns of economic models and the behavior of many daily practioneers in network industries.

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[1] This large topic will only be briefly be touched on below. For more on government regulations of standards see OECD [1991], David [1987], David and Greenstein [1990], and Farrell and Shapiro [1991]. See David and Steinmueller [1992] and Besen and Johnson [1986] for a particular emphasis on issues in telecommunications.

II. Invisible Hands: Market Based Decisions

In many cases the initial ownership of assets strongly limits the number of vendors that can feasibly produce for a market. As a result, economists have tended to analyze the development of economic networks as an outgrowth of an initial market structure, such as the number of firms. The discussion below will also initially make this assumption. It should be recognized, however, that heuristic convenience is not to be equated with analytical completeness. Under a long-run view, the ultimate integration into design and supply of interrelated components must be analyzed as an endogenous byproduct of standardization processes and technical innovation. In other words, one standardization episode can shape long-run market structure, which will then shape another standardization episode, and so on. Much more will be said below about when causation runs one way and when it is a two-way street.

a. Many buyers, many sellers, and market mechanisms

Economic networks may not easily arise when decision-making in a market is diffuse -- i.e., when a market has many buyers and many sellers, none of whom is responsible for a large percentage of economic activity. This is disturbing since diffuse market structures are typically very competitive and tend to allocate scarce resources efficiently through price mechanisms. Many policy issues would be simplified if market structures with diffuse decision-making were always desirable for economic networks.

When decision-making is diffuse, the problems that arise are often called "coordination problems" (Farrell and Saloner [1986]). Though all potential users and suppliers could benefit from standardization, every potential user of a standard is a small part of the whole. Each decision maker has too little incentive to make the

investments that will coordinate the activities of other users.[2] The diffusion of decision-making also can hinder adequate communication between all relevant parties. Thus, at first glance, it appears that network growth may be hindered because too few standards arise, if they arise at all, or they arise too late (Cabral [1987]).

When unsponsored economic networks develop, they tend to grow and shrink for many reasons that may have only a minor correspondence with the long-term economic welfare of market participants. This is because the development of an economic network is often characterized by "bandwagons" (Farrell and Saloner [1985],[1986b], David [1987], Postrel [1985]). For example, networks may be slow to start when they are small and many potential adopters "sit on the fence," waiting to make expensive and unrecoverable investments until a clear standard has been chosen by a large fraction of other users. Networks may not develop at all if most participants are "lukewarm" about a new standard due to technical uncertainty, for example, even though all would collectively benefit from it. Alternatively, bandwagons may also grow (remarkably!) quickly once a network's size becomes large enough to justify investments by potential adopters who, in the early phase of development, had delayed making commitments. The lack of communication between all the potentially affected decision makers exacerbates such bandwagons.

Bandwagons need not result in an optimal standard or an appropriate technology choice, particularly when early and later users possess very different needs (Arthur [1988], Cowan [1987]). The

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[2] At least since the writings of Hemenway [1975], it has been recognized that standards for networks have a "public goods" quality -- i.e., it is difficult to exclude anyone from using a standard and many economic agents can benefit from their use without influencing the costs to anyone else. As is generally the case with public goods, in the absence of actions by government or industry organizations, standards will be underprovided by unrestricted markets (Dybvig and Spatt [1983], Kindleberger [1983]).

problem is that users and suppliers can become "locked-in" to a technical alternative, i.e. find it very costly to change fundamental technical specifications (David [1985], Farrell and Saloner [1986], Greenstein [1990b]). An economic network may never standardize if users lock-in to a disparate variety of formats that each finds it costly to change later. Alternatively, if many potential adopters wait for a "shake-out", then crucial choices between technologies may be made by early adopters. Early adopters bear a disproportionate influence over standards if their decisions lead to technical designs that cannot easily be altered to accommodate the different needs of the later decision-makers. For example, the installed base of color television sets in the US today all use one set of standards that is incompatible with many of the new high-definition television (HDTV) standards possible. Many observers think it is too costly to abandon this installed base and, thus, recommend using a high-definition standard that is backward compatible with the installed base, even if doing so sacrifices some of the pictorial quality possible with unchosen HDTV technologies (Farrell and Shapiro [1992]).

It might be argued that the disproportionate influence of early users is justified because these same users bear a high risk for being intrepid, i.e., their investments in a standard can become obsolete or "orphaned".[3] However, this observation does not really address the question of whether society gets an optimal technology or not, which is the central policy issue. The timing and character of the emergence of a particular standard, if one emerges at all, will be sensitive to

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[3] "In network industries, successful innovations often harm the installed base of a user who bought equipment and training before the new technology was available or recognized as the incipient standard. If I develop a new mousetrap and you choose not to buy it, I have not harmed you. If I develop a new computer operating system, incompatible with the old one you already own, and you choose not to buy it but millions of their users do, then you will find your network benefits much diminished as a consequence of the innovation. This stranding externality has no direct parallel in industries without network effects (Farrell, 1987)."

many potentially arbitrary factors influencing the decision making of the first majority of adopters (David [1986]). This makes the outcome rather unpredictable at the start and leaves no assurance that a technically appropriate long-run solution will be result, particularly when viewed with hindsight (Cowan [1987]) -- i.e. society can be "locked-in" to the wrong standard ex post.

This conceptual paradigm corresponds with many historical cases. David [1985], [1986] showed how the interaction of uncoordinated decisions by typing schools, typewriter manufacturers, and early typists resulted in the adoption of the QWERTY keyboard. This is of interest because a superior alternative exists, yet market participants have never coordinated a switch.[4] Other examples from information technology markets are AM stereo (Besen and Johnson [1986]), FM stereo (Besen [1991]) and micro-processor design (Swann [1985], [1987], Wade [1992]).

Perhaps the most unsatisfying feature of the analysis of unsponsored networks to date is its use of a stricter concept of irreversibility than is warranted due to the realities of typical technological and economic evolution. Are some features of a standards more mutable than others? Are there degrees of lock-in? Economic analysis has yet to understand how these notions can be properly modified for situations where standards for components are evolving and in constant flux, as they are updated and revised for new market suppliers and applications.

b. Dueling sponsors.

The foregoing implies that the diffusion of decision making leads to situations where (1) communication and sponsorship are unlikely and (2) coordination problems are likely. Thus, it would seem to follow

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[4] Liebowitz and Margolis [1989] cast doubt on whether the historical evidence supports the view that Dvorack is a compelling alternative. They argue that this casts doubt on David's characterization of the episode.

that market structures with few vendors may not suffer as much from coordination problems (Sirbu and Stewart [1986]). However, such a conclusion is hasty if it is not qualified properly. In markets with few vendors, the proprietary interests of the vendors leads them to take strategic actions designed to produce outcomes they favor. While this reduces the severity of coordination problems, it does not eliminate them. A sponsoring firm's strategic behavior produces other types of distortions.

Perhaps the most common occurrence in a market with few vendors is "dueling sponsors" -- each sponsor has proprietary interests in one set of standards for arrays of components that perform similar functions. The VHS/Betamax duel in the VCR markets is a well-known case (Cusumano et.al. [1991]). Such battles are common today in the computer software and hardware industries (IBM vs. Apple in PCs, IBM vs DEC in minis, Wordstar vs Wordperfect in word processing, etc.), where the duels may start as multi-firm contests but quickly reduce to a handful of dominant participants. Do these duels lead to optimal economic networks, and, if not, what are the most problematic distortions?

An important distortion from dueling is that it may prevent the economic network from becoming as large as it possibly could be, even if all users would benefit from a larger network. This is because dueling sponsors have incentives to design incompatible systems if incompatibility raises the costs to users of switching to a rival sponsor's system (Klemperer [1987a], [1987b]). Indeed, evidence from the mainframe industry in the 1970s indicates that those costs could potentially be high enough to influence buyer behavior (Greenstein [1990b], [1991]).

Certainly, the sponsor of a system would like nothing better than to raise the costs to the experienced user from switching vendors, since it provides the sponsor with market power during any repeat purchase. However, this is not the whole story. Not only will some

firms design systems that are incompatible with rival systems, but they may actively seek to prevent the entry of gateway technologies -- i,e., bridges to make incompatible technologies compatible (Carlton and Klamer [1983]). The benefits to vendors from accessing a rival network's users is counter-balanced by the loss of market power from facing competition from a rival vendor. Vendors with larger markets are less likely to desire compatibility with smaller rivals (than the smaller rival does with them) because larger firms gain less from selling to a few more customers and potentially lose more from facing more competition (Katz and Shapiro [1985], Katz [1986], Berg [1985]). An example of this behavior might be IBM's role in blocking the development of ASCII standards for mainframe computers (see Brock [1975]) and allegedly in plug-compatible equipment markets as well (Brock [1989]).

Dueling sponsors will not design incompatible systems in every circumstance. When rival sponsors provide components that perform different functions, compatibility permits many "mix-and-match" possibilities between the components of rival systems (Matutes and Regibeau [1988], [1989], Economides [1988a], [1988b], [1990], Economides and Salop [1991], Einhorn [1989a], [1989b]). In turn, this raises the profitability of producing compatible components (despite increases in competition). The market for stereo equipment is a familiar example (Postrel [1990]). Thus, dueling sponsors are likely to find it worthwhile to make investments in gateway technologies when they do not produce every type of component, or if each has comparative advantage in the design and production of some but not all components. This is probably a good explanation for the willingness of so many firms, even ATT and IBM on occasion, to participate in the vertical disintegration of many parts of the computing and telecommunications markets.

Dueling standards may also be economically efficient if a variety of standards is appropriate for a variety of potential problems (Farrell and Saloner [1986c]). The crucial question is whether the

market will permit entry of a new standard suited to a minority of users; this may depend on the strength of "lock-in" effects or the success of actions of system sponsors to foreclose or induce entry of complementary products, such as software (Church and Gandal [1989], [1990], [1991], Gandal and Salant [1992]). For example, lock-in effects are present in the market for local-area networks, and yet, the different standards for local-area networks and metropolitan-area networks respond to the different needs of users. Thus, lack of uniform standards may not impose a big loss on society in this instance because it provides options to different users with different needs (Lehr [1990], [1991a]).

Competition and innovation couter balance some of the distortions from lock-in. Monopoly profits may be dissipated through competitive bidding between the rival system sponsors. Since many buyers anticipate that their vendors will later gain monopoly benefits from their exclusive sales of complementary products, they will demand compensation before they commit to a standard (Farrell [1987], Klemperer [1987a,b,c], [1989], Monroe [1987], Farrell and Shapiro [1988], [1989]).[5] Such demands can potentially elicit "promotional pricing" from sponsors (see Besen and Johnson [1986]), especially from those with long-run economic advantages (Katz and Shapiro [1986a], [1986b]). Notice, however, that this is a benefit that accrues to new users and not necessarily to users with an installed base of equipment.[6] In addition, competitive bidding for new customers may

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[5] Certainly buyers do not possess perfect foresight in all situations, nor are they able to pursue strategies that take advantage of the intertemporal link in vendor strategies. For example, Greenstein [1991] shows how the hierarchical relationships within an organization often weaken the links between decisions regarding large capital outlays, such as a computer system. Indeed, Cabral and Greenstein [1990] show that organizations can often be better off if they ignored these costs in their vendor decision.

[6] The critical issue is whether system sponsors can successfully "price-discriminate" -- i.e. identify separate groups of buyers and systematically charge them different prices and prevent one group of buyers from selling to the other. If price

spur incumbent system vendors to innovate. For example, some observers argue that inter-system competition was a primary driver of computer system innovation in the 1960s and 1970s (Fisher, McGowan and Greenwood [1983], Fisher, McKie, and Mancke [1983]).

As with unsponsored economic networks, the market's choice between dueling systems still retains the sensitivity to small events (Hanson [1984]). A well-researched example comes from the early history of electrical power supply. Though engineering evidence seems to suggest that alternative current is probably superior to direct current for widespread use, David and Bunn's [1988] study shows that many other factors, including "beauty contests" and the decisions of crucial industry participants, such as Edison and Westinghouse, and the character of the gateways between AC and DC, determined how alternative current was chosen over direct current. In a more current example, Cusumano, et. al. [1990] showed that the development of the VCR standard was sensitive to the relationship of Sony and Hitatchi Corporations, the seemingly minor (and temporary) ability of VHS to record longer and the timing of the introduction of video cassettes.

One of the more interesting features of duels is that dueling may induce actions that ultimately lead to the success of one economic network but the loss of the sponsor's control over it. For example, a firm may broadly license a technology to establish it as a standard, but in so doing, sacrifice its control over the standard and much of the monopoly profits associated with that control. Sun Microsystems' liberal licensing strategy with the SPARC workstations can be interpreted this way.[7] Another variant of this phenomenon is for a firm to design a product that is "open", i.e., that does not contain

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discrimination is feasible, then only new users benefit from system competition.

[7] However, a sponsor will sometimes give away the standard in the hopes of dominating markets for components later on. Thus, not all monopoly rents are necessarily lost (e.g., Farrell and Gallini [1988] or the discussion in David and Greenstein [1989]).

proprietary technology. The open system induces entry of more peripheral and software suppliers and hardware clones. This makes the hardware conforming to the standard more valuable to users, while the entry of more clones reduces the price. The development of software and peripherals for the IBM-compatible personal computer followed this pattern (Langlois and Robertson [1990]). Once the standard was widely accepted (partially as a result of all this entry), IBM no longer garnered much of the rents from being the original sponsor of the standard. Indeed, today IBM and a consortia of private firms are battling to determine the direction of the next generations of "IBM-compatible" machines.

One other interesting feature of duels is that conditions of competition can shift suddenly and assymettrically due to the availability of converters, translators and emulators from third parties. For example, a number of third party vendors today supply programs that enable Apple Macintosh computers to use IBM software, but they are not designed to allow IBM systems to use Macintosh system software. Thus, the benefit from these gatewasy is asymettric. Most of the advantages accrues to those owning a Macintosh system.

Perhaps the greatest weakness of the economic analysis of dueling systems is its excessive static nature. In view of the multiplicity of pricing and promotional strategies typically available to firms and the technical changes affecting most information technology networks, there is a need to arrive at a better understanding of the incentives to design and promote products that are incompatible or compatible with present and future generations (e.g., Rotemberg and Saloner [1991]). How can the analysis of duels be modified for situations where standards are in constant flux and where products undergo a predictable life-cycle?

c. A dominant seller as sponsor

A very natural solution to coordination problems arises in economic network that have only a single sponsor associated with them.

All design decisions, upgrading and maintenance problems are internalized within the structure of a single firm. Many readers will recognize this as the traditional model of telephone networks and IBM's vision for integrating computers and telecommunications under the System Network Architecture (SNA) model. Unifying control within a single firm generally eliminates competing designers and provides users with certainty about who controls the evolution of standards and their ultimate compatibility. This potential benefit from single firm sponsorship cannot be de-emphasized, especially in markets subject to uncertain and rapid changes in technology.

Unfortunately, single firm sponsorship by a supplier also brings much baggage with it. There is an old general concern that large firms have disproportionate influences upon market processes and they manipulate them to their advantage at the expense of society's long term interests. Similarly, economic networks may be dominated by the large firm (who sponsors the standard) and not necessarily to good ends. Most of these concerns fall under the realm of anti-trust economics.[8]

Anti-trust issues arise because a single sponsor is usually not alone. He is often competing with small plug-compatible component suppliers in some or all component markets. For example, from the mid 1950s on (and growing thereafter) AT&T faced competition in customer premise equipment markets. Similarly, IBM battled plug-compatible component suppliers from the later 1960s onward. Anti-trust concerns arise because the dominant firm always wishes to prevent the component firms from gaining market share (and may even want to drive them out of business), while society can possibly benefit from the added competition. Controlling and manipulating standards may enhance a sponsor's strategies aimed at gaining competitive advantage over

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[8] Besen and Saloner [1988] and David and Greenstein [1990] discuss this controversial subject at length, so only a brief summary of the issues will be provided here.

rivals.[9]

There are two difficult issues to address. First, under what conditions will a dominant firm manipulate standards to his advantage and to the detriment of potential entrants and consumers? Second, can and should such behavior be regulated, i.e., are the benefits from preventing inappropriate market conduct greater than the side-effects from imposing an imperfect regulatory rule? Most observers stumble on the first question, and even if observers clearly describe (in non-polemic tones) a sponsor's strategies that are inappropriate for society, they may fail on the second set of issues. Policy rules that prevent inappropriate behavior will almost always also deter perfectly acceptable behavior as well.

As a result, the relevant debates are unresolved. Open debate surrounds any analysis of "leveraging", for example, i.e. using monopoly power in one component market to gain competitive advantage in another. Most economists agree that courts have carelessly applied this concept (Bowman [1957]). Yet, there is no question that a system sponsor can delay entry of complementary component suppliers (Greenstein [1990a]), or foreclose entry altogether (Whinston [1989], Church and Gandal [1990b]). For example, AT&T's resistance to designing modular telecommunication connections delayed entry of competition for customer premises equipment (Brock [1986]).[10] The important (and unresolved) policy question is whether such behavior

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[9] The dominant firm can take actions like "refusing to sell the primary good to a rival; selling only complete systems and not their components; selling both system components but setting high prices for components if purchased separately; 'underpricing' components that compete with those sold by rivals; and 'overpricing' components that are needed by rivals to provide complete systems (Besen and Saloner [1988])."

[10] A sponsor's ability to influence its rivals may be further enhanced if many buyers are uncommitted to networks: if there is a short "window of opportunity" before buyers become locked into a supplier (David [1990], Farrell and Saloner [1986b]), delaying entry may deter it altogether.

should be or can be regulated to any good end. The main problem is that if courts get in the business of second-guessing every innovation by a dominant firm, even those with exclusionary features, it will have a chilling effect on the firm's willingness to introduce any innovation, which normally is not in society's long term interest.[11]

The legal debate is as unresolved as the academic debate. Though the number of cases involving the analysis of market power and standardization has been modest (see Knox [1984] and Greenstein [1990a] for summaries), it would not be surprising if these issues arise again in future information markets. Though the legacy of the IBM antitrust victories has left firms considerable latitude in the use of standardization for strategic purposes (Knox [1984], Menell [1987]), since such fundamental principles are at stake, these rulings will probably be further tested by future cases. For example, the recent anti-trust suits against Nintendo may foreshadow such a trend (Lunney [1990]).

Issues regarding sponsorship are likely to remain controversial as long as there is no consensus regarding the proper role for monopolies in nascent industries. The apparent biases inherent in a dominant firm's decision must be traded-off against apparent gains from the effects of coordinating product characteristics and production process specifications. Thus, this topic raises difficult (static) issues regarding the appropriate boundary for a natural monopoly in industries where compatibility is important, important

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[11] Similar questions permeate debate about whether product innovation in systems of interrelated components is always beneficial or is "predatory" in some sense (Ordover and Willig [1981], Ordover, Sykes and Willig [1985], Besen and Saloner [1988]). Another issue is whether "controlling standards," which various writers define differently, can be used to a controlling firm's benefit at all if competition between systems limits the returns to such behavior (Adams and Brock [1982], Braunstein and White [1985], Carlton and Klamer [1983], Fisher [1979]).

(dynamic) issues regarding the likelihood of innovation in the presence or absence of a monopolized network industry, and unresolvable (political) issues regarding the efficacy of regulatory institutions.

III. Invisible Advisors: Coordination, Cooperation, and its Costs

As noted above, there are many situations in which all component suppliers have an interest in seeing the emergence of standards and the growth of an economic network. Yet, structural impediments may produce coordination problems and lead no firm to sponsor a standard that others will adopt. The strong mutual interest all firms have in the emergence of an economic network can lead firms to forego market processes and attempt to develop standards in organizations that combine representation from many firms. How do these groups work and do they work well?

a. Consortia and competition

One institutional form for developing standards involves a "consortia" of firms who sponsor standards. Component suppliers jointly operate an organization responsible for designing, upgrading, and testing a standard. This solution to standardization problems is becoming increasingly popular in information industries, partially as an outgrowth of joint-research ventures (Weiss and Cargill [1992]). Though standards consortia do not have a well-documented history, a few examples have pointed out some of the economic strengths and pitfalls of developing standards through these groups.

The greatest economic benefit of these groups is that they may accelerate development of complementary components. Success is more likely when all the companies (who may directly compete in a particular component market) find a common interest in developing products that complement their competitive offering. The consortia help induce other firms to produce complementary components because the consortia's existence acts as a guarantee that the standard's

integrity will be maintained in the future. The involvement of Grocer's groups in the development of bar-codes for retail products is an example of this type of involvement (Kheen [1988]). Consortia may also help bridge regional isolation, as was necessary, for example, to establish national ATM networks (Salop [1989]).

Consortia are not a perfect solution to coordination problems. They can easily fall prey to some of the same structural impediments that prevented standardization in their absence. The experience with the development of UNIX standards amply illustrates these weaknesses (Saloner [1990]). The founding firms perceived the consortia as tools to further their own economic interests and block unfavorable outcomes. As a result, two different consortia sponsor two different UNIX standards, and industry participants have lined themselves up behind one or the other based on their economic self-interest. While two standards surely is better than the multiplicity that existed before, there does not seem to be sufficient heterogeneity in user needs to merit two standards. Society would probably be better off with one standard, but supplier self-interest will prevent that.

The other potential danger with consortia, as when any group of competing firms cooperate, is that they may aid collusive activities through joint pricing decisions (Salop [1989]). In addition, such organizations are founded to further the interests of existing firms, not potential entrants or users. Consortia may serve as vehicles to raise entry barriers, chiefly by stifling the development of standards that accommodate development of products that compete with the products of firms inside the consortia (USFTC [1983]). More understanding of consortia will be needed before it is clear whether this is a practical problem or an unfounded fear. After all, it may be difficult to both credibly invite development of complementary components and deter development of competing components.

b. Do voluntary standardization organizations work well?

One of the reasons private consortia are often unnecessary is

that other well-established professional organizations serve similar functions. Many large umbrella groups, such as CCITT, IEEE, ASTM and ANSI, have a long history of involvement in the development of standards (Cropper [1980], Hemenway [1975], Cargill [1989], Spring [1991])[12]. These groups serve as a forum for discussion, development and dissemination of information about standards (Weiss and Sirbu [1990]). In the past, such groups largely codified standards determined by market processes. Today a whole alphabet soup full of groups are involved with anticipating technical change in network standards and guiding their design (Witten [1983], Cargill [1989], David and Greenstein [1989a,b], OECD [1991]). Their role in designing "anticipatory" standards takes on special urgency in markets that lock-in to irreversible standards choices.

One important feature of most of these standardization organizations is that they are "voluntary".[13] In other words, using the standard is optional. Firms must still have some economic reasons for using the standard. Another important feature of voluntary organizations is that participating firms have discretion over the degree of their involvement. In other words, though most firms belong to the relevant umbrella groups, their contribution of resources to standards development can wax or wane for a variety of technical and strategic reasons. This can lead to either extraordinary investment in the process to influence outcomes or to "free-riding" off the activities of the organization.

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[12] More than 400 organizations have been estimated to be at work in this country developing, revising, and reviewing standard (U.S. Federal Trade Commission [1983], Toth [1984]), though a few groups tend to dominate the development of information technology standards.

[13] The major exception in the United States is when standards written by voluntary standards groups are required by law or administrative fiat, as with building codes (Rosenberg[1976], USFTC [1983]). When governments get involved, it is often for the purpose of writing or choosing a standard directly, rather than relying on those determined by the umbrella group. See the discussion below.

Voluntary standards organizations play many useful roles in solving coordination problems, especially those related to lack of communication. They can serve as a forum for affected parties to educate each other about the common perception of the problems to be solved (Sirbu and Hughes [1986]). They can also serve as a legal means to discuss and plan the development of a network of compatible components (Weiss and Sirbu [1990]), as well as document agreements about the technical specification of a standard and disseminate this information to interested parties [Sirbu and Zwimpfer [1985]). And perhaps most importantly, their standards can serve as a focal point to designers who must choose among many technical solutions when imbedding a standard in a component design. In other words, these groups are most likely to succeed when market participants mutually desire standardization, need to establish a mechanism for communication and need a mechanism to develop or choose a standard from one of many technical alternatives (Besen and Johnson [1986]).

No administrative process may be able to guide the development of standards when a slow administrative process cannot keep up with new technical developments (Lehr [1989]). If standard becomes too technically complex and fluid, the focal point is lost in a sea of rapidly changing market events. This is the problem at the core of one critique of ISDN: the value from anticipating standardization problems on such an ambitious level is reduced if as parts of the ISDN standard written, the character of technology has changed enough to make the standard inadequate. In other words, a standard does not serve as a guide to component designers if the standards organization must frequently append the standard. Market processes will predominate instead.

Voluntary standards groups are also no panacea for the structural impediments to standardization in some markets. They will fail to produce useful standards when the self-interest of participants prevents standardization in any event (Lehr [1992]). For example, a dominant firm need not follow the recommendations of a voluntary

standardization group. Moreover, it is not likely to do so if it believes that it can block entry and successfully market its products without the standard. IBM's marketing of systems using EBCDIC rather than ASCII is one such example (Brock [1975]). Similar impasses may occur in a market with dueling technologies, although a voluntary group can play an important role in a duel: if it chooses a particular standard, it could swing the competitive balance in favor of one standard rather than another. However, each sponsoring firm may try to block the endorsement of its rival's standard as a means to prevent this result, which may effectively prevent any standard from being adopted by the voluntary group. The strategies employed in such committee battles can become quite complex (Farrell and Saloner [1988], Lehr [1991b]).

Since their standards can influence economic outcomes, any interested and organized party will make investments in order to manipulate the process to its advantage. As a result, user interests tend to be systematically unrepresented, since users tend to be diffuse and not technically sophisticated enough to master many issues. In addition, large firms have an advantage in volunteering resources that influence the outcome, such as volunteering trained engineers who will write standards that reflect their employees' interests. Finally, "insiders" have the advantage in manipulating procedural rules, "shopping" between relevant committees and lobbying for their long-term interests (Lehr [1991b]). Thus, committees have their own focus, momentum, and inertia, which will necessarily shape the standards that arise. As a general rule, the consensus rules governing most groups tends to favor backward-looking designs of standards using existing technology.

As with consortia, voluntary standardization activities may aid collusive activities (USFTC [1983]). The suppliers that dominate standards-writing will want to further the interests of existing firms, not potential entrants or users. As with consortia, standards may serve as vehicles to raise entry barriers by stifling the

development of components from new entrants. These biases are well-known, and are often held in check by the presence of anti-trust lawyers and the professional ethics of the engineers who design standards.

In sum, voluntary standards organizations can improve outcomes for participants and society, particularly when they make up for the inadequate communication of a diffuse market structure. They are one more avenue through which a system may develop and one more channel through which firms may communicate. They are, however, just a committee, with no power to compel followers. In highly concentrated markets, their functions can be influenced by the narrow self-interest of dueling firms or dominant firms.

IV. Standardization, Innovation, and Industry evolution

The discussion until now has treated the growth of economic networks as the byproduct of initial conditions of a market. The number of participants, the ownership of assets and other chance market factors influence strategic interests, which determines market behavior, which in turn determines market outcomes. To this must be added an important feedback: standardization influences a market's structure. While this feedback is easily recognized, it is the least well-understood component of standardization processes. Usually several factors may be at work at once and they will not work in the same direction.

a. Standardization's effect on market structure

Standards may both encourage and discourage innovation. Standards may provide components suppliers a more secure set of interfaces around which to design a product and thus, may encourage research and development into the design of new components for a network (Putnum, Hayes and Bartlett [1982], David and Steinmueller [1992]). For example, secure telecommunication transmission standards were important in hastening innovation in customer premises markets, such

as facsimile machines and modems. Indeed, Noam [1991] has observed more generally that the success of a communications network sponsor, such as AT&T, comes from developing the technology of its network. Ironically, the sponsor's success lays the seeds for later third-party component competition.

Standards may also be an unintended hindrance for innovation on the network. An existing substitute network may hinder the growth of a new network, for example, as the existing AM network hindered the growth of the FM network (Besen [1991]). In addition, the standard embedded in much existing equipment may be inappropriate for a new application, and minority interests may be burdened with higher costs.

Standardization processes can lead to more concentration in a market or less concentration. As noted above, the factors producing less concentration are strong: sponsors may have incentives to license their standard as a means to induce development of new components. In addition, standards may encourage product innovation and new entry by reducing technical uncertainty. For example, the establishment of standards within the PC industry no doubt hastened the entry of multitudes of hardware, component and software suppliers, which makes the industry incredibly dynamic and competitive (Langlois and Robertson [1990], Langlois [1990]).

However, the factors leading to greater concentration are equally as strong: buyers often have strong incentives to use a single standard. If a firm has a proprietary right over the technically superior standard and network technology, then through appropriate strategic actions (and a little luck) the sponsor may be able to mushroom its advantages into dominant control of several technically related market niches. IBM's early success establishing standards in the mainframe market with the system 360 can be interpreted this way (Brock [1975], [1989], Fisher et. al. [1982], [1983]). Intel's ability to wrestle back control over the manufacturing of 8086-decedents can also be interpreted this way. Some observers claim that Microsoft will

be able to use its control of DOS for advantages in related markets.

Soothsaying about the effects of standardization on young economic networks usually takes a bit of chutzpa in practice. In product markets that regularly undergo radical product innovation it will not be clear how valuable a single standard will be, nor what the costs each technical alternative may impose on later technical developments, nor how large the network will grow as new applications are developed. As a result, it is difficult to predict a market's dynamics. For example, none of the important firms in the VCR industry in the later 1970s anticipated the consequences for hardware competition from the development of the rental movie market (Cusumano et. al. [1990]). In a more current case, technical uncertainty makes it difficult to predict whether the technical requirements implicit in ISDN will limit or enhance competition. After all, ISDN will influence product design and network growth, which in turn may influence other factors such as tariff structures, network controls and plant investment (David and Steinmueller [1990], [1992], Lehr [1989], Lehr and Noll [1989]).

In sum, the only predictable feature of many information technology networks is that they change as a result of many factors pulling in many directions. It is not surprising if two snap shots of any particular market niche taken sufficiently far apart in time may reveal different firms, radically different products and applications, and even different buyers. That is, many information industry markets more closely resemble the technical maturity and organizational stability of the pre-WWI American automobile industry, where the basic product design frequently underwent radical change, rather than the post-WWII American automobile industry, where most innovation was less radical, influencing only a few product traits at a time.

b. Lock-in and control of technical options.

Not much research bridges the distance between theoretical models of economic networks and the concerns of practioneers in network

industries. That is, most buyers and sellers in an evolving industries know that change will come and that its character will be unpredictable. As a result, most product designers and users of compatibility standards associate potential problems with being locked-in to a narrow technical choice. One of the most interesting and least understood aspects of standardization processes is how attempts to avoid lock-in influences design decisions and market outcomes in such a dynamic setting.

One approach to bridging this gap emphasizes the value market participants place on having "strategic flexibility", i.e., having a choice among many future technical options. This approach extends "option theory" to product design decision (e.g., Sanchez [1991]). Its starting premise is that much technology choice involves discontinuous choices among alternatives. Thus, an important determinant of an investment is the uncertain revenue stream associated with future technical alternatives. Product designers and technology users will expend resource today in order to not fore-close technical alternatives associated with potentially large revenue streams. The greater the uncertainty at one time, the greater the value placed on keeping technical choices open over time.

In the above approach the value of stategic flexibility may far outweigh the value of any other determinant of standardization. This is interesting because it provides a different spin on many dynamic factors influencing standardization.

An emphasis on options puts new light on the relevance of standards for both designers and buyers. For example, it explains how standards influences firm decisions on whether to design a new product for a given product line, delay introducing a new product or invest in capacity for an existing product line. A firm may choose to expend extra resources to build a standardized technical platform for many future applications because it cannot be certain which of many future designs will best suit its customers. A firm may also expend extra

resources to make its products compatible with a mix and match industry in order to give buyers assurance that many applications may be available in the future. A firm may hedge its bet by simultaneously employing different technical standards that permit it to reverse its committment to a technical alternative.

Buyers will also expend resources to leave open options affected by technical uncertainties. Buyers require evidence that their technical options will remain open. For example, the existence of many peripheral component suppliers assures that buyer that an economic network caters to a variety of needs. Alternatively, users may purchase general purpose technologies (Bresnahan and Trajenberg [1991]) rather than an application-specific technology as a means to leave open their options for future expansion. For example, Greenstein [1991] discussed how federal mainframe computer users in the 1970s telescoped future lock-in problems into the present and made investments in "modular" programming as a result.

Shifts in technical conditions also influence outcomes in administrative processes. If innovation frequently changes the conditions of competition (e.g, concentration, the primary applications) in an economic network, standards writers can expect to periodically revise their standards. Compromises will be reconsidered in light of new information that new technical solutions may become feasible. In anticipation of these changes standards committees may device a standard that anticipates these changes in order not to foreclose future technical possibilities (Weiss and Cargill [1992]).

IV. Epilogue

Economic networks may develop through market mechanisms or voluntary organizations that combine market participants. Each of these mechanisms may produce desirable outcomes or distort them, depending on the market structure, chance historical events and changes in the costs of technical alternatives. Diffuse market

structures produce coordination problems due to insufficient incentives to standardize and communication difficulties. More concentrated market structures will alleviate some of the communication problems, but strategic interests will distort incentives away from optimal outcomes. Administrative processes may also ameliorate communication problems, but distort outcomes in other ways.

Many desirable and distorted outcomes are possible in theory. In practice, it is often difficult to know what is a good or bad choice. This mix of theoretical possibilities and historical outcomes should warn economic observers and policy makers against unwarranted optimism or undue pessimism about the efficacy of using market mechanisms to guide the growth of economic networks.

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