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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 and indicate directions towards potential answers.

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 private telephone networks, potentially 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 private network development and growth today.

The primary purpose of this essay is to summarize for the non-specialist the 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 that is accessible to the non-specialist. Thus, extending this literature with an eye towards practical applications should have some value. A second purpose for this essay is to identify important issues that remain unaddressed and point towards the direction of answers.

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]). This concern for technology arises either out of the desire for all users to communicate with one another, as in a traditional telephone network (Rohlfs [1974]), or out of the need for all electronic components to work with each other, as when an industry-wide network of buyers uses the same "standard bundle" (Bresnahan and Greenstein [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. Only when AT&T controlled virtually the whole telephone network was the physical network and the economic network synonymous. Indeed, today 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.

As a technical matter, an "economic network" is centered around interoperability, which means that a component may serve as a sub-system within a larger arrangement of components. In the simplest case, compatibility-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 application software programs.

More generally, compatibility solves but one issue in a wider array of coordination problems. Most on-line commercial networks, such as Prodigy, Compuserve or America On-line, or the private networks of thousands of commercial organizations, such as Citibank and K-Mart, are sophisticated electronic networks. These often involve on-line transaction processing, employ a mix of sophisticated telecommunications and computing equipment, and must operate reliably on a daily basis. Accomplishing this involves all the coordination activities associated with the successful management of a business enterprise. Products and services must be defined and tied to billing, output must be controlled and its quality assured, electronic signals must be routed without hesitation and so on. Someone, a designer or some organization, must also plan and develop capital capacity and plan the requisite staffing to meet long run service needs. Sometimes these decisions involve coordinating actions within a single organization. More often then not, they involve coordinating decisions across divisions within the same company, or between upstream and downstream vendors, or between a vendor and a governmental decision maker.

Economic research to date focuses primarily on the factors influencing the development of compatibility standards. This focus on the nexus of economics and technology is a bit narrow, since it ignores important organizational costs. After all, for two networks to remain technically compatible two organizations must coordinate substantial personnel and operating costs. Nonetheless, this does not invalidate the merits of the analysis of compatibility, since interoperability is necessary for any coordination on any level. It simply means that standard analysis leaves aside lots of the messy details of coordinating organizations in practice. This review will try to point out where this hole matters and where it does not.

Finally, one other key to the literature is the economist's taxonomy of processes that develop economic networks. Unfettered market processes may develop economic networks as a de facto result of either a "sponsored" or an "unsponsored" market process (David and Greenstein [1990]). 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 and become part of an economic network (e.g., pre-divestiture 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, government bodies may also shape the development of economic networks (e.g, FCC).

There is no compelling reason for government organizations to become involved in the development of every network. 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 examines the incentives of market participants who are supplying and demanding compatibility standards for an economic network. Since the literature on this topic continually grows, in no way does this article represent a complete review of all the literature's ideas. Rather, it is a select look at the economic factors that will likely influence the development of private telecommunication networks.

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. This approach tends to work well for short run analysis. Under a long-run view, the ultimate supply of interrelated components and the embodiment of technical standards in networks capacity requires a different approach. Technical innovation influences the adoption of standards, and is influenced by it, which ultimately influences long run network development.

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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 [1992]. See David and Steinmueller [1992] and Besen and Johnson [1986] for an emphasis on issues in telecommunications.

a. Too many hands: Many buyers and many sellers

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 diffuse market structures give rise to desirable economic networks.

When decision-making is diffuse, the problems that arise are often called "coordination problems" (Farrell and Saloner [1985]). This is not a statement about whether an economic enterprise works properly. The main insight here is that all potential users and suppliers could benefit from as much technical interoperability as possible, but not enough arises. Because 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 design decisions of other users and lead to general interoperability.[2] The diffusion of decision-making also can hinder adequate communication that would render these coordination problems solved. The proliferation of slightly different Unix systems in the 1970s is an often cited example of this process. Thus, due to market structure alone, it appears that network growth may be hindered because standardization does not arise, or it arises too late (Cabral [1987]). This analysis immediately leads to one disturbing

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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]).

prediction for the growth of private telecommunications networks. When these networks grow larger and brush up against one another, they may be unable to work together for the simple reason that no one bothered to insure that they initially developed in a technically compatible manner.

When unsponsored economic networks develop and build capacity, 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 technical 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, but economists have little to say about precisely what type of communication channels are needed.

A very costly problem arises if capacity of a network becomes "locked-in" to a technical alternative, i.e. users and suppliers find it very costly to change fundamental technical specifications (Arthur [1988], David [1985], Farrell and Saloner [1986a], Greenstein [1991]). Either hardware or software embodies technical features that cannot be easily changed or humans cannot be easily retrained to work with different technology. These costs are especially high when a network must change (e.g., be upgraded, expanded, or replaced) and the network serves as an essential part of an organization's day to day operations. For example, the FAA's air traffic control system (Kelman [1990]) or a company's reservation system cannot easily be altered. Change risks significant downtime arising from the costs of fixing the almost inevitable mistakes that any change produces (Greenstein [1991]).

Lock-in potentially leads to two related problems. First, a network may not become as large or as valuable as possible because users lock-in to a disparate variety of formats and each finds it costly to change later. The second problem is related. If many potential adopters wait for a "shake-out", then crucial choices between technologies may be made by early adopters. Thus, 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 HDTV technologies or raises its cost (Johnson [1990], 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 network can become obsolete or "orphaned".[3] However, this observation does

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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

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 network, if one emerges at all, will be sensitive to 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 technology 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], Berg [1984], [1986]), FM stereo (Besen [1991]), micro-processor design (Swann [1985], [1987], Wade [1992]), and, as noted, Unix operating systems (Saloner [1989]).

Perhaps the most unsatisfying feature of the analysis of unsponsored networks to date is its use of a stricter concept of

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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)."

[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.

irreversibility than is warranted due to the realities of typical technological and economic evolution. Are some features of a technology more mutable than others? Are there degrees of lock-in? Economic analysis has yet to fully understand how these notions can be properly modified for situations where interoperability for components evolve in constant flux, as suppliers update and revise them for applications. The next section will discuss the growing analysis of converters, which partially addresses this issue.

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 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. Economists have analyzed the unimaginable number of ways in which these distortions arise.

b. Hand to hand combat: Dueling sponsors.

Perhaps the most common occurrence in a market with few vendors is "dueling sponsors" -- each sponsor has proprietary interests in an array of components that perform similar functions but competitors employ different technical standards. The VHS/Betamax duel in the VCR markets is a well-known and interesting case (Cusumano et.al. [1991], Yasunori and Imai [1992]). 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.) and increasingly in related telecommunications markets (e.g., FDDI vs

ATM), where the duels may start as multi-firm contests but quickly reduce to a handful of dominant participants, perhaps followed by a fringe of niche market suppliers. Network duels also commonly arise as sub-plots to related product market duels. For example, different banks may use incompatible ATM networks, or United Airlines and American Airlines sponsor incompatible reservation systems.

If recent experience is any guide, this type of market structure will likely characterize many, if not the majority, of private economic networks in future markets in telecommunications. Dueling involves a mix of sponsorship and competition, often arising gradually as initially unrelated networks take on similar tasks. Do these duels lead to optimal economic networks, and, if not, what are the most problematic distortions?

Economists are of two minds about dueling. On the one hand, 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,b,c], [1992]). Not only will sponsoring firms design systems that are incompatible with rival systems, but they may actively seek to prevent the entry of gateway technologies -- i,e., technical bridges between incompatible networks (Carlton and Klamer [1983]). In addition, the sponsor of a system would like nothing better than to raise the costs to the experienced user from switching vendors, since it makes a user reluctant to change networks.

Vendors like nothing more than to be the exclusive provider of a technology to a locked-in buyer. First, it provides the sponsor with market power during any repeat system purchase.

Second, it guarantees a stream of related business. For example, in computing networks locked-in buyers will purchase CPU upgrades from their system sponsors, and often a majority of their peripherals and software (Greenstein [1990b], [1991]). Third, locked-in users can be manipulated for competitive advantage. For example, in the case of computer reservation systems, the sponsors were accused of locking in travel agents and then manipulating the screen to favor the flights of the system sponsor (Rotemberg and Saloner [1991]).

The analysis is slightly different if the dueling firms are very different in size. A large system sponsor and small system sponsor do not possess the same incentives to be interoperable. A small firm usually wants interoperability and a large firm does not. 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]). Similar factors, as well as several pricing issues, prevented ATM networks from working together as one large network for many years (Phillips [1987], Salop [1990]).

Yet, economists are not uniformly pessimistic about dueling because dueling sponsors will not design incompatible systems in every circumstance. When rival sponsors provide components that perform different functions or complementary functions, compatibility permits many "mix-and-match" possibilities between the components of rival systems (Matutes and Regibeau [1987],

[1988], [1989], Economides [1988], Economides and Salop [1991]). 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]), as is the market for PC hardware clones and software applications (Langlois and Robertson [1990]). Thus, dueling sponsors are likely to find it worthwhile to make investments to reduce interoperability costs 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, which is a common occurrence when markets participants have different technical capabilities. This is probably a good explanation for the willingness of many firms, AT&T and IBM increasingly so, to participate in markets with open standards.

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 [1990a], [1990b], [1992], 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 interoperability may not impose a big loss on society in this instance because it provides options to different users with different needs (Lehr [1990], [1991a]).

Another reason for optimism is that competition and innovation counter 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 investing in network capacity with proprietary features (Klemperer [1987 b], [1989], [1992], Farrell and Shapiro [1988], [1989]).[5] Such demands can potentially elicit "promotional pricing" from sponsors (see Besen and Johnson [1986]). The good news is that the networks with long-run economic advantages are likely to provide bigger price discounts (Katz and Shapiro [1986a], [1986b]). The bad news is that this benefit sometimes accrues only to new users and not necessarily to users with an installed base of equipment.[6] In addition, competitive bidding for new customers may 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 (Arthus [1988], Hanson [1984]), which is some cause for concern. 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

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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 <u>and</u> prevent one group of buyers from selling to the other. If price discrimination is feasible, then only new users benefit from system competition.

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, most crucially, the timing of the introduction of video cassettes, which occurred unexpectedly and rather randomly from the viewpoint of the major VCR manufacturers.

One of the more fascinating 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 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

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[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]).

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 asymmetrically due to the availability of converters, translators and emulators from third parties (which reduces the costs of interoperability between networks). David and Bunn [1988] show that the introduction of the dynamo greatly influenced the AC/DC battle at the turn of the century. More recently, 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 gateways is asymmetric. Most of the advantages accrues to those owning a Macintosh system. Notice that since the benefits are asymmetric, the incentives to introduce a converter will probably not match society's. Moreover, as noted, parties that do not benefit from the introduction of a converter may actively seek to prevent their introduction. Economides and Woroch [1992] show how similar issues arise when telecommunication network providers consider connecting competitive access providers.

Perhaps the greatest weakness of the economic analysis of dueling systems is also its strength -- the long list of possible outcomes. Prediction is quite difficult, particularly in view of the multiplicity of pricing and promotional strategies typically available to firms and the technical changes affecting most information technology networks. How can the analysis of duels be modified for situations where standards are in constant flux and where products undergo a predictable life-cycle? There is a need to arrive at a more systematic 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]).

c. A strong hand: 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 or as IBM's vision for integrating computers and telecommunications under the System Network Architecture (SNA) model. Commercial networks such as Prodigy, America-Online, and Compuserve, have also tried to adopt this model, though their competition often forces them into duels. 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[8] 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 network) and not necessarily to good ends. Most of these concerns fall under the realm of anti-trust economics or traditional regulatory economics.

Anti-trust and regulatory issues inevitably arise because a

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[8] It is rare, but notable, to observe the opposite, a large buyer acting as a network sponsor. For example, the U.S. Department of Defense has sponsored a network of products using ADA. Another is the GM and Boeing sponsorship of the MAP/TOP standards. See Bartik [1985], Teresko [1986], and Bresnahan and Chopra [1989].

single sponsor is never alone.[9] He is often competing with small plug-compatible component suppliers in some or all component markets where standards are well-established. For example, IBM battled plug-compatible component suppliers from the later 1960s onward. Similarly, from the mid 1950s on (and growing thereafter) AT&T faced competition in customer premise equipment markets and long-distance. Today local Bell operating companies often face competitive by-pass to their services. 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 technical features of a product, or effectively raising the costs of interconnection, may enhance a sponsor's strategies aimed at gaining competitive advantage over rivals.[10]

There are two difficult issues regarding competitive behavior to address. First, under what conditions will a dominant firm manipulate a technology to his advantage <u>and</u> 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 legal or regulatory rule? Most

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

[10] 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])." Weiman and Levin [1992] argue that AT&T's behavior during the early history of the United State telephone system, when AT&T controlled critical nodes in the network and refused to connect potential rivals, also raises predatory questions.

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, many 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]), leading to enormous arguments over an appropriate definition. Definitions aside, there is no question that a network 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]).[11] The important (and unresolved) policy question is whether such behavior should be or can be regulated to any good end. One big problem, though not the only one, is that if courts get in the business of second-guessing every innovation by a dominant firm, especially those with exclusionary features, it is widely believed that it will have a chilling effect on many firm's willingness to introduce any innovation, which normally is not in society's long term interest.[12]

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[11] 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.

[12] 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

The related 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, it would not be surprising if these issues arise again in future telecommunications markets. The legacy of the IBM antitrust victories has left firms considerable latitude in the use of standardization for strategic purposes (Knox [1984], Menell [1987]). However, since such fundamental principles are at stake, these rulings will probably be further tested by future cases. For example, the FTC investigation of Microsoft and the recent anti-trust suits against Nintendo may foreshadow such a trend (Lunney [1990]). In addition, important rulings are likely to come from several on-going trials that raise issues in intellectual property rights in computer software standards, and also in trials that attempt to modify Judge Green's restrictions on the Regional Bell Operating Companies.[13]

Issues regarding sponsorship are likely to remain controversial as long as there is no consensus regarding the proper role for monopolies in nascent industries. From a grand policy perspective, 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

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[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]).

[13] Also important are many future regulatory decisions regarding interconnection and by-pass on local telephone networks, as well as rulings on the private and public boundaries on the growing electronic networks of this country. These will probably arise out of a mix of FCC decisions, state PUC decisions, Congressional law-making, and court decisions. For example, see Kahin [1992].

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 (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. No consensus on these issues is likely to emerge soon in telecommunications or any other network industry.

III. Invisible Advisors?: Cooperation, and its Costs

As noted above, there are many situations in which all component suppliers have an interest in seeing the emergence and the growth of an economic network. Yet, structural impediments may produce coordination problems. 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. A helping hand: Consortia and competition

One institutional form for developing standards involves industry groups, or a "consortia" of firms who sponsor an economic network. That is, suppliers jointly operate an organization responsible for designing, upgrading, and testing a compatibility-standard. This institutional arrangement is becoming increasingly popular in information technology industries, partially as an outgrowth of joint-research ventures (Weiss and Cargill [1992]). Though 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 a standard's integrity will be maintained in the future. Of course, there may still be insufficient investment in complementary products since no producer internalizes the entire interest of the network, but some investment is often better than nothing, which is enough to begin development of an economic network. 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 [1990]).

Consortia are not a perfect solution to coordination problems. They can easily fall prey to some of the same structural impediments that prevented network development in their absence. The experience with the development of UNIX standards in the 1980s 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 such organizations may further the interests of existing firms, possibly to the detriment of potential entrants or users. For example, consortia may aid collusive activities through joint pricing decisions (Salop [1990]), or may serve as vehicles to raise entry barriers, chiefly by stifling the development of technology 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 common 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. Another helping hand: voluntary standardization organizations

One of the reasons private consortia are often unnecessary is that other well-established professional organizations serve similar functions. Many large umbrella groups that cut across many industries, such as CCITT, IEEE, ASTM, and ANSI, have a long history of involvement in the development of technical standards (Cropper [1980], Hemenway [1975], Cargill [1989], Spring [1991])[14]. 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 industries and guiding their design (Witten [1983], Cargill [1989], David and Greenstein [1989, 1990], Besen [1990], OECD [1991]). Their role in designing "anticipatory" standards takes on special urgency in economic networks in danger of locking- in to irreversible standards

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[14] 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.

choices.

One important feature of most of these organizations is that they are "voluntary".[15] In other words, designers must have some economic reasons for embedding a technical standard in their product, since use is optional. 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 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.

Voluntary standards organizations play many useful roles in solving network 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

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[15] 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. On occasion government bodies will also rely on those standards determined by an industry umbrella group. See the discussion below.

interoperability, need to establish a mechanism for communication and need a mechanism to develop or choose one of many technical alternatives (Besen and Johnson [1986]).

Voluntary standards groups are also no panacea for the structural impediments to network development in some markets. They will fail to produce useful standards when the self-interest of participants prevents it 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]).[16] 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]).

In addition, no administrative process may be able to guide the development of a network when a slow administrative process cannot keep up with new technical developments (Lehr [1989]). When events become too technically complex and fluid, a focal point is easily lost. This problem is already arising as private telecommunications grow and private groups attempt to coordinate interconnection of their networks based on the ISDN model. One

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[16] Note, however, that any advantages IBM accrued were strictly temporary. Bridges between the two standards are common place and virtually costless today.

problem with ISDN is that the value from anticipating developments (on such an ambitious scale) is reduced if, as parts of the ISDN standard are written, the character of technology has changed enough to make the standard inadequate. In other words, the standard does not serve as a guide to component designers if the standards organization must frequently append the standard. Since no government administrative process could obviously do any better, market processes will usually predominate instead, coordination problems and all.

Since the decisions of voluntary groups 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 networks 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. Magical Hands: 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 diffusion of 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 long-run feedback: as network industries mature, standardization alters a market's structure. While this feedback is easily recognized, it is not well-understood. Usually several factors may be at work at once and they will not work in the same direction.

a. Nurturing hands?: Maturing networks and long run change

A mature network may contain features that both encourage and discourage innovation. Well defined technical 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], Link and Tassey [1987], 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 and standardizing the technology of its network. Ironically, the sponsor's success lays the seeds for later third-party component competition.

On the other hand, an installed base of users may also be an unintended hindrance for innovation on a mature network (Katz and Shapiro [1986a,b]. An existing substitute network may hinder the growth of a new networks, because the technology embedded in much existing equipment may be inappropriate for a new application, raising its cost. In addition, minority interests may be burdened with higher costs on an existing network, but may not be large enough to justify setting up a new network. For example, Besen [1991] argued that the existing AM network hindered the post-WWII growth of the FM network.

Economists are equally ambivalent about the influence of technical change on a network's market structure. As noted above, the factors producing less concentration are strong: network 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 open systems within the PC industry hastened the entry of multitudes of hardware, component and software suppliers, which makes the industry incredibly dynamic and competitive today (Langlois and Robertson [1990], Robertson and Langlois [1992]).

However, the factors leading to greater concentration are equally as strong: buyers often have strong incentives to use a single economic network. If a firm has a proprietary right over the technically superior 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 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 x86 microprocessor market can also be interpreted this way. Similarly, some observers claim that Microsoft will be able to use its control of MS-DOS and Windows for advantages in related markets.

Several case studies are beginning to sort between these contrasting ideas. Events from the micro-processor markets (Wade [1992]), computing markets (Bresnahan and Greenstein [1992]), and broadcasting (Owen and Wildman, Ch. 7 [1992]) point toward the following conclusion: First, there is a trade-off between sponsorship and type of innovation. If a network is largely sponsored than it can more easily introduce innovations on a systemic level, i.e. on a level that influences many components at once. Typically systemic innovations are technically complex and more easily coordinated within a single organization. One draw-back to sponsorship, however, is that sponsors of networks tend to resist too much innovation because sponsors do not want to cannibalize their own products. In contrast, economic networks with diffuse ownership, where dueling is more common, tend to lead to greater innovation from suppliers of component parts. However, diffuse ownership, even combined with established producer groups or standards-writing groups, does not tend to lead to systemic innovations, because of the difficulties of coordinating complex technical change across many organizations.

Second, there is a tension between the role of sponsorship in bringing about coordination and in leading to market power. When networks compete, there is a long run tendency for networks to become less sponsored, because many users resist the market power inherent in such sponsorship, choosing products with wider supplier bases whenever possible. However, many users also strongly desire that at least one market institution take on a central coordination role. Because of their long-term commercial interest in the network, a single sponsor can often do a better job at coordinating a network than producer groups or standards-writing groups. The best example of both these tensions comes from the last thirty years of platform competition in the computing market, where users have gradually been moving from sponsored networks, such as those based on the IBM360 mainframe platform or the DEC VAX platform, to unsponsored open PC networks, such as those based on the Intel x86 chip and MS-DOS operating system.

In any event, soothsaying about the long-run economic potential of a young economic network usually takes a bit of chutzpa (which, of course, does not prevent futuristic technologists from doing it). Some highly touted platforms gain wide acceptance and some do not. Just contrast the experience that followed the introduction of music on compact disks with what occurred after the introduction of digital audio tape. It is often hard to pinpoint the causes of success or failure. In product markets that regularly undergo radical product innovation it will not be clear at the outset how valuable a product or service 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 also difficult to predict a market's dynamics. For example, none of the important firms in the VCR industry in the later 1970s anticipated either the consequences for <u>hardware</u> competition from the development of the rental movie market, nor the power of the economic links between geographically separate markets (Cusumano et. al. [1990], Baba and Imai [1992]). 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]).

What is the bottom line of all this? Since new technologies are embedded in new generations of equipment, many network capacity investment decisions determine the ultimate capability of the network. While little can be predicted about the full nature of these investments, economists do largely predict that, whether or not a network is sponsored or unsponsored, vendors often do not have sufficient incentives to make their capacity interoperable with each other or with potential competitor networks. Thus, one can make a case for limited government intervention aimed at guaranteeing at least the minimal amount of interoperability needed to induce technical change and capacity investment. For example, this is a frequently used argument for government regulation of electronic protocols in the national electronic network (Kahin [1992]). Some observers fear wide-spread technical chaos in the absence of minimal standardization.

In sum, the only predictable feature of many information technology networks is that they change. 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. From an individual supplier's or user's perspective, this uncertainty complicates decisions with long-run consequences, since investment in physical equipment is expensive, as is investment in the assets complementary to any network, such as in trained support staff in an organization.

b. Hand-cuffed: 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 industry 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. This approach tends to lead to a rather sanguine view of a designer's ability to adjust to long run technical change in network technologies.

One recent approach to these issues emphasizes the value decision-makers place on having "strategic flexibility", i.e., having a choice among many future technical options. This approach extends "option theory" to product design decision (for one line of development, see 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. The value of strategic flexibility may far outweigh the value of any other determinant of technology choice. This is interesting because it provides a different spin on many dynamic factors influencing network development.

For example, it explains how standards influence 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 become part of the largest possible network (by designing a standardized technical platform) 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 network 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 commitment 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 Trajtenberg [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, designers can expect to periodically revise their products to remain interoperable. 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 technical platform that does not 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 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 ameliorate communication problems, but distort outcomes in other ways.

This paper's framework recognizes that in different markets a wide range of different circumstances determine important economic variables. In response to this heterogeneity, it provides a handy check-list of basic questions to ask about an economic network: How diffuse are the interests of the main market participants? Is there one dominant firm, several dueling firms, or no apparent leader at all? What are the incentives of the main market participants to cooperate and communicate? What costs do buyers of different technical alternatives face? Do industry groups play an important role in shaping industry standards? What is the rate of technical change and is its direction predictable within normal planning horizons?

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. Yet, if the dynamism in information technology markets in the United States in the last few decades is any guide to the future, then on balance the scales must lean towards an optimistic view of the increasing reliance on decentralized market mechanisms in telecommunications markets.

References

Adams, Walter and Brock, James W. [1982], Integrated monopoly and market power: System selling, compatibility standards, and market control, Quarterly Journal of Economics and Business, 22/4, pp. 29-42, Winter.

Arthur, Brian [1988], Competing technologies: An overview, in Technical Change and Economic Theory, Dosi, et al (Eds), London: Pinter Publishers.

Baba, Yasunori, and Imai, Ken-ichi [1992], Systemic Innovation and Cross-Border Networks: The Case of the Evolution of the VCR Systems, in Entrepreneurship, Technological Innovation, and Economic Growth: Studies in the Schumpeterian Tradition, (Eds.) Frederic M. Scherer and Mark Perlman, Ann Arbor: University of Michigan Press, 1992.

Bartik, Jean [1985], MAP: A user revolt for standards, Data Communications, 14(13, December), 147-156.

Berg, Sanford V. [1986], Public policy and corporate strategies in the AM stereo market, in Product Standardization and Competitive Strategy, H. Landis Gabel (ed.). Amsterdam: North Holland.

Berg, Sanford V. [1984], Issues in the Determination of Compatibility Standards: The FCC and AM Stereo, Mimeo, University of Florida, Gainesville, FL.

Besen, Stanley M. [1990], The European Telecommunications Standards Institute, Telecommunications Policy, 14(December), 521-30.

Besen, Stanley M. [1991], AM vs. FM: The Battle of the Bands, mimeo, Santa Monica, CA: The Rand Corporation.

Besen, Stanley M. and Johnson, Leland L. [1986], Compatibility Standards, Competition, and Innovation in the Broadcasting Industry, Santa Monica, CA: The Rand Corporation.

Besen, Stanley M. and Saloner, Garth [1988], Compatibility Standards and the Market for Telecommunications Services, in Changing the Rules: Technological Change, International Competition and Regulation in Telecommunications, R.W. Crandall and K. Flamm (Eds.), Washington, D.C.: The Brookings Institution.

Bowman, Ward [1957], Tying arrangement and the leverage problem, The Yale Law Journal, 67/1.

Braunstein, Yale M., and White, Lawrence J. [1985], Setting technical compatibility standards: An economic analysis, The Antitrust Bulletin, 30(2, Summer), 337-356.

Bresnahan, Timothy, and Chopra, Amit [1989], Users' role in standard setting: the local area network industry, Economics of Innovation and New Technology, 1(1/2), 97-110.

Bresnahan, Timothy, and Greenstein, Shane [1992], Technological Competition and the Structure of the Computer Industry, CEPR Discussion Paper No. 315, Stanford University, June 1992.

Bresnahan, Timothy, and Trajtenberg, Manuel [1992], General Purpose Technologies: "Engines of Growth?", Working Paper 16-92, Tel-Aviv University, August, 1992.

Brock, Gerald [1989], Dominant firm response to competitive challenge: Peripheral Equipment Manufacturers' Suits against IBM (1979-1983), in The Anti-trust Revolution, J. E. Kwoka and L. J. White (eds.), Glenview, IL: Scott, Foresman, and Co.

Brock, Gerald [1986], The Regulatory Change in Telecommunications: The dissolution of AT&T, in Regulatory Reform: What Actually Happened, L. W. Weiss and M. W. Klass (eds.), Boston: Little, Brown and Co.

Brock, Gerald [1975], Competition, Standards, and Self-Regulation in the Computer Industry, in Regulating the Product: Quality and Variety, Richard Caves and Marc Roberts (eds.), Cambridge, MA: Ballinger Publishing Co.

Cabral, Luis [1987], On the Adoption of Innovations with 'Network' Externalities, CEPR Technical Paper, number 97, May.

Cabral, Luis, and Shane Greenstein [1990], Switching costs and bidding parity in government procurement of computer systems. Journal of Law, Economics, and Organizations, Vol. 6, 2, Fall.

Cargill, Carl F. [1989], Information Technology Standardization: Theory, Process, and Organizations. Bedford, MA: Digital Press.

Carlton, Dennis W. & Klamer, Mark J. [1983], The need for coordination among firms, with special reference to network industries, University of Chicago Law Review, 50, 446-465.

Church, Jeffrey, and Neil Gandal [1990a], Complementary Network Externalities and Technological Adoption, Department of Economics, University of Calgary, Working paper 128, September.

Church, Jeffrey, and Neil Gandal [1990b], Network Effects and Software Provision, Boston University, Department of Economics, Working Paper 90-58, August.

Church, Jeffrey, and Neil Gandal [1992], Integration, Complementary Products and Variety, Tel Aviv University, Foerder Institute for Economic Research, Working Paper 3-92. January.

Cowan, Robin [1987], Backing the Wrong Horse: Sequential Choice Under Increasing Returns, Ph.D. Dissertation, Stanford University, Stanford, CA.

Cusumano, Michael A., Yiorgos Mylondadis, and Richard Rosenbloom, Strategic Maneuvering and Mass Market Dynamics : The Triumph of VHS over BETA, Working Paper 91-048, Harvard Business School.

Cropper, Walter V. [1980], The Voluntary Development of Consensus Standards in ASTM, ASTM Standardization News, 8(8, August), 14-24.

David, Paul A. and Bunn, Julie Ann [1988], The economics of gateway technologies and network evolution: Lessons from electrical supply history, Information Economics and Policy, 3(Fall), 165-202.

David, Paul A. [1985], Clio and the economics of QWERTY, American Economic Review, 75, pp. 332-336, May.

David, Paul [1987], Some New Standards for the Economics of Technological Standardization, in The Economic Theory of Technological Policy, P. Dasgupta and P.L. Stoneman (eds.), London: Cambridge University Press.

David, Paul A. [1986], Understanding the economics of QWERTY: The necessity of history, in Economic History and the Modern Economist, W.N. Parker (ed.), Oxford, England: Basil Blackwell.

David, Paul A. [1990], Narrow Windows, Blind Giants and Angry Orphans: The Dynamics of Systems Rivalries and Dilemmas of Technology Policy, in Innovation Diffusion, vol 3, F. Arcangeli et al (eds.), New York: Oxford University Press.

David, Paul A. and Shane Greenstein [1990], The economics of compatibility standards: An introduction to recent research, Economics of Innovation and New Technology, 1(1/2), 3-41.

David, Paul A. and Shane Greenstein [1989], Compatibility Standards and Information Technology -- Business Strategy, market Development and Public Policies: A Synopsis of Panelist's Statements and the Discussion at the CEPR Compatibility Standards Workshop., Center for Economic Policy Research Publication Number 159, Stanford University, Stanford, CA, May.

David, Paul A. and Steinmueller, W. Edward [1990], The ISDN bandwagon is coming -- Who will be there to climb aboard?: quandaries in the economics of data communication networks, Economics of Innovation and New Technology, 1(1/2), 43-62.

David Paul A. and Steinmueller, W. Edward [1992], The Economics of Compatibility Standards and Competition, TOP Working Paper, Stanford CA, Stanford University, Department of economics, January.

Dybvig, Phillip H. and Spatt, Chester S. [1983], Adoption externalities as public goods, Journal of Public Economics, 20, 231-247.

Economides, Nicholas [1988], Desirability of compatibility in the absence of network externalities, American Economic Review, 79(5) December, 1165-81.

Economides, Nicholas, and Steven Salop [1991], Competition and Integration Among Complements and Network Market Structure, NYU Working paper EC-91-2, January.

Economides, Nicholas, and Glenn Woroch, Benefits and Pitfalls of Network Interconnection, Working Paper EC-92-31, New York University, November 1992.

Farrell, Joseph and Gallinni, Nancy [1988], Second Sourcing as a Commitment, Quarterly Journal of Economics, 103(4, November), 673-694.

Farrell, Joseph and Saloner, Garth [1985], Standardization, Compatibility, and Innovation, Rand Journal of Economics, 16/1, Spring.

Farrell, Joseph and Saloner, Garth [1986a], Competition, Compatibility, and Standards: The Economics of Horses, Penguins and Lemmings, in Product Standardization as a Tool of Competitive Strategy, H. Landis Gabel (eds.), North-Holland.

Farrell, Joseph and Saloner, Garth [1986b], Installed base and compatibility: Innovation, product preannouncements, and predation, American Economic Review, 76, 940-955.

Farrell, Joseph and Saloner, Garth [1986c], Standardization and variety, Economics Letters, 20, pp. 71-74.

Farrell, Joseph and Saloner, Garth [1988], Coordination Through Committees and Markets, Rand Journal of Economics, 19(2), Summer, 235-252.

Farrell, Joseph and Shapiro, Carl [1989], Optimal Contracts and Lock-in, American Economic Review, 79(1,March), 51-68.

Farrell, Joseph and Shapiro, Carl [1988], Dynamic Competition with Switching Costs, Rand Journal of Economics, 19(1, Spring), 123-137.

Farrell, Joseph and Shapiro, Carl [1992], The Economics of HDTV Standards, TOP Working Paper, Stanford, CA, Stanford University, Department of economics, January.

Fisher, Franklin M. and McGowan, John J., & Greenwood, Joen E. [1983], Folded, Spindled, and Mutilated: Economic Analysis and U.S. vs. IBM, Cambridge, MA: MIT Press.

Fisher, Franklin M., McKie, James W., & Mancke, Richard B. [1983],IBM and the US Data Processing Industry: An Economic History, Praeger Publishers.

Greenstein, Shane [1990a], Creating economic advantage by setting compatibility standards: Can physical tie-ins extend monopoly power? Economics of Innovation and New Technology, 1(1/2), 63-83.

Greenstein, Shane [1991], Lock-in and the Costs of Switching Mainframe Computer Vendors: What Do Buyers See? University of Illinois, Faculty Working Paper 91-0133, Political Economy Series #48.

Greenstein, Shane [1990b], Did Installed Base Give an Incumbent Any (Measurable) Advantages in Federal Computer Procurement? University of Illinois, Faculty Working Paper 90-1718, Political Economy Series #42.

Gandal, Neil, and David Salant, [1992], Movie Wars, mimeo, GTE Laboratories, January.

Hanson, Ward A. [1984], Bandwagons and Orphans: Dynamic Pricing of Competing Technological Systems Subject to Decreasing Costs, TIP Workshop, Department of Economics, Stanford University, Palo Alto, CA, January.

Hemenway, D. [1975], Industrywide Voluntary Product Standards, Cambridge MA: Ballinger.

Johnson, Leland L. [1990], Development of High Definition Television: A Study in US Japan Trade Relations, Santa Monica, CA: The RAND Corporation.

Kahin, Brian [1992], Building Information Infrastructure, McGraw-Hill.

Katz, Michael [1986], The Economics of Standardization in Network Industries, Paper presented at the Fourteenth Annual Telecommunications Policy Research Conference, Arlie House, VA, April.

Katz, M. and Shapiro, Carl [1986a], Product Compatibility Choice in a Market with Technological Progress, Oxford Economic Papers, 38(November), 146-165.

Katz, Michael L. and Shapiro, Carl [1985], Network externalities, competition and compatibility, American Economic Review, 75, 424-440, June.

Katz, Michael L. and Shapiro, Carl [1986b], Technology adoption in the presence of network externalities, Journal of Political Economy, 94(August), 822-841.

Keehn, Stephen A. [1988], Adoption and Interfirm Diffusion of Innovation, Working Paper, Department of Economics, Palo Alto, CA; Stanford University, May.

Kindleberger, Charles P. [1983], Standards as public, collective and private goods, Kyklos, 36, 377-397.

Klemperer, Paul [1987a], Markets with consumer switching costs, Quarterly Journal of Economics, 102, 375-394.

Klemperer, Paul [1987b], The competitiveness of markets with switching costs, Rand Journal of Economics, 18(1, Spring), 138-150.

Klemperer, Paul [1987c], Entry deterrence in markets with consumer switching costs, Economic Journal, 97, 99-117.

Klemperer, Paul [1989], Price wars caused by switching costs, Review of Economic Studies, 56, 405-420.

Klemperer, Paul [1992], Competition When Consumers have Switching Costs: An Overview, 1992 Inaugural Lecture to the Annual Conference on Industrial Economic, Madrid, Spain.

Knox, Robert [1984], New Developments in the Law of Monopoly: the Impact of the IBM West Coast Cases, Golden Gate University Law Review, 14, 309-34.

Langlois, Richard N, and Paul L. Robertson [1990], Innovation in Modular system: Lessons from the Microcomputer and Stereo Component Industries, mimeo, Storrs, CT, University of Connecticut, Department of economics, April.

Lehr, William [1989], ISDN: An Economist's Primer for a new Telecommunications Technology, Presented in the Technology and Productivity Seminar, Stanford, CA, Stanford University.

Lehr, William [1990], Voluntary Standards, Multiple Markets, Standards Institutions, and the Allocation of Technical Capabilities, mimeo, Palo Alto, CA; Stanford University, November.

Lehr, William [1991a], The Case of Two Data Transport Standards: IEEE's 802.6 Metropolitan Area Network (MAN) versus the Ansi X3's Fiber Distributed Data Interface (FDDI). mimeo, Palo Alto, CA; Stanford University, April.

Lehr, William [1991b], The Political Economics of Voluntary Standard Setting, mimeo, Palo Alto, Ca; Stanford University, June.

Lehr, William [1992], Standardization: Understanding the Process, Journal of the American Society of Information Science, September.

Lehr, William, and Noll, Roger [1989], ISDN and the Small User: Regulatory Policy Issues, CEPR Working Paper number 175, Stanford University, July.

Liebowitz, S. J. and Margolis, S. E. [1990], The Fable of the Keys, Journal of Law and Economics, 33(1), April.

Link, Albert & Tassey, George [1987], The Impact of Standards on Technology-based Industries: the Case of Numerically Controlled Machine Tools in Automated Batch Manufacturing, in Product Standardization and Competitive Strategy, Gabel, H. L. (Eds.), Amsterdam: North Holland.

Lunney, Glynn [1990], Atari games v. nintendo: Does a closed system violate the antitrust laws? High Technology Law Journal, 5 (Spring), 29-73.

Matutes, Carmen, and Regibeau, Pierre [1987], Standardization in Multi-Component Industries, in Product Standardization and Competitive Strategy, Gabel, H. L. (Eds.), Amsterdam: North Holland.

Matutes, Carmen, and Regibeau, Pierre [1988], "Mix and match": Product compatibility without network externalities, Rand Journal of Economics, 19(2, Summer), 221-234.

Matutes, Carmen, and Regibeau, Pierre [1989], Standardization across Markets and Entry, Journal of Industrial Economics, 38, 4, June.

Menell, Peter [1987], Tailoring Protection for Computer Software, Stanford Law Review, 39(6), 1329-1372.

Noam, Eli. M [1991], Network Tipping and the Tragedy of the Common Network: Theory for the Formation and Breakdown of Public Telecommunications Networks, mimeo, Columbia University, February.

OECD [1991], Information Technology Standards: The Economic Dimension, Committee for Information, Computers and Communication Policy, Paris, France.

Ordover, Janusz D. and Willig, Robert D. [1981], An Economic Definition of Predatory Product Innovation, in Strategy, Predation and Antitrust, Salop (ed.), Washington, D.C.: Federal Trade Commission, 337.

Ordover, J.A., Sykes, A.O. and Willig, R.D. [1985], Nonprice Anticompetitive Behavior by Dominant Firms Toward the Producers of Complementary products, in Antitrust and Regulation: Essays in Memory of John McGowan, Franklin M. Fisher (eds.), Cambridge, MA: MIT Press, 115-130.

Owen, Bruce, and Wildman, Steven, Video Economics, Harvard University Press: Cambridge, MA. 1992.

Phillips, A. [1987], The Role of Standardization in Shared Bank Card Systems, in Product Standardization and Competitive Strategy, Gabel, H. L. (eds.), Amsterdam: North Holland.

Postrel, Steven [1985], Bandwagons and the coordination of standardization behavior, mimeo, UCLA Business School, Oct.

Postrel, Steven [1990], Competing networks and proprietary standards: The case of quadrophonic sound, Journal of Industrial Economics, 39(2), December.

Putnam, Hayes and Bartlett [1982], The Impact of Private Voluntary Standards on Industrial Innovation, Vol 1 and 2, Cambridge, MA, November.

Robertson, Paul L., and Langlois, Richard N. [1992], Modularity, Innovation, and the Firm: The Case of Audio Components, in Entrepreneurship, Technological Innovation, and Economic Growth: Studies in the Schumpeterian Tradition, (Eds.) Frederic M. Scherer and Mark Perlman, Ann Arbor: University of Michigan Press, 1992.

Rohlfs, Jeffrey [1974], A theory of interdependent demand for a communications service, Bell Journal of Economics, 5(1, Spring), 16-37.

Rosenberg, Ernest [1976], Standards and Industry Self-Regulation, California Management Review, XIX, 79, Fall.

Rotemberg, Julio, and Garth Saloner [1991], Interfirm Cooperation and Collaboration, in Ed. Michael Scott Morton, Information Technology and Organizational Transformation, New York: Oxford University Press.

Saloner, Garth [1989], The economics of computer interface standardization: the case of UNIX, Economics of Innovation and New Technology, 1(1/2), 135-56.

Salop, Steven C. [1988], Deregulating Self-Regulated ATM Networks, Economics of Innovation and New Technology, 1(1/2), 85-96.

Sanchez, Ron [1991], Strategic Flexibility, Real Options, and Production Strategy, PhD Dissertation, MIT, Cambridge, MA. June 1991.

Sirbu, Marvin & Hughes, Kent [1986], Standardization of Local Area Networks, Mimeo, Carnegie Mellon University, Dept. of Engineering and Public Policy.

Sirbu, M. & Stewart, S. [1986], Market Structure and the Emergence of Standards: A Test of the Modem Market, Mimeo, Carnegie Mellon, Department of Engineering and Public Policy, October.

Sirbu, M., and Zwimpfer, L. [1985], Computer Communication Standards: The Case of X.25, IEEE Communications, 23(3, March), 35-45.

Spring, Michael B. [1991], Information Technology Standards, in Annual Review of Information Science and Technology, Martin E. Williams, (ed.), Medford, N.J.: Learned Information for ASIS, 26.

Sterling, Christopher H. [1982], The FCC and Changing Technology Standards, Journal of Communication, 32(4, Autumn), 137-147.

Swann, G. M. P. [1987], Industry standard microprocessors and strategy of second source production, in Product Standardization and Competitive Strategy, Gabel, H. L. (eds.), Amsterdam: North Holland.

Swann, G.M.P. [1985], Product competition in microprocessors, Journal of Industrial Economics, XXXIV/1, 33-53, September.

Teresko, John [1986], MAP: Why GM Got the Bandwagon Rolling, Industry Week, vol. 231, November 10.

Toth , R.B. , and Associates [1984], Standards Activities of Organizations in the United States (Final Report), PB85-106151, in NBS Special Report 681, NTIS, August.

U.S. Federal Trade Commission [1983], Standards and Certification: Final Staff Report, FT 1.2:St 2/2/Final, Washington, D.C.: Government Printing Office, April.

Wade, James [1991], Battle of Network Standards: An Empirical Investigation of the Entry Rates of Competing Standards in the Microprocessor Market, Mimeo, Walter A. Haas School of Business, University of California at Berkeley, January.

Weiss, Martin B. H. and Marvin Sirbu [1990], Technological choice in voluntary standards setting committees: An empirical analysis: Economics of Innovation and New Technology, 1(1/2), 111-134.

Whinston, Michael [1989], Tying, Foreclosure, and Exclusion, Discussion paper 1342, Harvard Institute of Economic Research, Cambridge, MA., October.

Weiman, David F., and Levin, Richard, C., Preying for Monopoly?: The Case of Southern Bell Telephone Company, 1984-1912, Working paper, Yale University, September, 1992.

Witten, Ian H. [1983], Welcome to the standard jungle: An in depth look at the confusing world of computer connections, Byte, 8(2, February), 146-178.

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