

CHANGING COMPETITIVE DYNAMICS IN NETWORK INDUSTRIES: AN EXPLORATION OF SUN MICROSYSTEMS' OPEN SYSTEMS STRATEGY

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An integral part of competition is to deny rivals access to proprietary technical knowledge. Yet, Sun Microsystems provides rivals easy access to its technical knowledge and encourages them to enter its workstation market. This paper employs theoretical insights on technological systems and network externalities to understand Sun's open systems strategy. The paper also explores the changing nature of competition in network industries—industries characterized by network externalities and built around technological systems.

An important aspect of interfirm competition is to establish a position of advantage over rivals. An equally important aspect is to prevent rivals from imitating strategies that confer competitive advantages. For instance, Porter (1980) suggests that firms erect entry and mobility barriers to limit competition among themselves. Reed and DeFillippi (1990) explore how firms can generate causal ambiguity to prevent rivals from duplicating distinctive competencies. Teece (1987) highlights the importance of appropriability regimes that provide firms with an opportunity to earn above-normal profits through the introduction of new technologies.

These perspectives suggest that the sustenance of competitive advantage is as important as its creation (Ghemawat, 1986). *Why, then, would a firm provide rivals easy access to its technical knowledge¹ and encourage entry into its market? What are the sources of competitive advantage for a firm that provides rivals easy access to its technical knowledge?*

Key words: network externalities, open systems, economies of substitution, computer industry

¹ By technical knowledge, we mean knowledge about components and their relational attributes.

Answers to these questions capture significant changes taking place in the workstation market of the computer industry. Specifically, Sun Microsystems (Sun) has used an unconventional open systems strategy to grow within this market while fundamentally transforming it. We explore Sun's unconventional strategy² and the changing nature of competition in the workstation market. We believe that such an analysis will provide insights into similar changes that are taking place in the wider computer industry and other important industries such as telecommunications, office automation and consumer electronics.

² Several explanations can be offered to understand Sun's strategies. Porter (1980) suggests that firms invite 'good' competitors to fill out product lines that no one firm alone can provide. Otherwise, aggressive firms might enter the industry to exploit the unclaimed opportunities and also increase rivalry. Transaction cost economics (Williamson, 1975) suggests another explanation. Transactions involving specific assets can render buyers hostage to a monopoly supplier. Recognizing this, buyers may not adopt products and services offered by such monopolists. Therefore, it might be in a firm's interest to share its technology with others and create multiple sources to assuage buyers' anxieties about *post-hoc* opportunism.

In both cases, entry invitations are accommodations that firms make to supplement a different strategic thrust. However, for Sun, adopting nonproprietary technologies and encouraging entry into its markets have been central aspects of its competitive strategy.

All these industries consists of interrelated markets, each producing components of a larger technological system. These industries are also characterized by network externalities (Katz and Shapiro, 1985; Farrell and Saloner, 1986; David, 1987; Besen and Saloner, 1989). Network externalities arise when the benefits a user derives from a product increase as others use compatible products. For instance, the benefits derived by an individual subscribing to a data sharing computer network depend on the number of other users subscribing to that network. Similarly, a complementary product, such as computer software, becomes cheaper (or more readily available) as the size of the network increases. Beside these direct benefits, indirect benefits of belonging to a large network include improved quality and lower price of after-sales service.

In industries characterized by network externalities and built around technological systems (network industries), the degree to which different technological systems are compatible with each other determines users' relevant network boundaries. Incompatible systems circumscribe users' network boundaries. Within these boundaries, users have to buy system components from designated firms and can network only with those who own compatible systems.

Recent technological advances in hardware and software have made it possible to network different systems. Capitalizing on these changes, Sun has promoted compatibility in the workstation market by building its systems around industry standards and by encouraging others to follow its approach. Sun's open systems strategy has been very effective. As of 1989, Sun led the workstation market with a market share of 28.7 percent (Figure 1a). Since its founding in 1982, Sun's workstation installations have doubled in number every year (Figure 1b). Sun has experienced a steady growth in revenues (Figure 1c) while retaining its net margins (Figure 1d). In contrast, Apollo, the pioneer of the workstation market, steadily lost market share and was acquired by Hewlett Packard (HP) in 1989. An industry analyst ascribes Apollo's decline to its closed system strategy, a strategy that dissuaded compatibility by restricting access to its proprietary technology (CAE, 1989).

Workstation users benefited from Sun's open systems strategy as their relevant network boundaries expanded. Over time, users have compelled

other firms in the workstation market to adopt an open systems strategy and to offer compatible systems. As a result, the workstation market has changed from one characterized by unconnected closed networks to one characterized by a connected open network.

In industries characterized by unconnected closed networks, firms restrict access to their proprietary technical knowledge and thereby create several incompatible systems. In contrast, in industries characterized by a connected open network, firms allow easy access to technical knowledge and thereby create compatible systems. In such industries, standards-based technologies and network interconnections break several 'isolating mechanisms' (Rumelt, 1984) that: (1) prevent rivals from gaining access to technical knowledge embodied in components and their interface standards, and (2) keep users locked into networks because of high switching and transient incompatibility costs (Farrell and Saloner, 1986).

With the dissolution of isolating mechanisms, firms that wish to survive must introduce new products continually. Therefore, the workstation market is characterized by rapid technical change. In this rapidly changing environment, Sun exploits transient monopoly positions (MacMillan, McCaffery, and Wijk, 1985) that are created through its role as a technology sponsor. A sponsor is a firm willing to invest in the development of a technology while sharing breakthroughs with others to promote its technology as the industry standard. Even though sponsorship has its privileges, it raises questions about returns on R&D investments from products with short life spans. In this paper, we introduce the notion of economies of substitution to explain how Sun has been able to offer new products by economizing on the resource consumptive R&D process.

We begin the paper with a framework to understand competition in industries built around technological systems. This framework provides the background to understand how Sun has taken advantage of changes in the computer industry to implement its unconventional open systems strategy. Then, we explore how Sun has been able to grow (in terms of market share, revenues and profits) despite providing others easy access to its technical knowledge and inviting them to enter its market. Table 1 provides an abbreviated chronology of Sun's activities in the workstation market. The methods used to collect and analyze

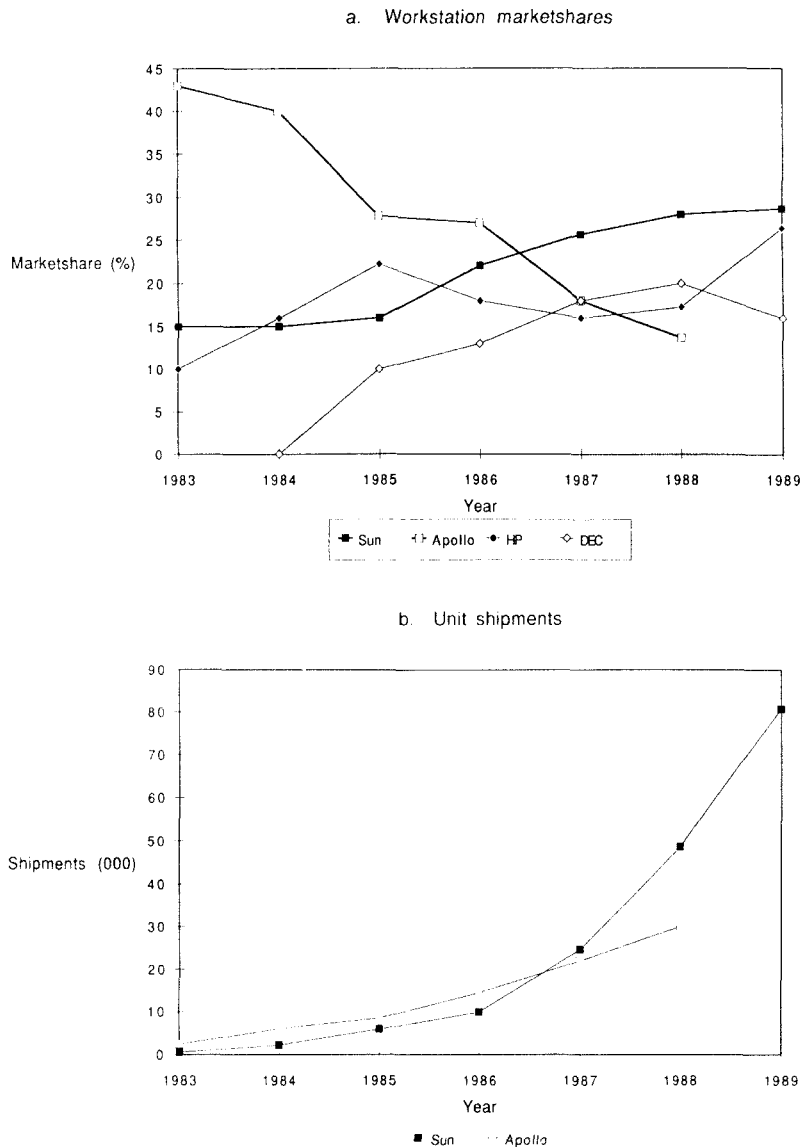


Figure 1. Sun vs. Apollo: 1983–89

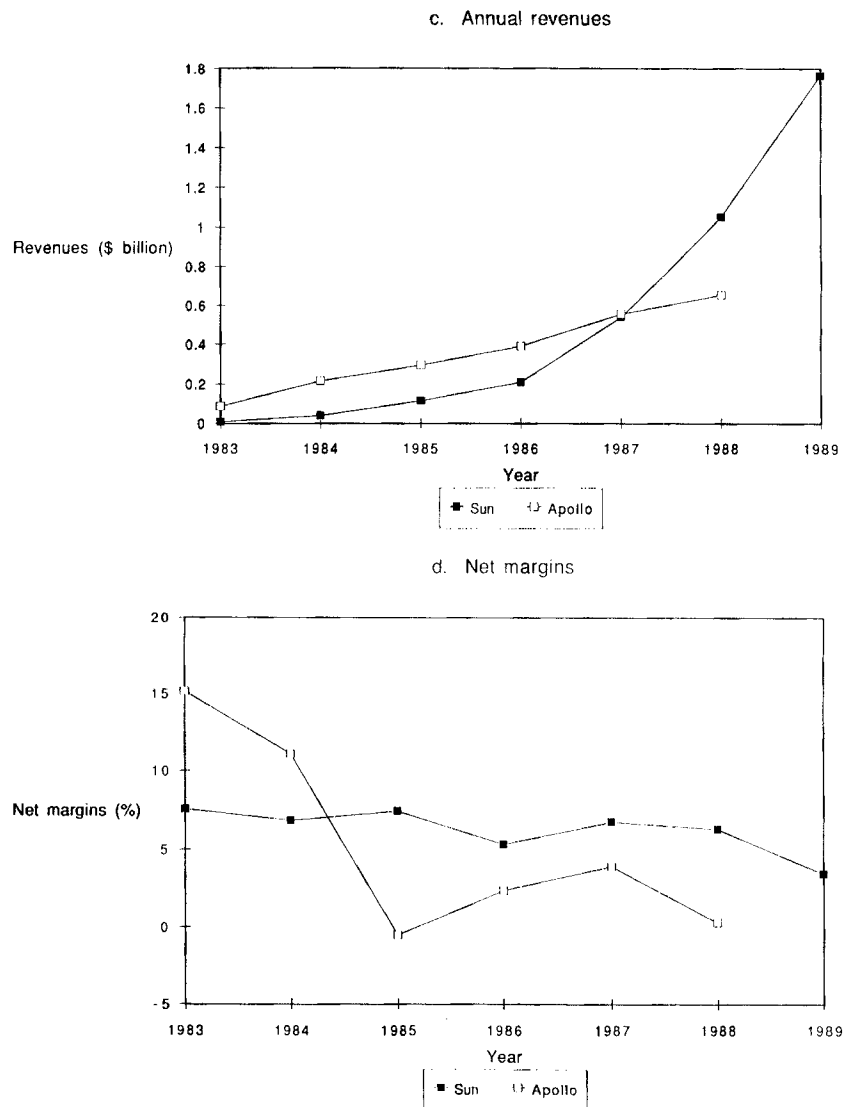
data on the workstation market are described in the Appendix.

CONCEPTUAL FRAMEWORK

Technological systems consist of a set of components that together provide utility to users. System performance is dependent not only upon constituent components, but also on the extent to which they are compatible with each other (Gabel, 1987: 93; Henderson and Clark, 1990; Tushman

and Rosenkopf, 1992). One way to ensure compatibility is to custom-design individual system components to facilitate their interactions. Another way to ensure compatibility is to design components that conform to a common set of standards. By standards, we mean codified specifications about components and their relational attributes.³

³ David (1987: 213) provides a comprehensive taxonomy of standards that include conformance to: (1) an ordinal scale, (2) a cardinal scale, or (3) a dichotomous set. For this paper, we focus on standards as a dichotomous set that either promote or hinder compatibility between system components.



Notes:

1. Sources: Sun and Apollo Annual Reports and Form 10Ks.
2. Marketshare is calculated as a firm's share of the workstation market in terms of revenues.
3. Apollo was acquired by HP in 1989. Apollo/HP combined share is shown against HP for 1989.

Figure 1. Continued

Technological systems that conform to different standards are incompatible with each other. Incompatible technological systems emerge as firms restrict access to their proprietary technical knowledge. Technical knowledge can be held proprietary through institutional property rights, or, as trade secrets by manufacturing components internally and restricting access to the manufacturing process.

Dominant firms that hold technical knowledge

proprietary in network industries gain competitive advantages that go beyond those conferred by low cost or differentiation. Proprietary control over technical knowledge provides dominant firms the power to set the rules by which rivals must play (Adams and Brock, 1982). Proprietary control over technical knowledge also protects dominant firms from new entrants because system-users incur transient incompatibility costs (Farrell and Saloner, 1986). These costs represent

Table 1. Sun Microsystems: Chronology of events

Date	Sun events	Workstation market events
1981		● Apollo pioneers wkstation mkt. with proprietary technologies.
1982	● Sun incorporated. ● Sun-1 line based on Motorola 68000 chip & other industry standards introduced.	
1983	● Sun-2 line based on Motorola 68010 chip introduced.	● DEC introduces Vaxstation I wkstation.
1984	● Network File System (NFS) introduced; NFS codes published & liberally licensed.	
1985	● Pact with AT&T to merge UNIX versions. ● Sun-3 line based on Motorola 68020 chip introduced.	● DEC introduces Vaxstation II wkstation.
1986	● SunLink software conforming to OSI specifications introduced. ● Products improving wkstation connectivity to DEC & IBM systems introduced. ● Sun-3/200 Series wkstations (4 MIPS) introduced. ● Partly merged Sun/AT&T UNIX version introduced. ● NeWS windowing software introduced & licensed. ● Jt. development and marketing pacts with Alliant, Convex, Matra, ICL (STC) announced. ● Sun goes public.	● IBM introduces RISC based RT-PC wkstations.
1987	● Software connecting IBM & Apple PCs introduced. ● 10 MIPS SPARC chip introduced. ● SPARC Sun-4 line wkstation introduced. ● Pact with AT&T to develop merged version of UNIX for SPARC. ● Jt. development pacts with Stratus, Xerox, & National Semiconductors announced. ● Centrum Systems West & Trancept Systems acquired. ● Value Added Reseller program launched.	● Intel, Apple & Japanese vendors enter wkstation mkt.
1988	● 7 MIPS desktop wkstation introduced. ● Intel 80386 based PCs (Sun386i line) introduced. ● OpenLook user interface developed with AT&T & Xerox. ● SPARC licensed to several chip manufacturers & system vendors. ● Users of SPARC form the SPARC vendor council.	● Sony enters U.S. wkstation mkt. ● Matsushita's Solbourne announces first SPARC clone. ● Intel introduces 80960 RISC chips. ● Apollo, DEC, IBM, HP & others form Open Software Foundation to pre-empt Sun-AT&T UNIX-SPARC system.
1989	● 12.5 MIPS SPARCstation-1, 16 MIPS SPARCstation 330 & 370 series introduced. ● Sun-3/80 & Sun-3/400 wkstations based on Motorola 68030 chip introduced. ● Sun-AT&T integrated UNIX version for SPARC announced. ● Trade group formed to promote SPARC & insure its open licensing.	● HP acquires Apollo. ● DEC introduces powerful wkstations aimed at Sun high-end products.

foregone network benefits that early adopters incur by embracing a network that has yet to emerge around the new technology. For these reasons, 'survival and success are not necessarily the result of "superior skill, foresight and industry." Indeed, they may be determined by the possession (and exercise) of naked power to set the rules by which any and all comers shall be allowed to play the game' (Adams and Brock, 1982: 31).

Table 2 represents these structural facets of competition. The framework identifies where the locus of power lies—with vertically integrated system-manufacturers or with specialized components manufacturers. This distinction determines competitive dynamics with respect to standards setting in network industries.

Quadrant 1 characterizes a structure where several integrated system-manufacturers are active. These system-manufacturers set standards internally and restrict others from offering compatible products by holding technical knowledge proprietary. However, system-manufacturers cannot shape competitive dynamics unilaterally by changing their standards because each viable system is incompatible with the other. Thus, in such markets, competition is manifest at the systems level. Customers can initially choose between systems, but once committed to a system, they are completely dependent upon the

integrated system-manufacturer for components and services.

Such a structure was characteristic of the mainframe market that dominated the computer industry in the early 1960s. Several viable system-manufacturers such as IBM, Control Data, Sperry, and Philco offered incompatible systems (Flamm, 1988: 102–105). However, no firm by itself could dictate industry-wide standards unilaterally to shape competition.

By the 1970s, this structure had evolved towards Quadrant 2 as IBM gained dominance (Adams and Brock, 1982; Flamm, 1988). The dominant integrated system-manufacturer operating in a Quadrant 2 structure enjoys sustainable competitive advantages because of its size and its control of interface specifications. Size results in lower manufacturing and R&D costs (through scale economies). Size also confers the benefit of an installed base of users who are reluctant to bear the transient incompatibility cost of switching to a new system (Farrell and Saloner, 1986). Consequently, entrants that attempt to offer systems comparable to those offered by the dominant system-manufacturer are at a distinct disadvantage.

There are two options for entrants and rivals to operate in a Quadrant 2 structure (Flamm, 1988). One option is to offer products for niche markets that do not attract the attention of the

Table 2. Technological systems and competitive dynamics

	Competitive market	Monopoly market
Integrated system-manufacturers	Quadrant 1 <ul style="list-style-type: none"> ● Standards set internally by each integrated system-manufacturer ● No firm can unilaterally change industry standards. 	Quadrant 2 <ul style="list-style-type: none"> ● Standards set by system monopolist ● System monopolist can unilaterally change industry standards.
Specialized component manufacturers	Quadrant 4 <ul style="list-style-type: none"> ● Standards set by network partners ● No firm can unilaterally change industry standards. 	Quadrant 3 <ul style="list-style-type: none"> ● Standards set by component monopolist ● Component monopolist can unilaterally change industry standards.

Adapted from W. Adams and J. W. Brock (1982). 'Integrated monopoly and market power: System selling, compatibility standards, and market control', *Quarterly Review of Economics and Business*, 22(4), pp. 29–42.

dominant system-manufacturer. A second option is to operate in compatible component markets designated by the dominant system-manufacturer. Firms specializing in such markets have to offer components that 'perform in a functionally identical way when plugged into' the dominant manufacturer's system (Flamm, 1988: 214). The dominant system-manufacturer still retains control over these complementary markets through its ability to undertake undisclosed interface manipulations that can render its system 'allergic to rivals' components' (Adams and Brock, 1982: 36).

The computer industry evolved to this structure in the 1960s and 1970s, with IBM becoming the dominant integrated system-manufacturer in the mainframe market. Competition at the systems level deteriorated in the 1970s as several integrated system-manufacturers went out of business (e.g., Philco) or withdrew into niche markets that IBM did not serve (e.g., Sperry, Honeywell). As entry into the mainframe market became difficult at the systems level, entry occurred in new niche markets such as minicomputers (e.g., DEC) and supercomputers (e.g., Cray), or, in plug-compatible component markets (e.g., RCA).

As the above description suggests, integrated system-manufacturing provides a source of competitive advantage through the manipulation of undisclosed interface specifications. Integrated system-manufacturers also have the opportunity to bundle their products and engage in tie-in sales thereby reaping above normal profits (e.g., Burstein, 1960; Dansby and Conrad, 1984; Matutes and Regibeau, 1988). Therefore, integrated system-manufacturing might appear to be an appealing source of competitive advantage. However, for products such as computers, where network externality benefits are significant, there are other considerations that shape a firm's decision on whether to manufacture all components internally. These considerations stem from network benefits that users derive from the availability of complementary products such as computer software and the ability to interact with others who also use compatible products. Consequently, rather than remain an integrated system-manufacturer, a firm in a network industry might choose to increase system viability by licensing its technology to other firms in complementary markets and to rivals (Conner, 1990).

Competitive pressures on a firm increase if it licenses its technology to rivals. This is not the case if it licenses technology to firms in complementary markets (Barnett, 1990). These strategic initiatives at the firm level are representative of market structures characterized by Quadrants 3 and 4 respectively.

Quadrant 3 represents a structure where at least one specialized component manufacturer has monopoly control over a critical component of the technological system. As every component is necessary for system performance, firms in other complementary markets must adhere to component specifications that this specialized component monopolist adopts. Consequently, the component monopolist can control the ground rules for entry and rivalry in complementary markets by controlling, unilaterally, key standards embodied in its components.

These evolutionary dynamics occurred in the PC market in the late 1970s. Witnessing the phenomenal growth of the PC market, IBM introduced its own PC in 1981. To hasten the introduction of its PCs and cut development costs, IBM relied on off-the-shelf components like Intel's 8088 microprocessor and Microsoft's MS-DOS operating system. As the IBM-PC and its clones became widely accepted, Intel and Microsoft became monopoly suppliers to the PC market. These specialized component manufacturers gained control because of their potential to change component standards unilaterally. For instance, Microsoft has shifted its emphasis from the DOS operating system to a Windows based operating system in direct competition with IBM's OS/2 operating system. Subsequently, IBM has had to design Windows compatibility into its OS/2 operating system.

While helping to establish Intel and Microsoft as monopolists at the components level, IBM's entry strategy failed to establish itself as a monopolist at the systems level. According to industry analysts, 'the-off-the-shelf strategy showed potential rivals how to use parts available to anyone' (*Business Week*, 1991b: 29). As rivals began offering IBM-PC clones, IBM's share of the PC market dropped from 75 percent in 1981 to 18 percent in 1991 (*Business Week*, 1991b). To counter the influx of IBM-PC clones, IBM introduced a system that others could not clone easily. IBM's PS/2 series computers incorporated a patented micro-channel architecture in an

attempt to gain proprietary control over the PC architecture and shift the PC market towards Quadrant 2.

Sun Microsystems too entered the workstation market with a system built using off-the-shelf components. However, in contrast to IBM, Sun has persisted with an open systems approach that has led to the creation of a structure congruent with Quadrant 4. Quadrant 4 represents a situation where competitive markets exist at both the systems and the components level. No system- or component manufacturer is able to change compatibility standards unilaterally. Any change in standards requires the involvement of all firms who agreed initially upon the standard.

Competition in a structure characterized by Quadrant 4 is very different from competition that prevailed when Sun entered the workstation market in 1982. Before 1982, firms in the workstation market competed by creating and maintaining proprietary control over an installed base of users who could not abandon their networks easily. Apollo, the company that pioneered the workstation market, exemplified this approach. Apollo discouraged multisystem compatibility and restricted access to its proprietary technical knowledge by manufacturing several components internally (Bhide, 1989). Without alternative sources for system components, Apollo's customers had to buy software and hardware products from Apollo and its designated suppliers to ensure system performance.

SUN'S UNCONVENTIONAL OPEN SYSTEMS STRATEGY

Several technological advances occurred in the late 1970s providing the context for Sun's unconventional open systems strategy. In particular, speedy transmission of data at lower cost and advances in microprocessor technology made it possible to network computers in distant locations and to spread computing demands between them. As benefits of networking and distributed computing became apparent during the early 1980s, business firms began exploring ways to connect their assorted range of computer systems. However, firms had discouraged multisystem compatibility by restricting access to their proprietary technical knowledge. Therefore, their

closed systems were ill suited for networking operations (Flamm, 1988).

Sun's open systems workstations were designed to facilitate networking. The most important aspect of Sun's open systems strategy was reliance on industry standards for system components and interface (Bhide, 1989; Joy, 1990). Among the various standard components, Sun chose the Berkeley version of AT&T's UNIX operating system, Motorola's 680 × 0 microprocessor, and Xerox's Ethernet network architecture. Reliance on industry standards implied that technical knowledge was freely accessible to others—both to firms in complementary markets and to rivals in Sun's own market. Users and value-added resellers could determine more easily how to connect system components manufactured by different vendors. Moreover, compatibility between systems improved as Sun used standard components and interfaces. Easy access to technical knowledge also led to the entry of firms that developed Sun-compatible clones.

However, easy access to technical knowledge alone is not sufficient to create a viable open network. Even an open network will remain small and isolated unless a critical mass of users and firms support it. Once such open networks gain support, cumulative technical progress that network firms create and share with each other can lead to rapid improvements in performance. Users are attracted to the open network by improvements in system performance. As the size of a network increases, so do the benefits to the users and the viability of the system.

Sun developed new technologies that enhanced system performance and compatibility to initiate and sustain the growth of its open network. Several technological advances represented a recombination of existing components, or architectural innovations (Henderson and Clark, 1990). However, as obvious improvements in computing power and connectivities possible with standard off-the-shelf components were exhausted, Sun had to resort to component innovations within the firm. For instance, Sun developed the Network File System (NFS) to improve data sharing between different computer systems. Besides NFS, Sun developed a new microprocessor chip (SPARC) that increased workstation performance significantly.

The internal development of components to extend technological frontiers was in potential

conflict with Sun's open systems strategy. Firms that had followed Sun's open systems strategy feared that Sun would adopt a proprietary architecture by restricting access to technologies developed internally. However, instead of restricting access to its technologies, Sun liberally licensed them to others to accelerate their acceptance as industry standards. For instance, Sun published NFS protocol specifications to promote it as the industry standard. Sun also liberally licensed out its SPARC microprocessor technology.

Providing rivals access to technologies that are being continually improved represents an act of sponsorship on Sun's part. We define a technology sponsor as a firm willing to invest in the development of a technology while sharing breakthroughs with others to promote its technology as the industry standard.⁴ Besides liberally licensing NFS and SPARC, Sun undertook actions to sponsor its UNIX operating system by collaborating with AT&T. AT&T had already begun sponsoring its version of the UNIX operating system. Collaborating with AT&T placed Sun right at the center of the UNIX sponsorship effort.

The sponsorship of NFS, SPARC and UNIX (three key components of the workstation) attracted both users and firms to Sun's standards-based open network. Firms joined because they had easy access to critical technologies that made them part of a growing network not controlled by any one firm (Quadrant 4 of Table 2). Users joined because their relevant network boundaries expanded. As the number of users and firms embracing the new open network increased, its growth became self-sustaining, gathering greater momentum and legitimacy over time (*Electronic Business*, 1989: 48). As a result, the workstation market and Sun's share grew steadily despite a slump in the wider computer industry.

At first, dominant computer firms such as IBM and Digital Equipment Corporation (DEC) did not perceive Sun's actions as threats. Although these firms eventually realized the threat that Sun's actions posed to their operations, the

potential to cannibalize their existing products constrained their movements (*The New York Times*, 1990). Moreover, these firms were reluctant to open their installed bases to new entrants by agreeing to adopt industry-wide standards.⁵

Sun exploited dominant computer firms' reluctance to adopt industry standards by being the first to offer open systems. Realizing the advantages of networking and compatibility, users who joined this emerging open network began demanding greater compatibility from other firms. As the workstation market began encroaching into other market segments of the computer industry, incumbent firms (e.g., IBM, Apollo and DEC) also began offering workstations based on versions of the UNIX operating system (See chronology in Table 1). Also, entrants such as Solbourne introduced Sun clones based on technologies licensed from Sun. Noting these developments, an industry analyst stated that Sun might become a victim of its own success. 'They gave IBM the idea, and they gave HP the idea, and to a certain extent, they gave DEC the idea' for adopting standards (*Electronic Business*, 1986: 87). As a result, an important question was: *How can Sun survive in this connected open network?*

SUN'S SOURCE OF COMPETITIVE ADVANTAGE

During early stages, the viability of Sun's strategy was based on its ability and willingness to be the first to break proprietary barriers. For instance, inability to access system components and their interface specifications constituted one barrier. Sun was able to overcome this barrier by creating a system employing standard, off-the-shelf components. Inability to share data between systems manufactured by different vendors constituted another barrier. Sun transcended this barrier by choosing the UNIX operating system and by developing NFS. A third barrier was the inability to use the same software on different systems. Sun attempted to overcome this barrier by collaborating with AT&T to sponsor the development of a standardized version of UNIX.

With each step, Sun progressively transformed

⁴ Katz and Shapiro (1986) define a sponsor differently. They define a sponsor as a firm willing to make investments to establish its proprietary technology. Investments are in the form of 'penetration pricing' that are recouped later by pricing in excess of marginal costs.

⁵ See Besen and Saloner (1989) for theoretical justifications.

an industry consisting of unconnected closed networks to an industry characterized by a connected open network. The dissolution of each proprietary layer attracted new users whose relevant network boundaries were extended. Realizing that its affiliation with users would be transitory as competing firms imitated its strategies, Sun progressively shifted its focus to introduce technologies that would dissolve a different proprietary barrier.

So far, the approach of being the first to destroy proprietary barriers has served Sun well. However, the logical culmination of this approach is to have an industry where the technological system will be truly open. *What will Sun's sources of revenues and growth be under these conditions?*

Mr. William Joy of Sun Microsystems stated that Sun would survive in this connected open network by 'being nimbler than its competitors in bringing out an endless succession of software and hardware products' (*The New York Times*, 1988: 29). Sun's past record provides evidence of its innovative abilities (See chronology in Table 1). These innovations have translated into yearly introduction of products, each product increasing computing speed and networking capabilities (Figure 2). Highlighting Sun's willingness to cannibalize its own products in order to survive in an environment characterized by easy entry, Ms Carol Bartz, then a Sun Vice President stated: 'We wouldn't hesitate to bring out a new product at a price and performance level that absolutely destroyed an existing line. Why should we wait for the competition to do it? That is a brand new concept in this business and we have proved you can make money doing it' (*Fortune*, 1987: 90).

How is Sun able to introduce products at a faster rate than its rivals? An answer to this question lies in the act of sponsorship. Even though a sponsor shares breakthroughs with others, sponsorship has its privileges. First, it provides the sponsoring firm earliest access to the technology. Second, a time-lag exists between access to technology and its implementation by others (Mansfield, 1985; Rumelt, 1987). Moreover, the sponsor is able to implement its technology faster than others because learning-by-doing (Arrow, 1962; Dosi, 1984: 146) provides the sponsor with a deeper appreciation of its technology. Therefore, the sponsor enjoys transient monopoly positions (MacMillan *et al.*,

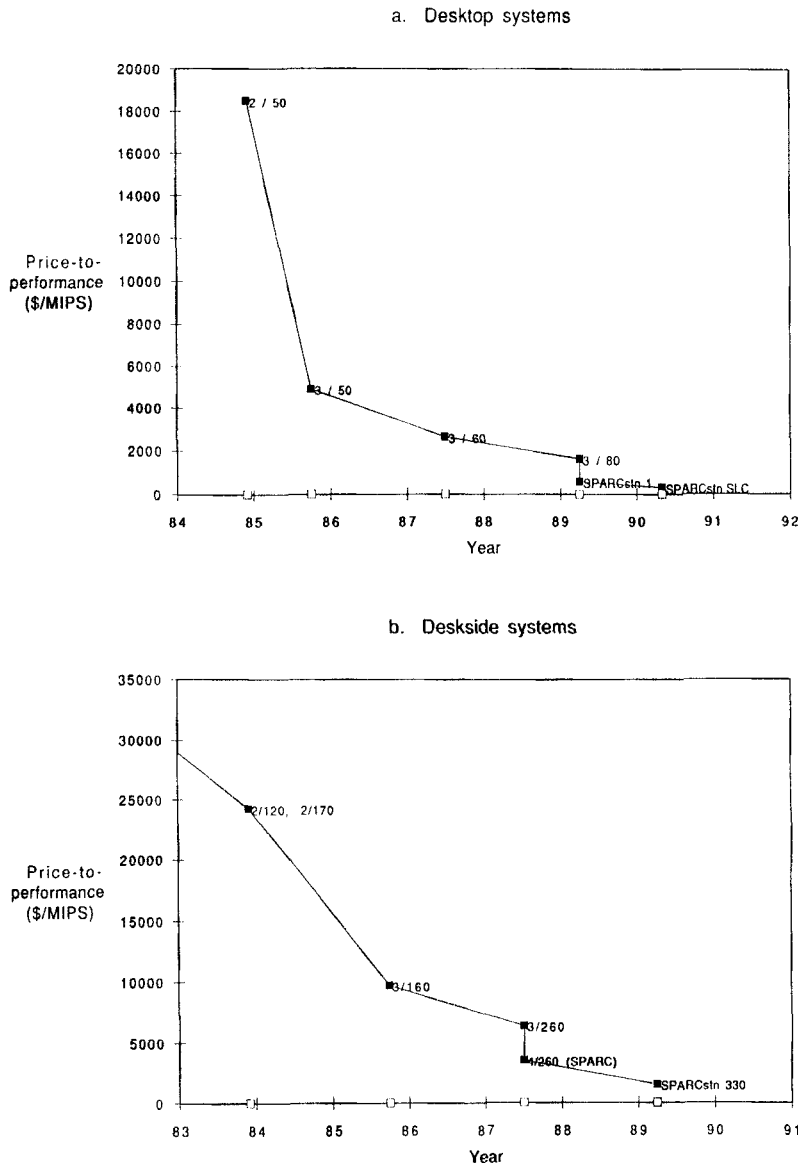
1985) during which it can design and implement future elements of its technological system before its rivals. As Mr. Bernard Lacroute, then Executive V.P. of Sun observed: 'Copying something that moves faster than you can copy isn't a good business to be in' (*Electronic Business*, 1987b: 58).

For instance, between the inception of the SPARC idea in 1983 and its introduction and licensing to other firms in 1987, Sun had ample time to exploit its potential. Sun's agreement with AT&T in 1987 to customize UNIX to SPARC also illustrates the benefits of asymmetric temporal access to technological breakthroughs that sponsors enjoy. Even though AT&T and Sun were committed to licensing new UNIX versions liberally, rivals felt that Sun might enjoy a significant lead over them in software development (*Datamation*, 1988: 22).

However sponsorship implies a short period within which to recoup R&D investments. In unconnected closed networks, innovators can recoup R&D investments by charging high premiums from users locked into their networks. Even if rivals offer substitute products, early innovators, sustained by economies of scale, can reduce prices consistent with competitive pressures. However, in a market segment characterized by open networks, it is not possible to recoup R&D investments by charging high premiums from users locked into particular networks. Survival in an open systems environment depends upon the continual introduction of new products⁶ (Astley and Rajam, 1987). Short product life spans preclude sustained above-normal profits through economies of scale. *What, then, are Sun's bases for revenues and growth?*

Licensing income that accrues as a part of sponsorship efforts provides a stream of revenues to the sponsor. However, to attract a critical mass of firms to its system, the sponsor has to set licensing fees at a reasonably low level (*Computerworld*, 1989). As Sun's CEO, Mr. Scott McNealy stated about Sun's SPARC chips, 'Our goal is not to make money off our chip royalties but to extend the acceptance of our architecture' (*Electronic Business*, 1987a: 34).

⁶ One industry analyst estimated that in 1986 alone, twelve 32-bit UNIX-based machines had been introduced by IBM, Apollo, Sun and others in the work-station market (*Computing Canada*, 1986).



Notes:

1. Sources: Trade journals and newspapers like Computerworld and The Wall Street Journal.
2. Workstation prices are those quoted for entry-level configurations. Prices have been adjusted for inflation (base: 1982-84).
3. Price-to-performance has been calculated in terms of \$/MIPS because SPECmarks as a unit of performance was introduced only in 1989.

Figure 2. Sun Workstations: Price-to-performance

Licensing fees from sponsorship, therefore, cannot be the source of sustained revenues and growth.

Economies of scope provide a partial explanation for Sun's revenues and profits. Economies of scope exist when the cost of joint production of two outputs is less than the cost of producing

each output separately (Panzer and Willig, 1981). One source for economies of scope is a firm's ability to deploy its technical competencies across different products without congestion (Teece, 1980). Sun has realized economies of scope by employing its competencies across a variety of complementary products sharing a

common technology base (Fortune, 1987: 89). For instance, Sun employs its competence in open systems to realize economies of scope between software and hardware products. Open systems require knowledge of how hardware and software products can be integrated across different vendors' systems. Specifically, software knowledge is essential to design hardware and vice versa (Langowitz, 1987). This complementarity between software and hardware reduces Sun's overall software and hardware development costs.

However, there are limits to the economies that scope can offer (Teece, 1980). Eventually, as the demands for sharing know-how increase, bottlenecks in the form of over-extended scientists, engineers and manufacturing personnel occur. Thus, economies of scope provide only a partial explanation for Sun's continued growth and profits in this rapidly changing environment.

We introduce the notion of economies of substitution to understand Sun's ability to recoup R&D investments from products with short life cycles. We use the term substitution to suggest that technological progress can be accomplished by substituting only certain components of the multicomponents system while retaining others. For any given increase in performance, a trade-off exists between the cost of incorporating existing components into the design of a new system and the cost of designing the entire system afresh without constraints imposed by earlier designs. *Economies of substitution exist when the cost of designing a higher performance system, through the partial retention of existing components, is lower than the cost of designing the system afresh.*

To understand how economies of substitution can be realized, we need an appreciation of the design and evolution of technological systems. Rosenberg (1982) offers one perspective. He states that there are time lags in the evolution of different system components. As a result, improvements in system performance have to be accomplished through advances in specific components even while the potentials of others are exhausted. These new components have to be integrated into the system to realize improvements in system performance—a process that is facilitated if components conform to standardized interface specifications. Conforming to standardized interface specifications represents

a modular design in which intertemporal substitution of components can occur easily.

A second perspective on the design and evolution of technological systems recognizes its hierarchical organization (Simon, 1962; Clark, 1985; Hughes, 1987). Component choices at any level of the hierarchy outline operational boundaries for lower order components and subsystems. At the apex of the system hierarchy, it is possible to choose components that possess performance capabilities not fully exploited at early design stages. These unused technological degrees of freedom in higher order components provide designers the latitude to increase system performance through innovations in lower order components. Because innovations occur in lower order components, both designers and users can maintain system upgradability whereby different product generations are compatible with each other.

Together, modularity and upgradability result in modular upgradability—a concept that is becoming important now in the computer industry. Modularity provides system designers with the flexibility to substitute only certain system components while retaining others. Upgradability provides designers with the opportunity to work on an already established technological platform thereby preserving their core knowledge-base. In this way, modular upgradability leads to the preservation of knowledge across generations and 'simplifies the task of coping with very short life cycles of microprocessors' (The New York Times, 1991a).⁷

Modular upgradability and its benefits are illustrated by Sun's SPARCstation 10 series. Its modular design and built-in technological degrees

⁷ Texas Instruments' (TI) PRISM chip is one example where modular upgradability results in economies of substitution. Modules from TI's circuit library are reused to create standard and semicustom products leading to lower qualification costs and reduced product development cycle time and costs (Texas Instruments, News Release # SC-92075, SC-92076, September, 1992.).

Object oriented software programming (OOP) is another example where modular upgradability results in economies of substitution. OOP is an approach to build large programs from many small, prefabricated modules. With data collected from Hewlett Packard, Pfleeger (1991) found that employing reusable modules preserves knowledge and enhances software productivity. However, even reusable modules need to be modified to fit into new software. It is for this reason that OOP pays attention to designs that conform to standardized interface specifications that result in the reduction of incorporation cost.

of freedom enable users to increase system performance by plugging in faster microprocessors and memory modules as they become available. In addition, the SPARCstation 10 series can be upgraded easily to multiple processing and other future technologies. For instance, anticipating the integration of telephones and computers, the SPARCstation 10 provides Integrated Services Digital Network (ISDN) capabilities as a built-in-feature. ISDN has the high bandwidth required for sending multimedia information such as video, audio, and other data across digital phone lines. Moreover, SPARC modules and bus architecture can accommodate advances in microprocessor technology that might occur in the next 3–5 years (Van Hosen, 1992).

Sun engineers point out that these features will result in preserving users' investments even as advances occur in microprocessor performance.⁸ Indeed, Sun offers its users the assurance of 'no penalty upgrades' where the price of an upgrade plus user investments in an existing system will be equal to the price of a new system. These details for Sun and Hewlett Packard—Sun's closest competitor in the workstation market—are summarized in Table 3. This table highlights the benefits of economies of substitution to users. However, our calculations are only indicative of the presence of economies of substitution for the manufacturer because pricing and upgrade policies mask the true economies that manufacturers realize through modular upgradability.

First, we calculated the investment retention that occurs when users upgrade their systems by subtracting the upgrade price from the price of a new system (row #1). These calculations indicate that users retain some portion of their investments when they upgrade their systems. Retention is 100 percent in the case of Sun's SPARCstation 10 multiprocessor series that has in-built technological degrees of freedom and can be upgraded modularly by the addition of new microprocessors.

Next, we compared the percentage additional investment incurred by users when they upgrade (row #2) with the percentage increase in performance achieved by the upgrade (row #3). This comparison provides us with a measure of the value that users derive from upgrades. However, in making this comparison, we must control for the original price-to-performance values that users derive from their existing systems. Therefore, we provide price-to-performance values for users' existing systems (row #4).

These calculations indicate that Sun's systems provide greater upgrade value than HP systems even after controlling for the initial price-to-performance values. For instance, Sun's SPARCstation IPX and HP's model 9000/720 have comparable price-to-performance values. For an additional investment of 107 percent, Sun's SPARCstation IPX can be upgraded to a SPARCstation 10/30, increasing performance by 132 percent. In contrast, the HP model 9000/720 provides only a 29 percent increase in performance when upgraded to HP model 9000/730 for an additional investment of 47 percent.

We also explored the upgrade value more directly by calculating the additional price users pay for every unit increase in performance (row #5). Again, controlling for initial price-to-performance values to users, Sun's systems appear to provide greater upgrade value than HP workstations. Moreover, the upgrade value for Sun systems increases over time. However, this statement does not hold for HP systems.

These figures are only indicative of economies that modular upgradability provides through the preservation of knowledge. Besides enabling the preservation of knowledge across generations, modular upgradability also creates new knowledge that enhances, rather than destroys, existing knowledge. This competency enhancing knowledge (Tushman and Anderson, 1986) arises from experience. Most researchers have examined how experience results in the reduction of costs with cumulative production volumes within a production generation. However, experience can reduce costs even across generations (Udayagiri, 1991). In particular, we argue that modular upgradability allows for the transfer of learning across generations because core platforms (with many unexploited degrees of technological freedom) are retained. This provides researchers with an opportunity to generate new knowledge

⁸ Upgradability between different product generations makes it possible for a firm to offer product innovations continually that users can immediately incorporate into their existing product configurations. Inability to upgrade can be detrimental to the rapid diffusion of new innovations. This is because users will be reluctant to purchase products that cannot be upgraded, specially when their investments become obsolete under conditions of rapid technological change (Rosenberg, 1982).

Table 3. Modular upgradability details

#	Particulars	Uniprocessors				Multiprocessors	
		SUN		HP		SUN	
	Upgrade	SPARC10/30	SPARC10/41	HP9000/705	HP9000/730	SPARC10/41	SPARC10/52
	• From (old)						
1	• To (new)						
	• Price ^b						
	• Old	\$10,995	\$20,495	\$12,490	\$24,390	\$26,995	\$39,995
	• New	\$20,495	\$26,995	\$17,490	\$30,390	\$39,995	\$57,995
	• Upgrade ^c	\$11,795	\$ 6,500	\$ 7,500	\$11,400	\$13,000	\$18,000
1	• Retention: (Price of New less Upgrade price) ^d						
	• Conservative estimate	—	\$13,995	\$ 2,490	\$ 7,590	\$13,995	\$39,995
2	• Aggressive estimate	\$ 8,700	\$20,495	\$ 9,990	\$18,990	\$26,995	\$39,995
	• Addl. Invest. (Upgrade price/price of Old)	107%	32%	60%	47%	48%	45%
Performance							
	• Old	24.7 SPECmarks	57.3 SPECmarks	34 SPECmarks	59.5 SPECmarks	71.2 SPECmarks	109 SPECmarkruput89
	• New	57.3 SPECmarks	71.2 SPECmarks	49.7 SPECmarks	76.8 SPECmarks	109 SPECmarkruput89	218 SPECmarkruput89
3	• Difference	32.6 SPECmarks	23.9 SPECmarks	15.7 SPECmarks	17.3 SPECmarks	NA*	109 SPECmarkruput89
	• Addl. Perf. (Perf. difference/Perf. of Old)	132%	42%	46%	29%	NA	100%
4	Price-to-performance (old)	445\$/SPECmarks	358\$/SPECmarks	367\$/SPECmarks	410\$/SPECmarks	379\$/SPECmarks	367 \$/SPECmarkruput89
5	Upgrade price/performance diff. ^e	362\$/SPECmarks	272\$/SPECmarks	477\$/SPECmarks	658\$/SPECmarks	NA	165 \$/SPECmarkruput89

NOTES: *Sun and HP models have been chosen on the basis of comparable performance and configuration. Configuration details are available from authors.

^bSource of data: SPARC End User U.S. Price List (Sun Microsystems Computer Corporation) Effective May 19, 1992 & HP Apollo 9000 Series 400 & Series 700 U.S. Pricing & Configuration Guide, Revised May 1992.

^cFor SPARCstation 10 Series, Sun offers 'no penalty' upgrades; i.e., price of old system plus upgrade price equals price of new system.

^dAggressive estimates of customers' investment retention are based on the assumption that the value of components returned by users to the company is zero; Conservative estimates are based on the assumption that the value of the components returned to the company equals the price of the upgrade.

^eSPARCstation 10 Series 52 model is a multiprocessor system while the 41 model is a uniprocessor system. Therefore, their performances cannot be compared.

Table 4. Competitive dynamics in network industries

	Unconnected closed networks	Connected open networks
System attributes	<ul style="list-style-type: none"> • Incompatible technological systems • System created with custom designed components 	<ul style="list-style-type: none"> • Compatible technological systems across vendors and product generations • System created with off-the-shelf components with standard interfaces
Firm strategies	<ul style="list-style-type: none"> • Control standards by restricting access to proprietary technical knowledge 	<ul style="list-style-type: none"> • Shape standards through sponsorship by providing rivals and firms in complementary markets easy access to technical knowledge.
Source of sustainable advantage	<ul style="list-style-type: none"> • Sustained above-normal profits from proprietary locked-in installed base and economies of scale 	<ul style="list-style-type: none"> • Transient monopoly position from sponsorship exploited by economies of scope and substitution

based on what they have already mastered (Wheelwright and Clark, 1992). Learning across generations occurs as designers gain a deep appreciation of the future potential of the base technological platform that they have retained even as they replace other system components. Learning consists of appreciating: (1) which aspects of the platform will lead to future improvements, (2) which aspects will lead to dead ends, and (3) how new lower order components fit in with the base platform.

This facet of economies of substitution is best illustrated by Sun's Scalable Processor Architecture (SPARC). SPARC is Sun's version of Reduced Instruction Set Computing (RISC) chips. According to analysts, SPARC is the only practical implementation of RISC that is flexible enough to be implemented on a variety of substrate materials including Silicon and Gallium Arsenide (*Minimicro Systems*, 1988: 17). This implies that significant technological degrees of freedom are present in the SPARC chip that can be exploited as advances in substrate materials occur. In addition, different performance attributes of the SPARC microprocessor can be enhanced without undertaking a complete redesign of the basic platform. SPARC products also maintain binary compatibility between product generations whereby software created for one generation can be employed readily on a subsequent generation.

Modular upgradability leads to economies of substitution in another way. Economies are realized if firms can conduct customer trials and

incorporate their suggestions for improvement by substituting certain system components while retaining others. Rosenberg (1982) points out that this user learning and incorporation process is essential to the evolution of complex multicomponent systems because system optimization and problem detection can occur only through large-scale customer trials. Insofar as the system design incorporates modular upgradability, designers will find it easy and economical to carry out these modifications.

Langowitz reports this aspect of economies of substitution in his analysis of Sun's activities. Sun is first to the market with products that may be somewhat 'underdone' (Langowitz, 1986). Learning from users' feedback, Sun modifies elements of its complex systems at low additional cost to itself and its lead users.

To summarize, economies of substitution occur due to preservation and enhancement of existing knowledge through the use of standardized interface specifications and technological platforms with wide degrees of freedom. Sun has been the first firm in the workstation market to embrace a high degree of modular upgradability in its SPARCstation 10 series. Modular upgradability, and economies of substitution that arise, has become important in this market where rapid technological change has shortened product life spans. As Sun's CEO, Mr. Scott McNealy stated, Sun has 'changed the fundamentals of the computer business the same way Henry Ford changed the fundamentals of the automobile business' (*Fortune*, 1987: 90).

CONCLUSION

This paper has explored Sun's unconventional strategy in a market characterized by network externalities and built around technological systems. Before Sun's entry into the workstation market in 1982, firms created and sustained competitive advantage over rivals by discouraging multisystem compatibility, by custom-designing key system components internally and by restricting access to proprietary technical knowledge. In contrast, Sun has encouraged multisystem compatibility by employing standard, off-the-shelf components and by providing other firms easy access to its technologies. Because of Sun's actions, connected open networks have replaced unconnected closed networks.

Competitive dynamics in connected open networks are very different from those in unconnected closed networks. Choice of off-the-shelf components, compatibility between products manufactured by different firms and easy access to technical knowledge result in breaking several sources of above-normal returns that are possible in the case of unconnected closed networks. Survival and growth in a connected open network must be conceptualized in dynamic terms (Astley and Rajam, 1987). In such an environment, firms have to innovate continually and sponsor their technologies to promote system viability. Even though a sponsor shares technological breakthroughs with other firms, it has first access to the technology, thereby enjoying a transient monopoly position (MacMillan *et al.*, 1985). As a result, the firm can appropriate returns through the continual introduction of new products.

The liberal licensing of proprietary technologies to shape industry standards raises important questions about returns on R&D investments. It is here that economies of scope and substitution play a part. Whereas economies of scope represent a lateral extension of core technological platforms, economies of substitution represent a vertical progression on technological platforms with unexploited degrees of freedom. Scope and substitution economize on the long resource consumptive process of knowledge creation by creating complementary products for existing technological platforms. Besides economizing on the knowledge creation process, scope establishes compatibility between system components whereas substitution ensures upgradability and

accumulation of knowledge across different product generations.

Technological advances in networking have triggered these changes in the workstation market. These technological advances have shifted the locus of innovation from firms to users by making connections between computers economically possible. As users demand compatibility between computer systems, firms feel compelled to offer open systems. Capturing the changing nature of competition in the workstation market, Sun's CEO, Scott McNealy stated, 'In the past, computer companies have been able to charge a premium for proprietary technology; in the future, they will have to offer a discount' (*Fortune*, 1987: 90).

We see similar dynamics in other network industries such as telecommunications, office-automation and consumer electronics as they converge due to technological advances that facilitate networking (Astley and Fombrun, 1983).⁹ As these technologies converge, networking and interfaces between technologies assume greater importance. Under these circumstances, firms must question the conventional wisdom of restricting access to proprietary technologies and discouraging multisystem com-

⁹ In the telecommunications industry, the need for networking and standardization has been debated for a long time. There are reports of an open systems approach being mandated by the Federal Communications Commission (*The New York Times*, 1991b). Elements of the open systems strategy were in evidence in the strategies pursued by JVC Corp. as they encouraged the widespread diffusion of their VHS video format over Sony's Beta format (Nayak and Ketteringham, 1986). The importance of modular upgradability and its connections with economies of substitution have been recognized by leading industrialists in the U.S. Recently, a meeting of executives from 15 leading U.S. companies was convened at Lehigh University to discuss what the U.S. must do to remain competitive (*Business Week*, 1991a). These executives suggested that U.S. products must be designed around the notion of modular upgradability so that even 'cars could later be upgraded easily by consumers eager to drive the latest technological marvels.'

Even in the new portable computers market of the computer industry, there has been a move to employ a public standard for the bus employed for portable computers. Nearly 250 makers of computers, memory chips, and related components, including IBM, Apple, Intel, Microsoft, and NEC have united behind this public standard under the auspices of the Personal Computer Memory Card International Association. The standard spells out the specifications for the bus and the interchangeable plastic-coated cards that fit into it. When inserted into a slot on the side of a computer, these cards can boost memory, provide networking capabilities, or, with a phone cord attached, act as a modem (*Business Week*, 1992: 68).

patibility. Shaping standards by sharing technical knowledge (with firms in complementary markets and with rivals) may be more important than controlling standards by restricting access to proprietary technical knowledge. As experiences of Apollo, IBM and DEC in the workstation market of the computer industry illustrate, a reluctance to adopt an open systems strategy that results in multisystem compatibility can hurt a firm's competitive position. This paper introduces concepts with which to explore the competitive implications of standards-based open systems strategy to theory and practice.

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APPENDIX: DATA COLLECTION METHODOLOGY

Using 'Sun Microsystems' and 'workstations' as key words, we identified articles published in the popular press and trade journals listed in several commercially available data bases and indices. These data bases and indices included: *ABI Inform*, *Business Periodicals Index*, *Funk & Scott Index*, *The Wall Street Journal Index* and *The New York Times Index*. By content analyzing entries from these sources (consisting of 370 entries spanning the period November, 1984 to July, 1989), we identified articles that gave insights to elements of Sun's strategy. Besides these articles, we analyzed Sun's press releases since its inception. These press releases provided a unique chronology of events in Sun's history.

We also read cases on Sun (Bhide, 1989; Freeze, 1988; Green, 1990; Langowitz, 1987; Soll, 1990) and collected data from a recent book on Sun (Hall and Barry, 1990). For our upgradability calculations, we used the most recent price lists published by Sun and Hewlett Packard. We also interviewed Sun engineers and executives using a semistructured protocol that sought answers to the following questions:

- What are open systems?
- Are they important in the computer industry? If so, why?
- How can a company create and sustain open systems?
- How can a company survive in an environment characterized by open systems?

Data collected from these sources served as the bases for our own detailed case on the workstation market and Sun's role in it. Literature on technological systems and network externalities helped sharpen our understanding of the competitive dynamics in the workstation market.