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SUPPORTING DIVERSITY IN TECHNOLOGY: THE ROLE OF MIS MANAGERS

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ABSTRACT

Markets for information technology products such as computers and operating systems are characterized by significant externalities. Research in economics shows that markets characterized by externalities often come to be dominated by few (often single) products (which may or may not be technically superior). Such domination threatens technological diversity, which, this paper argues, is valuable to users of computing. The paper suggests actions by IS managers that support diversity in the face of market dynamics favoring concentration.

1. INTRODUCTION

This paper deals with the issue of how diverse information technologies (IT) can co-exist in user organizations. Certain economic characteristics of IT products work against the preservation of diversity, leading instead to the domination of markets by one or very few technological alternatives. Section 2 of the paper identifies these economic characteristics of IT products. Section 3 applies concepts from the economics of compatibility and standardization (supported by historical evidence) to explain why the economic characteristics identified in section 2 lead to market concentration, with corresponding loss of diversity. Section 4 points out the benefits of technological diversity in the IT resources of organizations, i.e., why diversity is worth striving for. Section 5 concludes the paper by examining what IS managers can do to counter the tendency toward the loss of technological diversity.

2. ECONOMIC CHARACTERISTICS OF IT PRODUCTS

The controversy surrounding Microsoft's domination of the PC operating system and package software markets (*Business Week* 1993) is just the most recent instance where customers have worried about the loss of diversity in IT products. Similar concerns have been voiced about IBM's role in the mainframe market of the 1960s and early 1970s, and about the role of Intel in the microprocessor market of the 1980s. A logical question that follows from these observations is:

“What features of IT products contribute to concentration of market share?”

Two features that differentiate IT products from other industrial products are:

- (a) **The systemic nature of IT products.** At the level of the single computer, hardware, operating systems and application packages must work together in a coordinated manner for the computer to satisfy customers' needs. Individual computers are themselves components in networks, which, in turn, comprise the higher level IT architecture of an organization. By “the systemic nature of IT products” we refer to the fact that individual IT products are components of higher level systems which actually deliver the service of information processing to user organizations (Matutes and Regibeau 1987). The choice and performance of IT products is, therefore, strongly determined by factors other than the intrinsic capability of the product, such as its relationship to other components in the network. In later sections, we will discuss how this systemic nature affects technological diversity.
- (b) **The network externalities in the usage of IT products.** An “externality” is defined as an action that brings direct benefits or costs to others, but these do not sufficiently enter into the utility calculus of the decision maker (Hemenway 1988). The term “network externality” refers to the increase in the utility of a product to a user due to the presence of other users in the “network” (Katz and Shapiro 1985).¹ The

utility that a given user derives from an IT product increases with the number of other agents using the product. The utility of communication technologies such as e-mail depends directly on who else uses it (and, thus, can be reached by it). In other cases, the benefits from others' usage of the same product is indirect and market-mediated. Hardware platforms with a larger installed base are more likely to be supported by software vendors; also, spare parts and service for such platforms may be easier to find. Benefits arising to existing users from the actions of other adopters of a product are externalities because the purchase decisions of subsequent adopters do not fully take into account the benefits or costs accruing to existing users. The effect of network externalities on market structure will be described in the following section.

3. MARKETS FOR SYSTEMIC PRODUCTS WITH NETWORK EXTERNALITIES

The **systemicity** of IT products creates a need for compatibility: an assembly of incompatible products cannot meet the needs of the customer. Benefits from compatibility lead to demand-side economies of scale (i.e., "benefits to doing what others do") in three ways (Farrell and Saloner 1986):

- **Interchangeability of complementary products** such as software applications and storage media. For example, all IBM-compatible personal computers can run the same software and can read and write to identically formatted fixed and floppy disk drives. Interchangeability of complementary products makes it easier to buy, maintain, and operate components of a network.
- **Ease of communication.** Compatible IT products can communicate with one another. In fact, with the growing emphasis on connectivity, the value of computers depends heavily on their "networking" (communication) capabilities.
- **Cost savings.** The interchangeability of complementary products consolidates their markets, allowing vendors to "mass produce" these products. Whether the resulting costs savings are passed on to customers depends on the competitive forces in the particular market.

When compatibility is important, the providers of "integrated" systems stand to benefit significantly. Not only can IT products from an integrated vendor be tailored to work smoothly with one another, such a vendor can make it difficult for third parties to supply compatible components by

- (a) non-disclosure and manipulation of component interfaces, and
- (b) predatory pricing on particular components through "bundling."

Integrated vendors can exploit compatibility to drive out competition, leading to significant loss of technological diversity (Greenstein 1990). Such allegations have been leveled recently against Microsoft Corporation (*Business Week* 1993), whose share of the Windows applications market is viewed by many as disproportionately large. Microsoft Excel holds 73% of the Windows spreadsheet market (compared to the 20% share of Lotus, the DOS spreadsheet leader), while Microsoft Word holds 53% of the Windows word processing market (WordPerfect, the DOS word processing leader, has 31% of this market). Detractors of Microsoft allege that Microsoft's applications programmers have advance details of its operating system software and the company is slow to share vital information with third party developers. They also charge Microsoft with offering low-ball prices on application programs, cross-subsidizing them with the profits from operating systems sales, and bundling extra programs (such as disk compression, memory management and networking software) with the operating system.

Attempts by integrated vendors to deter third party suppliers of IT components are not altogether new. In the early 1970s, several IBM system component competitors sued IBM for system redesigns initiated by IBM which altered the interfaces of the components (Greenstein 1990). For instance, peripheral makers were denied access to interface specifications between the IBM System 370 CPUs and the 3330 disk drives, delaying their product introductions in spite of their having built the requisite technological capability (Brock 1975). Disentangling "predatory intent" from legitimate product alterations is often difficult, hence the integrated vendor enjoys significant leeway.

Network externalities associated with IT products also favor the concentration of market share in the hands of one or few vendors. A number of mechanisms may convert an initial multiple-vendor market to an oligopoly or a monopoly: these include learning effects, coordination effects and adaptive expectations (Arthur 1988). Learning effects act to improve products or lower their costs as their prevalence increases. Coordination effects confer advantages to "going along" with other agents taking similar action. Adaptive expectations refers to the condition where increased prevalence of a technology in the market enhances beliefs of its further prevalence. All these mechanisms are self-reinforcing, so that the initial starting state combined with early random events push the dynamics of the market

into domination by one or very few products. In the presence of self-reinforcing mechanisms, markets are characterized by:

- possible inefficiency (technically superior products may not predominate),
- sequential-choice lock-in into technologies with lower long-run potential, and
- path-dependence (early history and “luck” choose between multiple equilibria).

David (1985) describes the stability of the QWERTY keyboard layout in spite of superior alternatives being proposed from time to time. Through an interplay of learning effects (typing skills were developed around the layout) and adaptive expectations, the popularity of QWERTY further increased the probability of its adoption by new customers. In spite of their technical superiority, other layouts such as the Dvorak keyboard could not compete against QWERTY. This example illustrates the conditions of technical inefficiency, lock-in, and path-dependency suggested by Arthur, where historical events have locked users into what is widely regarded as a less efficient technology.

4. THE CASE FOR DIVERSITY OF TECHNOLOGY

Except under strict assumptions — simultaneous, non-sequential adoption by all customers and the availability of perfect information to all customers about the preferences of all other customers — the adoption process for systemic products with network externalities cannot be guaranteed to maximize social welfare. Since these assumptions are violated most of the time, socially detrimental outcomes of individually “rational” adoption decisions cannot be ruled out; for example, an innovative new technology that would have made all users better off may not be adopted. Coordination problems² (“excess inertia”) as well as the so-called “penguin effect³” contribute to such an outcome (Farrell and Saloner 1985, 1986).

Social welfare apart, diversity allows a user organization to use the best tools for each aspect of its task. The freedom to choose appropriate tools for specific tasks can impact the productivity of computing significantly. PCs may be the platform of choice for end-user developed systems, while a network of workstations may be the most efficient solution for the processing power and stability requirements of mission-critical applications. A graphical user interface may be the most attractive for developing executive infor-

mation systems, while highly secure mainframe environments may be chosen for processing sensitive or classified information. Serving the complex information processing needs of today's corporation without technological diversity is like undertaking a complex construction project equipped with only a hammer for a tool: progress, if any, is bound to be painfully slow. Diversity allows the user organization to address each of its different information processing tasks with state-of-the-art IT for that task. *All other things being equal*, the choice of a tool appropriate for the problem at hand can make a significant difference.

All other things are never equal, however, and that brings us to another reason why diversity is important. Through an interaction of preferences and history, different individuals come to have differential skills in different technologies (often to the extent of expertise in one technology and ignorance in all others). It is in the organization's economic interest to exploit the existing skills of its employees instead of requiring them to learn new technologies. Not only is technology learning a slow and expensive process, earlier knowledge of another technology can interact in unexpected ways (ranging from beneficial transfer to “destructive” interference) with the current one being learned. In many situations, it may make sense in cost-benefit terms for the organization to accommodate an employee's preference for a familiar technology rather than re-train the employee altogether. Diversity of technology is a reflection of such an accommodative strategy.

Compared to most other technologies, IT is still characterized by a high rate of innovation. Investing in diverse technologies develops the absorptive capacity (Cohen and Levinthal 1990) of the firm in the long term. Absorptive capacity refers to the ability of the firm to recognize the value of new technology, assimilate it and apply it to commercial ends. Firms which do not develop absorptive capacity by investment in diverse technologies are poorly placed to recognize and exploit breakthroughs in these technologies. Once off the “technology escalator,” it is often difficult to get back on.

A conscious acceptance of technological diversity also protects an organization against over-reliance on a single vendor (Saloner 1990). Sunk investment in a proprietary technology (in the form of hardware, software and training) and the tailoring of organizational systems around the technology are considerations contributing to a **technology lock-in** in the long term. The single vendor may exploit such lock-in by increasing prices. Hartman and Teece (1990) found that, in the minicomputer industry, vendors often priced entry-level systems aggressively to lock in customers. Once the customer's switching costs rise, these vendors raise prices on subsequent generations of systems.

Another hazard of depending on a single vendor is that, if the vendor goes out of business, support for a proprietary technology may be hard to find and user organizations are left stranded. Users of Wang business machines (the vendor went bankrupt recently) encountered this situation, although Digital has decided that providing support for Wang equipment is an attractive commercial proposition.

5. THE ROLE OF IS MANAGERS

We have shown that certain economic features of IT are not conducive to diversity of technology, i.e., self-reinforcing mechanisms drive concentration of market share into one or very few technologies. We have also argued that user organizations benefit in both the short and the long term by consciously supporting diversity. If diversity is indeed desirable, but the market mechanism does not work in its favor, other approaches must be found to sustain diversity.

The self-reinforcing diversity-reducing dynamic of the market is not easy to counteract. Although some coordination problems may be overcome by communications between IS managers of different organizations, others are exacerbated by such communication. The "penguin habit" of waiting to watch the other guy go first is often rewarded by organizations. However, the community of IS managers can still act in ways that correct the market's tendency to suppress diversity. Among the actions that can promote diversity in technology are:

(a) **Promoting standardization:** At first sight, standardization appears contrary to the aim of diversity. After all, if all products are standardized, where is the scope for diversity? The type of standardization advocated here may be more precisely termed "interface standardization" in contrast to "reference" or "minimum quality" standardization, which promotes similarity between products. Interface standardization only requires adherence to well-specified input and output conventions in the interests of inter-operability of technology provided by different vendors. Given the systemic nature of IT products, emergence of standards for inter-component interfaces allows customers to "mix and match" components to assemble systems closer to their needs than existing integrated solutions (Matutes and Regibeau 1987). Mix-and-match variety thus favors the co-existence of diverse technologies.

Interface standards may be voluntary or regulated, and both of these processes of standardization have advantages and disadvantages (Cargill 1989). There is some evidence to show that standardization differentially affects the competitive standing of vendors, so that

standards are resisted by the dominant vendors of a product (Brock 1975; Greenstein 1990). In the past, the government, in its dual role of a regulator and a large customer, has taken the initiative in standard setting for many technologies including programming languages and telecommunications. However, given the increasing share of IT buying by the private sector and its greater technological sophistication, IS managers in the private sector will have to promote standardization of products by vendors. By actively participating in standard setting processes, IS managers can aid the development of interface standards that support product diversity.

(b) **Supporting products with open and standardized interfaces:** IS managers can express a preference for products with open and standardized interfaces over proprietary, closed architectures. Products conforming to standards afford multi-vendor interoperability, leaving the user organization the flexibility to assemble configurations of components closely matched to their specific needs. Multiple expansion and upgrade paths are also left open for the future, providing the capability to capitalize on technological breakthroughs wherever they occur. Given the intuitive appeal of standardized products, it is not surprising that IS managers are already seeking proof that the products they buy will operate in open architectures such as X/OPEN (*Software Magazine* 1992). Testing conformance to standards is becoming increasingly complex, but organizations specializing in conformance testing are arising to provide this essential service. Products that violate interface standards often tempt IS managers with higher performance (like US Robotics modems which claimed higher data transfer rates than modems following standard protocols). An eye to the big picture should help managers avoid decisions that bind users to proprietary products.

(c) **Investing in gateway technologies:** One way to simultaneously operate incompatible technologies is to invest in gateway technologies. David (1987) provides several examples of gateway technologies, most notably the rotary converter which enabled DC electric motors to be supplied current from AC generation plants and transmission lines. More familiar examples of gateway technologies are programs that bridge different hardware and operating systems, allowing the transfer of data and programs between DOS, Apple and Unix systems. Gateway products permit the *ex post facto* integration of incompatible systems, and thus help organizations to cope with technological diversity. Unfortunately, gateway technologies are invariably threatened by integrated system vendors' ability to

switch interfaces at short notice, rendering the current generation of gateway products obsolete. For instance, Sun Microsystems has recently announced its intention to provide a Windows application binary interface (ABI) to run on Unix systems so that shrink-wrapped Windows applications could run on Unix systems without either Windows or DOS being installed (*PC Week* 1993). Even before the ABI gateway is launched, there are already fears that Microsoft may modify its application programmer interface (API), undermining the utility of the proposed gateway. IS managers, working together through trade associations and professional forums, can discourage such attempts to perpetuate proprietary practices.

This paper has argued that diversity in technology, which is valuable to IT users, is often suppressed by market forces which interact with characteristics of IT (such as system-icity and network externalities) to favor convergence on one or very few technologies. While there are clear social and individual benefits from standardization, the potential costs of premature convergence on particular technologies to the exclusion of others are only beginning to be appreciated. The self-reinforcing nature of economic mechanisms gives markets for IT products the characteristics of dynamic systems with positive feedback. Such systems may have multiple equilibria, only a few of which can be claimed to be optimal. Depending on chance events in the early history of such markets, products that come to dominate such markets may turn out to be sub-optimal *ex post*.

While no catch-all prescription (such as coordination of technology purchases through professional networks) for action by IS managers to support diversity is available at present, a conscious effort by the IS community to participate in standard setting, support products with open standardized interfaces, and invest in gateway technologies can go a long way. As in any situation involving externalities, the self-interest of individual user organizations and the interest of the broader user community diverge significantly. While no heroic commitment of time, effort and money to the social interest should be expected from a user organization, IS managers' awareness of the long-run benefits of technological diversity and the forces that run counter to it can lead to more informed choices of technology.

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7. ENDNOTES

1. The scope of the network is different for different products. For a communication technology, the network includes all the geographically dispersed members who are connected by the technology, whereas, from the point of view of desktop computers, the immediate office environment may define the relevant network.
2. Coordination problems manifest themselves as "symmetric" and "asymmetric" inertia. In the former case, all customers are moderately in favor of the new technology, but the adoption bandwagon never gets rolling because each customer is unaware of the preferences of others. Symmetric inertia can be overcome by nonbinding communication of preferences and intentions between potential adopters. Asymmetric inertia arises from differences in the technology preferences of different customers, who choose to maintain the *status quo*, though the total benefits from switching would exceed the total costs. Asymmetric inertia may be exacerbated by communication aimed at reducing symmetric inertia (Farrel and Saloner 1985).
3. Even though all customers would like to adopt the new technology, each would prefer that others go first (and bear the initial risk and transient incompatibility costs).