



Winning the Standards Race: Building Installed Base and the Availability of Complementary Goods

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In markets that have forces encouraging the adoption of a dominant design, the size of a technology's installed base and the availability of complementary goods may be the most important factors determining its success or failure. This article examines the path dependent nature of technology trajectories, and the self-reinforcing effects of installed base and complementary goods. The article posits that firms can greatly influence their installed base and the availability of complementary goods through their distribution, alliance and marketing strategies. Both theory and examples are used to demonstrate how firms can manage the dynamics of technology selection in their favor.
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In many markets, forces encourage the selection of a single technology standard. This standard, or 'dominant design,'¹ may be embodied in a product design, the system architecture of a family of products, or the process by which products or services are provided. Standards may be specified by government or industry groups, such as the NTSC color standard in television broadcasting (which was approved by the FCC in 1953 and endures today), or the digital video disk standard proposed by the DVD Forum (a consortium of companies that included Hitachi, JVC, Matsushita, Mitsubishi, Philips, Pioneer, Sony, Thomson, Time Warner, and Toshiba).

A standard may be a dominant design in a core product which then constrains possible configurations in the end products (such as the internal combustion

engine, which has been a defining characteristic of automobiles since the 1908 introduction of Ford's Model T). A standard may also be a process protocol that has little impact on product configuration, but ensures that producers adhere to some designated practices (such as ISO 9000 quality certification).

Standards may be enforced (as by government), or they may be voluntary guidelines that firms adhere to because they facilitate compatibility and cooperation. They may be embodied in 'open' systems that are free to the public (such as UNIX, an operating system originally developed by AT&T's Bell Laboratories in the late 1960s whose specifications could be licensed by any vendor), or they may be proprietary systems that are owned and controlled by a single firm (such as Microsoft's Windows or Intel's X86 microprocessor line). Standards may be overturned when a successive generation of technology makes the design obsolete, but standards are also often capable of shaping the technological progress in an area — enabling and constraining what designs are likely to emerge in the future.

When a market is still in the process of selecting a dominant design, many alternative technologies may be on offer. Coalitions may emerge and shift, as groups of companies adopt and promote competing technology platforms. Firms sponsoring a particular technology usually have a considerable investment in the design — both in terms of physical assets and learning — so they have a keen interest in supporting a technology they believe has a good chance of

becoming the standard. If the firm supports a technology that is not chosen as the dominant design, it may be forced to adopt the dominant technology, forfeiting the capital, learning and brand equity invested in its original technology. Even worse — a firm may find itself locked out of the market completely if it is unable to adopt the dominant technology (Schilling, 1998a).

By contrast, if a firm's proprietary technology is chosen as a dominant design, *and* the firm is able to protect the technology, the firm may be able to earn near-monopoly rents (however, protecting a technology can also dramatically decrease the likelihood of that technology being chosen as a dominant design). Furthermore, when a firm's technology is chosen as a dominant design, it is in a good position to shape the evolution of the industry, greatly influencing what future generations of products will look like. This can enable the firm to dominate the product category through several product generations. For these reasons and others, technology trajectories tend to be path dependent.

In a previous study, the author tested a model of the process of technological lock out (Schilling, 1998b), and found that despite idiosyncratic influences and path dependency, the process could be modeled and that certain factors have a regular and predictable influence on the likelihood of technology success. A major implication of that study is that the firm could strategically influence those factors, thereby improving its chances of success in a standards battle. This article builds on this research by looking more specifically at two of the most significant of those factors, installed base and availability of complementary goods, and shows how firms can use their technology deployment strategies to leverage the dynamics of technology selection in their favor.

The paper begins by looking at the implications of path dependency and increasing returns to adoption, including the learning effects, network effects and signaling effects of attaining an installed base (or complementary goods) advantage. The paper then discusses how firms can manage the network effects and signaling effects to initiate (and accelerate) the 'virtuous cycle' of self-reinforcing feedback effects that improve the technology's chances of becoming the dominant design. In the course of developing this framework, the paper draws heavily from examples of firms that have used these strategies to their benefit. The last section discusses the research implications of the framework, and gives direction for future inquiry.

Path Dependency: Randomness and Order

Technology trajectories — the path a technology takes in the course of its evolution — are often characterized by 'path dependency,' meaning that relatively small historical events may have a great impact on the final outcome. Though the technology's quality and technical advantage undoubtedly influence its fate, other factors, unrelated to the technical superiority or inferiority may also play important roles (Arthur, 1989; England, 1994; Katz and Shapiro, 1986). For instance, timing is crucial; early technology offerings can become so entrenched that subsequent technologies, even if considered technically superior, may be unable to gain a foothold in the market. How, and by whom, the technology is sponsored may also impact adoption. If, for example, a large and powerful firm aggressively sponsors a technology (perhaps even pressuring suppliers or distributors to support the technology) that technology may gain a controlling share of the market, locking out alternative technologies.

When small or random events can have large impacts on final outcomes, it is often assumed that all control and predictability is lost. Because we cannot anticipate random events, or foresee which minor events will impact selection, it appears impossible for us to know how the technology selection will unfold. However, examining a large number of standards races reveals a number of consistent patterns — technology selection is not as random as it might first appear.

“A firm may find itself locked out of the market completely if it is unable to adopt the dominant technology”

Though idiosyncratic events do influence final outcomes, their effects accrue in an ordered way (Schilling, 1998a). In fact, there are a number of factors that *regularly* and *predictably* influence technology selection. In the author's previous study of 89 firms that had competed in standards battles, the results indicated that a firm's likelihood of being locked out of the market was significantly related to its learning emphasis ($P < 0.01$), its timing of entry ($P < 0.05$), the size of its installed base ($P < 0.05$), and the availability of complementary goods ($P < 0.01$) (Schilling, 1998b). Furthermore, the size of installed base and availability of complementary goods, the two variables we will examine in-depth here, are significantly and positively correlated (0.689, $P < 0.01$). This relationship is an important element of the technology selection process (as discussed later), and yields many implications for the strategic deployment of a new technology.

Once a technology begins to be adopted by users, there are a number of self-reinforcing feedback effects which cause the technology's functionality

and market attractiveness to improve. These feedback effects — also referred to as increasing returns to adoption — may give an early technology or a widely deployed technology an advantage that is virtually insurmountable — that is, until the technology is rendered obsolete by a new generation of technologies.

Increasing Returns to Adoption

Complex technologies often exhibit increasing returns to adoption in that the more they are used, the more they are improved (Arthur, 1989, 1994). A technology that is adopted usually generates revenue that can be used to further develop and refine the technology. Furthermore, as the technology is used, greater knowledge and understanding of the technology accrue as byproducts that may then enable improvements both in the technology itself, and in its applications. Finally, as a technology becomes more widely adopted, complementary assets are often developed which are specialized to operate with the technology. These effects can result in a self-reinforcing mechanism that increases the dominance of a technology regardless of its superiority or inferiority to competing technologies.

Increasing returns to adoption can be split into three major categories of effects: learning curve effects, network externality effects, and signaling effects.

Learning curve effects. There is ample empirical evidence that as a technology is used, it is further developed and is made more effective and efficient (Hall and Howel, 1985; Lapre *et al.*, 1999; Levy, 1965; Yelle, 1979). At the individual firm level, firms become better skilled at using the technology, and find ways to use it more productively, including developing an organizational context which improves the implementation of the technology. At the aggregate level, the more firms that are using the technology and refining it, developing complementary technologies to improve its effectiveness and efficiency, the more attractive the technology becomes to other firms.

Learning curve advantages have the potential to be a powerful sustainable advantage. They are much more difficult to imitate than network externality or signaling effects — they are path dependent, cumulative, and often have socially complex or tacit elements to them (Reed and DeFillippi, 1990). However, because of many of the very same properties, a firm's learning trajectory can also become the source of core rigidities (Leonard-Barton, 1992), potentially leading to critical weaknesses and inflexibility. Learning within a firm is cumulative and self-reinforcing. Firms will tend to use and build on their existing knowledge base rather than entering unfamiliar areas, therefore 'what the firm can hope to do technologically in the future is narrowly constrained

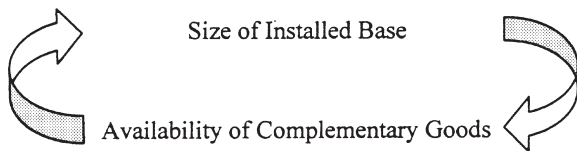
by what they have been capable of doing in the past' (Dosi, 1988, p. 1130).

As a technology is refined and learning accumulates along a particular technology trajectory, it also shapes the problem-solving techniques that are used, often resulting in a very 'sticky' technological paradigm which directs future technological inquiry in the area (Dosi, 1988). This is one of the ways that the selection of a dominant design tends to influence the nature of subsequent dominant designs.

Network externality effects. The second category of effects is known as network externalities (or positive consumption externalities). In a market characterized by network externalities, a user's benefit from using a good increases with the number of other users of the same good (Choi, 1994; Katz and Shapiro, 1986, 1992; Thum, 1994). The classic examples of markets demonstrating network externality effects are those involving physical networks, such as railroads or telecommunications. Railroads are more valuable as the size of the railroad network (and therefore the number of available destinations) increases. Similarly, a telephone is not much use to you if you can only call a few people with it — the amount of utility the phone gives you is directly related to the size of the network (Garud and Kumaraswamy, 1993).

Network externalities can also arise in markets that do not have physical networks. For example, a user's benefit from using a good may increase with the number of users of the same good when compatibility is important (Farrell and Saloner, 1985). A user may choose a computer platform based on the number of other users of that platform, rather than on the technological benefits of a particular platform, because it increases the ease of exchanging files. Choosing a platform with the largest installed base increases the number of computers with which the user's files will be compatible. Furthermore, the value of the user's training in a particular platform becomes more valuable as the size of the installed base of the platform increases. If the user must invest considerable effort in learning to use a computer platform, the user will probably choose to invest this effort in learning the format they believe will be most widely used.

Network externalities also arise when complementary goods are important (Farrell and Saloner, 1985). Many products are only functional or desirable when there is a set of complementary goods available for them (e.g. videotapes for VCRs, film for cameras, etc.). Products that have a large installed base are likely to attract more developers of complementary goods. Since the availability of complementary goods will influence users' choice among competing platforms, the availability of complementary goods then, in turn, influences the size of the installed base. A virtuous cycle ensues:



The effect of this cycle is vividly demonstrated by Microsoft's dominance of the operating system and graphical user interface markets. In 1980, IBM approached Gary Kildall, founder of Digital Research and the inventor of CP/M (then the dominant operating system for personal computers), to arrange to have CP/M bundled on the first IBM personal computer. Kildall, for reasons that are still contested in computer circles, did not sign with IBM.

Since IBM was already purchasing other software programs from Microsoft, they called Bill Gates to ask if he could also provide an operating system. That event had a profound impact on the shape of the computer industry as we know it today. Gates provided an operating system, MS-DOS, which rapidly gained a huge installed base as customers clamored for IBM and IBM-compatible PCs. Microsoft was later able to leverage its dominance in operating systems to secure a dominant position with a graphical user interface designed to sit on top of DOS: Windows. Microsoft also worked vigorously to ensure that compatible applications were developed for DOS and Windows, both making applications itself and encouraging third-party developers to support the platform.

The network externality benefits of using Windows and Windows-compatible software, which gained an early advantage in installed base and availability of complementary goods, enabled the platform to lock several would-be contenders such as Geoworks and Next (and, some would argue, Apple) completely out of the market.

Signaling effects. Even in absence of network externalities and learning curve effects, the size of the installed base may influence a technology's likelihood of adoption as a dominant standard. The size of the installed base (or even the *perceived* size of the installed base) may serve as a signal to consumers about the quality or value of a good when those attributes are uncertain or difficult for the consumer to measure. For many products, the actual mechanics of the product are nearly impossible for consumers to observe and evaluate. Furthermore, though the consumer may be able to observe the quality or functionality of the product through use, it may take extended use or training with the product before the consumer judges the product's performance. After the consumer has spent the time or money involved in gaining the required familiarity with the product, the consumer faces switching costs and may feel reluctant to try another product even if the consumer has judged the current product to be of poor quality. To avoid such a situation the consumer may rely on

the installed base as a signal that other consumers have already evaluated the performance of the product and judged it favorably.²

The installed base of a technology may also send a strong signal to producers of complementary goods. If producing the complementary goods requires specialized assets, or if there are costs associated with varying production (both of which are likely to be true), complementary goods producers may prefer to produce goods compatible with only one technology design. Other things being equal, a complementary goods producer is more likely to produce complementary goods for the technology they perceive to have the highest installed base, since a larger installed base means more potential customers for the complementary goods. Furthermore, if there is uncertainty about which technologies will succeed or fail, the size of the installed base acts as an indicator of the technology's likelihood of success.

Though learning curve effects are difficult (if not impossible) to reap in the absence of an existing installed base, there are a variety of strategies firms can employ to increase their network externality and signaling effects. The firm then has the opportunity to reap learning advantages as the size of its installed base and availability of complementary goods begin to swell.

Accelerating the 'Virtuous Cycle'

When the market is likely to select a single dominant standard, and when the size of the installed base drives consumer choice and the production of complementary goods, the firm needs to employ marketing, distribution and pricing strategies that will rapidly deploy the technology, even if this means forfeiting returns in the short run. First, a firm can diffuse its technology through licensing arrangements and open systems. Protecting the technology with appropriability mechanisms (such as patents, keeping the technology secret, etc.) will slow the technology's diffusion into the marketplace and increase the risk of having the technology locked out altogether. Second, a company can use inter-organizational linkages with distributors, complementary goods producers, or customers of its technology to gain an advantage in quickly establishing an installed base or increasing the availability of complementary goods. Third, a firm may also increase the size of the installed base through aggressive promotion and penetration pricing. In fact, the firm may be able to influence consumers' *perception* of the existing installed base of the technology (through, for example, 'vaporware') and thus increase the likelihood that consumers choose that technology and subsequently increase the *actual* installed base.

Diffusion Versus Protection of Proprietary Technology

Traditionally the literature on innovation has focused on the strength of appropriability mechanisms as the determinant of profitability of innovation (Cohen and Levin, 1989). By protecting its proprietary systems through patents, secrecy, or other mechanisms, a firm can ensure that it reaps the bulk of the rewards from its technology development investment. Unfortunately, wholly proprietary systems are usually not compatible with the products offered by other manufacturers — other manufacturers are unable to develop components that may interact with the proprietary system because its operation is based on protected technology. Proprietary systems are also usually more expensive than open systems because they are not subject to the same degree of price competition, and because they do not reap the manufacturing efficiencies that arise from having many different firms working on improving their production. Because of their higher cost and poorer availability of complementary goods, proprietary systems face a high risk of rejection under conditions of strong network externalities.

IBM's microchannel is an excellent example of this. The firm protected its proprietary server bus architecture and charged very high prices to other manufacturers who wanted to build devices to the microchannel specifications. As a consequence, even though microchannel may have had some technical advantages over standard ISA or PCI bus architectures, manufacturers of hard drives, video cards, modems, and other peripheral devices decided they did not need to support microchannel. Consumers also avoided microchannel machines because the upgrades were too costly. IBM's market share slid, and they eventually gave up manufacturing microchannel machines.

IBM shot themselves in the foot. They came out with micro-channel and then charged a small fortune if any other manufacturer wanted to build devices to the micro-channel specification. So, hard drive, video card, modem, etc. manufacturers decided they really didn't need IBM. Dell, Gateway, Austin and all of the other clone machines were doing just fine. There was still a good market. As a result, the consumer side got smart (except for business early on) and avoided the micro-channel machines because upgrades were too costly. As IBM continued to lose market

share, they went back to the more standard ISA and PCI bus architectures. I don't think IBM manufactures a micro-channel machine anymore. They'd probably tell you that the new buses are better and they dropped it, but it is more likely that they out-marketed themselves (Vince Muehe, ISD, 27 October 1996).

In such cases, it may be a better strategy for the firm to deliberately diffuse its technology, freely disseminating its technology architecture for use by other manufacturers or engaging in liberal licensing agreements. Such an open systems strategy proved to be critical to the success of Sun Microsystems in diffusing their UNIX technology (Garud and Kumaraswamy, 1993), and many have argued that the failure of Apple to open their systems is what has led to the steep decline of the Macintosh. Because of their protection of their proprietary architecture, Macintosh computers are disproportionately expensive compared to their IBM-compatible counterparts, and software for the platform is much more limited.

Only if there are few competitors, an existing range of complementary goods, and/or the technology has a great margin of improvement (perceived or realized) over other options, can a firm consider protecting the proprietary elements of its technology and still hope to attain a sufficient installed base to avoid lock out under conditions of strong network externalities (see Table 1). If the margin of improvement is very great, the technology may be selected as a dominant design even if the costs associated with it are higher. If the margin of improvement is great, but not sufficiently great to become a dominant design despite higher costs, the technology may still persist as a niche solution. In either case, the firm must be very careful to assess the balance between the technology's margin of improvement, and the installed base advantages of diffusing the technology.

The downside of open systems is that they are often quickly commoditized, and may provide little appropriability of rents to their developers. While the technology may become a dominant standard, it may not generate much profit for the producer unless it leverages other, more profitable, activities of the firm.

Modularity. Another option that combines much of the compatibility of open systems with the appropriability of proprietary systems is to employ a modular

Table 1 Diffusion versus Protection of Proprietary Technology under Conditions of Strong Network Externalities

Consider diffusion when...	Consider protection when...
Technology leverages other profitable activities of the firm	Technology offers great margin of improvement, and that margin of improvement is readily apparent to customers
Technology requires third-party development of complementary goods	Technology is compatible with a wide range of existing complementary goods
Competitors are able to offer a strategically equivalent technology	Competitors do not pose a significant threat

design. Modular product systems can utilize proprietary technology *within* components of the system, but use a standards-based interface to *interact* with other components or systems (Baldwin and Clark, 1997; Sanchez and Mahoney, 1996). For instance, a minicomputer's main functionality may be based on proprietary technology, however the minicomputer may then also provide standards-based input/output mechanisms so that the minicomputer may be mixed and matched with other components.

The standard interface defines the rules of exchange (whether the exchange be data, energy, or other resources), enabling even highly disparate technologies to be made compatible so long as they conform to the interface. Furthermore, by providing information-hiding capacity, a standard interface enables a firm to make its technology compatible with those of other producers while still concealing the mechanics of its core functionality (Fichman and Kemmerer, 1993).

Many product systems are migrating towards increasing modularity; computer hardware is one of the most visible examples of this trend, but other product systems such as software, home appliances, and even publishing are beginning to employ increasing modularity. By enabling the mixing and matching of components, modularity exponentially increases the number of potential product configurations derivable from a given set of product technologies. In addition to yielding flexibility in product configurations, modularity also enables components of a product system to be upgraded without replacing the entire system — this is an extremely valuable attribute when the product technology is undergoing rapid change (Garud and Kumaraswamy, 1995).

However, modularity may also forfeit some advantages of integration. Some product components may deliver enhanced performance through optimization with other components of the system, and will lose some of their functionality through adaptation to a standard interface. The performance advantages of integration must therefore be balanced against the flexibility and compatibility advantages of modularity. Furthermore, modular systems erode a firm's ability to control the architecture of a product system (Henderson and Clark, 1990). Some have argued that this is precisely why Microsoft Windows has remained imperfectly modular — by limiting access to the 'hooks' that enable software to interact with Windows, Microsoft has retained a great degree of control over the architecture of software, and consequently retained greater market power. If a firm

already possesses a technology that is a dominant design in its market, that firm may gain greater market power by integrating other products with its dominant design. Such firms may wish to avoid the development of modular systems, and may fight the development and adoption of standard interfaces.

Inter-Organizational Linkages

A firm can also rapidly deploy its technology (or encourage production of complementary goods) through inter-organizational linkages such as exclusive contracts, alliances, joint ventures, and bundling arrangements.

“By simultaneously boosting both installed base and the availability of complementary goods, the firm can accelerate the self-perpetuating network externality cycle”

Contracts, alliances and joint ventures. Through contractual arrangements with distributors, complementary goods providers, and even large end-users (such as universities or government agencies), a firm can ensure that its technology is used in exchange for price discounts, special service contracts, advertising assistance or other inducements.

Nintendo, for example, uses a contracting strategy to build the availability of complementary goods for its game consoles. Though its game consoles are based on a protected, proprietary technology, Nintendo has fostered the proliferation of Nintendo games through exclusive contracts and 'sweetheart deals' with video game developers.

Microsoft used an exclusive contract arrangement to build its installed base of Internet Explorer. By the time Microsoft realized the importance of web-based software applications, Netscape Navigator already had a significant installed base lead. To catch up, Microsoft signed an exclusive contract with online-service provider America Online to rapidly deploy its own web browser, Internet Explorer.

Another well-known example is Matsushita, which used contracts and alliances to boost both the installed base and the availability of complementary goods of its VHS video recorder technology. Matsushita used both liberal licensing and aggressive marketing pacts with RCA and General Electric (and others) to deploy its VHS technology. Through effectively managing alliances, Matsushita was able to build a larger installed base of VHS video recorders and available movies, defeating rival Sony's Beta technology, even though Beta beat VHS to market and was considered by many to be a superior technology.

By simultaneously boosting both installed base and

the availability of complementary goods, the firm can accelerate the self-perpetuating network externality cycle. If the firm is unable to induce complementary goods producers to support its technology through such contracts, the firm may need to partially subsidize complementary goods production, or invest in the production of the complementary goods itself. Note that this is one of the areas where strategy under conditions of network externalities varies from traditional strategic imperatives: in general, the strategic management literature warns firms away from diversifying into areas that are beyond the scope of the firm's core capabilities; however in the case of a firm whose core technology requires complementary goods, it may be required to expand beyond such scope in order to ensure the survival of its core technology.

Bundling. A firm can also 'piggyback' on the success of a complementary technology that already has a large installed base by setting up a bundling arrangement with a provider of the successful technology (Eppen *et al.*, 1991). By providing its product in tandem with another product that is already in wide use, the firm can quickly get its technology into the hands of consumers. Even if consumers may have preferred to use a different technology, switching costs may prevent consumers from changing over. Furthermore, as consumers become familiar with the product, this familiarity increases the consumers' ties to the technology (for instance, through the cost of retraining) and may increase the likelihood of the consumers choosing this technology in future purchase decisions.

Bundling arrangements have proven to be a very successful way for firms to build their installed base and ensure provision of complementary goods. Consider, for example, Conner Peripherals (whose disk drives were bundled with Compaq's personal computers), Microsoft's MS-DOS (whose initial bundling with IBM lead to bundling arrangements with almost all PC clone makers, and also facilitated the later bundling of Windows with PCs), Iomega's Zip Drives (which are bundled with many desktop and laptop computers, giving it an installed base lead over 100 Mb floppy drives which had a backward-compatibility advantage), and Motorola StarTac (whose cables are bundled with Megahertz modems designed for wireless communication).

MS Windows 3.0 beat our Ensemble 1.0 product to market by about 6 months. Then Microsoft's practice of requiring OEM's to pay for bundling MS-DOS and Windows on 100% of their machines made it impossible for Geoworks to obtain a critical number of OEM contracts. Another factor was Microsoft's vast resources for promotion, development and marketing, compared to Geoworks' lesser availability of such resources. (Steve Main, Manager Technical Services, Geoworks)

We were able to get the technology out into the market

early to develop a standard. We were effective in soliciting software vendors to write to that platform to solidify the standard. Once you get it going, it's a snowball effect. The more applications you have available for a platform, the more people will want to use that platform. And of course, the more people that want to use that platform, the more software vendors will want to write to that platform. (B.J. Whalen, Product Manager, Microsoft)

Aggressive Marketing and Promotion

Firms can build their installed base through extensive advertising and promotion, including the use of penetration pricing and investment in consumer education.

Advertising is a powerful signaling device that may help a firm build both its *actual* and *perceived* installed base. Microsoft has been particularly successful in using product announcements and advertising to pre-emptively signal a market of its intention to capture a market, causing customers to postpone purchases until Microsoft's product is available. For example, in the early 1990s, a number of startup companies were competing to establish a personal digital assistant (PDA) standard. Several companies (including Go Corp., Momenta, and EO Corp.) had introduced products that were enthusiastically received at trade events. However, when Microsoft announced that it was entering the pen-based arena, many of the early customers withdrew their orders to wait and see Microsoft's products. Microsoft's previous experience in the computer industry was a strong indicator that if Microsoft entered PDAs, it would likely control the dominant standard and its products would have the greatest software compatibility. Furthermore, if a PDA had a Microsoft interface and software, it would capitalize on consumers' current training and experience with Microsoft products. In reality, Microsoft would not actually become serious about pen-based computing for several years, by which time Go, Momenta and EO had all failed due to a lack of capital.

The market developed much more slowly than we expected, causing our development costs to far exceed our earning potential...the announcement of Pen Windows by Microsoft caused the existing customers and the potential customers to stop their plans until they found out what Microsoft was doing. By the time it was clear that Microsoft was just dabbling in the market, the serious companies such as Go were desperately low on capital. (Bob McMahon, formerly of Go Corp)

Penetration pricing. Some products are sold below cost or even given away for free (as with Microsoft Internet Explorer and Netscape Navigator). Though the companies lose money in establishing their installed base, they do so in hopes of securing the standard and thereby reaping profits either through future price increases, or through the sale of profitable complementary products. For instance, Sony Playsta-

tions were introduced at a price significantly below cost in order to compete against dominant video-game console manufacturers, Nintendo and Sega. By 1998, Sony had brought the retail price of its consoles down to \$149. This price allowed it to be marketed through the mass discount store channel, and to tap a new market segment (Sony has gained a substantial adult customer base, in contrast to Nintendo and Sega, whose customers are predominantly males under the age of 18). Sony subsequently built a larger installed base than Sega, and garnered impressive royalties from games sold for the machines.

Consumer education. Marketing can also increase the rate at which new-to-the-world technologies are adopted by increasing customers' awareness and comfort level with the new technology. New technologies may require considerable investment in building a customer's awareness of the product. Companies introducing new technologies, therefore, often have to invest in marketing for the entire product category. This 'missionary' work may then be exploited by later entrants who do not bear as great of a marketing expense burden. Unfortunately, it may also be more difficult for companies that are introducing new-to-the-world technologies to obtain capital. Though it is often assumed that capital markets are perfectly efficient and that for every worthwhile project there will be an investor, this may not be true for new companies in emerging markets. When a *new technology* is introduced by a *new firm*, neither the technology nor the firm have experience or credibility with which to assure investors that the product will be successful.

The technology itself was naturally attuned to big, expensive machines, and people don't like to gamble lots of money on startups. (Bob Colwell, Director of IA32 Architecture, Intel Corp [formerly of Multiflow]).

This creates great uncertainty for investors, particularly if initial start-up costs are high. Furthermore, the payback period for emerging technologies may be too long to fit the portfolio profiles sought by investors. New technologies introduced by well-established companies, on the other hand, already have a capital base from which to draw. Furthermore, the previous success of the firm may provide the necessary assurance to investors that the project is

worth investing in (because the company has a good track record of choosing successful projects), or that even if the project is not successful, the investor will still be paid back (because the company can draw from the revenues of other products). Note that this provides a contrast to the argument often made that well-established firms suffer from excess inertia which puts them at a disadvantage in competing in emerging industries, or responding to generational shifts in products (Anderson and Tushman, 1990).

Because advertising and promotion can play a significant role in building an installed base, large firms may have an advantage over small firms. Large firms have more resources, enabling them to afford to spend more on advertising, and withstand longer periods of lower profits due to penetration pricing. Large firms also have more credibility, and presumably more absorptive capacity (Cohen and Levinthal, 1990). However, large firms may also have more inertia, or 'core rigidities.' The advantages of being *large* versus the advantages of being *new* act as opposing forces; whether the latter or the former are greater likely depends on (a) the resource intensity of the new technology (start-up and marketing costs, etc.), (b) the margin of improvement the technology offers to customers (products which provide very obvious advantages to consumers will be adopted sooner, and likely attract more investors, than products that have less obvious advantages and that may rely more on the credibility of the sponsoring firm), and (c) the degree to which the new technology builds on (or requires) previous experience and skill in related markets (thus leveraging the absorptive capacity and core capabilities of incumbent firms). This is summarized in Table 2.

Smaller firms can reap some of the advantages of the well-established firm by using interorganizational linkages to tap into a well-established firm's capital, marketing systems, credibility, and capabilities, in exchange for a share of future gains from the technology. For example, Conner Peripherals became a major player in the disk drive market through its alliance with Compaq Computers, and Lotus gained much deeper marketing pockets when it was bought by IBM.

Notes was a revolutionary technology, but there was no

Table 2 Advantages to Being a Well-established Firm in Introducing a New Technology

Advantages to being a well-established firm increased by:	Advantages to being a well-established firm decreased by:
High start-up capital requirements for producing new technology	Low start-up capital requirements for producing new technology
High marketing requirements of new technology	Low marketing requirements for new technology
Uncertainty about advantages of new technology	Technology provides very clear advantages over previous technologies
Capabilities (research and development, manufacturing, distribution, etc.) necessary for the technology are related to/build upon previously acquired skills and experience	Technology requires new-to-the-world capabilities

money to tell the public about it. I left Lotus about 3 months before IBM bought them. Since then, IBM has thrown a great deal of money at marketing Notes, and the results of that showed in the sales. (Rocky Oliver, Product Development Manager [formerly of Lotus])

Implications for Future Research

This article has argued that the size of the installed base and the availability of complementary goods regularly and predictably impact the likelihood of a technology being selected as a dominant design. The article further posits that the firm may influence the size of its installed base (and the speed at which it attains it) and the availability of complementary goods, through its distribution, alliance, and marketing strategies.

One of the most interesting aspects of industries in which technologies compete to become a standard, is that the dynamics of technology selection yield strategic implications that are different — if not antithetical — to traditional strategic management imperatives. For example, conventional strategic wisdom would suggest that if you develop a new and valuable technology, you should go to great lengths to protect it and prevent other firms from imitating it. If the technology is imitable, it will yield no competitive advantage. However, under conditions of network externalities, it may be in the best interest of a firm to diffuse its technology — encouraging rapid adoption and imitation, so long as the firm may still find a way to capitalize on creating the new standard. There are many other areas in which the strategy for winning a standards race requires a logic that is counterintuitive to conventional strategic management, including:

- ❖ whether the firm should be involved in the production of complementary goods;
- ❖ the optimal degree of vertical integration or ties to other manufacturers, customers, or distributors;
- ❖ optimal pricing and promotion strategies;
- ❖ the rate at which technology should be upgraded;
- ❖ the firm's involvement in coalitions or political or government groups, and many others.

Though this article has not developed an explicit causal model, the recommendations developed here implicitly posit a set of hypotheses about the factors driving installed base and the availability of complementary goods. Given the importance of these two factors in shaping technology adoption, further investigation of such a model is warranted. Future research should attempt to build a comprehensive and explicit causal model of installed base and complementary goods, and subject it to empirical test. In addition to looking at how firm strategies impact

installed base and complementary goods, research should attempt to identify the product attributes and economic and competitive factors shaping the rate at which installed base is attained, and how those factors interact.

Such a model should be able to answer such questions as, 'When is the margin of improvement offered by a technology sufficient to warrant protection rather than diffusion?,' 'What factors influence the optimal pricing strategies for product introduction under conditions of network externalities?,' 'When will the performance advantages of integration exceed the flexibility advantages of utilizing a modular product system?' and others. This article is only a first step in this direction; this is a rich and relatively untapped area for strategic management scholars. Hopefully this article will facilitate and inspire future inquiry in this area.

Notes

1. A dominant design is 'a single architecture that establishes dominance in a product class.' (Anderson and Tushman, 1990; Abernathy, 1978; Sahal, 1981)
2. Note, however, that because other consumers experience switching costs as well, the installed base may, in fact, be an indication that consumers tried the product first, rather than an indication that consumers judged the product favorably.

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