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Competing through Standards: DOS/V and Japan's PC Market

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Abstract

A series of normative rules have been developed for how to establish dominant product compatibility standards. These rules include the importance of complementary assets, multi-firm coalitions, having the first dominant design, and that standard success brings firm success. But the case of Japanese PC standards shows how it's possible to compete outside these rules. NEC followed conventional wisdom in establishing its proprietary PC-98 architecture standard as the dominant design: it was first with a Japanese MS-DOS system and aggressively courted Japanese software houses. Conventional competitive responses failed, including proprietary standards and multi-firm coalitions. The later IBM-led DOS/V standard undercut the PC-98's first-mover advantages and reshaped the market. However, the results remind us that standards success does not assure firm success.

Competition to establish product compatibility standards is one of the most crucial battlegrounds in high-technology markets. Ever since the IBM's 360-series locked most of the mainframe market into a single product line — despite whatever technical or cost advantages its rivals might offer — producers have sought to establish standards to assure long-term profits. The extraordinary profit margins sustained in recent years by Microsoft and Intel illustrate vividly the value of controlling a dominant technology standard.

Consumers' perceptions of such competition now color market outcomes. Remembering heated standards battles in VCRs and PCs, consumers today try to handicap standards competitions to pick the likely winner and avoid potential standards orphans. Once there is a clear perception that one standard will dominate, users join that standard's bandwagon and cement its dominant position.

Fearing defeat in such a battle of perceptions, firms rush to gain early credibility through huge investments intended to establish their product as the dominant industry standard. For example, in the current "browser wars," Netscape gave away millions of copies of its browser software while Microsoft bundled its own with the Windows operating systems: each hoped to control a major Internet standard.[1]

The assumption behind such aggressive tactics is that a well-established dominant standard is invulnerable. This perception colors the actions of incumbents—who milk their market for monopoly profits—as well as challengers, who avoid what they anticipate to be futile challenges. It also affects the decisions of those who make complementary assets, generically described as "software", but including pre-recorded music and video, not just the computer kind.

Standards are not perpetual: they can be and are displaced by technological progress. Usually, it's because the category itself becomes obsolete (e.g., Columbia's 33 rpm record), or due to declining markets,

such as IBM's mainframes and Digital's minicomputers.[2] Much more rare is the case when a long-established standard held by a profitable large firm is displaced by a competing standard *in the same product category.*

This paper discusses one such case, that of the Japanese personal computer market, where a seemingly invulnerable dominant standard was toppled in just a few years. Moving first to exploit the technological discontinuity of the 16-bit microprocessor, NEC used conventional tactics to establish its proprietary PC-98 architecture as the dominant standard for Japanese PCs. The PC-98 standard share exceeded 60% of the market for more than a decade, while its many challengers were stuck in single digits — exactly what we might expect from a successful dominant standard.

What was not expected was DOS/V, a new product standard from IBM Japan that in four years passed the PC-98 and forced even NEC to offer its own DOS/V machines. On the other hand, IBM did not expect that the stunning success of its DOS/V standard would leave its own market share unchanged, while enabling a competitor to double its market share in just one year. And few would have predicted that the net effect of DOS/V might be to hurt — rather than help — U.S. PC makers by increasing competition in their home market.

The case of how the DOS/V standard supplanted the PC-98 raises two general questions. The first is what enables a firm like NEC to hold its advantage for such a long period of time? The second is, under what conditions is such a standard vulnerable to competition? We'll first review relevant theories that have been developed for standards competition, then examine how those theories were applied in the case of Japanese PCs. Finally, we'll discuss how some little-understood caveats make a dominant standard like the PC-98 vulnerable to challengers.

The Race to Establish a Dominant Standard

In examining competition in the Japanese PC industry, we're concerned with the forces that shape competition between high-tech products based on competing product compatibility standards. These include not only computers (PCs, mainframes, workstations, videogame consoles) but also many products related to pre-recorded entertainment (record players, VCRs) and telecommunications (cellular phones). In all cases there are other complementary assets — such as prerecorded videotapes— that are shared between all products that adhere to the same standard (VHS VCRs) but cannot be used without modification by products of a competing standard (Beta VCRs).[3]

These classes of high-tech products are enabled by a discontinuous change in technology. A pioneering firm recognizes the opportunity and introduces the first product in such a category. Next, there is a period of considerable technological uncertainty as various competing products are developed based on this infant technology. Eventually, the opportunities and limits of the technology are recognized and most products adhere to a recognizably common set of design characteristics.

In most cases, there will be multiple compatibility standards that conform to this dominant design, so the next step is competition to establish the most popular standard: this standards competition is usually fierce, because once established, a dominant standard is rarely supplanted. When the winning standard is known, firms compete for market share and dominance — until the product category is made obsolete by another technological change.

In the case of the Japanese PC industry, the technological change was the invention of the microprocessor which enabled the personal computer. In Japan (as in the U.S.), the dominant design was established based on a 16-bit microprocessor, and the most popular standard was based on Intel's processor standard. This standard remained successful for more than a decade due to the advantages inherent to such incumbent standards.

We'll first look at the advantages that accrue to such successful standards, because they color the strategies used in all phases of standards competition. Next, we'll look at how opportunities are created by technological discontinuities and how competing products eventually stabilize around a common trajectory. Finally, we'll look at how this opportunity to create a successful standard based on technological change accelerates the natural impulse of many firms to pioneer new markets.

Advantages of Successful Standards

Standards competition adds a new dimension to product competition because of the role played by standard-specific complementary assets. These specialized assets make it difficult for a later entrant overtake a successfully established dominant standard, such as the IBM PC or NEC's PC-98, for two reasons. First, users face a high cost if they want to switch standards; second, users benefit by belonging to the largest network of similar adopters.

A user investment in standard-specific assets makes it expensive to abandon that standard in favor of another, so the customer is more likely to buy successive products that adhere to the same standard. Such user switching costs can be seen in camcorders or PCs (where users own software specific to a given

The other class of effect — positive network externalities — means that the more people who join a network of users, the more each user benefits.[5] The benefit is usually indirect, i.e., the larger the network, the more attractive it is to providers of complementary assets such as software. So if more customers buy Sega than Nintendo video game players, Sega owners generally will have a wider variety of video games available. The size of a network of existing users — plus the associated complementary assets — requires challengers to aggressively court existing producers of complementary assets, as 3DO and Sony did when they entered the video game market.

To overcome such switching costs and network externalities, manufacturers employ various strategies to make it easier for users to switch to their competing standard. Thus Microsoft's Internet browser automatically reads bookmark files created by Netscape's browser (reducing switching costs), while many digital cellular telephones in the U.S. are also compatible with the older analog standard (eliminating differences in network externalities). Sometimes products try to address both issues, as when Apple's PowerMacintosh and Digital's VAX minicomputer incorporated emulation modes to run software applications written for their own earlier (incompatible) processors.[6]

Switching costs are reduced while network externalities are increased by a group of related standards. Such a "modular" approach allows buyers to mix-and-match individual modules that work together because of well-defined interconnection standards. So a consumer can buy a home stereo using a CD-player, amplifier and speakers from different firms, just as companies assemble personal computer systems based on PC, monitor, software and printer from disparate suppliers.[7]

It should be noted that a standard's competitive success is often related to reasons that have nothing to do with standards.[8] These might include being first to market, having specific performance advantages, or being promoted by a company or companies with greater market power than their rivals; all three helped NEC with its PC-98 standard. In fact, real-world competition is so often confounded by a variety of differences that judging the pure effect of standards "lock-in" is impossible: for example, both Microsoft and Intel today have strong marketing and engineering advantages beyond the market share bandwagons of their shared "Wintel" architecture.

Technological Discontinuities and Dominant Design

New opportunities for standards competition are created by shifts in technology. As prior research has shown, this shift contains two distinct events — a *technological discontinuity* that eventually leads to

The first phase immediately follows such a technological discontinuity, which introduces tremendous uncertainty and a multiplicity of implementations into a given market. Eventually a dominant design is established which sets a benchmark combination of product attributes; development in the second phase focuses on a improving upon that benchmark.[9]

Many technological discontinuities are an entirely "new to the world" product or technological innovation. Others reflect the introduction of an existing technology to a new industry or geographical market. Or, they may come from an acceleration of the customary rate of change for an industry — what Intel co-founder Andrew Grove refers to as a "10X" force — much as the difference between a wave and a tsunami. In all cases, however, the discontinuity marks a paradigm shift or break in the basis of competition before and afterwards: Grove terms this a "strategic inflection point."[10]

An example of discontinuity caused by technological innovation can be seen with the microprocessor, which was originally invented for use in calculators but became the basis of the personal computer. Such a new product technology can eventually transform the way that producers and users view existing products. But there is usually a long period of uncertainty, of false starts and trial and error, between invention of a technology and a clear approach for its application emerges in the form of a dominant design. In the case of the microprocessor, it was 10 years from the Intel 4004 until the dominant design for personal computers, the IBM PC; for graphical user interfaces (GUIs), 11 years from the Xerox Alto to the Apple Macintosh.[11]

As the latter example suggests, there is no guarantee that the firm that invents the technology will be the one to establish the dominant design. Also, a dominant design (the first product with the right mix of attributes) is not the dominant standard (the standard selected by the most users), and so the firm that establishes the dominant design (as the Macintosh did in GUIs) may be unable to establish a dominant standard (in this case, Microsoft's Windows) . However, creation of dominant designs has often corresponded to ownership of dominant standards, as with the IBM 360 mainframe, DEC VAX-11 minicomputer, IBM PC, or Netscape's browser.

Pioneer Advantages and Disadvantages

How do technological discontinuities, dominant designs and the advantages of successful standards relate to the desire of firms to pioneer new markets? The technological discontinuity creates a new market opportunity which eventually results in a dominant standard. As a result, firms are wary to give rivals too much of a head start (lest it become insurmountable) and compete to establish the dominant design — the

of use. NEC's PC-98 is an example where the dominant design — the first 16-bit PC to support the Japanese language — went on to become its market's dominant standard.

The imperatives specific to standards competition combine with more general tendencies by firms to be the "first mover" or "pioneer", in hopes of gaining certain advantages available to early entrants.[12] Three types of pioneer advantages are provided by increases in firm capabilities or barriers to later entry:

- *Technological leadership.* A pioneer often gains from learning curve experience with a new technology, as Intel did in microprocessors. In industries where intellectual property protection is an important factor, the leader may also establish legal barriers that slow followers, as Intel did to protect its franchise in x86 microprocessors.
- *Pre-emption.* The pioneer can discourage followers by pre-empting scarce assets, such as suppliers, distributors or partners. For example, Nintendo's early success with game consoles won it support from the best videogame designers on both sides of the Pacific.
- *Lock-in.* Early entrants benefit when products have high switching costs that "lock-in" customers and suppliers, as is common with tightly-controlled standards.

Pioneers may also take advantage of the psychology of buyers, who often stick with the first brand that performs adequately. Early entrants can also shape buyer perceptions of the category, so that later entrants are judged by their deviations from the pioneer; this prototyping effect worked for Compaq in transportable computers and for Netscape in Internet browsers. The picture is somewhat different for more knowledgeable industrial buyers, but they also tend to dismiss a late entrant as merely a "me-too" product.[13]

Despite these powerful advantages, there are limits to the advantages held by the first entrant.[14] Prior to establishment of a dominant design, market entry carries high risks because radically new products may fail and hurt the reputation of the company and even the product category; late entrants avoid such trial-and-error efforts and gain by watching the mistakes of the pioneers. Knowledge and workers leak from the leader to competitors; in the U.S., such leakage can even be used to establish competitors as unintended spin-offs of the pioneering firms.[15]

Between and within standards, a major focus of late entrants is co-opting the pioneer's complementary assets. Many companies established to make Apple II hardware and software were courted by IBM, and Apple in turn courted IBM PC suppliers when it launched its later Macintosh. IBM's PC clone competitors built upon the extensive global supplier base that was developed by IBM at considerable cost; clone makers

Product categories created by new technologies also share certain risks common to other high-growth markets. Key success factors often change as the market matures, as when an industry inevitably shifts from being technology-driven to distribution-driven. High growth markets attract many competitors, decreasing price margins needed to sustain a technological advantage and threatening the inevitable shake-out.[16]

Finally, one can never underestimate incumbent inertia. A pioneer's tendency towards complacency is exacerbated when substantial visible barriers to entry protect a dominant standard for an extended period. Also, owners of a dominant standard are particularly reticent to cannibalize that standard, given the risk of undermining the barriers that shielded that standard (and high profits) in the first place.[17]

Heuristics for Establishing Dominant Standards

What we know about standards, technological change and pioneer advantage can be used to deduce four heuristics generally used by high-tech firms competing through standards, as will be shown in the Japanese PC industry.

1. Winner is first to dominant design

Once a technological discontinuity enables a new form of competition, firms race to establish their standard as the basis for the dominant design, as IBM did with the IBM PC. Where once the sought-after advantages were measured in years, recent battles related to the Internet and electronic commerce measure leads in terms of months or even weeks. This heuristic drives firms to establish their standard at any cost, using a penetration pricing strategy to buy market share — as demonstrated by the extreme case of free pricing of competing Web browsers from Netscape and Microsoft.

2. Complementary assets determine winner

Received wisdom holds that the availability of complementary assets was one of two determining factors in the great standards battles of the 1980's: VHS vs. Beta and IBM vs. Macintosh. In both cases, the winning standard accumulated a superior variety of "software" that provided positive network externalities while increasing switching costs away from the dominant standard.

3. Multi-firm coalitions beat individual firms.

The other lesson assumed from the VHS and IBM PC victories was the importance of multi-firm coalitions. Both Sony and Apple, it is thought, could not survive as solitary standards champions against superior market power, distribution and credibility of coalitions legitimated by multiple partners. This

tendency is exacerbated by user fears of choosing a losing standard — since users know (or learned from owners of a Beta VCR) about the high switching costs if their initial choice proves to be wrong.[18]

4. Standard success leads to firm success

These three tactics are used by firms to promote their standards in the belief that a winning standard will directly lead to greater firm profits. For example, having the Intel 8086-series adopted as part of the leading PC standard means that Intel has three-fourths of the microprocessor market, while the success of VHS gave Matsushita (and its JVC affiliate) more than 40% of the global production of VCRs.[19] In cases where standards are protected by strong intellectual property rights, the standard-setter can expect to appropriate the lion's share of the profits, as in the Nintendo, Sega and Sony proprietary video game systems. This is less likely where intra-standard competition is possible (as in IBM-compatible PCs) or even actively encouraged (with VHS or Sun's SPARC microprocessor), but the standard-setter enjoys certain benefits by virtue of shaping the rules of competition: the cost is vulnerability to intra-standard competition.

Conclusions

These are not the only heuristics that can be derived from theories and practice of standards competition, but they are ones particularly relevant to PC standards competition in both the U.S. and Japan. In Japan, the pattern for all four heuristics was reversed in the shift from the PC-98 to DOS/V. The reasons for such reversals provide unfamiliar insights into the nature of standards competition.

Japanese PCs in the 1980's: PC-98 as the Dominant Standard

In the personal computer industry, the same rules of standards competition applied to both the U.S. and Japan, but different strategies were employed in the two markets. Despite this divergence, the U.S. standard directly influenced Japanese standards competition — both initially with the PC-98, and later with its DOS/V challenger.

Global Dominant Design: IBM PC

In the U.S., the dominant design for personal computers was established by IBM with the August 1981 launch of the IBM PC. The IBM PC took advantage of a major technological discontinuity — the shift to 16-bit microprocessors — that provided both faster computers and allowed for larger, more complex software. This discontinuity nullified the head start of various (mutually incompatible) 8-bit PCs, such as the Apple II

Two other factors helped establish the IBM PC as the dominant standard. IBM's name and reputation immediately gave the PC credibility as a mainstream business tool; as a result, IBM's share of global PC sales jumped to 17% by 1985.[20] Meanwhile, the long-term growth of the IBM PC standard was fueled by its modular open architecture, which enabled competition not only among a wide variety of complementary products, but also direct competition to the IBM PC in the form of PC "clones."

This spurred the growth of a vast supply network of firms competing in every type of hardware and software, drawing new entrants to each and expanding the market. Strong competition drove continuous price/performance improvements in hardware, while software producers were attracted to a growing user base, increasing the value of the standard and locking in users. Meanwhile, switching costs, network externalities and economies of scale of the IBM PC standard enabled it to withstand its only serious challenge from Apple Macintosh, which held a decade-long advantage in ease-of-use. The net result was that the IBM PC became the standard for most of the industrialized world.[21]

The wide range of producers cemented the IBM PC standard, but did not help IBM itself. Widespread cloning was a symptom of the loss of control by IBM, which failed to contractually restrict its key suppliers (Intel and Microsoft) from selling to other PC makers. IBM's last defense — provided by intellectual property law — fell when clone makers imitated low-level software contained in the IBM PC without infringing on IBM's copyrights. After that, Microsoft and Intel controlled the two vital and defensible technology standards, the operating system and microprocessor — symbolized by the changing name of the standard from "IBM-compatible" to "Wintel."

So, unlike its success in mainframes, IBM's success in establishing the PC standard did not assure it global leadership: in 1994, IBM was passed in worldwide PC sales by Compaq, the surviving first follower in the PC clone business.

The major exception to the success of the IBM PC standard was Japan. There, an incompatible variant of the IBM PC — NEC's PC-98 — survived as the dominant standard for more than a decade, protected by high barriers to entry.

Japanese PC Industry: High Barriers to Entry

While the IBM PC standard quickly spread to most of the world, a different type of standards competition took place in Japan. NEC carried out a highly successful strategy to establish its PC-98 as the dominant standard, and for about a decade, enjoyed the benefits of owning that standard.[22]

Because Japan has been the world's second largest market for computers for two decades, one would also expect it to be a large market for personal computers. But throughout the 1980's, PC penetration remained comparatively low, in part because high entry barriers reduced competition and kept prices high.[23] These barriers centered on an oligopolistic industry structure and major technical problems of Japanese language computing.

Problems of Industrial Structure

The Japanese computer industry is dominated by large vertically-integrated Japanese electronics companies. These companies produce telecommunications switches, mainframe computers and semiconductors, and many are also leading producers of consumer electronics.[24]

Three Japanese companies — Fujitsu, Hitachi and NEC — account for 60% of the Japanese market for mainframe computers, as well as a major share of the world market. The other large maker of mainframe computers is second-ranked IBM Japan. Despite tensions with Japanese rivals who benefited from government-sponsored technology efforts, IBM Japan had spent 60 years moving closer to its rivals to overcome suspicions it faced as a foreign-owned company.[25]

These four firms were well-situated to develop and sell personal computers for business customers in Japan, as was Toshiba, Japan's second largest semiconductor maker (after NEC). More importantly, their large size, world-class technologies and strong market positions made it difficult for other firms — domestic or foreign — to compete in the Japanese computer market. While small startup companies could enter the U.S. PC market quite easily, the barriers to entry were much higher for newcomers in Japan, partly because of the high costs of establishing distribution channels and partly because of the conservative buying habits of Japanese corporations.

Technical Challenges of Japanese Language

Offering computing products for the Japanese market raises two broad classes of technical changes for U.S.-designed computer hardware, operating systems and application software. These issues had already existed for mainframe and minicomputers, but were magnified by the personal computer.[26]

One is a basic problem of translation — of software, documentation, packaging and marketing materials — which is time-consuming but technologically straightforward. In the Americas and Europe, most countries use variations of the Roman alphabet, so language is a small entry barrier for makers of PCs and printers,

The second problem in Japan is support for the thousands of characters required for East Asian languages based on Chinese characters. The computer must store and display many more characters (6,000 for Japanese vs. 200 for European languages) at higher resolution; it must also provide a way to input those characters: the solution adopted was the front-end processor (FEP), which uses complex dictionaries for phonetic input of the *kanji* characters.

Both input and font display are fundamental requirements for a computer architecture, posing a substantial entry barrier to the Japanese PC market. They also required major changes to printers and application software, limiting the availability of imports from the U.S. and Europe.

Beyond acting as a barrier to entry, the Japanese language was related to two other factors that kept early market penetration rates low. Its complexity prevented the general use of mechanical and electro-mechanical typewriters, meaning few Japanese had keyboard skills until PCs and *wordpro* electronic typewriters became popular in the 1980s. Also, early PCs lacked the computer power necessary to handle the more demanding Japanese character display: not until the introduction of PCs based on the Intel 386 (1987) and Intel 486 (1990) did performance for ordinary word-processing become acceptably fast. (See Table 1) As a result, office automation minicomputers remained popular in Japan longer than elsewhere.

(Here insert Table 1: Event history in U.S. and Japanese PC markets)

Japan's Dominant Design: NEC PC-9801

NEC's approach to PCs was unique among the four major Japanese computer makers. The other three — Fujitsu, IBM Japan and Hitachi viewed the PC as a supplement to their mainframe business, marketing it primarily as an access terminal for large computers while trying to avoid cannibalization of mainframe sales.

As the smallest of the top mainframe vendors, NEC had less concern about cannibalization and recognized the importance of the PC earlier, focusing on an opportunity its competitors missed. Although Hitachi and Sharp actually introduced PCs earlier, NEC surpassed them by establishing a firm market position built upon its chain of retail microcomputer stores. Its 8-bit PC-8001 held around 44% of the Japanese PC market from 1980-1982.[27]

NEC was the first Japanese firm to respond to the U.S. 16-bit dominant design, unveiling its PC-9801 in October 1982, only 14 months after the IBM PC and a year before major Japanese competitors. Based on NEC's own Intel-compatible processors, the PC-98 architecture differed from U.S. PCs in that the computer

version of Microsoft's MS-DOS operating system. NEC held 80% of the 16-bit market for several years; despite competition from new entrants, its share remained above 50% until the mid-1990s.

NEC built upon its first mover advantage by following a textbook strategy for establishing a dominant standard based on complementary assets.[28] In addition to advantages carried over from the PC-8001 (including its retail stores), NEC moved aggressively to promote development of the essential complementary asset — PC-98 application software. By distributing detailed specifications and free computers to third party developers, by 1986 it had won the widest selection of application software, including the best-selling word processor (Ichitaro) and spreadsheet (Lotus 1-2-3).

By 1990, NEC had 1,800 vendors selling 11,500 packages of PC-98 compatible software.[29] NEC's control of complementary assets was magnified by the scarcity of a key resource: skilled Japanese programmers. Software either had to be developed domestically from scratch, or, because of the incompatibility of Japanese PCs with the global standard, extensively rewritten for the Japanese market. Given the shortage of experienced programmers, exacerbated by the fragmentation of the market between multiple standards, it was natural that developers concentrated their efforts on the most successful standard, the PC-98.[30]

Competitor Response

NEC was the first of many companies to develop proprietary extensions to the IBM PC standard to support the Japanese language. Others included Fujitsu, IBM Japan, Hitachi and Toshiba: each was incompatible with each other, with the dominant PC-98 standard, and with the IBM PC standard sold around the world. None of NEC's competitors ever managed to gain more than a 15% market share in Japan. As a consequence, they were unable to attract the range of application software found on the PC-98.

Several joint attempts were made by rival firms to dislodge NEC from its PC position, the most serious being the "AX" version of the PC/AT standard proposed by 19 Japanese companies. However, AX failed to gain market share, in part because leading supporters (Sanyo, Sharp, Mitsubishi, Oki, Kyocera) did not include any major PC makers.

Other than IBM Japan, the only other foreign-owned company with measurable PC market share in the 1980's was Apple Japan. Apple sold a version of its proprietary Macintosh product, which earned a niche position in the graphics arts markets based on ease of use and the availability of U.S.-developed graphics software packages.

Finally, one firm — Seiko Epson — decided not to compete with PC-98 but to emulate it. Having earlier developed successful 8-bit laptops, it announced the first NEC-compatible laptop in 1987 as well as desktop "clones." NEC sued for copyright infringement, but the two firms settled out of court; Seiko's strategy of producing clones at a slight discount eventually helped solidify the PC-98 standard.

Market Positions, 1991

By 1991, the PC-98 standard had nearly 60% of the market, most of that held by NEC, the market leader in 16-bit PCs since 1982.[31] The other PC-98 maker, Seiko Epson, was second, closely followed by three other firms — Fujitsu, IBM Japan and Toshiba — with incompatible Intel-based PCs. The remaining 18% was split between a variety of firms, including the various members of the AX consortium (which together held less than 5% share; see Table 2). Annual sales remained virtually flat from 1990 to 1993, ranging between 2.1 and 2.5 million units; by comparison, U.S. sales increased from 9 million to 14.5 million during this period.

(Here insert Table 2: 1991 Japan PC market share)

Japan's PC penetration remained comparatively low for a major industrialized country, at only 8.7 PCs per 100 people in 1994, compared to 28.4 for the U.S. Why? There were several major reasons. One is that PC prices were high, roughly double that of the U.S. Secondly, the DOS-based interfaces of PCs were hard to use, exacerbated by limited white collar keyboard skills. Finally, sales during the 1990-1993 period suffered from an ongoing recession following the speculative "bubble economy" of the late 1980's.

Competitive Analysis, 1991

The success of the PC-98 during the 1980's supports two of the earlier heuristics for standards competition — which were also supported by the success of the IBM PC in the U.S.:

Winner is first to dominant design. As in the U.S., the winning Japanese standard was the first to establish a dominant design.

Complementary assets determine winner. Again, as with the IBM PC, the PC-98 maintained its market position through an overwhelming array of complementary assets, including application software, distribution channels, support and maintenance organizations.

For the two remaining heuristics, the PC standards battles in Japan and the U.S. had differing results:

Multi-firm coalitions beat individual firms. This was true in the U.S., where the largest number of

the dominant standard controlled by a single firm — NEC's PC-98 — and lost. This suggests that having many large firms in a standards coalition is neither necessary nor sufficient for success.

Standard success leads to firm success. Unlike IBM, by establishing the dominant standard NEC was able to garner the majority of both PC sales and the associated profits; one estimate said that NEC's PC sales accounted for 40% of the parent company's total 1991 profits.[32]

In 1991, NEC had a greater market share than its next four competitors combined. Protected both by the inherent advantages of a dominant standard and also specific barriers to entry in the Japanese market, NEC profited greatly from the PC-98 standard. However, the high prices and low market penetration suggested that NEC was vulnerable — if these advantages could be overcome by competitors.

The DOS/V Revolution

For NEC's prospective challengers, incremental improvement would not suffice because NEC held all the high cards. Instead, it was the ideal opportunity for what strategist Gary Hamel refers to as "strategy as revolution," or overturning the old industrial order in favor of the new.[33] That revolution came — enabled by the DOS/V computer architecture — albeit through a more serendipitous process than Hamel advocates. By 1995, DOS/V had replaced the PC-98 had the leading standard and NEC itself was forced to offer DOS/V products. The PC-98 weaknesses included low market penetration, an unexpected technological discontinuity and NEC's limited control over its own standard; it was toppled by a rival standard that successfully leveraged global economies of scale.

Development of the DOS/V Standard

What is DOS/V? It is a software-only solution to the Japanese language problem, replacing the combination of hardware and software used by the PC-98 and most of its rivals. Its main advantage was that it ran on the same global-standard IBM PC-compatibles sold by IBM, Toshiba and Compaq in the rest of the world, thus allowing these makers to apply global economies of scale to reduce their Japanese-market costs.[34] As a side benefit, it also ran U.S. or European software without modifications (albeit with English menus).

DOS/V was developed initially by IBM Japan.[35] It would be nice to say that IBM Japan sought to reshape the PC market with DOS/V. But the firm's initial goal was reducing its development costs by using the same PCs worldwide — the sort of incrementalism Hamel decries rather than the considered revolution

It would also be nice to say that DOS/V was an innovative breakthrough. But the software-only concept mimicked Apple's approach to the Japanese market since the first KanjiTalk Macintosh in 1986. It was also the approach used by PC-compatible machines in smaller or poorer Asian markets that would not support customized hardware. In effect, DOS/V liberated companies from a flaw in the dominant design: the PC-98 included hardware modifications to support the Japanese language, and all subsequent Japanese makers of Intel-based PCs (including IBM Japan) had followed suit.

Transforming the Marketplace, 1991-1995

Launching DOS/V

DOS/V was pre-announced by IBM Japan in Oct. 1990, and IBM Japan and several other firms shipped the first DOS/V-based PCs the following year. To institutionalize support for DOS/V, IBM Japan formed a new consortium (the Open Application Development Group, or OADG) in March 1991. IBM transferred to OADG the necessary marketing and technical expertise to support DOS/V, which had won the support of 23 hardware and software makers by the end of 1991. Toshiba, Sanyo and Canon joined that year, shipping DOS/V machines along with several other non-OADG firms (including Compaq, Dell and Packard Bell).

Of NEC's major rivals, IBM Japan unequivocally backed DOS/V from the beginning, as did the foreign makers (except Apple) and the minor market players, which had nothing to lose. The second major PC maker to join was Toshiba, which saw the same benefit as IBM Japan — leveraging its much larger overseas sales to reduce production costs for the Japanese market.

The other major computer firm, Fujitsu, publicly fought DOS/V in an attempt to maintain support for two incompatible series of Intel-based PCs, the corporate FMR and consumer/education-oriented FM Towns. Then in October 1993, it switched sides, announcing its new DOS/V compatible FMV series. In late 1994, even Seiko Epson announced its shift from PC-98 clones to DOS/V, which accounted for the majority of its 1995 sales.

The support of major PC makers and explicit attempts to court software developers enabled DOS/V to overcome its early lack of software. By 1994, DOS/V was compatible with more than 5,000 software packages — quite an increase in four years, though still only one-third the number available on the PC-98.

New Entrants Spark Price Competition

Many smaller Japanese PC makers joined the OADG in 1992, including most of the former members of

including five major U.S. firms—Compaq, Dell, DEC, Gateway 2000, and Packard Bell—as well as Acer (Taiwan) and Olivetti (Italy)

To gain market share, Compaq chose to compete on price, leading to what was referred to as the "Compaq shock" of 1992.[37] Shaking up an oligopolistic price system in which other firms generally matched NEC's high prices, Compaq introduced new PCs at prices closer to U.S. levels. Other competitors also predicted their prices would hold, but were proven wrong as all (including NEC) were forced to address Compaq's prices — particularly since consumers had become much more cost conscious during the post-bubble recession of 1991-1994.

NEC tried to rebut the DOS/V challenge by claiming that the PC-98 was faster because it used hardware to support Japanese characters. But any distinction between PC-98 and DOS/V was soon blurred further by a strategic decision by Microsoft.

Windows 3.1: An Unexpected Technological Discontinuity

In addition to IBM's introduction of DOS/V, the other major factor reducing entry barriers and NEC's product differentiation was the increased modularity in the Japanese version of Windows 3.1.

In Japan as in the U.S., it was not until version 3.0 that Windows had a significant impact: even so, 3.0 was purchased on only about 10% of the Intel-based PCs sold in 1991 and 1992. Windows 3.1, introduced in May 1993, was much more popular for two reasons. First, (like its U.S. counterpart) it corrected most of the serious problems in the previous 3.0 version. More significantly, Microsoft made a strategic decision to introduce a single architecture for all MS-DOS systems: PC-98, DOS/V, and other DOS-based systems like Fujitsu's FMR. This approach continued with Windows 95, where Microsoft was able to reduce the Japanese translation lag to only three months and capitalize on the spillover of its US Windows 95 marketing blitz.

For both Windows 3.1 and Windows 95, application software written to support Japanese Windows could run on all Windows-based PCs. Rivals successfully argued that the PC-98 had no functionality advantages under Windows. Meanwhile, the shift in the market to Windows applications eliminated the advantage NEC had in its large library of DOS-based PC-98 software. NEC's was still aided by its vast distribution channels, close ties to corporate users and strong brand recognition, but those even those strengths would not be enough when NEC was challenged by a competitor with comparable assets: Fujitsu.

Fujitsu Shock

The end of the recession and the "Compaq shock" helped the market grow 50% from 1992 to 1994. But it was not until a second round of price-cutting — the "Fujitsu shock" of 1995 — that the market exploded, with sales increasing 60% in just one year.[38]

Sales were helped by growing consumer interest prompted by the "multimedia" fad in 1994 and Internet fever in 1995 (which in turn were fueled by inflated rhetoric on both sides of the Pacific about forthcoming "information superhighways.")[39] PC makers responded by designing machines for the untapped home market that featured CD-ROM drives and stereo speakers.

However, the biggest impact came from the "Fujitsu shock", when Fujitsu cut prices below even the low-priced imports. Competitors charged that by losing $200-500 on every PC sold, Fujitsu was buying market share; Fujitsu attributed its losses to long-term investments in distribution that could not be amortized over short-term sales.

But no one argued about the results. While Compaq's price cuts had only a minor impact on the market — 3% of the market after three years — Fujitsu's were another story. It nearly quadrupled its sales in one year, selling almost 1 million PCs in 1995, and its market share more than doubled to 17.5%, second only to NEC; it also grew the overall PC market at the same time (Figure 1).

(Here insert Figure 1, sales of PCs in Japan, 1990-1995)

Why did Fujitsu suddenly shift from a sleepy also-ran to the fastest-growing Japanese PC maker? The urgency came from the declining mainframe market, where it was the leading Japanese producer. About 40% of the company's computer revenues came from mainframe products in 1992 — much higher than for NEC, Hitachi or Toshiba.[40] So when Japanese mainframe production fell 40% in two years from its 1991 peak, Fujitsu fell from a ¥12 billion profit in 1991 to its first-ever losses, totaling ¥33 billion in 1992 and ¥38 billion in 1993.

Fujitsu confronted the long-term decline of mainframes and the increasing importance of PCs by cutting prices, mobilizing its large distributor network and ramping up production in an all-out bid for market share. It cut costs and increased volumes by turning over production of lower end machines to Taiwan's Acer, and used its increased efficiencies to expand from domestic to global markets.

How did NEC respond to relentless cost pressure from its new rivals? First, it shifted procurement of many PC parts from Japan to Southeast Asia, particularly in 1995 when the dollar dropped to 80 yen to the

dollar. NEC increased the fraction of imported components from 20% in 1992 to more than 90% for desktop PCs shipped in late 1995, and even announced plans to move PC design to its Hong Kong subsidiary.[41]

At the same time, NEC took advantage of the financial troubles of a low-cost U.S. producer of PCs, Packard Bell, by buying effective control of the firm in 1995 in a complex three-way transaction involving Machines Bull of France.[42] NEC merged all non-Japanese PC sales with Packard Bell in July 1996, and in October 1996 announced plans to import DOS/V machines from the U.S. under the "Packard Bell-NEC" brand name. NEC's decision was a tacit admission that the shift to DOS/V was unstoppable, and that it needed to offer DOS/V products.

Results of the DOS/V Revolution

Winners and Losers

Three firms enjoyed the full benefits of the DOS/V revolution:

- *Microsoft* gained sales, not only because increased PC sales sold more operating systems, but also because the use of the IBM PC standard made it easier to adapt its U.S. applications to the Japanese market. Its sales increased faster than any of the next four largest PC software makers in the Japanese market.[43]
- *Intel* was a member of OADG and supplier of microprocessors to every firm save Apple, thus participating in the growth of the Japanese market; like Microsoft, it has no serious competitors.
- *Fujitsu* quickly exploited the DOS/V market opportunity to neutralize NEC's early lead, and was also ready with increased capacity when the market exploded in 1995. Its aggressive shift to DOS/V also enabled it to offer attractive products for the global PC market, something it could not even consider a few years ago.

As any economist would have predicted, consumers also benefited from increased competition and lower prices, which now matched international levels. Many new users moved to adopt PCs, develop networks, and connect to the Internet.

Not surprisingly, the losers were the two firms wedded to the PC-98:

- *Seiko Epson* was the biggest loser, dropping from being a major producer to largely irrelevant. It lost its position as a low-priced solution when DOS/V opened the market, and lacked both the expertise and the global economies of scale to match the low costs of the foreign producers, or the newly-revitalized Fujitsu and NEC.

- *NEC* lost market share, market dominance and its profit sanctuary, while it faces mammoth problems reviving the struggling Packard Bell and Zenith Data Systems while to integrating three production networks into one. Still, NEC's sales more than doubled from 1993 to 1995; by offering low-end DOS/V computers through Packard Bell, it may be able to continue a slight price premium for PC-98. Meanwhile, any cost reductions help its efforts to expand PC exports.

The results for the other three major PC producers are less clear. IBM Japan was successful in reducing its costs and its sales increased threefold from 1993 to 1995, but it failed to appreciably increase market share. Toshiba lost market share in Japan, but, like IBM, it gained from producing one PC design worldwide; meanwhile, its global market position is improving, jumping from 8th to 5th in mid-1996. Apple saw its sales increase 650% (and share increase fivefold) from 1990 to 1994, but was unable to sustain that growth due to executive blunders in the U.S. and the concomitant concern about its future.

(Here insert Table 3: Japan and global market shares of major firms)

Unintended Consequences: New Entrants in the U.S. Market

Foreign makers new to the Japanese market made only limited headway. Compaq went from no sales in 1991 to 3% market share in 1994, and gained 42% of the lucrative PC server market in 1995. However, its share plateaued when it was unable to respond to Fujitsu's pricing in 1995, while it lost its leading position in servers to NEC in 1996.[44] Dell, Acer and DEC were unable to match even Compaq's limited success.

Even worse, foreign DOS/V challengers unintentionally widened the geographic scope of competition. Various Japanese firms have entered (or re-entered) the U.S. market, and, except for NEC, are doing so using hardware designs sold in Japan for use with DOS/V. Fujitsu, Hitachi and NEC hope to establish their positions using laptops, while Toshiba seeks to expand from laptops to desktops and Sony seeks to use the home market to establish its first successful computer product.

(Here insert Table 4: Global revenues for leading PC makers)

While IBM and Compaq saw Japan's PC-98 standard as vulnerable to an outside challenge, a few foresaw that increased domestic competition would ultimately improve the efficiency of Japanese makers and their PC exports. However, one analyst noted in 1992:

> Longer term, IBM's and Apple's success in Japan could make Japan a stronger competitor in PCs. The Japanese computer industry will never admit it, but the tradition of closed architectures and high hardware and software prices has been a disaster for Japan. Proportional to population, Japan's installed

> U.S. in every PC industry trend — from networking and downsizing to the growth of sophisticated packaged software. By shutting itself off from the world, Japan was never able to build much of a personal computer export industry.[45]

U.S. firms may take comfort from past exaggerated predictions of Japanese success which assumed Japanese electronics firms would triumph in PCs as they had in consumer electronics. One such prediction came from Intel's Andrew Grove, who in 1990 forecast that Japanese companies would capture over 40% of the worldwide PC market by 1992, with U.S. companies' share falling to 38%.[46]

At the same time, Japanese PC makers have already improved their technical and marketing proficiency based on lessons learned in Japan from the DOS/V challenge. Their new offerings in the U.S. market are bound to cost existing firms both market share and profits, particularly in the notebook market. However, the ultimate test for both U.S. and Japanese makers will not be decided in their respective home markets, but in the overall global market.

Lessons and Implications

Lessons

Evaluation of Standards Heuristics

The success of DOS/V challenges several assumptions about standards contests, such as the belief that an established standard cannot be defeated except through a major technological discontinuity, such as the shift from mainframes to PCs. NEC followed the standards book to establish and defend the PC-98 as the dominant standard, yet it lost that dominance in only a few years.

Three heuristics for standards competitions that had held in the earlier PC-98 era did not hold in the competition with DOS/V.

- *Winner is first to dominant design.* As we might have expected, the dominant design — the PC-98 became the dominant standard as well, but it lost that dominance after a decade to DOS/V.
- *Complementary assets determine winner.* The PC-98 built a strong advantage over its Japanese rivals, but it was surpassed in hardware by the global PC standard, while the shift to Windows nullified its software advantage.
- *Standard success leads to firm success*. For NEC, the success of the PC-98 brought firm success and its decline has cost it profits and influence. However, in originating the new dominant standard in

Japan, IBM repeated its pattern of the U.S.: in both cases, surrendering market leadership to intra-standard rivals.

Meanwhile, the fourth heuristic — that multi-firm coalitions beat individual firms — did not hold true in the 1980's with the AX coalition, but was affirmed in the 1990s with DOS/V. Both coalitions included large, powerful Japanese firms, but DOS/V (unlike AX) included those rivals with established PC competencies and market positions.

PC-98's Latent Vulnerabilities

Why did the Japanese PC case have such an unusual outcome? Several latent vulnerabilities of the PC-98 were successfully exposed and exploited by its challengers:

- *Low market penetration.* A dominant standard benefits from the high switching costs for leaving that standard, but these costs are only borne by those who have already adopted the technology. New users are not faced with sunk investments and can easily adopt an attractive new standard.[47] This reminds us that even a dominant standard is vulnerable in markets with low penetration rates.
- *Divergence from global standards.* Dominant standards benefit from economies of scale, which the PC-98 enjoyed in the Japanese market. DOS/V reduced hardware costs by drawing on a larger, more efficient global production network that supported the IBM PC. Meanwhile, the compatibility of DOS/V and Windows 3.1 (J) with global standards widened the variety of software imports.
- *Failure to Control the Standard.* Like IBM, NEC eventually lost control of its own standard. Its original advantage was based on its own microprocessors and a proprietary version of MS-DOS, but it was forced to switch to Intel chips while DOS/V and Windows made obsolete its MS-DOS advantage. NEC could not prevent IBM from introducing DOS/V, nor could it keep Microsoft from making Windows 3.1 compatible with both the PC-98 and DOS/V.

Discontinuities in Technology are Context-Dependent

We tend to think of technological discontinuities only in terms of the underlying technology, ignoring the dependency on specific market conditions. If we contrast the shift from MS-DOS based applications to those designed for Microsoft Windows between the U.S. and Japan, we can see how the same technological change may be an incremental change for one market segment, but a discontinuity for another. In both countries, Windows changed the application software competition, requiring new applications to provide the

ease of use inherent in the graphical interface and rendering obsolete many existing software competencies; market leadership shifted between the DOS-based and Windows-based application vendors.

For PC makers, Windows had negligible impact on PC makers in the U.S., but had a tremendous impact in Japan. Under DOS, the PC-98 had the largest library of available applications, which were incompatible with Intel-based PCs. But when Japanese users sought applications for Windows, the same applications worked across all Intel-based platforms, obsoleting one of NEC's major complementary assets, its large DOS software library.

So the effect on switching costs was thus the same in both countries — in both cases, users had to shift from DOS to Windows applications. But the impact on network externalities was different — IBM PC clones all remained within the same network (of compatible applications) with DOS and Windows, while in Japan, Windows merged multiple networks into one, nullifying NEC's hard-fought advantage.

This difference shows the risk of blindly projecting the results of technological change worldwide without considering the potential interactions with specific local market conditions. Just because the rules of competition are unchanged in one market (as with U.S. PC makers), doesn't mean that they will remain unchanged in another (as NEC discovered).

Risks of Building Standards Coalitions

Finally, DOS/V illustrates the key dilemma of standards coalitions: when building an alliance to establish a standard, there are risks associated not only powerful enemies, but with power allies as well.

If you build a coalition that leaves strong competitors outside the coalition — as Sun Microsystems did with its SPARC processor, or Apple has recently with its Mac OS — you can gain the greatest share of the profits and continue to drive the standard.[48] However, not having strong allies runs two risks: first, your standard may not become the dominant standard; second, your standard may not grow the standard share (or overall market) through improved competition and customer value.

DOS/V became the dominant standard, grew its share and the overall market. However, it demonstrates the opposite risk — by inviting in powerful rivals to make the standard successful, IBM Japan opened itself to fierce intra-standard competition. Intra-standard share is highly vulnerable to attack, because, by definition, the switching costs within a standard are very low and the network externalities (such as software) accrue to all firms.[49] So a high share in 1995 does not assure a high share in 2000 unless a firm is able to maintain more traditional sources of competitive advantage, such as core competencies and consumer brand

This intra-standard vulnerability highlights the risks of sacrificing current profits to gain market share in the hope that such share assures future profits.[50] For example, by aggressively pricing consumer PCs, Packard Bell held the largest share of the U.S. market and was fourth worldwide in 1994, but razor-thin margins forced it to cancel a public offering and led to its eventual sale to NEC and Bull.

Conclusions

Conventional wisdom holds that winning standards can be achieved by if you're first to dominant design, amass an advantage in complementary assets and use a multi-firm coalition. If you achieve this, then your standard's success will also bring success to your firm.

These heuristics for standards competition are not wrong, but like all rules of thumb they have their caveats. The successful challenge to the PC-98 from DOS/V highlights possible vulnerabilities for a seemingly invincible standard. It also reminds us that the effect of technological change must be considered in the context of specific market conditions, and that what constitutes a minor change for one market may have a major impact in another. Finally, establishing a successful standard does not assure the success of the standards creator.

More generally, the success in dislodging the PC-98 reminds us that rules of standards competition are made to be broken, and that challengers (and incumbents) should examine even the most successful standard for opportunities to foment strategic revolution.

Tables and Figures

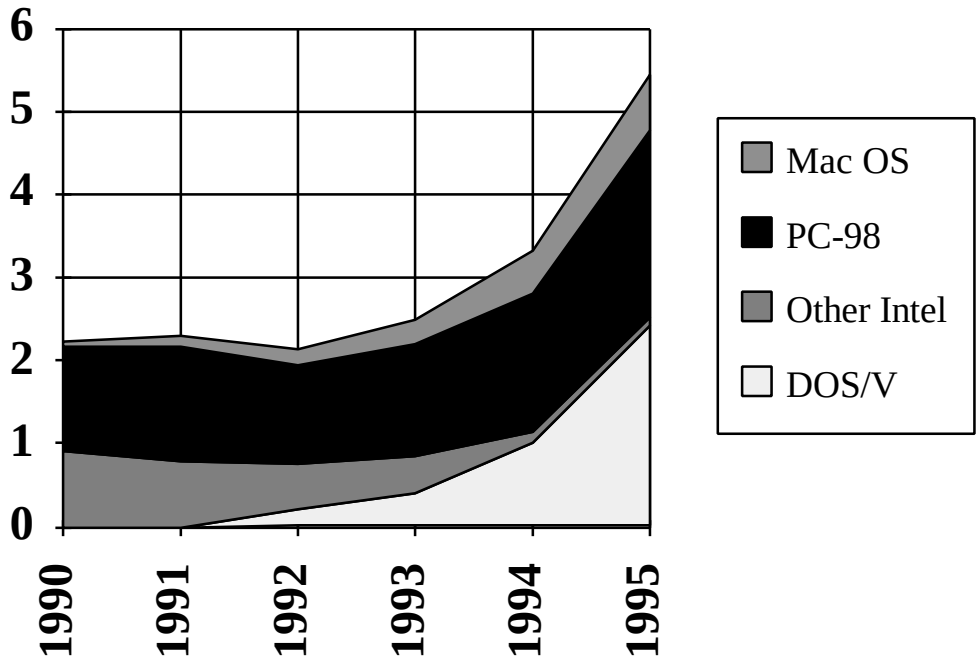
Year	Japan	U.S.
1981		• IBM PC
1982	• NEC PC-98	• Compaq Portable
1983		• IBM XT • Lotus 1-2-3
1984	• Fujitsu FM-16	• Apple Macintosh • IBM PC-AT
1985	• Ichitaro for PC-98	• Windows 1.0
1986	• Apple KanjiTalk 1.0 • Lotus 1-2-3J	
1987	• Seiko Epson PC-98 clone • Toshiba AT-compatible laptop • Fujitsu FMR • AX Consortium formed	• 386-based PCs
1988		• Toshiba AT-compatible laptop
1989	• Fujitsu FM Towns	
1990	• IBM Japan announces DOS/V	• 486-based PCs • Windows 3.0
1991	• Windows 3.0 (J) • OADG formed • DOS/V-based PCs	• Macintosh System 7.0
1992	• KanjiTalk 7.1 • “Compaq shock” price cuts	• Windows 3.1
1993	• Windows 3.1 (J) • Fujitsu backs DOS/V	
1994	• Seiko Epson backs DOS/V	• Windows NT • Pentium-based PCs
1995	• “Fujitsu shock” price cuts • Windows 95	• NEC buys stake in Packard Bell • Windows 95
1996	• NEC-Packard Bell backs DOS/V	• NEC increases stake in Packard Bell • Fujitsu, Hitachi enter market

Table 1: Event history in U.S. and Japanese PC markets

Rank	Firm	Share	Standard
1	NEC	51.0%	PC-98
2	Seiko Epson	8.5%	PC-98
3	Fujitsu	8.2%	(own)
4	IBM Japan	7.6%	(own)
5	Toshiba	6.8%	(own)
6	Apple	5.8%	(own)
	Other	12.2%	various

Source: Nomura Research Institute

Table 2: Leading PC makers, market share and standard in Japan market, 1991



Source: IDC Japan

Figure 1: Sales of PCs in Japan, 1990-1995

	1991 share		1995 share	
Firm	Japan†	World††	Japan†	u††
NEC	51.0%	10.1	41.2%	8.1
Seiko Epson	8.5	n/a	2.5	n/a
Fujitsu	8.2	4.1	17.5	n/a
Toshiba	6.8	4.2	3.7	3.6
IBM	7.6	18.2	8.8	12.3
Compaq	0.0	5.2	3.3	13.1
Apple	5.8	10.1	12.6	10.1
Other	12.2	49.8	10.3	52.8

† Unit sales; source: Nomura Research Institute
†† Revenues; source: McKinsey & Co. (1995 data not yet available, 1994 shown)

Table 3: Comparison of Japanese and world market shares, 1995

Company	Country	I.T. Revenue	Net income % of total	Total revenue	IT/total ratio
IBM	U.S.	$71,940	6%	$71,940	100%
Fujitsu	Japan	26,798	2%	39,974	67%
NEC	Japan	19,350	2%	43,000	45%
Hitachi	Japan	16,208	N/A	85,306	19%
Compaq	U.S.	14,800	5%	14,800	100%
Toshiba	Japan	11,380	2%	54,192	19%
Apple	U.S.	11,378	1%	11,378	100%
Microsoft	U.S.	7,418	25%	7,418	100%
Acer	Taiwan	5,700	N/A	5,700	100%
Dell	U.S.	5,296	5%	5,300	100%
Packard Bell	U.S.	4,300	N/A	4,300	100%
Intel	U.S.	3,240	22%	16,202	20%
Seiko Epson	Japan	2,026	N/A	4,310	47%

Source: "The Datamation 100,"*Datamation*, June 15, 1996

Table 4: Global revenues, IT revenues and profits for leading PC makers in 1995

Notes

[1] For a recent summary of this competiton, see Henry Chesbrough, "Leveraging Complementarities to Establish and Control Technical Standards in the Internet Access Software Market," *Strategic Management Society 16th International Conference*, Nov. 1996.

[2] An interesting discussion of how the two competing record formats were standardized is given by Richard Langlois and Paul Robertson, *Firms, Markets and Economic Change* (London: Routledge, 1995), pp. 77-87.

[3] David Teece refers to this as "co-specialized assets." See "Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy," *Research Policy* 15, 6 (Dec. 1986): 285-305.

[4] Distributors and service facilities may make considerable investments in specialized assets for many types of products (e.g., PCs and copy machines), so the effect of such partner investments are not specific to standards competition.

[5] A classic example of negative externality is pollution, where the more people who move to an area, the more pollution that all residents must endure.

[6] A theoretical framework for such approaches is given by Joseph Farrell and Garth Saloner, "Converters, Compatibility and the Control of Interfaces," *Journal of Industrial Economics*, 60, 1 (March 1992): 9-35.

[7] See Langlois and Robertson, op cit. as well as their earlier article "Networks and innovation in a modular system: Lessons from the microcomputer and stereo component industries," *Research Policy*, 21, 4 (Aug. 1992): 297-313.

[8] For a particularly skeptical look at such standards bandwagon effects, see S.J. Liebowitz and Stephen E. Margolis, "Network Externality — An Uncommon Tragedy," *Journal of Economic Perspectives*, 8, 2 (Spring 1994):133-150.

[9] On the topic of technological discontinuities and dominant designs, see James Utterback, *Mastering the Dynamics of Innovation* (Boston: Harvard Business School Press, 1994), pp. 23-55; also Philip Anderson and Michael Tushman, "Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change,"*Administrative Science Quarterly*, 35, 4 (Dec 1990):604-633 and James Utterback and Fernando Suarez, "Innovation, competition, and industry structure," *Research Policy* 22, 1 (Feb 1993):1-21.

[10] Andrew Grove, *Only the Paranoid Survive* (New York: Doubleday, 1996), pp. 30-32. The analogies between technological discontinuities and shifts in scientific paradigms are made by Teece, op cit.

[11] For a chastening account of Xerox's failure to exploit its invention of GUIs and other technologies essential to personal computing, see Douglas Smith and Robert Alexander, *Fumbling the Future*, (New York: Morrow, 1988).

[12]

Advantages," *Strategic Management Journal*, 9 (Summer 1988): 41-58; for a more recent review, see also Roger Kerin, P. Rajan Varadarajan and Robert Peterson, "First-Mover Advantage: A Synthesis, Conceptual Framework, and Research Propositions," *Journal of Marketing*, 56 (Oct 1992): 33-52.

[13] Consumer preference effects have been most extensively researched by Gregory Carpenter and Kent Nakamoto: see their article "Consumer Preference Formation and Pioneering Advantage," *Journal of Marketing Research*, 26, 3 (Aug 1989): 285-298, as well as "Reflections on 'Consumer Preference Formation and Pioneering Advantage'," *Journal of Marketing Research*, 31 (Nov 1994): 570-573. For discussion of reseller preference, see Frank Alpert, Michael Kamins, and John Graham, "An Examination of Reseller Buyer Attitudes Toward Order of Brand Entry," *Journal of Marketing*, 56, 3 (Jul 1992): 25-37.

[14] See Gerard Tellis and Peter Golder, "First to market, first to fail? Real causes of enduring market leadership," *Sloan Management Review*, 37, 2 (Winter 1996): 65-75, as well as Lieberman and Montgomery, op cit.

[15] See George Day and Jonathan Freeman, "Burnout or Fadeout: The Risks of Early Entry Into High Technology Markets," in Michael Lawless, and Luis Gomez-Mejia, eds. *Strategic management in high technology firms*. (Greenwich, Conn.: JAI Press, 1990). For a discussion of Silicon Valley spin-offs, see Homa Bahrami and Stuart Evans, "Flexible Re-Cycling and High-Technology Entrepreneurship," *California Management Review*, 37, 3 (Spring 1995): 62-89.

[16] See David Aaker and George Day, "The Perils of High-Growth Markets," *Strategic Management Journal*, 7, 5 (Sep/Oct 1986): 409-421; Steven P. Schnaars, "When Entering Growth Markets, Are Pioneers Better than Poachers?" *Business Horizons*, 29, 2 (Mar/Apr 1986): 27-36. Schnaars, *the book*

[17] See Michael Tushman and Charles O'Reilly III, "The Ambidextrous Organization: Managing Evolutionary and Revolutionary Change," *California Management Review*, 38, 4 (Summer 1996): 8-30.

[18] See Michael Cusumano, Yiorgos Mylonadis and Richard Rosenbloom, "Strategic maneuvering and mass-market dynamics: The triumph of VHS over Beta," *Business History Review* 66, 1 (Spring 1992):51-94.; Richard Langlois, "External economies and economic progress: The case of the microcomputer industry," *Business History Review* 66, 1 (Spring 1992):1-50; Stanley Besen and Joseph Farrell, "Choosing How To Compete — Strategies and Tactics in Standardization," *Journal of Economic Perspectives*, 8, 2 (Spring 1994):117-131.

[19] For microprocessors, see David Yoffie, "Competing in the Age of Digital Convergence," *California Management Review*, 38, 4 (Summer 1996): 31-53; for VCR's, C.K. Prahalad, "Weak Signals Versus Strong Paradigms," *Journal of Marketing Research*, 32, 3, (Aug. 1995): iii-vi.

[20] Langlois, op cit.

Jason Dedrick, *Competing in Computers* (forthcoming).

[22] This discussion is adopted from Joel West, "Moderators of the Diffusion of Technological Innovation: Growth of the Japanese PC Industry," Working Paper, Center for Research on Information Technologies and Organizations, University of California, Irvine, January 1996; and Kraemer and Dedrick, op cit.

[23] Many other factors have been suggested, including centralized administration of large Japanese firms (favoring mainframe computers) and the small desk space available in Japanese homes and offices.

[24] For a current discussion of the structure of the Japanese electronics industry, see Joel West, Jason Dedrick and Kenneth L. Kraemer, "Back to the Future: Japan's NII Plans," in Brian Kahin and Ernest Wilson, eds., *National Information Initiatives: Vision and Policy Design* (Cambridge, Mass.: MIT Press, 1996), p. 65.

[25] Japanese efforts to catch up with IBM are described in Kenneth Flamm, *Targeting the Computer* (Washington, D.C.: Brookings, 1987) and Marie Anchordoguy, *Computers Inc.* (Cambridge, Mass.: Harvard University Press, 1989). Example of IBM Japan's uneasy relationship with fellow computer makers are given by Mark Mason, *American Multinationals and Japan*, (Cambridge, Mass.: Harvard University Press, 1992) and Joel West, "Software Rights and Japan's Shift to an Information Society,"*Asian Survey*, December 1995.

[26] The best discussion of these issues is found in Ken Lunde's *Understanding Japanese Information Processing* (Sebastopol, Calif.: O'Reilly, 1993).

[27] Martin Fransman, *Japan's Computer and Communications Industry* (Oxford: Oxford University Press, 1995), pp. 273-274; Tetsuo Horiguchi, *Personal Computers in Japan*. NTIS PB84-176510 (Tokyo: PB Co., Ltd., 1983), pp. 30-31. In his book *Computers and Communications* (Cambridge, MA: MIT Press, 1986), former chairman Koji Kobayashi credits NEC with inventing the PC with its TK-80 kit computer, though U.S. analysts usually attribute the breakthrough to MITS for its Altair 8800.

[28] See for example Teece, op cit.

[29] Fransman, op cit., p. 276.

[30] Tom Cottrell argues that such fragmentation delayed development of both the software industry and the PC market itself. See "Standards and the Arrested Development of Japan's Microcomputer Software Industry," in David Mowery, ed., *The international computer software industry* (New York: Oxford University Press, 1996).[31] Unless otherwise noted, statistics for unit sales and market share in the Japanese PC market are based on unpublished figures provided courtesy IDC Japan.

[32] Andrew Tanzer, "A message from Akihabara," *Forbes*, June 8, 1992, p. 42.

[34] As an example, in 1992, NEC sold about 1 million of the 2 million PCs sold in Japan, while IBM Japan only sold about 150,000. However, IBM sold about 3 million of the 30 million PCs sold worldwide, and more than 20 million of these PC's were part of the IBM PC standard.

[35] The discussion of DOS/V is based on 1994 and 1995 interviews conducted with executives of IBM Japan, the Open Application Development Group, and other industry observers and participants.

[36] To illustrate the global economies of scale, in 1992, NEC sold about 1 million of the 2 million PCs sold in Japan, while IBM Japan only sold about 150,000. But in the global market, IBM sold about 3 million PCs, while more than 20 million of the total 30 million PCs sold were part of the IBM PC standard.

[37] Other notable "shokku" in contemporary Japanese history include the Nixon shocks of 1972 (depreciating the dollar and recognizing China) and the oil price shocks of 1973 and 1979.

[38] IDC Japan, "IDC Japan Forecasts Japanese Market to Surpass 10 Million Units by 1997," press release, February 6, 1996.

[39] Joel West, "Utopianism and National Competitiveness in Technology Rhetoric: The Case of Japan's Information Infrastructure," *The Information Society*, 12, 3 (July 1996): 251-272.

[40] Robert Poe, "Can Fujitsu reinvent itself?" *Electronic Business Asia*, 4, 1 (Jan. 1993): 34-41; Karen Juliussen and Egil Juliussen, *Computer Industry Almanac*, 1993, p. 389; *Electronics Business Asia*, September 1993, p. 46-47.

[41] Benjamin Fulford, "Price war forces PC industry restructuring; manufacturers turn to imports as margins on profits plummet," *Nikkei Weekly*, February 26, 1996, p. 2.

[42] NEC bought a 19.9% share of Packard Bell in 1995, upping its stake to 47% of the company with a cash infusion in 1996; Bull contributed the PC division it previous acquired from Zenith. See Lee Gomes, "Packard Bell's debt to Intel is trimmed to $113 million," *The Wall Street Journal*, June 10, 1996; Jim Carlton, "Tight squeeze: Packard Bell is beset by new competition, customer complaints," *The Wall Street Journal*, March 26, 1996.

[43] *Nikkei Pasokon*, Aug. 26, 1996, Aug. 28, 1995.

[44] "NEC tops April-June PC server shipments," *Nihon Keizai Shimbun*, August 27, 1996.

[45] Tanzer, op cit.

[46] New York Times, "Japan Computer Lead Seen," May 2, 1990, p. 17.

[47] Besen and Farrell, op cit.

[48] Raghu Garud and Arun Kumaraswamy, "Changing competitive dynamics in network industries: An exploration of Sun

[49] Meanwhile, NEC's comparatively slow decline shows that high switching costs and network externalities slows switching between standards.

[50] Regarding the risks of confusing market share with success, see Cathy Anterasian, John Graham and R. Bruce Money, "Are U.S. managers superstitious about market share?" *Sloan Management Review* 37, 4 (Summer 1996):67-77; J. Scott Armstrong and Fred Collopy, "Competitor Orientation: Effects of Objectives and Information on Managerial Decisions and Profitability," *Journal of Marketing Research*, 33, 2 (May 1996): 188-199; Kevin and Jackie Frieberg, *NUTS! Southwest Airlines' Crazy Recipe for Business and Personal Success* (Austin, Texas: Bard Books, 1996).