COMPETITIVE STRATEGY UNDER STANDARDIZATION IN THE PERSONAL COMPUTER INDUSTRY AND ITS INFLUENCES ON NEW ENTRANTS

by

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ABSTRACT

The crucial role played by a compatibility standard in various industries is widely discussed in the literature. The critical influence of this role is especially true in the personal computer industry, where a large number of end users with diversified needs and strong bargaining power participate directly in purchasing decisions. Where a large number of software and peripheral vendors act as complementary assets providers, a "compatibility standard" becomes one of the most strategically important factors for all participants in the industry. A correct decision regarding compatibility standard can affect a new entrant strongly enough so that the firm may ultimately become a leader of industry growth. The "dominant design" concept was defined by Abernathy & Utterback (1978).

This thesis provides proof that "dominant design" in the PC industry consists of a set of operating systems, microprocessor and bus architecture, and plays a conceptual role in the industry. Regarding industry development patterns of PC hardware, many new entrants came in after the "dominant design" had been established, therefore the pattern is different from that of the Abernathy/Utterback model. Through a process of investigation, this thesis finds that ownership of the key technological components of the "dominant design" do not belong to PC manufacturers, and result in a different pattern.

Conversely, regarding complementary asset providers such as software vendors, we provide proof that "dominant design" creates a new business base, thus stimulating an increase in the number of new software entrants. Software vendors tend to concentrate on a small set of right operating system selections rather than diversifying their energies, and they stay with their early selection.

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I am grateful to my wife, Kitoshi, and to my son, Michihiro, without whose understanding and cooperation throughout my work at Sloan, I couldn't have come this far. This thesis is dedicated to my family.

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CHAPTER 1 --- INTRODUCTION

Since IBM introduced its System/360 and ushered in the concept of "compatibility" which allowed users to reuse their software through several generations of products in 1966, "compatibility" has been one of the most important strategic factors for computer hardware vendors. Although punch cards as a single input device were regarded as a "compatibility" interface for the previous generation computers, it had been almost impossible to reuse the same punch cards for a different machine. The emergence of an "operating system" enabled this to be done. After the IBM System/360 was introduced, IBM dominated the market and captured a large portion of the Fortune 500 companies. Since IBM was highly vertically integrated, it could provide all the solutions their customers needed. Additionally, in many cases, user softwares were developed by the user themselves, by IBM's field system engineers, or by contracted system houses, and was dedicated for the user's specific needs. Under this condition, "compatibility" had become crucial for hardware vendors other than IBM. So, the main issue for the remaining hardware vendors then became how to capture customers preferred to the dominating IBM mainframe computers and even to replace them at the customer sites. As the result, the success of the System/360 line encouraged the growth of "plug compatible hardware vendors" (PCMs), which found it profitable to copy IBM's products and to "plug" their machines into the standard interfaces and software developed by IBM (Cespedes and King 1988).

On the other hand, in the personal computer industry where millions of computers are sold to various kind of users and the user needs are highly diversified, the personal computer business has an unique aspect of "compatibility." It is very difficult for any single manufacturer to vertically integrate its PC business. A large number of "third-party" vendors, such as application software vendors and peripheral vendors, are doing business by complementing this lack of capability of the hardware vendors. Most important, these third-party vendors have an absolute freedom to make strategic decisions toward "compatibility," independently from the hardware vendors' decisions. This characteristic seems to differentiate the competitive strategy in the PC industry from that in the mainframe industry. So, in the personal computer industry, availability of specialized complementary assets, such as application softwares and users' derivative programs, becomes an extremely important factor in deciding the total value of the computer and which technology will become the dominating compatibility standard. In this regard, understanding the dynamism of the industry influenced by the emergence of a new compatibility standard must be valuable for a participant in managing its strategy.

Especially in the growing stage of the industry, a "compatibility standard" seems to play a very similar role to machines into the standard interfaces and software developed by IBM (Cespedes and King 1988).

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Especially in the growing stage of the industry, a "compatibility standard" seems to play a very similar role to

"Dominant Design" which, as Abernathy & Utterback(1978) discussed, creates a new, stable business base and stimulates the growth of the industry. Since new entrants will soon account for the majority, the path toward an intended "compatibility standard" must be crucial for the firm.

Chapter 2 of this thesis will investigate the general characteristics of compatibility standards. Chapter 3 discusses the strategic implications of "compatibility standards" in the personal computer industry and why an "operating system" is emphasized in strategic discussions. We examine major criteria and incentives, include switching cost and network externalities for software vendors and PC hardware vendors used in adopting a new "compatibility standard." Adoption decisions of compatibility standards will be discussed in Chapter 4. Chapter 5 describes hypothesis and research methodology that pertains to the interrelationship among the three-sector movement, in terms of number of new entrants and exit firms. Chapter 6 will describe and analyze the result of the empirical study. Finally, Chapter 7 provides further discussion and conclusions, including research issues remaining for the future study.

CHAPTER 2 --- What are the Characteristics of "Compatibility Standard" in Personal Computers?

2.1 What is standard? Mandatory standards, and voluntary consensus based on de facto and de jure standards

There are several different kinds of compatibility standard around the computer industry. The first-level categorization are voluntary consensus standards and mandatory or regulatory standards (Fernane, 1991). According to Cargill(1989), regulatory standards are more appropriate in situations where there exists only a single acceptable solution, whereas voluntary standards developed through consensus are more acceptable in circumstances where there are multiple competing solutions. A typical example of such mandatory standards are government standards such as Military Specifications and Standards (MIL), and Federal Standards (FS). Another example is the set of standards declared by the EC's standards committee, Commite Europeen de Normalisation (CEN). Although each of these is a voluntary consensus standard, once the public authority has regulated an explicit set of individual standards, it becomes mandatory. Any technology or product not meeting the standards would be eliminated. Because the CEN requirements have absolute power over firms which aim to penetrate the EC market after 1992, the developed products must meet the mandatory requirements.

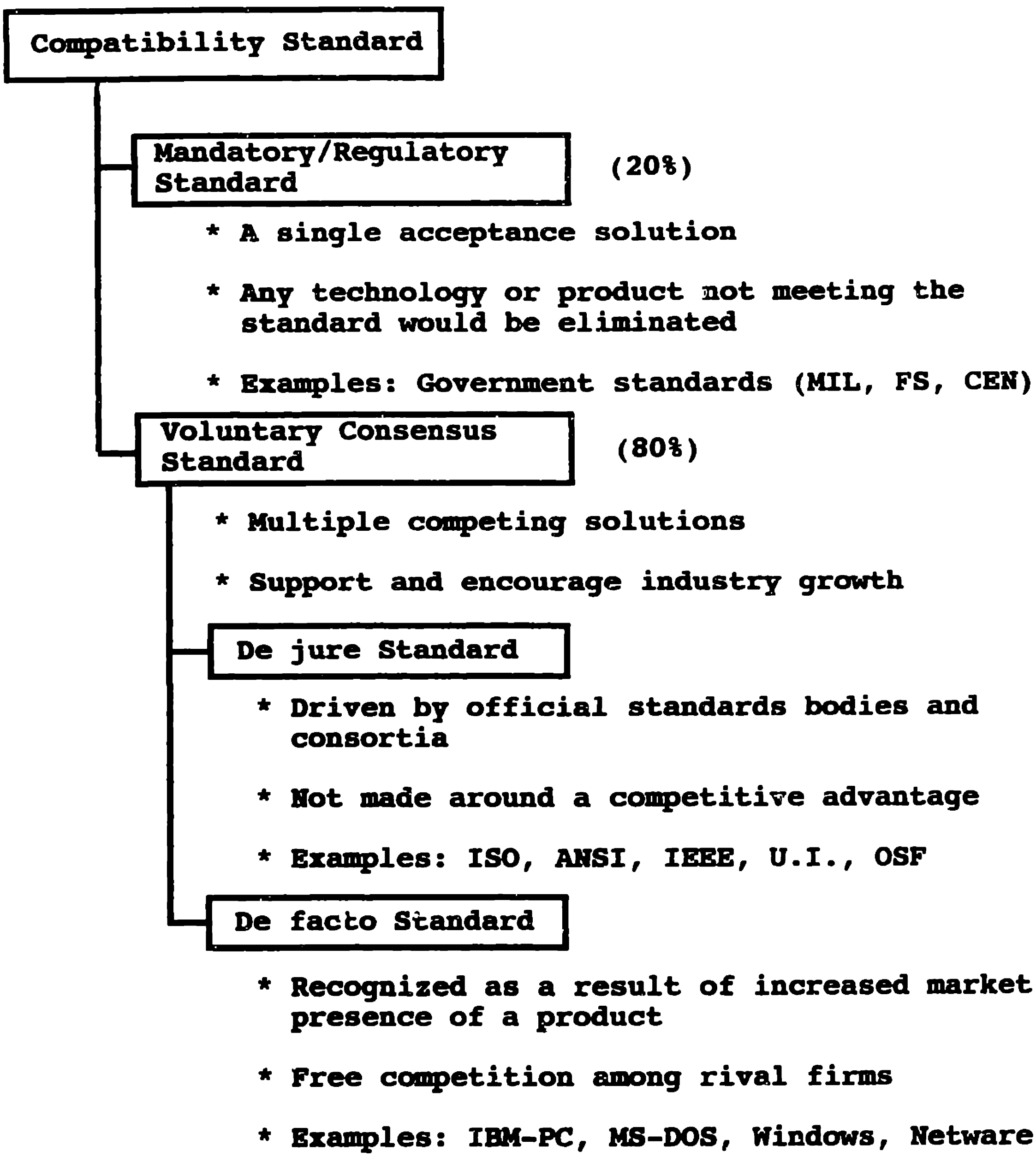


Figure 1. Compatibility standards in the computer industry

Source: Fernane (1991)

On the other hand, voluntary consensus standards are developed to support and encourage industry growth (Fernane, 1991). Those are estimated to comprise approximately 80% of all industrial standards (Reddy, 1990). Of these, explicit or de jure standards are usually driven by official standard bodies such as ISO, ANSI, IEEE, ECMA and other consortia including U.I., OSF, and X-Open. The latter three consortia were formed to solve the problem of existing multiple versions for the UNIX operating system, which had created disadvantages in terms of inefficient development of complementary assets for the majority of industry participants. Since such standards may reduce or even eliminate competition among rival standardized firms, de jure standards are usually made not around a competitive advantage of a leading firm but around technologies for which standardization will bring a larger benefit than will keep them closed.

De facto standards are often recognized as a result of the increased market presence of a product implementation which is proprietarily owned by a single or several firms. Since the emergence of de facto standards usually resulted through free competition among rival firms, many economic theories [e.g. bandwagon effects (Harhoff 1988); bandwagon equilibria (Farrell & Saloner 1986)] have tried to explain its mechanisms. A typical example of this is the IBM-PC. Since IBM launched its PC in 1981, the company has promoted and encouraged software and peripheral vendors to develop their products for the IBM PC, in order to attract more users. IBM also allowed the emergence of clone vendors to drive its proprietary design to become a de facto standard architecture. Furthermore, the followers assumed that the IBM design was very likely to become a leading design, on which lots of complementary assets such as application software and peripherals became available gratis, and concluded that following IBM would be beneficial.

Ferrell & Saloner(1988) consider the mechanism by which standards are set. In the pure committee game, all firms agree to abide by the decision of the committee, which meets at intervals over time until a decision is reached. In each meeting, firms can insist on their own preferences or concede to agree to other standards. In the pure bandwagon game, there are no meetings. In each time period, each firm chooses to commit to its preferred choice or wait. A firm that chooses to commit early is trying to start the bandwagon rolling and persuade followers to adopt its choice. In the hybrid, the committee meets, but if it does not reach agreement, individual firms may decide to commit to their choice and try to start the bandwagon (Teisberg 1992). A typical example of the bandwagon game is the IBM PC compatible standard. One pure committee game is the UNIX standardization movement, in which all major players participate in the discussions through consortia such as UNIX International (U.I.), Office Software Foundation (OSF), and X-Open, although they have not yet concluded a single UNIX standard and seem to run the bandwagon game among the three standards.

2.2 "Compatibility" issues of personal computer

2.2.1 What does "compatible" mean? -- Levels of compatibility

The word "compatible" is frequently used in the personal computer industry. What does it mean? The following are general definitions of "compatibility" of a personal computer (Toong 1985):

(1) APPLICATION COMPATIBLE

Application with the same functionality available across different computers. Each application program must be implemented for each computer architecture. For example, a brand of application software available for both IBM PC and Apple Macintosh computer is "application compatible". Application software developer must implement differently and must test the software for each computer.

(2) DATA COMPATIBLE

Data compatibility allows users to read and write a data file across machines. However a program can not run on different PCs.

(3) OPERATING SYSTEM COMPATIBLE

The same operating system environment is provided across machines. As far as an application program is implemented with the operating system level commands, the program can run on different machines.

(4) WINDOW SYSTEM COMPATIBLE[1]

The same window system environment is provided across machines. As far as an application program is implemented with the window system's level commands as well as underneath operating system's ones, the same application program can run on different machines.

(5) FUNCTIONALLY COMPATIBLE

Same program can be used on different machines with minimal conversion.

(6) FULLY COMPATIBLE

This highest level compatibility results when hardware vendors develop machines that are intrinsically close enough to the target computer that they can run programs developed for other computers without modification.

In order to keep "appropriability" of its own product with off-the-shelf technologies, a firm can try to set a trap to cause incompatibility by creating a proprietary part. For

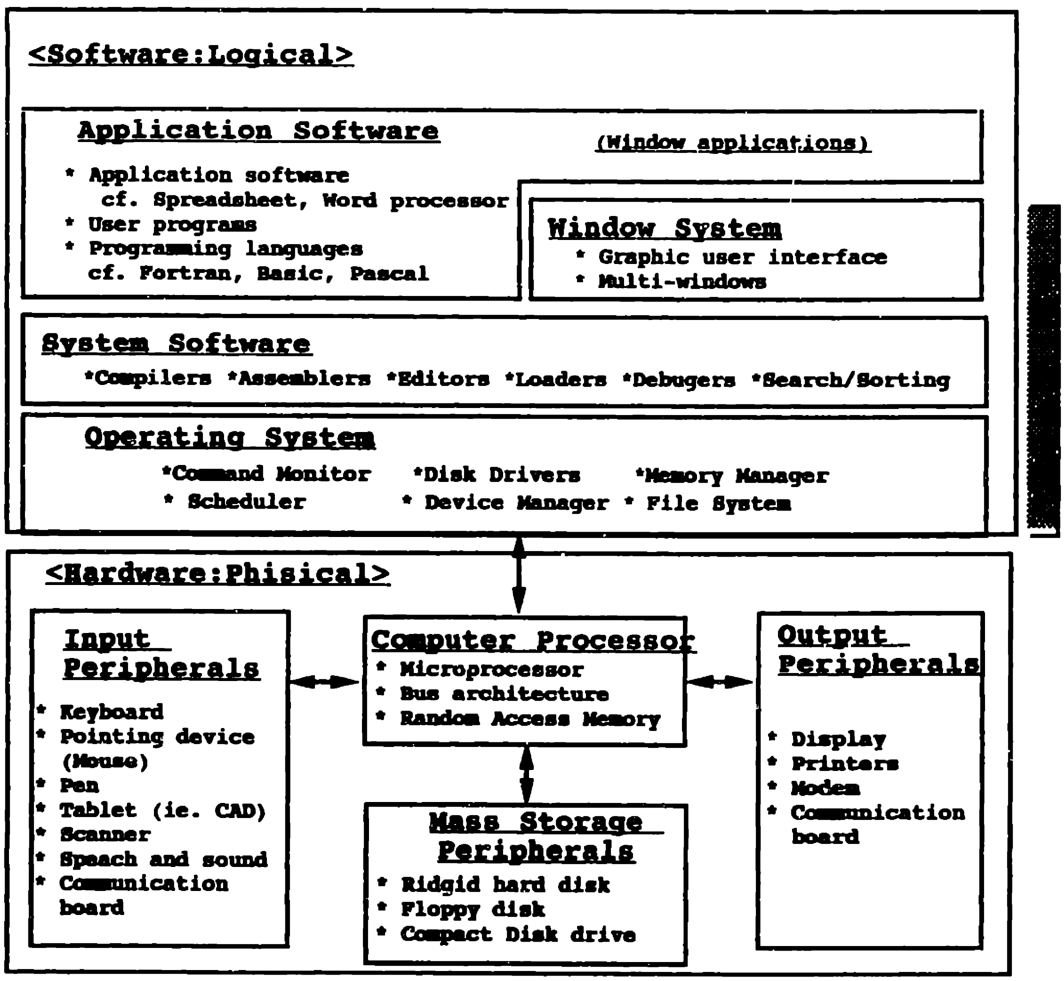
1 Added by the author based on updated information.

example, although IBM took the "open architecture" policy for the IBM PC, IBM closed BIOS (Basic Input/Output System) specifications at the outset. It also used a proprietary method of loading Microsoft Basic by locating "kernel" of BASIC on ROM.

As the result of these traps, in the early 80s it was generally thought that nobody could develop an "100% compatible machine" with the IBM-PC. So, in 1984, IBM-PC compatibles occupied 23.6% of the market while IBM had 41.5%. However, by 1990, IBM's market share had declined to 16.6% while the IBM-clones' had increased to more than 70% (International Data Corporation, 1992). This shows that imitators could easily emulate BIOS or "the traps set by IBM" to accomplish "full compatibility," then overcome IBM in the long run. This will be discussed in the following section.

2.2.2 Interdependencies among components in the PC

Figure 2 shows a typical structure of a personal computer. There are many interfaces between major components which require a clear interface definition and so are the places for compatibility standardization.



■ : **The area that commercialized "Operating Systems" cover.**

cf. MS-DOS, OS/2, Mac-OS, UNIX System-V

Figure 2. Structure of a Personal Computer

The following table explains where are the place for compatibility standards and whether or not any standard exists. It also shows each component's dependencies and its directions with other components:

Table 1. Compatibility Standards in Personal Computers (1)

Component Items	**Selected by**	**Dependency**[1] **To: ---->** **From: <----** **Mutual:<--->**	**Related Standards**	**Notes**
<Hardware>				
Micro-processor (CPU)	Manufacturer	Operating System <------>	Intel80x86 Motorola 680x0	OS is written for a specific micro-processor.
Bus architec-ture	Manufacturer	I/O peripherals <-------	PC-AT Bus, EISA VME, MCA	MCA was proprietary and then disclosed.
Memory (DRAM)	Manufacturer	Circuit board/CPU -------->	Standardized 16 pins etc.	Any alternative can be used.
Rigid hard disk drive	Manufacturer Plug compatible peripheral vendors	Bus architecture -------->	PC-AT Bus, etc SCSI interface (External disks)	PC firm disclose spec. to disk component vendors.
Floppy disk drive	Manufacturer Plug compatible peripheral vendors	Bus architecture --------> Users' media (3.5"/5") <------->	PC-AT Bus, etc SCSI interface (External disks) Disk format	PC firm disclose spec. to disk component vendors.
Compact disk drive	Manufacturer Plug compatible peripheral vendors	Bus architecture -------->	N/A	Consumer elec. company and computer vendors are working on standardization.

1 Please refer to page 28.

Table 1. Compatibility Standards in Personal Computers (2)

Component Items	**Selected by**	**Dependency** **To: ---->** **From: <----** **Mutual:<--->**	**Related Standards**	**Notes**
Magnetic tape drive	Manufacturer Plug compatible peripheral vendors	Bus architecture --------> Users' media <-------->	PC-AT Bus, etc SCSI interface (External disks)	PC firm disclose spec. to disk component vendors.
Keyboard	Manufacturer	Bus architecture --------> Users' familiarity ------->	No standard interface "QWERTY" key formation	Key formation has been firmly standardized.
Pointing device	Manufacturer Plug compatible peripheral vendors	Operating System -------> Bus architecture --------> Users' familiarity ------->	PC-AT Bus, etc User interface (# of buttons)	Mouse is standard feature for Macintosh. IBM sell it as an option. Microsoft sells it for MS-DOS users.
Scanner	Manufacturer Plug compatible peripheral vendors	Bus architecture --------> Operating System -------> Application softwares ------->	PC-AT Bus, etc MS-DOS, Mac OS etc. Application specific scanner driver	PC manufacturer disclose spec. to scanner component vendors.
Printer	Manufacturer Plug compatible peripheral vendors	I/O interface or Bus architecture --------> Operating System -------> Application softwares ------->	RS232C, PC-AT Bus etc MS-DOS, Mac OS etc. Application specific scanner driver Page description language(PDL) Postscript	PC manufacturer disclose spec. to scanner component vendors. PDL will give freedom for printer vendors.

Table 1. Compatibility Standards in Personal Computers (3)

Component Items	Selected by	Dependency To: ----> From: <---- Mutual:<--->	Related Standards	Notes
<Software>				
Operating system	Manufacturer Software vendors	Microprocessor <--------> Application softwares <------- I/O peripherals <-------	MS-DOS, OS/2, Mac OS, UNIX etc.	Few OS vendor dominate the industry. (MS-DOS, UNIX) Apple keep Mac OS proprietary.
Window system	Manufacturer Software vendors	Operating System -------> Application softwares <-------	Windows Mac GUI, OS/2's Presentation Manager etc.	Mac OS and OS/2 include window system as a part.
System software	Manufacturer Software vendors	Operating System -------> Application softwares <-------	C-compiler Programming languages EMACS	OS supplier is also the supplier of many system softwares. "OS" package include the system environment.
Application software	Users	System software -------> Operating System -------> Other softwares <-------->	MS-DOS, Windows, OS/2, Mac OS etc. Pascal, Basic, C, Assembly etc. Lotus 123 compatible etc.	Many application software bypass language compiler to directly access to the OS level.

There exist specialized relationships between each section (please see Table 1). These interdependencies influence the strategic decisions of the participants in each related area.

Operating System

Of those, "Operating System" most frequently appears in the dependency column, because it plays a central role of interface between the hardware and the software. Functions of operating system are defined as follows (Toong 1985):

- Command monitor

  Wait for command from the application side
- Memory management

  Allocate memory addresses for the system and application program use and efficiently manage the limited memory by segmenting, relocating and paging
- Disk Driver

  Provide an interface with disk units to read or write software code
- Scheduler

  Schedule all the tasks requested by prioritizing them
- Device manager

  Control I/O devices such as CRT, Keyboard, Printer and other peripherals and send to/from the devices

- File system

  Manage software files in disks and memories

Within these definitions, it is not clear that "operating system" is really influential on application software, one of the most important strategic elements in the PC business. Let's investigate this issue further.

<u>Application software</u>

Although application software is widely thought to be written purely in a generic programming language such as "BASIC", "Pascal" or "C", the reality is not that simple. Figure 2 shows that programming software interfaces with compilers of system software and so does not directly interface with "operating system". However, many application softwares directly access to the "operating system" in order to speed up its execution speed (Toong 1985). A program in high level language is to be translated into assembly and then translated into machine code by the "operating system" so that it can execute hardwares according to the command requested by the application program. However, these translations slow the execution speed of the application tremendously. As a sophistication and complexity level of an application program increases because of increasing competition, its execution speed becomes crucial. Many software developers solve the speed problem by bypassing the language level and sometimes even the operating system.

Furthermore, the recent wide acceptance of "window system" in the marketplace creates another level of "incompatibility" for application software. Writing an application software for a specific multi-window environment requires programmers to use a set of graphic commands to display and control the program in the window environment. Although a large portion of the application software, unrelated to the display and user interface capabilities, can run on the operating system level below the window level, the graphic functions of applications must be written specifically for the window system and therefore would cause "incompatibility". Apple's Macintosh computer, which included window system as a part of its operating system, requires software developers to comply from the beginning with the "window system level compatibility" as well as with the "operating system level compatibility." This creates an "appropriability" for Apple while it creates a critical "cospecialized" situation for software vendors.

2.3 Summary

In the personal computer industry, many de facto and other standards have been established. The following list shows examples of major standards:

De facto standards:

Operating system	--	MS-DOS (Microsoft Corporation)
		CP/M[1] (Digital Research)
		MAC OS (Apple Computer)
		XENIX (Microsoft Corporation)
		etc.
Microprocessor	--	Intel 80x86, Motorola 680x0
		etc.
Bus-architecture	--	PC-AT Bus (IBM), MCA (IBM)
		Apple Desktop Bus (Apple) etc.
Network OS	--	Netware (Novell)

De jure standards:

Bus-architecture	--	VME Bus (IEEE) etc.
I/O interface	--	RS232C, SCSI (IEEE) etc.
Keyboard	--	QWERTY (ANSI), JIS-Kanji (JIS) etc.
Programming languages	--	Fortran, BASIC (ANSI)etc.
Memory (DRAM)	--	256K/1M/4M (IEEE)
Network protocols	--	Token-ring (IBM/ISO), Ethernet(ISO) etc.

Mandatory standard -- Emission (FCC), Safety (UL)

Many standards have been established in the industry. However, since there exist complicated interdependencies, any

[1] A leading operating system in the early 1980's.

single compatibility cannot guarantee full compatibility between the related components. Furthermore, adoption of any single standard cannot allow a firm to control strategically important complementary assets such as application software.

In the following chapter, the strategic meaning of compatibility standard will be discussed.

CHAPTER 3 --- Strategic Discussions on "Compatibility Standard" in the PC industry

3.1 Complementary assets and control factor

3.1.1 Specialized/cospecialized assets and appropriability

Teece (1986) discussed the strategic importance of complementary assets. Complementary assets for a computer hardware manufacturer to create its competitive advantage is discussed as follows:

> Computer hardware typically requires specialized software, both for the operating system as well as for applications. Even when an innovation is autonomous, as with plug compatible components, certain complementary capabilities or assets will be needed for successful commercialization.

It is crucial for a hardware vendor to acquire and control these complementary assets by vertical integration, contractual approaches, or mechanisms to motivate complementary asset providers.

In his discussion, Teece (1986) also introduced two categories of complementary assets, "specialized assets" and "cospecialized assets". Table 1 in Capter 2 of this thesis, shows these "specialized" and "cospecialized" relationships as the arrows "--->" and "<---" for "specialized" and "<--->" for "cospecialized".

Theoretically, adoptions of open standard technologies must resolve specialized relationships between a specific hardware manufacturer and complementary assets providers. However, components have multiple inter-dependencies. So, in reality, if at least one of the technologies is strictly controlled by an innovation firm, open standardizations of the rest of the related technologies are of no help to imitators in developing fully compatible machines. This will secure the appropriability of the innovation firm. To protect the proprietary part, copyright is normally declared. There appeared another issue. How weak or tight should the "appropriability" be? IBM left a proprietary part as BIOS in order to retain its "appropriability" and tried to protect it by copyright, but the proprietary part was soon emulated by imitators through reading the specification of BIOS I/O signals which was widely publicized for peripheral vendors, and the "appropriability" was ultimately destroyed. IBM then re-establish a new appropriability by the new bus technology, Micro Channel Architecture (MCA), and a new operating system, OS/2, which included some IBM proprietary enhancement, and faced difficulty in leading one of the most important complementary assets providers, software application vendors. Since software applications are cospecialized to a specific machine if it includes proprietary parts, the software vendor will move based on how profitable it would be to follow the new cospecialized relationship with the hardware vendor. How can hardware vendors control this situation?

3.1.2 Controllability of complementary assets and hardware vendors' decisions in an R&D approach

There are several approaches for hardware vendors to acquire complementary assets when a hardware vendor develops a personal computer, such as (1) Contractual approach, (2) Vertical integration (Self development), and (3) Drive third vendors by incentives. The choice must depend on the firm's capability, speed to market, and/or strategy toward "appropriability".

Figure 3 shows an analysis of a firm response to R&D approach. The firm's decision is analyzed using two dimensions, variety of technology and product differentiation. Product differentiation more explicitly represents customers' priority in their purchasing decision, and is therefore strategic importance. The other important factor is variation of selection, which represents diversification of user needs.

Let's investigate the proper approach of a hardware vendor for each Quadrant. In order to take a contractual approach, a hardware vendor normally provides explicit specifications for many of the technology components of its machines. For example, major variables in design specification of microprocessors are brand (Intel, Motorola etc.), clock frequency (20MHz, 25MHz etc.), and bit length (8bit, 16bit, 32 bit, etc.). Although the firm may source the same component from multiple vendors, the specifications

Two-Dimentional Framework for Analysis of Firm Response to R&D Approach

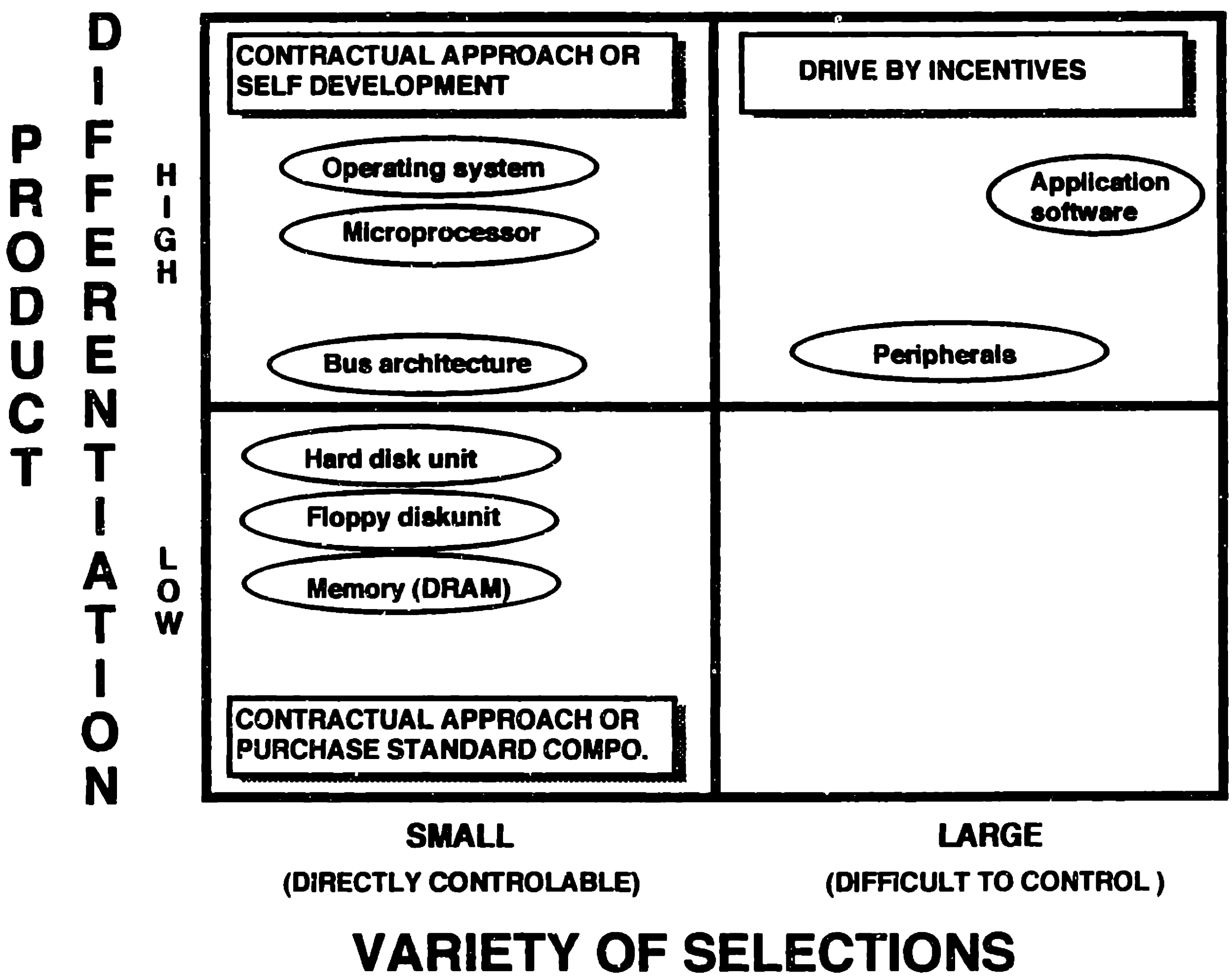


Figure 3

must be the same. Many PC components have very limited number of variations, usually less than 10. In such cases, the firm can relatively easily control those complementary assets by contractual approach or even internal development if its capability allows. Of these, low differentiation components are very likely to be standardized, because PC hardware vendors do not need to pursue "appropriability" of those technology components while component vendors must sell their components to as many PC hardware vendors as possible. This results in high availability of low-cost standard components. Thus, Quadrant II and III are directly controllable by PC hardware vendors.

On the other hand, in the case of application software in Quadrant I, a seemingly infinite number of selections reflect an infinite number of user needs. There are two options for a PC manufacturer:(1) a contractual approach with a limited number of software vendors to develop "generic" or "basic" softwares; and (2) driving third-party software vendors voluntarily to develop software by providing incentives. The situation is the same for third-party peripheral vendors. The most important incentive for third-party vendors is expectation of growth of the target machine.

In the IBM-PC case, Teece (1986) analyzed the critical success factors in quick acquisition of complementary assets as follows:

- IBM's brand name -- reputation in the computer industry

- IBM's market and service efforts to guarantee its success in the PC market
- Adopting an open system architecture
- Making the operating system information publicly available.

Teece concluded that effective management over complementary assets is the key.

There is an example to confirm the importance of the complementary assets acquisition. Xerox's ill-fated "STAR" workstation (or the so-called "D-machine") is an extreme opposite example. It adopted a closed architecture, a proprietary "Pilot" operating system, and proprietary components. Everything including application software must have been developed internally by Xerox or through very limited contractual approaches with outside vendors. All the technological components were cospecialized. As a result, Xerox had to invest huge amount of R&D money in every technological improvement for microprocessors, operating systems, and peripherals, while almost no software vendor voluntarily wrote any application software for Xerox's proprietary computers. In 1988, Xerox finally withdrew from the computer hardware business. Although Xerox could keep a very strong appropriability around the proprietary technologies from beginning to the end, the story still ended in disaster.

However, just motivating the complementary assets providers to cooperate with the hardware vendor cannot guarantee a firm's success. The firm must also keep controlling them strategically for a long term. Although IBM successfully started its PC business with the approach described above, the 1990 16.6% IBM market share does not indicate its ultimate success. However, the total market share of IBM and its compatible machines with MS-DOS and PC-AT Bus has continued to grow through the last decade, finally reaching more than 80% of the market. In this sense, IBM was ultimately successful as the de facto standard setter, and has contributed greatly to the creation of the huge PC industry, but nevertheless could not become the single dominant firm. To explain this phenomenon, Abernathy & Utterback's "Dominant Design" is discussed in the following section.

3.2 Standardizations and "Dominant Design"

Abernathy & Utterback (1978) have provided a framework to explain the evolutionary stages of an industry. They discuss three stages: the "Fluid pattern," where small, fluid entrepreneurial units conduct trial-and-error to experiment new ideas and designs; the "Specific pattern," where incremental cost reduction and quality improvement become the main emphasis and a smaller number of large firms take advantage of high-volume production and economies of scale; and, in between these two, the "Transition pattern," where a single design that satisfies most user needs began to emerge as the more promising. The single design is called "Dominant Design."

In the case of the personal computer industry, a set of technologies, Intel 80X86 microprocessor, PC-AT Bus and MS-DOS operating system, can be regard as "Dominant Design," because this set, in other words "IBM compatible", represents more than 80% of the product in the marketplace. Figure 4 shows the emergence of "Dominant Design" in the PC industry. Availability of a wide variety of software applications is one of the most important user needs, and the set of technologies indirectly satisfies these needs by providing a stable business base for software developers. These three technologies are largely standardized (as de facto standard). As far as a computer uses the same set, it can satisfy compatibility of software from generation to generation.

So, how did the emergence of "dominant design" shape the industry and affect new entrants? According to this framework, if the number of small new entrepreneurial firms is large before the dominant design emerges, it will decline thereafter. However, IBM, a large firm which must enjoy economies of scale in the Abernathy & Utterback framework, declined its market share against IBM clone vendors, resulting in many smaller clone vendors representing 65% of the market.

The difference in this case may be caused by an interesting characteristic of the personal computer which IBM initiated with its first PC. IBM developed its PC by fabricating "Off-the-shelf" technologies. Since then, the IBM PC as well as its compatibles, in nature, has been an assembled set of standard technologies. As a result, those who really enjoy economies of scale are standard technology component vendors rather than PC vendors. In fact, the two owners of the core de facto standard technologies, Microsoft Corporation and Intel, dominate 80% of the market and enjoy high volume and economies of scale. Other component vendors for rigid hard disk, floppy disk and other peripherals also benefit from selling large volume of AT-Bus compatible components.

Because of the availability of low-cost standard components which are no larger dependent on the innovator, IBM, the industry is open to all including small entrepreneurial firms who now have a chance to create another level of innovations. Clark & Henderson (1989) suggest "Architectural innovation," which is based on existing technologies but assembled differently. The Laptop computer is an excellent example of this innovation based on the dominant design (Kai 1991).

In terms of the nature of business, the sales volume of PCs has increased tremendously, and the cost of PCs has dropped significantly. The IBM PC priced $4,995 in 1981, while in 1991 Tandy's 1400FD with the same level of capability did $999. This high volume and cost reduction orientation is as suggested by Abernathy & Utterback.

Emergence of Conceptual "Dominant Design" for Personal Computer

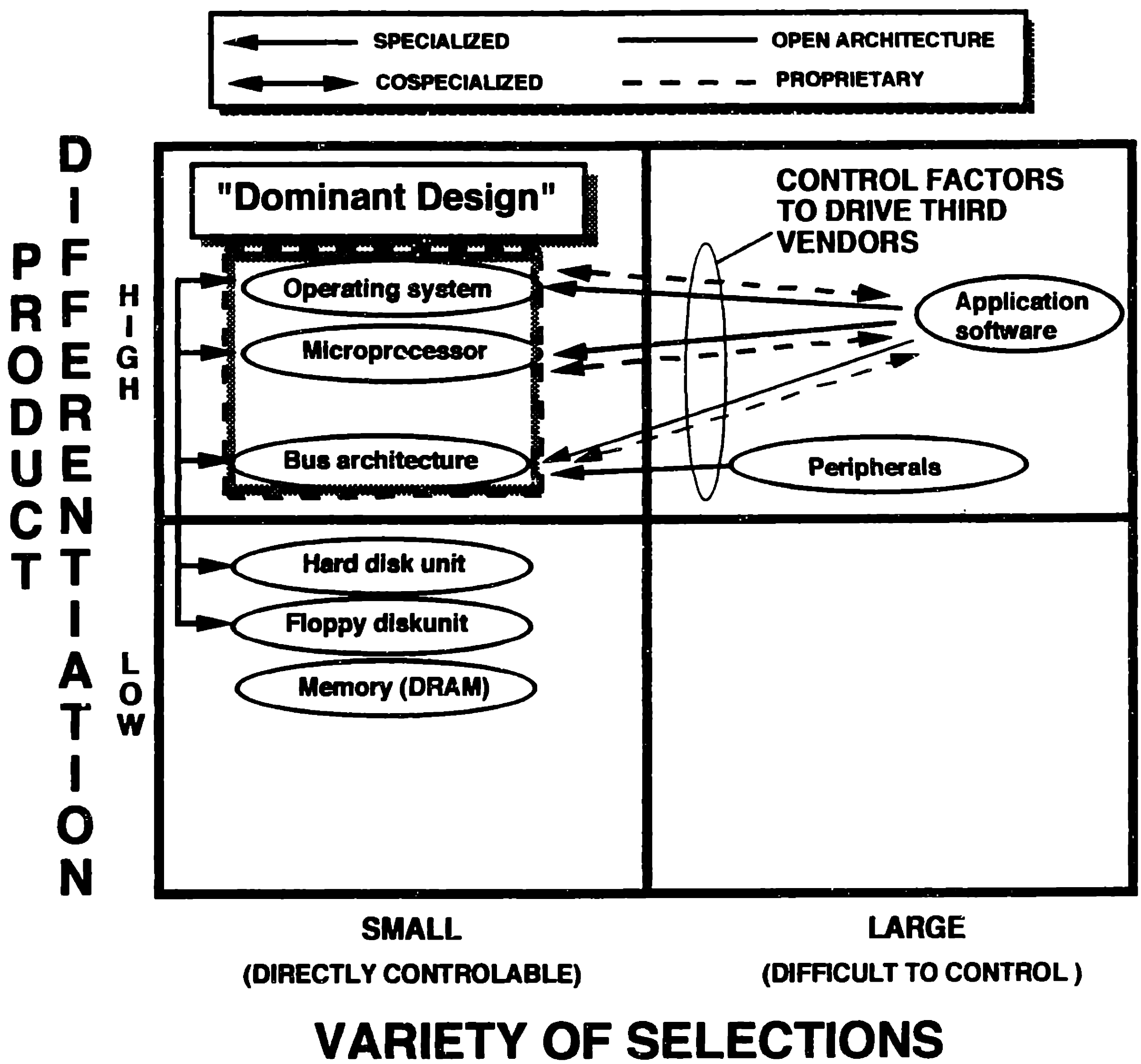


Figure 4

3.3 Summary

In this chapter, the strategic importance of managing complementary assets and the nature of "Dominant Design" have been discussed. Because this industry is largely dependent on industry standard technologies, how standards affect new entrants' and incumbents' behaviors must be investigated in order to understand how best to manage technological change in the industry.

In the following chapter, decision factors of participants regarding compatibility standards in the PC industry, including software firms, will be discussed.

CHAPTER 4 --- Decision Factors of Participants toward Adoption of "Compatibility Standard"

4.1 Adoption and new entry decisions by PC hardware vendors

4.1.1 Hardware vendors with proprietary OS and architecture

For the computer hardware vendor, there are two options regarding selecting an operating system. One is to develop its own proprietary operating system exclusively for its machines. In this case, incentives for the firm are as follows:

- Differentiate itself by implementing sophisticated features in the OS as a competitive advantage
- Easy to control over enhancement and migration
- Possibility to enjoy a monopoly pricing when the OS becomes a dominant design

A typical example is the Apple Computer. Apple Computer aims to differentiate its Macintosh products from competitors by its excellent user-friendly graphic user interface (GUI) environment embedded on their proprietary OS. So, if a user wants to use the user interface, s/he must buy Macintosh hardware. Since profit from the hardware is larger than that from the OS, if the Macintosh can dominate the market successfully, this approach becomes beneficial.

However, the firm also must accept a larger risk. Since application software, crucial complementary assets, are cospecialized to the proprietary OS and architecture, it is difficult to encourage software vendors voluntarily to develop applications for the proprietary machine. As discussed in Chapter 3, the firm has to create those assets either by a contractual approach or by itself. It must take a longer time and a larger investment for the development than in the non-exclusive case. Once the firm reaches a market share sufficient large to provide business for these software firms, they will be attracted by the opportunity and will write applications for the machine, even voluntarily. Since Apple Computer understood this mechanism in the case of marketing the Macintosh, they first contracted with a very small number of software firms to develop eight basic softwares at the launch. Apple then provided special salespeople called "Evangelists." They actively visited third-party software and peripheral vendors to motivate them to develop their products for the Macintosh.

In this case, since all complementary assets are cospecialized, the manufacturer of the proprietary machines must take care of everything by itself. Disadvantages of proprietary OS and architecture are:

- R&D support and service for OS must be provided by the manufacturer
- R&D support and service for hardware must be provided by the manufacturer
- Encourage third-party vendors by contractual approach

- Slow in diffusion because of limited manufacturing capability

Because this approach requires a large investment for acquiring complementary assets, as well as internal development, cost to enter are very high. On the other hand, since vendor channels and internal development know-hows must be specialized, switching costs to a new operating system also must be very high. In terms of stimulating other new entries, the manufacturer with proprietary technology bans any other from adopting the technology to enter the industry.

<Summary>

Cost to enter: Very high
Switching cost: Very high
New Entrant: Not allowed

4.1.2 Hardware vendors with open standard OS and architecture

As discussed in the previous sections, adopting standard technologies is a typical approach for the majority of the PC hardware vendors. Potential advantages are listed below:

- Small or no R&D, support, and service in OS (by license only)
- Small R&D, support, and service in hardware

- Fast in diffusion (MFG & MKTG by many firms)
- Must use a chip set for which the OS supplier provide micro code (MS-DOS for Intel chips, CP/M for Z80 and Intel chips)

Since the operating system is developed by an OS vendor, technical support and user support information are to be provided by the OS vendor by license. Information about the OS is usually available publicly through magazines and computer instruction books. So, the manufacturer can minimize its R&D, and support and service efforts for operating systems. Regarding other hardware components, low cost standard components which resulted from economies of scale are usually available. Since multiple firms are allowed to adopt the open standard technologies and sell their products in the market, diffusion speed must be fast. This will attract complementary asset providers to develop products for the open standard, which will increase the value of the product to end users and ultimately generate a better cycle.

On the other hand, there are several disadvantages. In this case, since competitors can use the identical standard technologies, the firm must differentiate its products by better features, better cost performance, higher quality of service & sales operation, brand name, or larger customer base. It is also difficult for the single firm to enhance a feature of the OS or other standard components, because it will cause incompatibility with the standard environment.

If the firm is the first mover to a new open standard, it needs to encourage third-party vendors to develop complementary products with their own expenses as do the proprietary OS adopters. In addition, the firm must make sure customers using another current standard OS will benefit sufficiently from switching to the new OS. Otherwise, the new standard would not be the next standard in a real sense.

If the firm is a follower or imitator, it will be able to enjoy having complementary assets developed by the bandwagon with small or no expenses. It also may acquire the know-how to make machines, and can develop them with small R&D effort.

When a new OS is provided for the same chip set and architecture, it is easy to expand to support the new OS in addition to the current one. This will become a great advantage when the firm is in transition from one OS to another, such as from CP/M to MS-DOS, or from MS-DOS to OS/2.

A new entrant is expected to grow significantly because of the follower's benefits.

<Summary>

Cost to enter: Very low

Switching cost: Relatively low

New entrant: Increase (very much)

4.2 Decision factors for software vendors

4.2.1 Characteristic of the software business

The general characteristics of the software vendor must first be discussed. There are two categories of software vendors: (1) software vendors for mass market such as "system software vendors" and "application software vendors"; and (2) contract-based software vendors. The latter develop customized softwares for a specific user by contract. So, the nature of the business is low-volume and high-margin. Since the R&D expense is to be passed on the user, their profit is secured. Because of this, contract-based software developers are not so sensitive to "standardization" and its externality as are system and application software vendors. So, in our discussion, we will focus on software vendors for mass market.

The software business in general is regarded as non-capital intensive. A large portion of R&D expense comes from labor cost rather than investment for equipment. So, many think that software firms can try a new product idea or concept with very small capital investment. This is why many small start-up firms can enter the software business and their exit or switching cost are thought to be low. This is true when the firm's "idea" or software product in a specific segment of the market is in the "Fluid pattern" stage. However, once the new software product is put in orbit, significant capitalization is required. Figure 5 shows the capital requirement structure of a typical software application development, of which 75.4% is made for advertisement, and 86% is related to sales and marketing efforts. The remaining 14% is spent for R&D-related activities. This indicates that capturing a large number of customers is their investment motivation, and therefore the large market share and the diffusion speed of a "specialized" computer environment must be one of the most important decision factors for the software firm.

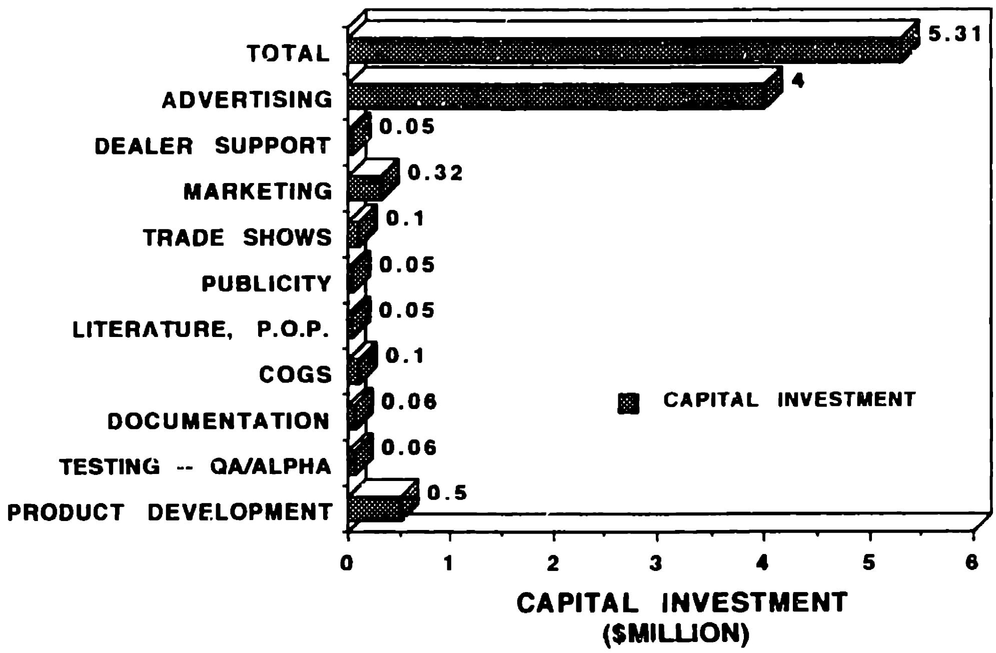
The question is which is more important for the software firm, installed base or new sales. Douglas G. Carlston, former President of Brodebund Software, describs in his book (1985) about the ill-fated decisions of the exit software vendors :

> ...the corporate newcomers talked a lot about "installed base" - the millions and millions of home computers that had already been sold. ..... installed base does not make a whit of difference when the principal channels for the sale of software are stores that still make most of their living selling hardware .... So, until independent software channels become the principle channels for the sale of software, the size of the real software market depends on the rate of sale of computers, not the install base.

At any rate, how to acquire another complementary asset, or distribution channel, is crucial for the software firms.

CAPITAL REQUIREMENTS OF SOFTWARE BUSINESS

(CASE: COMPANY-A)



CAPITAL INVESTMENT STRUCTURE FOR R&D AND MARKETING/SALES

(WITHOUT ADVERTISING)

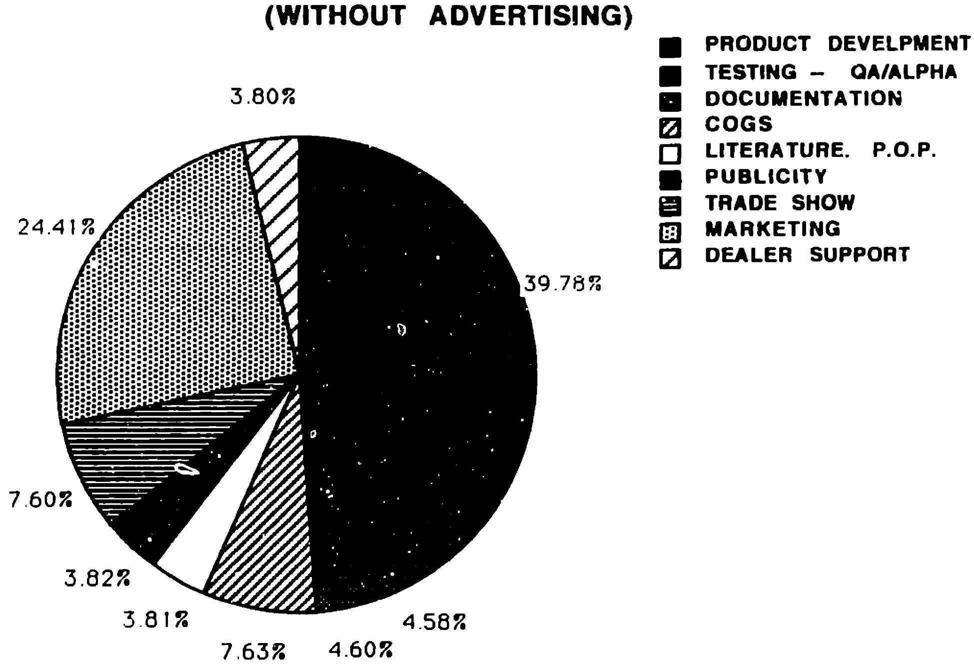


Figure 5

Source: Toong (1985)

Critical factors for a successful software business are summarized as follows (Toong 1985):

- Must have good ideas/ concepts of new software applications
- Good access to distribution channels
  * Publishers
  * Distributors
  * Dealers
- Marketing promotion campaign
- Continuous improvement of the product features
- Sufficient capitalization to enable the above factors

To realize these critical success factors, a company must choose the correct cospecialized target environment which is a set of operating systems, microprocessors, and bus architecture. The operating system is especially crucial to the software firm because of its influence on features of software products, while the other two technologies are basically a "compatibility" issue.

Thus, selecting the best operating system must be made a priority decision factor. Benefits of the correct OS selection are:

- Richness of commands and features to allow the firm to implement new ideas
- Expect the continuous enhancement for which successful OS vendor can afford R&D

- Large market size for specialized OS which is based on prospective sales growth and installed base (economies of scale)
- Market-side complementary assets such as independent software distribution channels are more likely to become available

On the other hand, if the software firm once selected one OS as its target, it is likely to be locked into the selected OS. Switching to a different OS requires a different set of expertise in R&D and a different set of marketing channels, although the idea/concept of the software application remains the same.

Investment for computer equipment for software development is not trivial for the relatively small software firm. This also becomes a criterion for switching.

<Summary>

Cost to enter: **Engineers' familiarity and expertise in programming; development machines**

Switching cost: **Very high (always)**

4.2.2 Software vendors for proprietary OS and architecture

Developing software for a proprietary OS is riskier than for an existing standard OS because software products are cospecialized to the selected OS. The destiny of cospecialized software firms depends fully on the success of the hardware manufacturer. If the manufacturer fails and exits, the software firm cannot survive. Since most necessary complementary assets are provided by the proprietary PC manufacturer, its diffusion speed is slow. This situation cannot satisfy the success factors discussed above. So, no software firm may voluntarily develop a software application for the machine until a significant diffusion has been accomplished. Additionally, it is very difficult to hire skilled engineers with experience in the proprietary technology. This job requires specialized education which may cause a delay and inefficiency of R&D.

As discussed in the hardware manufacture's section above, those proprietary OS is likely to have an advantage in richness of commands and features, so early movers may benefit from the richness of the OS, which may in turn reduce R&D cost and increase attractiveness of the resulting software. Secondly, these proprietary hardware vendors must take a contractual approach to acquire cospecialized assets in the early stage. Sales of a certain volume of software products may be guaranteed by the hardware vendor under a contract agreement. Furthermore, the hardware vendor may provide some marketing aid, distribution channels, and even its sales forces to sell the software products, because the hardware vendor cannot sell its hardwares without application software. This cospecialized relationship is extremely beneficial to the early movers of a proprietary OS. Early movers may also benefit from being a single supplier of software in an exclusive application area, until other software houses begin to develop a wide variety of software.

On the other hand, late movers to a proprietary OS and architecture have a relatively lower risk than do early movers, because a critical mass of the target market has at that point already been established. Also, it will have become easier to hire skilled engineers who are familiar with the proprietary OS technology.

Risks and benefits for early and late movers are summarized as follows:

<Early movers>

Risks

- Diffusion speed must be slow ----> uncertainty is high
- Products are cospecialized to the proprietary firm
- Success or failure depend fully on the hardware vendor
- Hard to find experienced engineers for the proprietary technology

Benefits

- May reduce R&D cost and increase attractiveness of the resulted software
- Contract to sell a certain volume by the hardware vendor
- Marketing support to be provided by the hardware vendor
- First mover benefit in a certain application area

<Summary>

Cost to enter:	**Very high (hardware vendor will pay)**
Switching cost:	**Very high (always)**
New entrant:	**Very small (contracted with the hardware vendor)**

<Late movers>

Risks

- Less risky because critical mass has been established
- Equally low risk to moving to the existing standard
- Easier to hire software engineers who have experience in the OS than the earlier stage

<Summary>

Cost to enter:	**Relatively lower than the earlier stage**
Switching cost:	**Very high (always)**
New entrant:	**To be increased (moderate and delayed)**

4.2.3 Software vendors for open standard OS and architecture

Developing softwares for open-standard OS and architecture is more secure than for proprietary OS, because multiple hardware companies will support the same OS and any single company's exit decision will not lead to a disappearance of all of the supporting firms. An open-standard approach is more likely to lead to a new de facto standard because of its fast diffusion speed. Since any hardware vendor is allowed to adopt open-standard technology, manufacturing capability must satisfy the growth of demand. Rapid growth brings economies of scale for standard component suppliers, which then will result in cost reduction of PC hardware, which in turn can accelerate the diffusion speed. This mechanism will result in a large market size to which many application software vendors are attracted. The open standard approach stimulates complementary assets providers, including technical publishers, who will deliver a large amount of information about open-standard technology to software engineers. Deeper technical information about operating systems is also available, enough to nurture a large population of software engineers for the new technology. It must be easy to hire experienced engineers for the technology, and will reduce a software firm's initial education cost.

Although these mechanisms exist, if a software firm cannot assure the diffusion of the new technology, it will not take risks in the early stage to move to the emerging new OS. So, adopters of another operating system who hold an adequate business base on the different target architecture do not need to jump into the emerging standard in the early stage. They can afford to wait and see what happens. Only if they feel a tremendous threat, such as an immediate creation of a network externality from the emerging architecture, they will move. Many new entrants or new adopters are smaller firms who bet on an emerging standard and seek an opportunity to become the first mover in a specific application niche market before its competitors enter.

On the other hand, late movers have seen the diffusion speed of the emerging architecture, and adopt only when they are confident that a credible business base is established. Late movers are usually firms who has a sufficient capital to compete in the mass marketing or who have a new idea with which to create a niche market.

<Summary>

Cost to enter: Very low

Switching cost: Very high

(depends on similarity to the new OS)

New entrant: To be increased

(Significantly)

4.3 Decision factors for PC end users

The last and most important sector is PC end users. End users in general have no idea about which operating system and architecture is more technically sophisticated. They care more about which specific machine or set of technologies (at the level of "Dominant Design") will give them most benefit. Figure 6 shows a survey result of selection criteria among 1,900 corporate customers, conducted in 1989 by Sentry Market Research.

SOFTWARE SELECTION CRITERIA OF MICROCOMPUTER CUSTOMERS

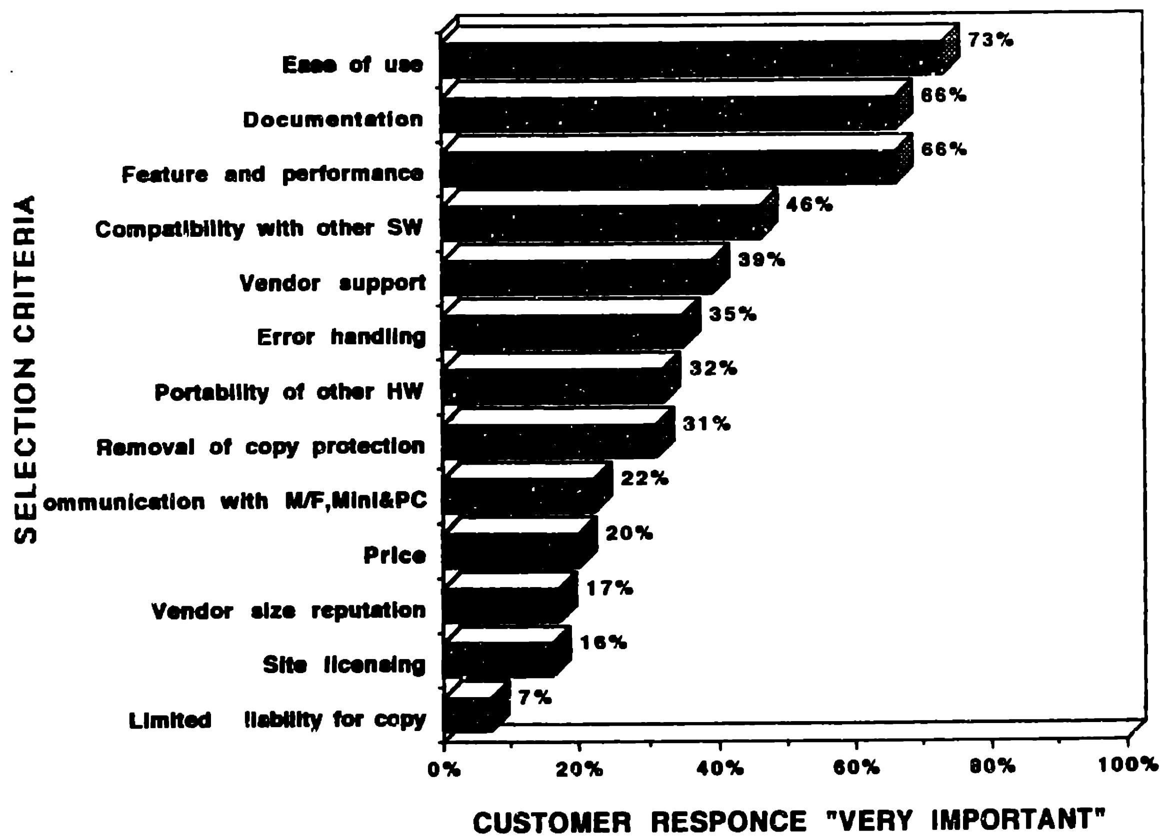


Figure 6

Source: Sentry Market Research, Software Magazine, 1989

Seventy three percent of the surveyed customers claim the feature "Easy of use" to be very important. This result implies good user interface, familiarity with a computer environment, and availability of application softwares to solve user problems. Answers related to "compatibility standard" or "Dominant Design" are "compatibility with other software" (46%), "portability to other hardware" (32%), and "communication with mainframe, mini and other personal computers" (22%). "Ease of use" (73%) and "Documentation" or public information availability (66%) are closely related to the "compatibility standard" issue. "Removal of copy protection" (31%), "Limited liability for unauthorized copying" (7%), and "Site licensing" (16%) imply mobility of softwares, therefore are also related to the "compatibility standard" issue. The low percentage for "Vendor size and reputation" (17%) indicates that customers do not care about a company but about "compatible standard." "Feature and performance" (66%) implies continuous improvement in product features, which is described in the previous section as one of the most important elements for software vendor.

Let's analyze the differences of selection criteria before and after the dominant design, and the switch to a new architecture have emerged. Before the dominant standard set is established, the following criteria must be important to end users:

- Availability of software applications to solve their problems

- Performance of hardware
- Availability of service, support, and education, including publications

  ----> Learning cost

  ----> Life cycle cost

Especially in the early stage of the emerging new standards, customers must worry about the sustainability of the standards and of the company which offers the standards.

- Continuity of platform supplies and incremental improvement

  ----> Security of their software assets

  ----> Credibility of a hardware supplier

  OR

  ----> Credibility of the compatible environment ("Dominant Design": compatibility is guaranteed)

Once the compatibility standards are firmly established, this sustainability concern disappears. So, when the personal computer industry is immature, a large number of new end users make a purchase decision based on the factors above, and contributing to the shaping of the industry and therefore to the creation of a new set of standard technologies, a dominant design. Another issue will then come out; an emergence of "inertia of the current standards."

Ferrel & Saloner(1986) discussed switching decisions from one standard to another in this phase. Especially in the personal computer market where a tremendous number of individual purchase decisions are made by customers, hardware vendors cannot simply push a newly adopted technology onto customers. What factors may prevent the customers from switching to a new operating system and architecture?

The following are the factors to be considered in switching to a new operating system and architecture:

- Inertia of existing users' software assets including application packages and user programs

  ----> Makes their switching cost significantly high
- Requires to purchase a new hardware

  ----> Trade off with benefits
- Requires learning a new user environment

  ----> Time and education cost

To overcome these inertia, benefits from switching to a new operating system must be significantly high. Otherwise they will refuse to switch and stay with the current standards. Although every customer expects incremental improvement, slight improvement cannot be enough to overcome the inertia. The question is, how much radical change is enough? Sometimes a manufacturer misunderstands the threshold level of the customer's decision.

A typical case is that of the OS/2 introduction by Microsoft and IBM in December 1987. OS/2 offered new features of multi-processing, multi-window, graphic user interface, and desk-top metaphor, which Apple's Macintosh had already accomplished, as well as a compatibility environment for MS-DOS applications. However, it also required users to individual purchase decisions are made by customers, hardware vendors cannot simply push a newly adopted technology onto customers. What factors may prevent the customers from switching to a new operating system and architecture?

The following are the factors to be considered in switching to a new operating system and architecture:

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- Requires learning a new user environment
  ----> Time and education cost

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Figure 7 shows the installed base of an operating system as of September 1991. Four million units of Windows 3.0 have been sold since 1990, while only 600,000 units of OS/2 have been installed.

The most interesting aspect of this case is the fact that Microsoft has ownership of MS-DOS, de facto standard OS, and the new OS/2, but still failed to switch users to OS/2. Microsoft's seriousness about OS/2 development can be confirmed by its >$30 million R&D expenditure for OS/2, and the prediction of Mr. Gates, Chairman of Microsoft (Business Week, September 12, 1988):

> ... Microsoft Chairman William H. Gates III predicted that by late 1989, OS/2 would "dominate" its field....and says "We're patient people. All the progress is in the right direction"
> Even his successful experiences in the defacto standard setting of MS-DOS didn't help to understand the rule of the new game of switching to a new standard

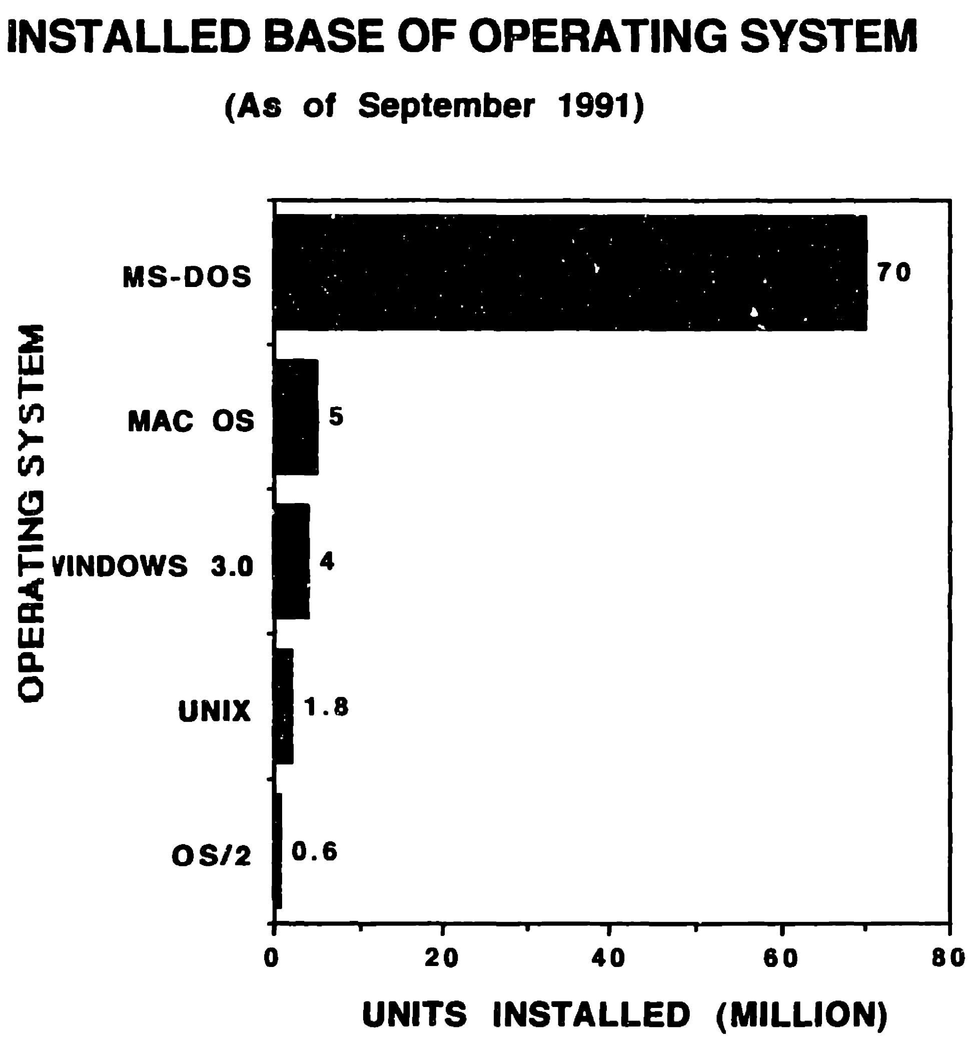


Figure 7

Source: International Data Corporation, 1991

In the same article, Mr. John F. Thorlin, an associate director at Dataquest commented (Business Week, September 12, 1988):

> ...By Gates's target year of 1991, the cost of extra memory should be substantially lower. By 1992, it will be as cheap to run OS/2 as DOS. At that point, OS/2 may replace MS-DOS as the operating system that hardware vendors sell with their new machines

The reality is different from these expectations. OS/2 still is far from a new de facto standard operating system. Microsoft then changed its strategy from betting on OS/2 to leveraging the MS-DOS installed base and enhanced it by Windows, while IBM bet on OS/2 and decided to go with it.

Through this lesson, it is clear that the switching decision was in the hands of end users rather than hardware vendors. The nature of the standardization game must have been changed.

CHAPTER 5 --- Hypothesis and Methodology: The Roughly Hypothesized Industry Development Pattern

Through the previous chapters, basic mechanisms in the personal computer industry have been discussed. In this chapter, to understand the mechanisms that shape and drive the personal computer industry, the previous discussions will be summarized as several hypotheses.

5.1 How does the emergence of a new compatibility standard influence on PC hardware vendors?

5.1.1 "Dominant Design" exists in the PC industry

<Hypothesis-I>

Before a dominant design has emerged, a tremendous amount of trial-and-error by several different designs or set of technologies must have occurred. These are then resolved into a single dominant set of technologies which can be regarded as the "Dominant Design" of Abernathy and Utterback (1978).

The "Dominant Design" in the personal computer is a set of:

- Intel 80X86 microprocessor
- MS-DOS operating system
- IBM-PC AT Bus architecture

<Methodology>

The number of PC products with certain design features developed by all the PC hardware vendors from 1970 through 1989 will be counted.

Substances are:

- Operating system
- Microprocessor
- Bus architecture

----> will be investigated by a different data source

(Sources): Data Sources, Ziff-Davis Publishing Company 1983, 1986, 1989, 1991 editions

5.1.2 Number of new entrants and their entry decisions

<Hypothesis-II>

Because a new "dominant design" stabilizes the industry, and new entrants can then take advantage of the already established design and highly standardized low-cost components, the number of new entrants will increase. Adopters of a wrong standard(s) are more likely to exit from the industry. In a transition phase, in order to avoid a fatal situation, new entrant PC hardware vendors as well as incumbent firms take a strategy to cover as many likely standard as possible.

Notably, this phenomenon of hardware vendors is different from that which the Abernathy and Utterback's model suggests, while their model does fit to the suppliers of individual elements of the "Dominant Design".

<Methodology>

The number of new entrant PC hardware vendors from 1970 through 1989 will be counted, and their entrance decisions for standard technology will be investigated. The behavior of hardware vendors which once adopted a wrong standard will also be investigated. In addition, R&D vitality will be measured by how many different models are developed.

(Sources): Data Sources, Ziff-Davis Publishing Company
1983, 1986, 1989, 1991 Hardware editions

5.2 How does the emergence of a new compatibility standard influence on PC software vendors?

5.2.1 Creation of a new business base by a "Dominant Design"

<Hypothesis-III>

Because PC software vendors, especially application software firms, are complementary assets for a personal computer, the emergence of a new and stable target environment which is a set of compatibility standards, "Dominant Design," will create a new business base for these software firms. Therefore the number of new entrant PC software firms is increased. For a proprietary operating system and architecture, the increase in the number of new entrants must be very slow in the early stage, and gradually become faster, but much slower than for a standard architecture.

<Methodology>

Number of software firms established in Massachusetts from 1960 through 1990 will be counted in order to know the macro trend of the software firms. This data includes software firms which are headquartered outside Massachusetts with branch operations in this state, so that it can be regarded as the movement of the whole software industry. We have investigated 1204 software firms.

(Data Sources): The Complete Guide to the Massachusetts Software Industry, Massachusetts Computer Software Council, 1990

5.2.2 Behavior of PC software vendors

<Hypothesis-IV>

Supporting several different operating systems and architectures requires multiple efforts for a software firm, because software products are somewhat specialized to a specific operating system and architecture. So, they are more likely to stay with one target environment rather than many operating systems.

A firm that has selected a wrong standard is more likely to exit than to survive. Although it may try to switch to a right target, supporting the current standard diversifies its efforts and therefore prevents it from successfully switching to a right standard. A firm supporting a proprietary operating system tries to support other operating system environments to reduce risks because its products are cospecialized to the proprietary environment.

<Methodology>

The Massachusetts database unfortunately does not allow us to count exit firms for a micro level investigation. So, we complement this by investigating the behavior of randomly-sampled software firms. Around 100 software firms will be randomly selected, and investigated by decision on target operating system, change the target, multiple operating system support, and mortality rate. For the wrong target selection cases, 27 CP/M adopters will be randomly selected and investigated. For the proprietary operating system case, 40 software firms for Apple's Macintosh will be randomly selected and investigated.

(Sources): Data Sources, Ziff-Davis Publishing Company
1985, 1987, 1989, 1990 Software editions

CHAPTER 6 --- Empirical Study and Analysis

6.1 How does the emergence of a new compatibility standard influence on PC hardware vendors?

6.1.1 "Dominant Design" in the PC industry

Figure 8 shows what type of operating system is adopted for how many new products introduced in the market. Of product models launched from 1970 through 1989, 3292 have been investigated. When the IBM-PC was launched in 1981, the leading design in operating systems was the CP/M of Digital Research. Many different types of operating systems, represented in the graph by "others," were also adopted by the second-largest portion of the new products. During the first several years after the emergence of IBM-PC and MS-DOS (PC-DOS), MS-DOS was not a leading design. However, in 1984 it became the leader, and kept a dominant position thereafter. CP/M tried to get out of a situation which was cospecialized to Zilog microprocessor, and wrote CP/M for the Intel microprocessor and thus for the IBM-PC, but couldn't defeat MS-DOS which IBM sold mainly with the IBM-PC. In the figure, it contains the UNIX operating system, which is thought of as an operating system for workstations. Nevertheless, MS-DOS still dominates the market significantly. We can therefore conclude that MS-DOS is the single dominating design in the industry.

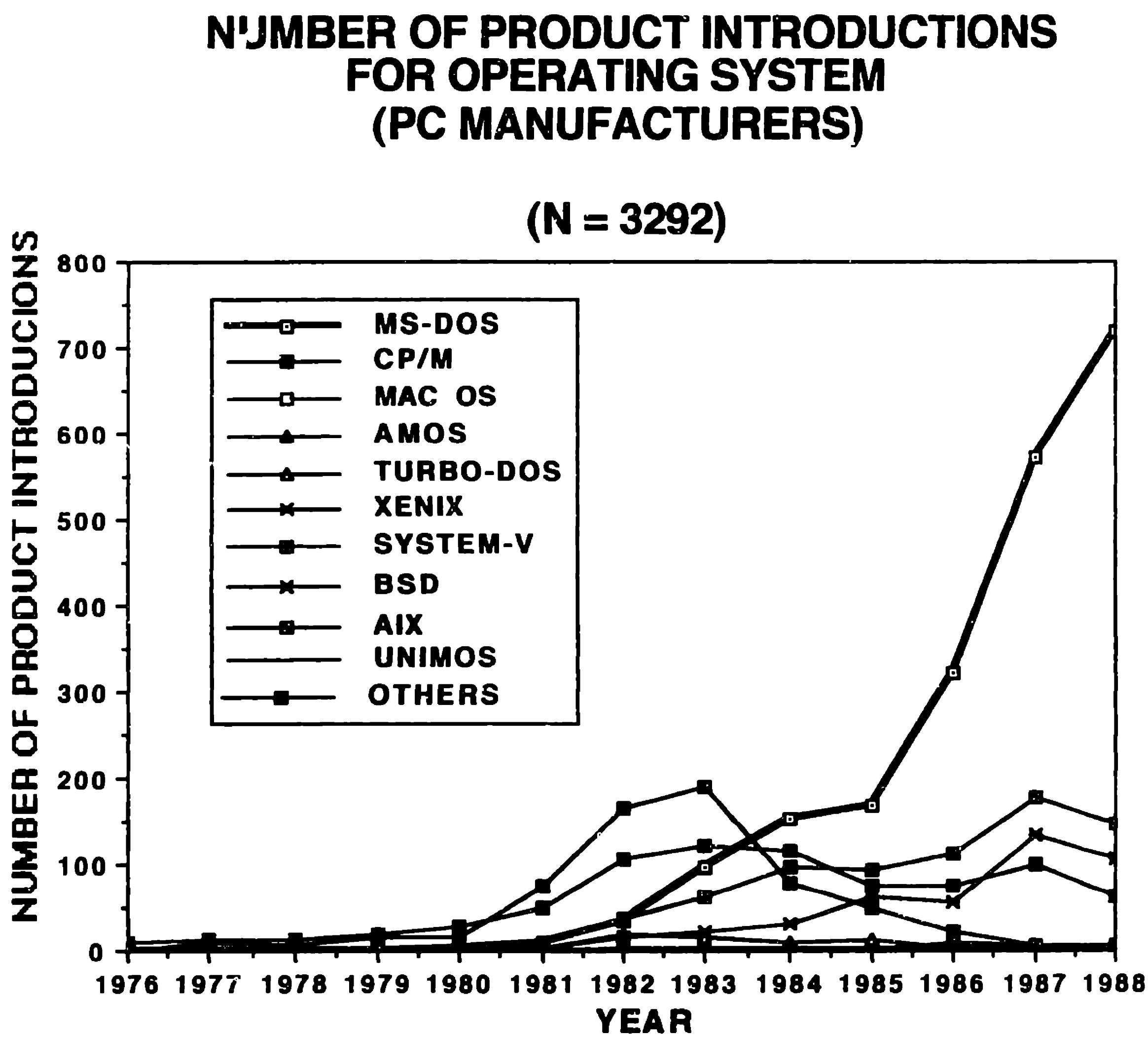


Figure 8

Source: Reassembled by the author, Data Sources

Ziff-Davis Publishing Company, 1983-1989

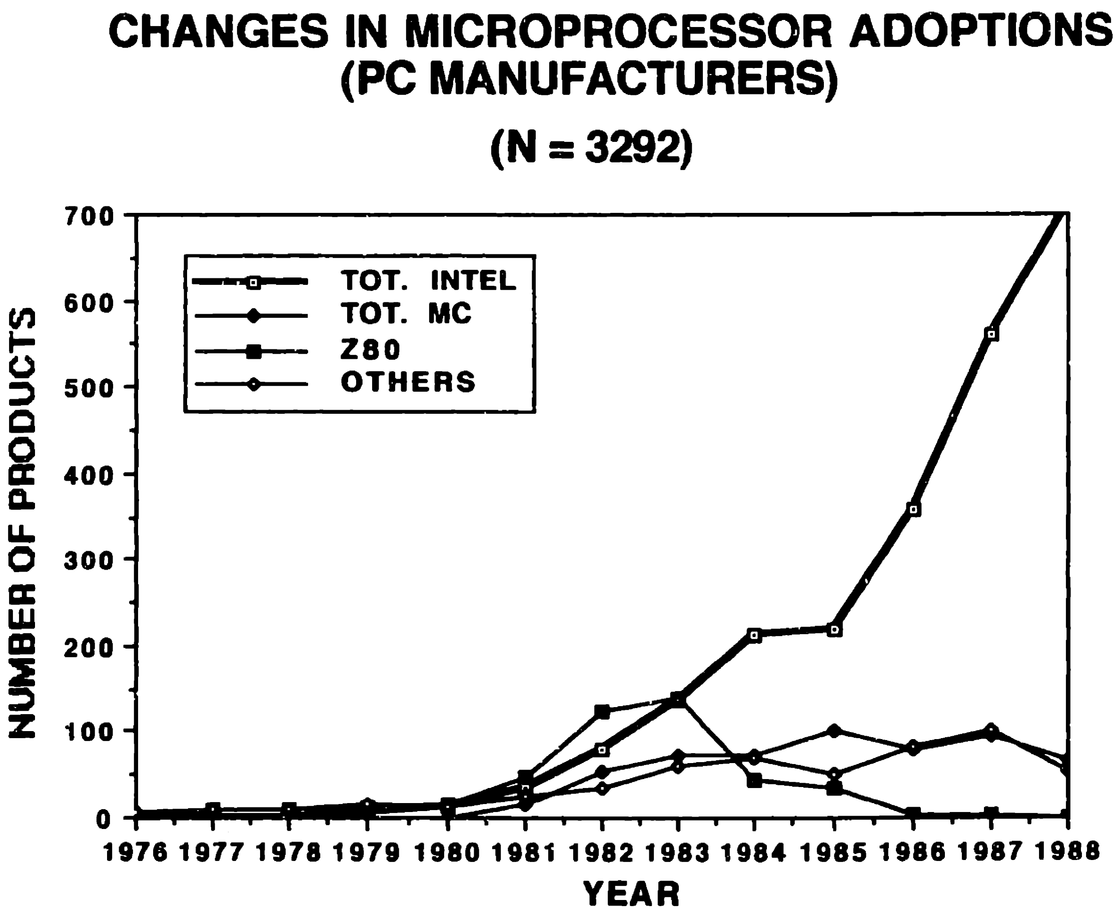


Figure 9
Source: Reassembled by the author, Data Sources
Ziff-Davis Publishing Company, 1983-1989

On the other hand, Figure 9 shows adoptions of microprocessor by new products. The Intel microprocessor, which MS-DOS is written for, has also tracked a path similar to that of the MS-DOS.

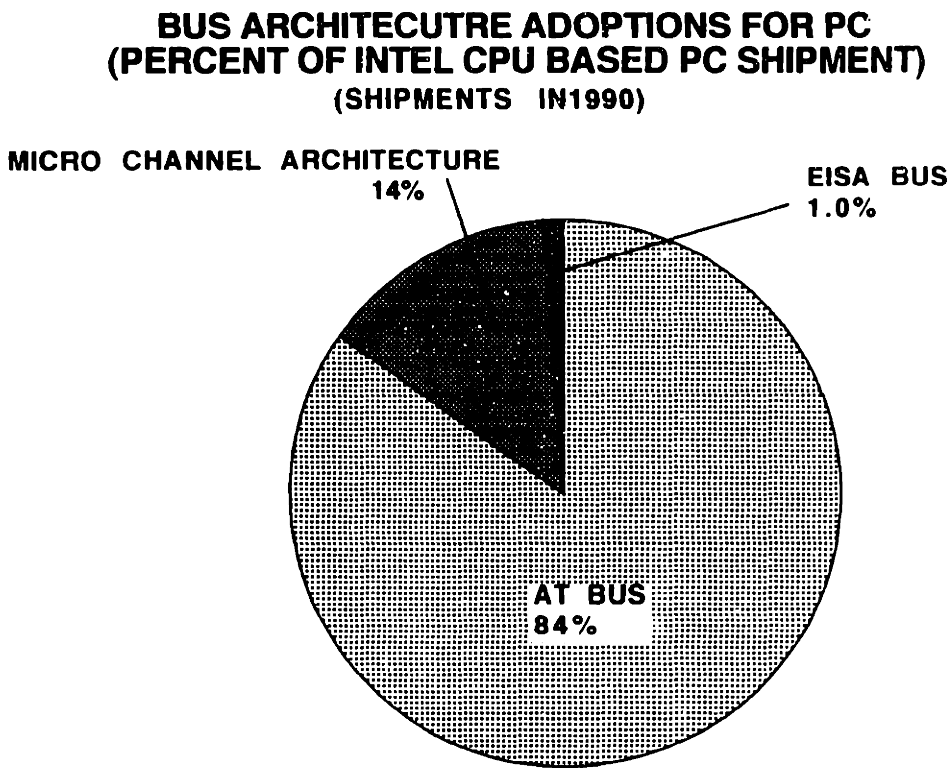
In 1981, Zilog's Z80 microprocessors which were specialized to CP/M led the market. However, in 1983, new products with Intel's microprocessor overcame products with Zilog's microprocessor and has dominated the market ever since. This is also regarded as a single dominating design.

The third element of "Dominant Design" we hypothesized is bus architecture, which is specialized to the Intel microprocessor. Figure 10 (a),(b) shows the percentage and units of bus adoption by Intel-based products in 1991. AT Bus was introduced with IBM-PC AT. It dominates 84% of Intel-based products, which dominate the market.

More than 80% of personal computer products introduced into the market are facilitated with a set of MS-DOS operating system, Intel 80X86 microprocessor, and AT Bus architecture. And as one of the most important complementary asset, software applications are specialized to the dominant set of technologies rather than to a company such as IBM.

Summary

We have hypothesized (Hypothesis-I in Chapter 5), that "Dominant Design," which consists of Intel 80x86, MS-DOS operating system, and IBM-PC AT Bus architecture, has definitely emerged in the personal computer industry.



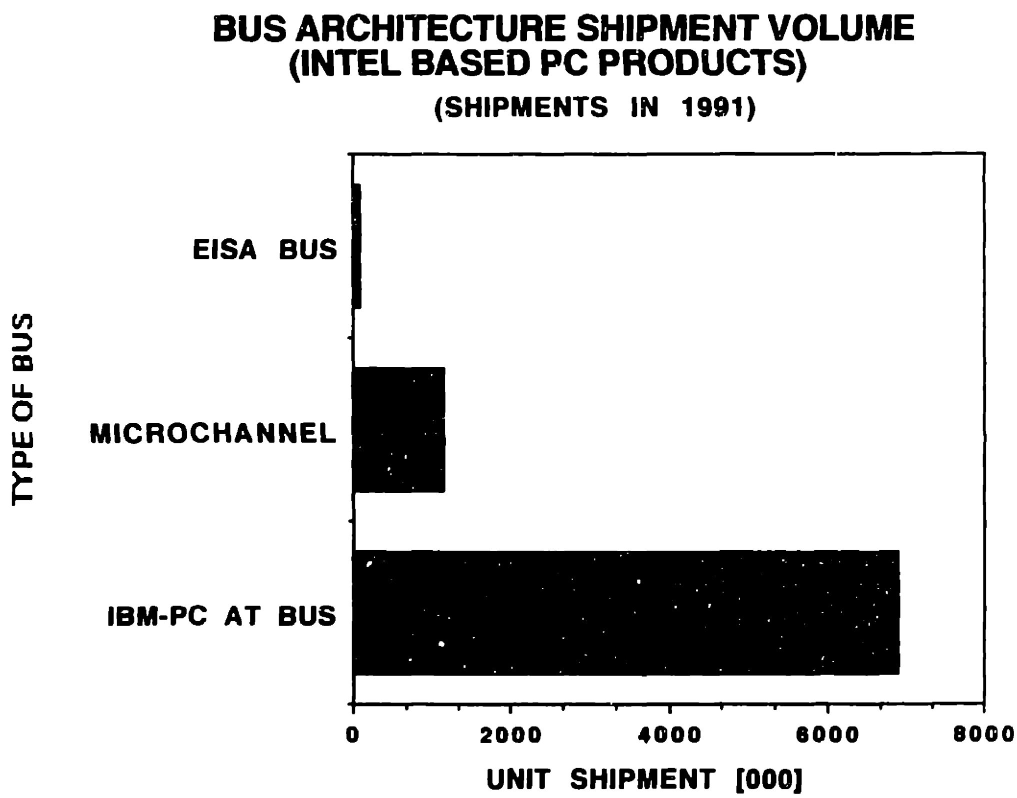


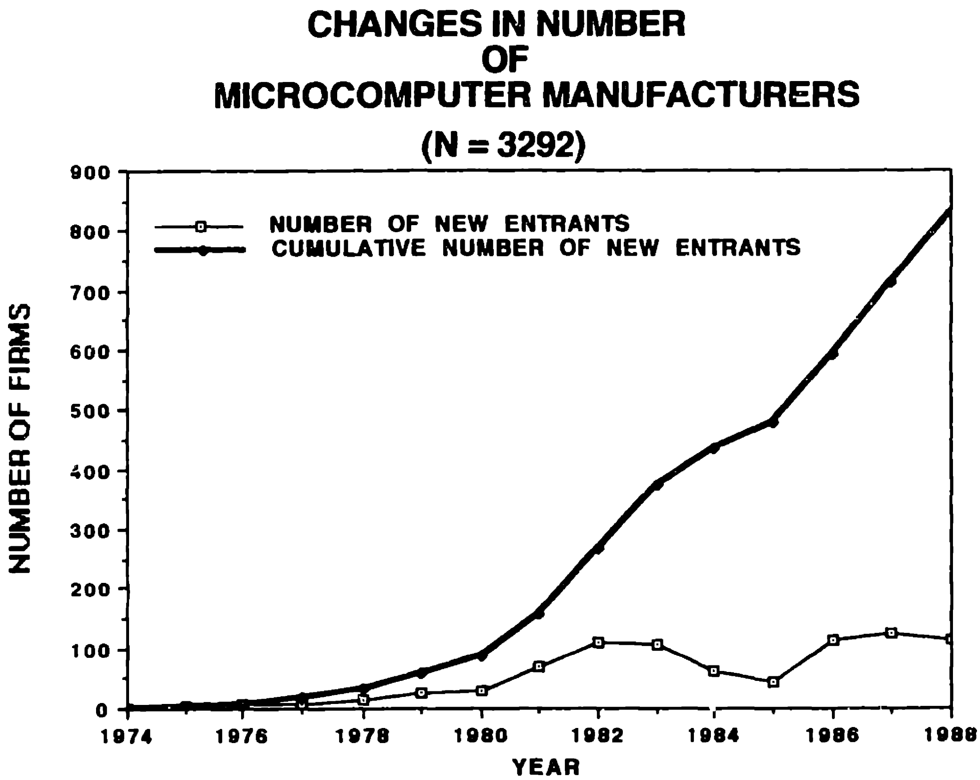
Figure 10 (a), (b)

Source: Computerworld, International Data Corporation, 1991

6.1.2 The number of new entrants and their entry decisions

We have hypothesized that the number of new entrant would increase with the emergence of the dominant design. Figure 11 shows the research results of 846 hardware vendors. Regarding the number of new entrants, in 1981, when IBM entered the PC market, a significant increase is observed. There were two major waves of new entrants, the first from 1981 to 1984, and the other occurring from 1985 to 1988. Figure 12 shows the changes in new entrant firms' decisions on the selection of operating system; Figure 13 shows the new entrants' decisions on microprocessor. As the graph shows, the new entrants in the first wave seems to be trying to figure out who will win; so, CP/M was the leading operating system for new entrants during that period.

The fact that IBM, the well established computer giant, entered the PC market, might have encouraged new entrants to expect the growth of the industry rather than the specific compatibility standard. Many new entrants in that period adopted a multiple operating system, including MS-DOS (or PC-DOS) and CP/M as well as other operating systems, indicating the existence of uncertainty. With the decline of CP/M, the number of new entrants declined from 1983 to 1985. Then, in the second wave, many new entrants who were very sure about the successful future of the new dominant design, MS-DOS operating system and Intel microprocessor, entered from 1985 through 1988.



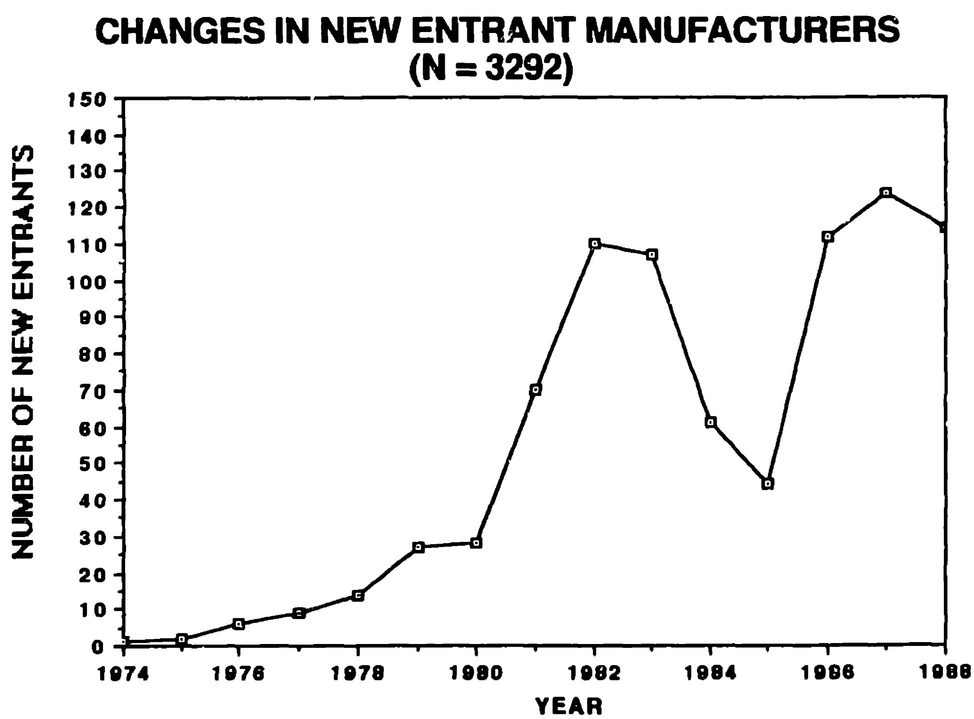


Figure 11 (a), (b)

Source: Reassembled by the author, Data Sources

Ziff-Davis Publishing Company, 1983 - 1989

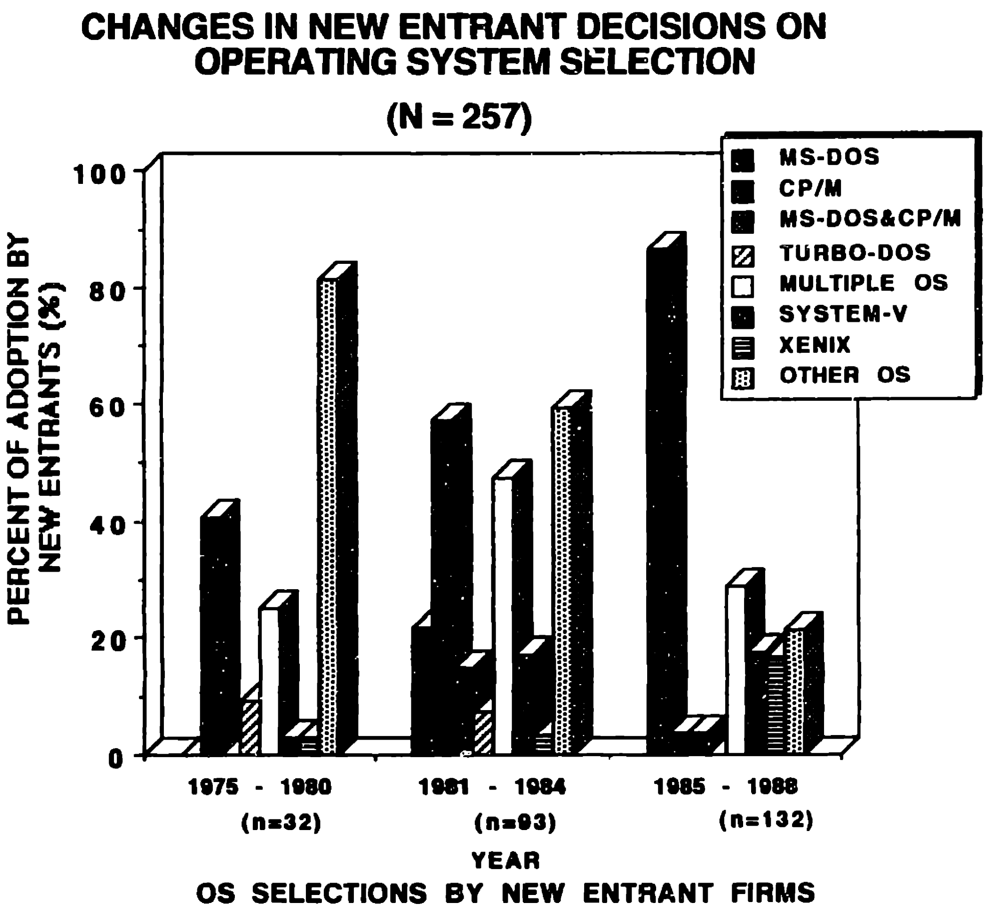


Figure 12

Source: Reassembled by the author, Data Sources

Ziff-Davis Publishing Company, 1983-1989

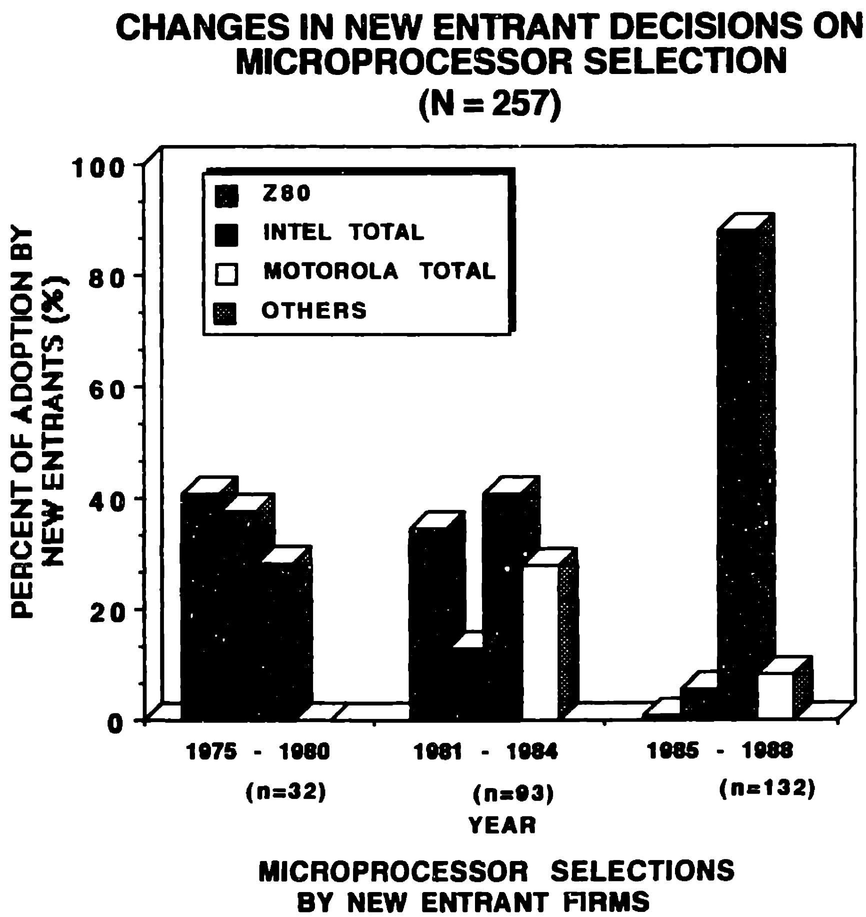


Figure 13

Source: Reassembled by the author, Data Sources

Ziff-Davis Publishing Company, 1983-1989

The emergence of the new stable compatibility standard encouraged many new entrants to come into the industry.

Figure 14 shows the number of different product models developed. This represents the R&D vitality of the industry. Surprisingly, even after the dominant design was fixed, R&D vitality continued to increase. This must indicate the existence of a different level of innovation. The laptop computer is an example of another innovation which occurred in the personal computer industry in the late 1980's.

On the other hand, what are the major reasons for exits? Figure 15 shows the relations between OS selection and exit. In the early 1980's, a wrong selection of CP/M seemed to be the main reason for exit. However, for the late 1980's, we can see no big difference among the operating system selections of the exit firms. Even the MS-DOS or "Dominant Design" adopters left the industry. This implies changes in the competitive nature of the PC industry. On the other hand, as Figure 16 shows, many firms in the transition stage tried to reduce risks by adopting both the current leading standard, CP/M, and an emerging leading standard, MS-DOS. Digital Research, the owner of CP/M, tried to reduce risks also by breaking cospecialized relationships with Zilog processor, Z80 series, and porting CP/M on Intel 8080 and 8086 CPU. However, the standardization game and "Dominant Design" did not allow for two "leading" standards, then both CP/M and Zilog were shakeout.

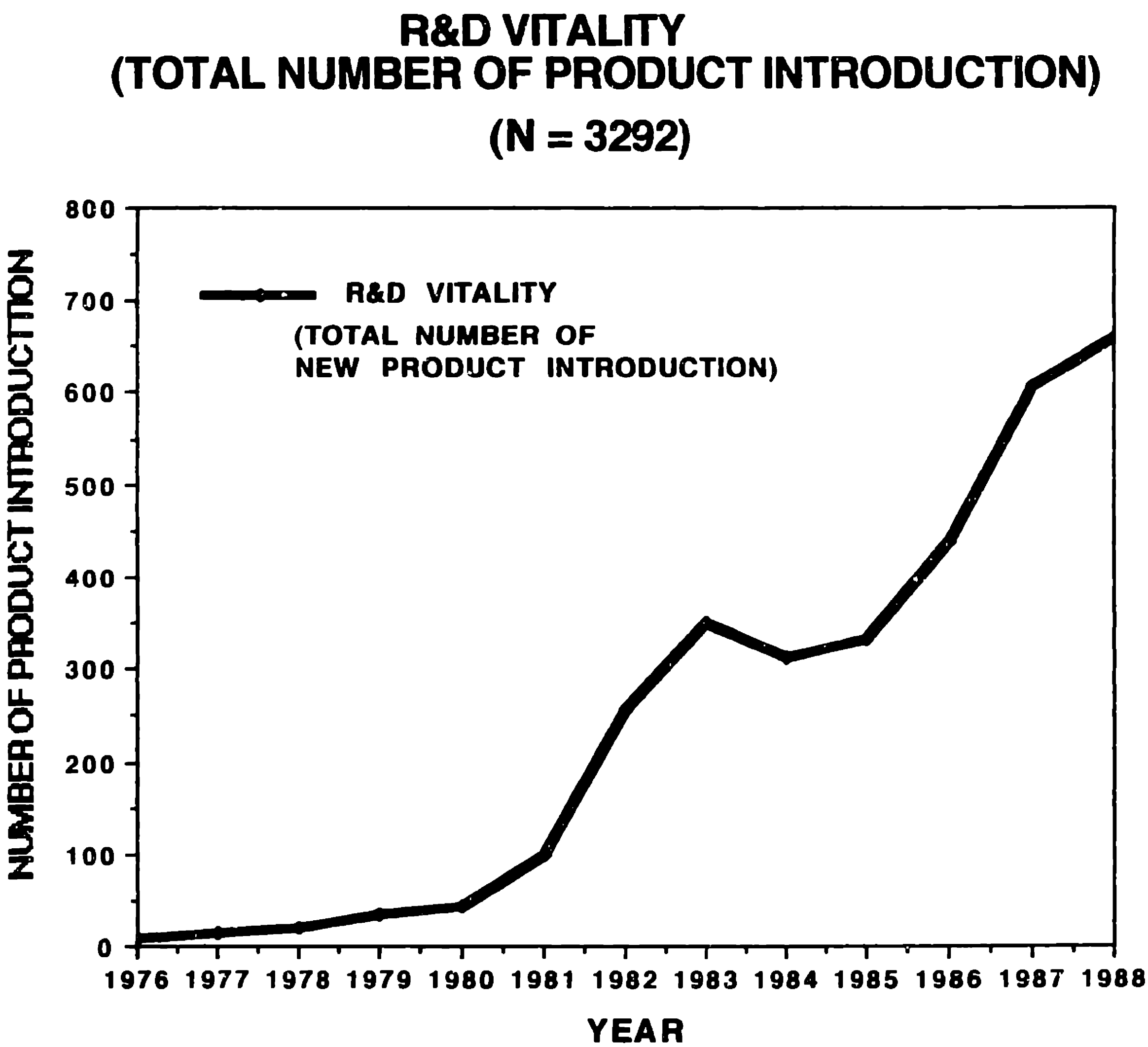


Figure 14

Source: Reassembled by the author, Data Sources

Ziff-Davis Publishing Company, 1983-1989

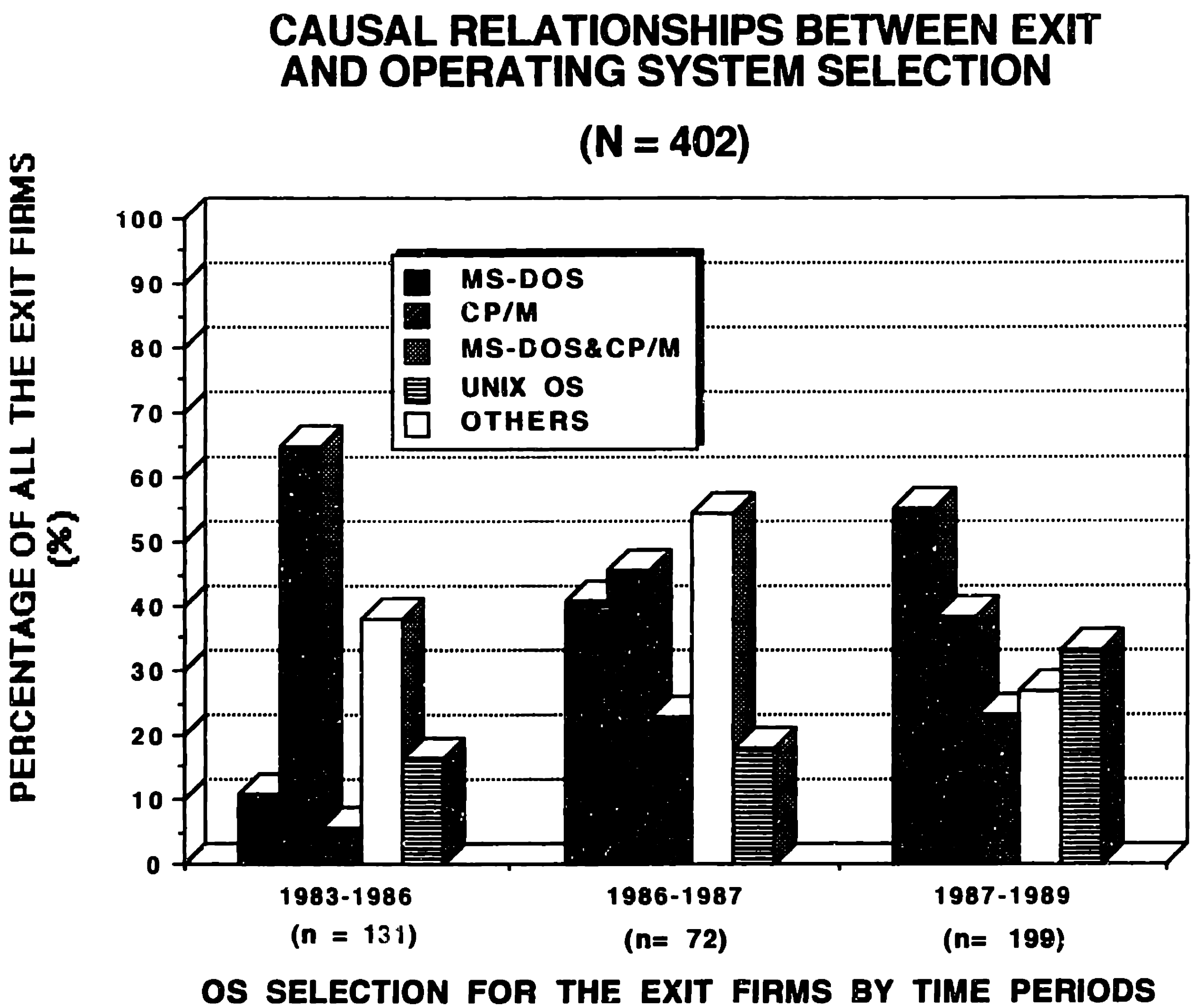


Figure 15

Source: Reassembled by the author, Data Sources

Ziff-Davis Publishing Company, 1983 - 1989

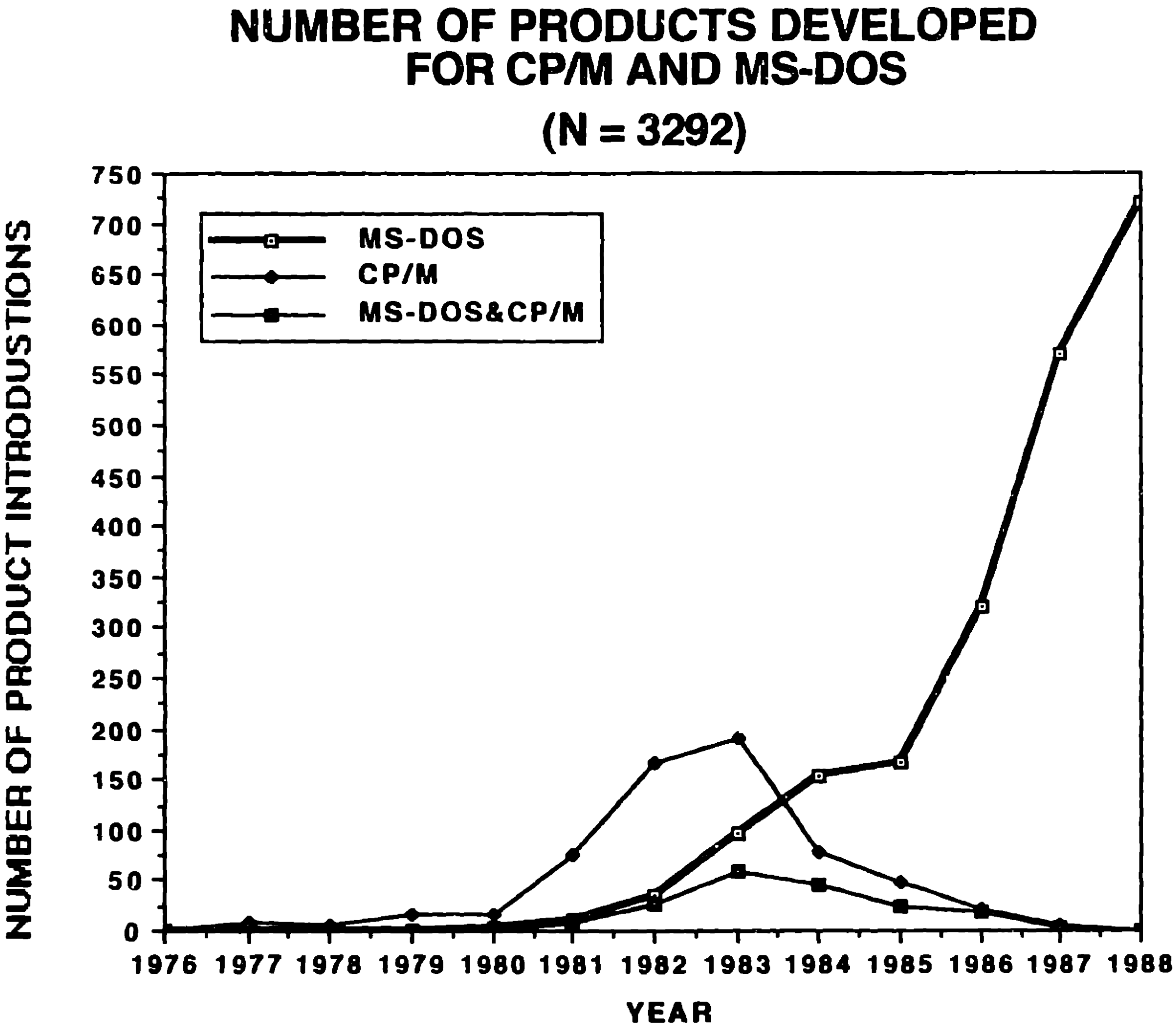


Figure 16

Source: Reassembled by the author, Data Sources

Ziff-Davis Publishing Company, 1983-1989

Summary

According to Hypothesis-II in Chapter 5, the emergence of the new dominant standard increased the number of new entrants. Two waves of new entrants were observed in this study. During the first wave, we could observe both trial-and-error of different technologies and increase of new entrant. This pattern is the same as suggested by the Abernathy/Utterback model. However, the model cannot explain the second wave, because many new firms with "Dominant Design" entered, and no single large corporation dominated the industry and enjoyed economies of scale. Standardizations (de facto standardization) of the three core components of the "Dominant Design", operating system, microprocessor, and Bus architecture, changed the development pattern of the PC industry.

Many hardware vendors tried to reduce risks of adopting a wrong standard by adopting multiple operating systems in the transition phase. Once the "Dominant Design" had emerged, adoption decisions become clear. A wrong technology selection was a major cause of exit in the early stage of the new dominant design, while the major cause of exit changed in the latter stage.

All in all, Hypothesis-II is proved.

6.2 How does the emergence of a new compatibility standard influence on PC software vendors?

6.2.1 Creation of a new business base by the emergence of a "Dominant Design"

In this section, how the emergence of the dominant standard influenced computer software vendors as a whole will be investigated. Figure 17 shows dates when new software firms, of those still operating in 1990, were established in Massachusetts. As Figure 17 shows, the number of new establishments increased sharply right after the entry of IBM into the PC business. Of course, prior to that point, from around 1977, a symptom of the growth can be observed. However, the increase from 1981 is much steeper, and was sustainable. The first increase, in 1977, is easily synchronized with the emergence of Apple and Tandy. The number of new entrants matured in the mid-1980's, then gradually declined during the late 1980's, indicating that a new business base had emerged in the early 1980's. The market, including niches, had become crowded, reducing incentives for new entrants in the late 1980's.

Regarding Apple's Macintosh computer which uses a proprietary operating system and architecture, the contribution to industry growth must be much slower and smaller than the open standard operating system and architecture.

NUMBER OF SW FIRMS ESTABLISHED IN MASS.

(Of those firms existing in 1990: N = 1204)

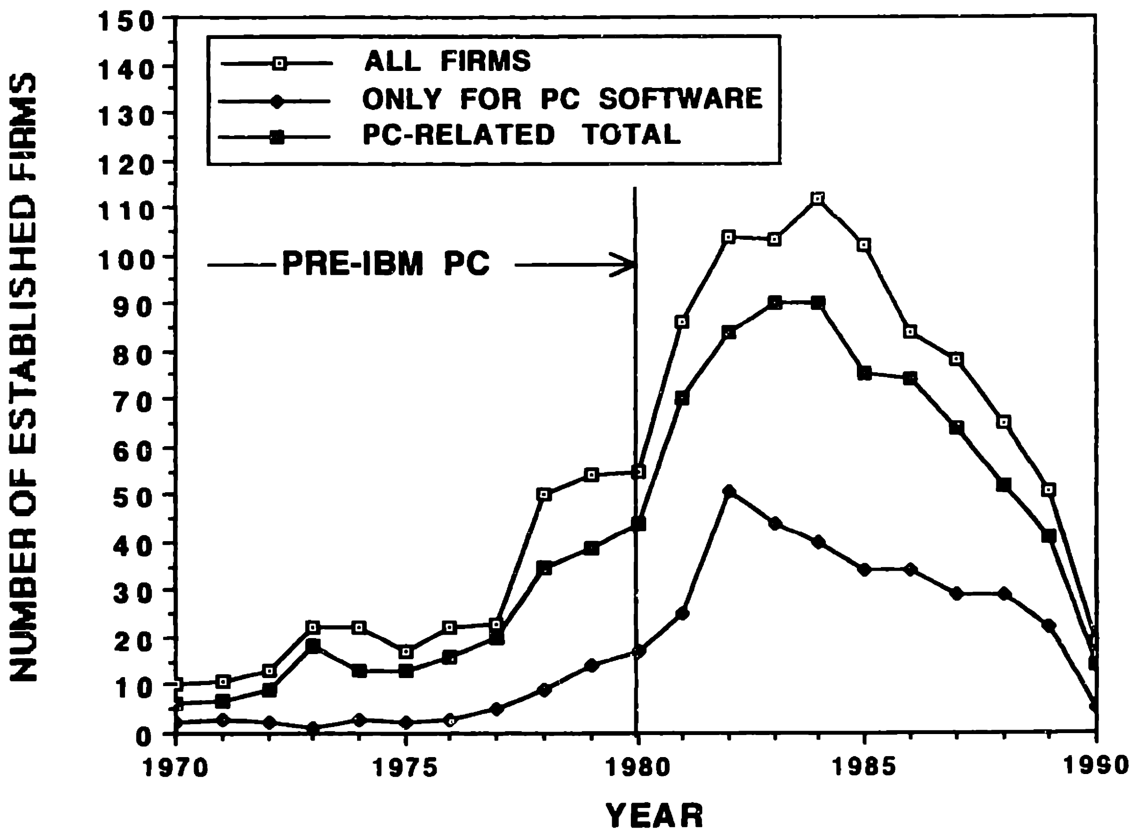
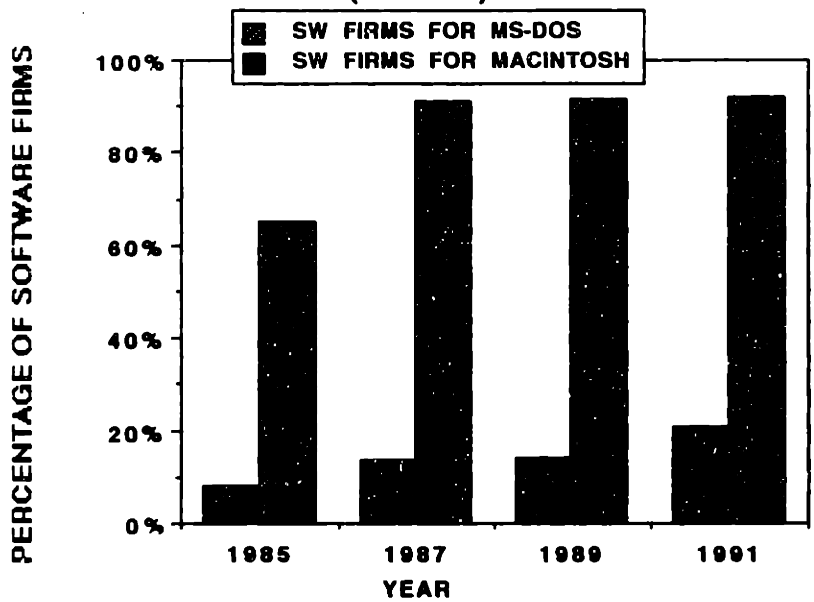


Figure 17

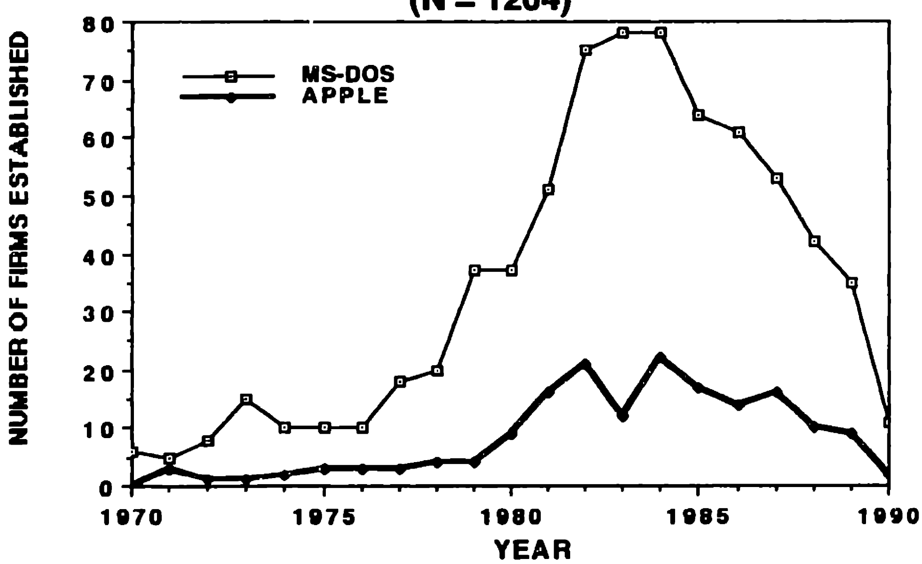
Source: Reassembled by the author, The Complete Guide to The Massachusetts Software Industry, 1990

Figure 18(a) shows the percentage of 108 randomly sampled software firms supporting Macintosh operating system and MS-DOS from 1985 through 1991. While MS-DOS, launched in 1981, reached 62% by 1985 and 94% in 1987, Macintosh, launched in 1984, reached just to 17% in 1989, four years after the launch. As Figure 18(b) shows, the level of establishment of new firms for the Apple Computer remained low all through the 1980's. Although Macintosh is technologically revolutionary, it could not contribute to industry growth as much as did IBM-PC. Of course, Apple computer charged a premium price for the Macintosh in the early stage, so profitability was not as bad as its market share would indicate. In reality, Apple always struggled to attract software vendors. In 1990, Apple introduced low-cost Macintosh products, the Macintosh LC Classic series. This measure must be the reason for the slight increase between 1989 and 1991, shown in Figure 18(a). It was at that time that Apple started to face financial difficulties, because the profit from proprietaries of Macintosh was eroded and failed to accelerate its market share. Apple has now established a joint venture with IBM to create a new "open standard" operating system and architecture (Business Week, 1991).

SOFTWARE FIRMS SUPPORTING MAC OS AND MS-DOS
(N = 108)



ESTABLISHED YEAR OF SOFTWARE FIRMS SUPPORTING APPLE COMPUTER* AND MS-DOS IN 1990
(N = 1204)



*Including Apple DOS and Macintosh software vendors

Figure 18 (a), (b)

Source: Reassembled by the author, Data Sources, Ziff-Davis, Publishing Company, 1985-1991, and The Complete Guide to the Massachusetts Software Industry

Summary

According to our Hypothesis-III, the number of software firm foundations was sharply increased by the emergence of the "Dominant Design." Although new entrants had been stimulated prior to the IBM entry in 1981, the influence of the IBM-PC is much greater, and was sustainable. This fact indicates that the "Dominant Design" created a more stable and larger business base for software vendors.

In the case of the proprietary OS, Apple Macintosh, we observed a very slow increase in adoptions by software firms in comparison with the MS-DOS case. This supports the latter part of Hypothesis-III.

6.2.2 Behavior and decisions of PC software vendors

Results of randomly-sampled software firms

In this section, behavior of PC software vendors will be investigated. In our study, 108 application software firms were randomly selected, and their decisions on seven major movements from 1986 through 1991 were researched. The nine major decisions and their results investigated were:

I. ENTRY DECISIONS:

(a) Adopt a single OS or multiple OS

<Of those single OS adopters>

(b) Go only with MS-DOS or another OS

<Of those multiple OS adopters>

(c) Go with MS-DOS or other OS

II. DECISIONS AFTERWARDS:

<Of those single OS adopters>

(d) Stay exclusively with the originally selected OS

(e) Switch to other OS

(f) Expand its OS coverage

<Of those multiple OS adopters>

(g) Not change the originally selected OSs

(h) Focus on a smaller set of the original selection

(i) Expand its OS coverage

III. RESULTS (EXIT OR SURVIVE)

(j) Exit

(k) Survive

Figure 19 shows the results, respectively.

Regarding the OS changing decisions of the single OS adopters, 70.7% (n=41) stayed with their original selection. Only 15.5% (n=9) abolished their original selection. On the other hand, 48% (n=24) of the sampled multiple OS adopters narrowed their original selection, while only 14% (n=16) decided to expand their selection. The group of single OS adopters also shows a very low rate of expansion, 13.8% (n=8). This indicates that these firms leaned toward focusing rather than diversifying.

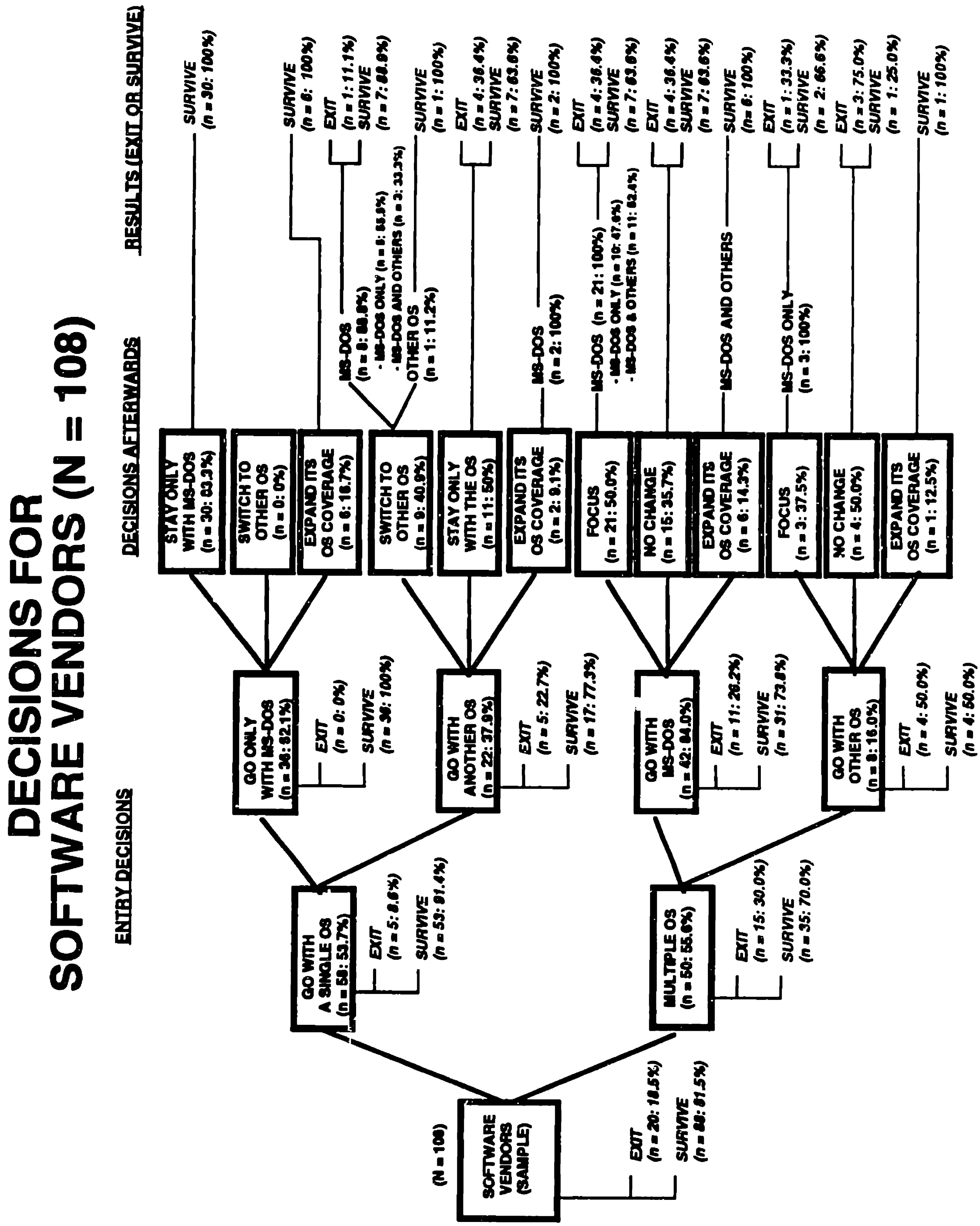


Figure 19

Source: Reassembled by the author, Data Sources

Ziff-Davis Publishing Company, 1985-1991

It is interesting to note that the survival rate of the single OS adopters, 91.4%, is higher than that of the multiple OS adopters, 70%, implying that supporting many OS may have become a heavy burden and therefore unfavoured by software firms.

Of course, some of those software firms expanded from one to another. However, the results indicate that changes such as switching, expanding, or focusing, cannot occur in a short period. The coverge of the market appears to be sustainable. Therefore when they select a new operating system, their decision must be very serious.

As can be observed in Figure 16, many hardware vendors tried to cover as many operating system as possible in order to secure their destination (in that case CP/M and MS-DOS). In the case of application software firms, the same symptom is observed. Of the 108 firms investigated , half adopted multiple OS rather than a single OS. This must be a large percentage, because as noted in the previous chapter, software R&D and marketing require a large capital, and therefore their burden to support multiple OS is heavy.

In terms of the tendency for selection of the dominant standard OS, MS-DOS, of those single OS adopters, 62.1% (n=36) of firms selected MS-DOS and 83.3% (n=30) stayed with MS-DOS and survived perfectly. On the other hand, 36% (n=8) of the other single OS adopters who had not selected MS-DOS at the beginning switched, mainly to MS-DOS. Overall, 79.3% (n=46) of all the sampled single OS adopters came to adopt

MS-DOS. Although 79% (n=85) of all the sampled firms entered the market before 1985, 68.5% (n=58) entered with MS-DOS. Of firms who entered with MS-DOS, 44.6% (n=26) support only MS-DOS. This indicate that, in 1985 and before, many software firms were still trying to figure out who will win. This phenomenon is similar to what we learned from the study of PC hardware vendors. However, when we focus on the late 1980's, of the 14 new entrants after 1987 in the sample, 11 firms, or 78.5%, targeted MS-DOS.

Since MS-DOS became the dominating standard which is a right decision for software firms, 100% of MS-DOS adopters stayed with MS-DOS. Finally, the overall exit rate of the sampled firm is 18.5%. Fourteen firms of the 20 exit firms in the sample were CP/M adopters.

Results of a wrong operating system adoption: CP/M

Figure 20 shows the result of the research about the 27 sampled software firms which supported CP/M as of 1985. The exit rate of the CP/M adoption is 40.7% higher than the average exit rate, 18.5%. Many of the wrong operating system adopters shifted to MS-DOS, the dominant operating system (58.3% or n=17), or reduced risks by creating a portfolio with other operating system (55.6% or n=15). The survival rate of these firms shifting from only CP/M to MS-DOS is fairly high, at 85.7%.

Results of a proprietary operating system adoption: Macintosh

Figure 21 shows cases of proprietary operating system, Apple's Macintosh, adopters. Fourty application software firms which support Macintosh OS were researched. Of all the new entrants, 67.5% (n=27) supporting Macintosh were only with Macintosh. Of firms which adopted only Macintosh OS when entering, 96.3% (n=26) stayed with Macintosh exclusively. This indicates that 70% (n=28) of all the Macintosh software firms are "dedicated" for Macintosh. This is a significant difference between Macintosh adopters and others. The exit rate shown in Figure 21, 30% is not significantly higher than the average.

Summary

The study of 108 sampled firms indicates that those software vendors tend to focus on a smaller number of operating systems rather than to diversify. This proves Hypothesis-IV. However, the study showed that half of the firms sampled support multiple OS rather than a single OS. This is because many firms must try to reduce the risks of selecting a wrong standard.

The exit rate of the CP/M adopters, 40.7%, which is much higher than the average, 18.5%, indicates that a wrong OS selection is more likely to cause exit than is a right selection. However. many of the CP/M adopters could switch (29.6%) or transit through multiple OS adoptions (40.7%) to come to support MS-DOS. Although the high mortality rate could prove the hypothesis, their switching rate is higher than expected.

Finally, for proprietary OS adopters, the hypothesis that many must try to support multiple OS to reduce risks could not be proven. Conversely, many tend to go only with the proprietary OS and bet on it.

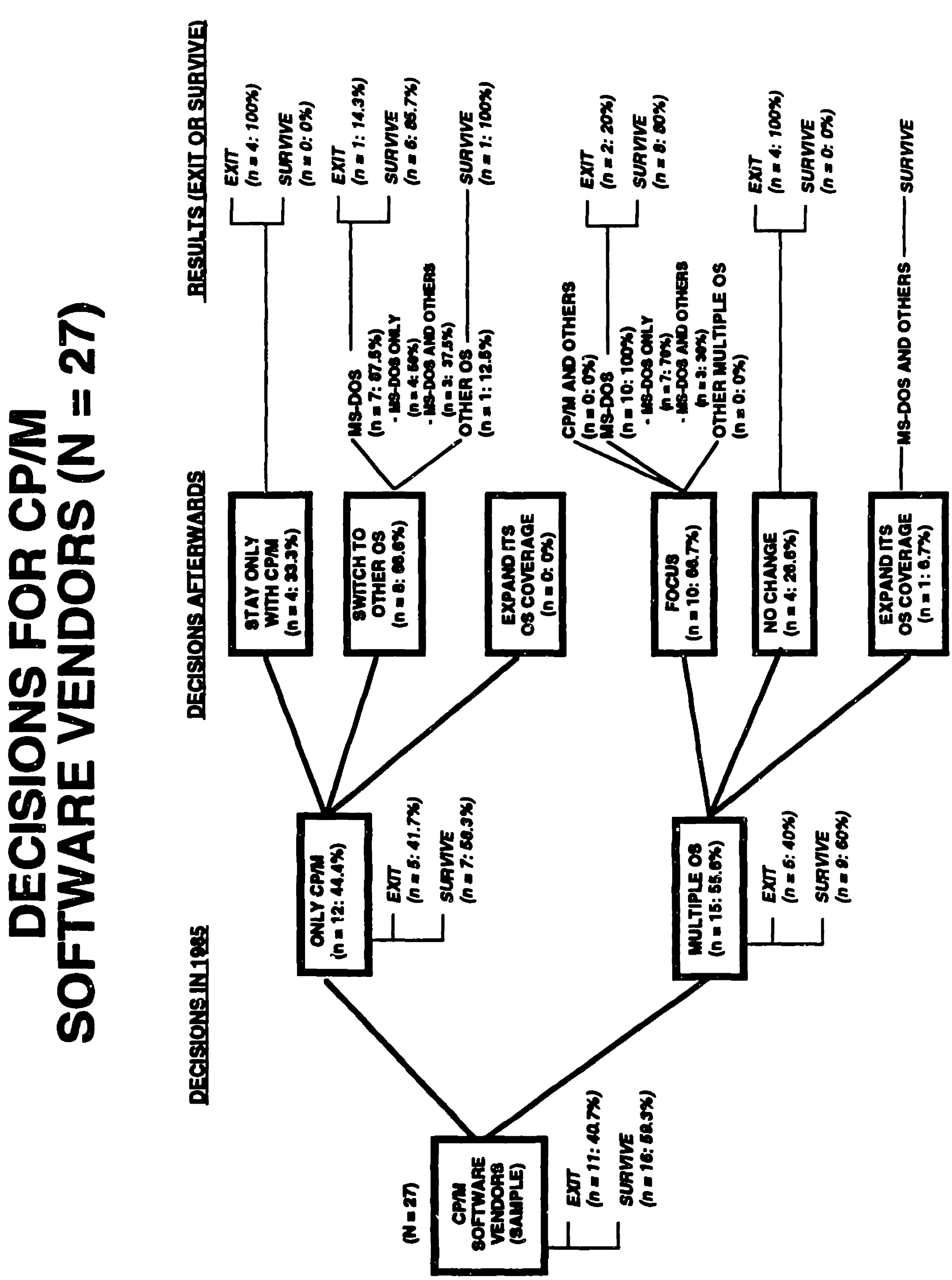


Figure 20

Source: Reassembled by the author, Data Sources

Ziff-Davis Publishing Company, 1983-1989

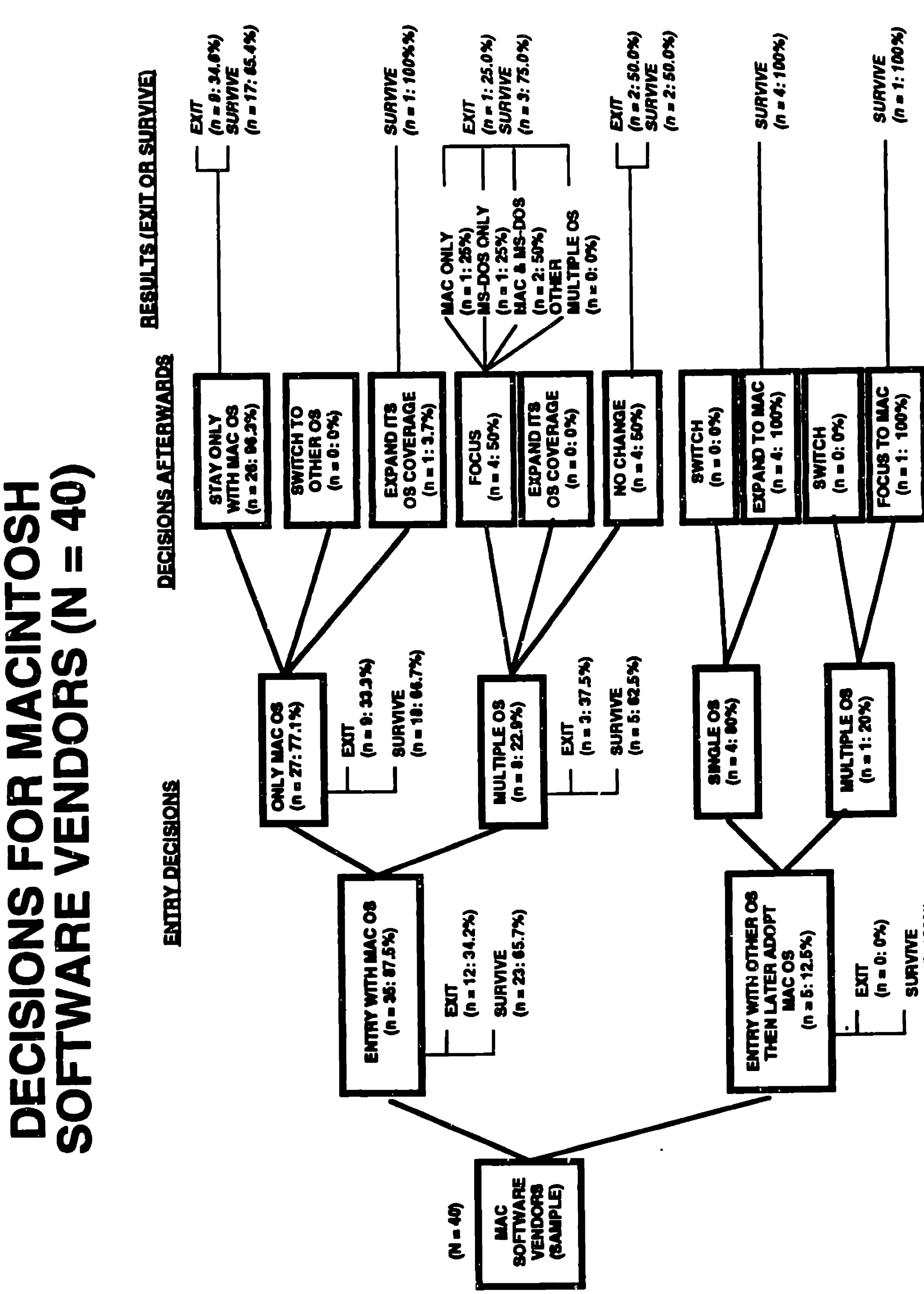


Figure 21

Source: Reassembled by the author, Data Sources

Ziff-Davis Publishing Company, 1983-1989

CHAPTER 7 --- Discussion and Conclusion

As we have studied, the emergence of the new dominant standards had a tremendous impact on the shape of the personal computer industry and its growth. Because of very strong technological interdependencies between hardware hardware vendors and very important complementary assets such as application softwares and hardware peripherals, one who successfully led "uncontrollable" complementary asset providers would achieve the final victory.

However, another issue can be seen for "open standard." As we have studied, after the "Dominant Design" appeared in the industry, it is not the standard setter, who benefits, in this case IBM, but owners of core standard technologies such as Microsoft Corporation and Intel. These suppliers can enjoy economies of scale and allow many firms who want to start a new PC hardware business or another level of innovation based on the "Dominant Design" to start with very low-cost technology components. When IBM tried to reconstruct "appropriability" by the introduction of Microchannel Architecture Bus and enhanced version of OS/2, they failed. On the other hand, Apple took a "closed standard" approach with the Macintosh, then faced difficulties in diffusing its environment among software firms and end users. This is a critical trade-off.

So, who controls the direction of technology? Obviously, IBM does not. The author assumes that the major feature changes of the personal computer occur on the operating system and software side rather than by microprocessors whose main emphasis is speed. A major feature change will attract end users and thereby application software vendors. This is part of the reason the stock of Microsoft Corporation is rising while that of IBM and Apple decline; and it is why IBM and Apple, competitors, form joint ventures -- Talligent and Kalleida -- to create a new and hopefully "dominant" standard. As Teece (1986) notes, if owners of complementary assets are stronger, the result of the game changes. This relationship between innovators and complementary asset providers is not static, but changes according to industry growth, because decisions of complementary asset providers and end users change accordingly. So, a personal computer firm must from time to time dynamically create a proper strategy.

This shift of the situation against the complementary sector is a possible theme for future research.

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