Global Competitiveness of U.S. Advanced-Technology Industries: Computers

Investigation No. 332-339

Publication 2705 December 1993

U.S. International Trade Commission

Washington, DC 20436

U.S. International Trade Commission

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ublication 2705

December 1993

PREFACE

Following receipt on June 11, 1992, of a request from the Senate Committee on Finance (appendix A), the U.S. International Trade Commission instituted investigations on Cellular Communications (332-329), Large Civil Aircraft (332-332), and Computers (332-339), under section 332(g) of the Tariff Act of 1930 (19 U.S.C. 1332(g)). The purpose of each investigation is to examine the global competitiveness of the U.S. industry. These investigations follow three prior competitive assessments provided to the Finance Committee during September-October 1991. The Finance Committee requested that the Commission furnish reports on the results of the three investigations within eighteen months. This report is the last of the three and examines the computer hardware industry. Competition in the computer software and service industries is not examined in this report.

Copies of the notice of the investigation were posted in the Office of the Secretary, U.S. International Trade Commission, Washington, DC 20436, and the notice was published in the *Federal Register* (57 F.R. 55567) on November 25, 1992 (appendix B). The Commission held a public hearing in connection with the investigation on March 17, 1993. All persons were allowed to appear by counsel or in person, to present information and to be heard. In addition, interested parties were invited to submit written statements concerning the investigation.

The information and analysis provided in this report are for the purpose of this report only. Nothing in this report should be considered to indicate how the Commission would find in an investigation conducted under statutory authority covering the same or similar subject matter.

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EXECUTIVE SUMMARY

This study of the U.S. computer hardware industry is the last of three competitive assessments of selected U.S. advanced-technology industries requested by the Senate Committee on Finance on June 11, 1992. The other two concern the cellular communications and large civil aircraft industries. These three studies are part of an ongoing series of competitive assessments that the Commission began in 1990 at the request of the Finance Committee.

In this study, the Commission has been requested to examine all factors found to be relevant to the global competitiveness of the U.S. computer hardware industry. The request letter specifies that the factors to be examined by the Commission may include, but are not limited to, government policies, regulatory and trade impediments, and research and development (R&D) financing and expenditures. Competitiveness is assessed in terms of global market share. Global market share is recognized as an imperfect indicator, but it possesses certain advantages over other potential indicators, especially in terms of data availability and integrity.

This study principally examines the computer hardware industry, which for purposes of discussion is divided into four segments: personal computers (PCs), workstations, mainframes and minicomputers, and supercomputers. Computer software and services are discussed only insofar as they affect the present and future competitiveness of hardware manufacturers. The analysis focuses principally on the computer hardware industries of the United States, Europe, and Japan, which together account for virtually all internationally active computer hardware manufacturers.

Industry Conditions

The global market for computer hardware was valued at $114 billion (current dollars) in 1992. Global sales of mainframes and minicomputers generated revenues of $56 billion; PCs $46 billion; workstations $10 billion; and supercomputers $2 billion. Computer manufacturers employed 1.1 million workers worldwide. It is estimated that the global computer hardware industry will generate revenues of $150 billion (current dollars) in 1997, whereas global employment in the industry will decline slightly.

- Global revenues for U.S. computer manufacturers reached $69 billion (current dollars) in 1992, comprising 61 percent of the worldwide total.
- U.S. computer manufacturers employed 688,500 workers in 1992, comprising 63 percent of the worldwide total.
- Revenues of U.S. computer manufacturers grew at an annual rate of about 3 percent from 1988 to 1992, whereas employment in the U.S. computer hardware industry declined by about 5 percent annually. By contrast, revenues generated by U.S. computer software and service providers, valued at $119 billion in 1992, are growing at an annual rate of 14 percent or more, and employment among these firms is growing in excess of 6 percent per year.
- Revenues of European computer manufacturers grew at an annual rate comparable to that of U.S. firms, averaging about 3 percent from 1988 to 1992, while annual revenues of Japanese firms grew by 9 percent, on average.

Prevailing Global Trends

Technological innovation and new consumer preferences are driving two global trends, computer platform downsizing and commoditization. These, in turn, are compelling computer hardware manufacturers to modify traditional corporate structures and practices. In addition, computer hardware firms are finding it necessary to expand into the computer software and service industries.

- Significant advances in microprocessor and networking technology have fueled the downsizing of computer platforms. Computer users are moving operations off mainframes and minicomputers and onto networks of increasingly powerful workstations and PCs. Consequently, sales of mainframes and minicomputers, traditionally the mainstay of the world's largest computer hardware manufacturers, have decreased by 10 percent since 1990.
- Commoditization began in the PC market following the introduction of standardized components, which in turn led to the market entry of many firms producing largely undifferentiated products. Commoditization resulted in greater price sensitivity in the PC market and, ultimately, in the markets for mainframes and minicomputers, which increasingly compete with PCs as a result of computer platform downsizing.
- Computer platform downsizing and commoditization have reduced computer hardware manufacturers' returns, motivating these firms to seek out business activities with higher returns. Many computer hardware firms are pursuing rapidly expanding opportunities in the high value-added computer software and service industries, either as a means to supplement decreasing hardware revenues, or as a means to exit the computer hardware market altogether.

Competitive Position of U.S. Firms

U.S. hardware manufacturers remain among the most competitive firms in the global computer industry, as measured by global market share. Five U.S. firms rank among the industry's largest 10 firms. Japan accounts for three such firms, and Europe accounts for two.

U.S. firms account for no less than 50 percent of global sales in each computer hardware market, reflecting their ability to compete successfully in terms of price and processing power.

With respect to personal computer manufacturers:

- U.S. firms account for over 55 percent of the $46 billion global PC market. Principal U.S. firms include International Business Machines (IBM), Apple, Compaq, and Dell.
- IBM currently accounts for 12 percent of the global PC market, but has lost 29 percentage points in market share since 1985. Apple, Compaq, and Dell have posted modest market share gains of between 1 and 5 percentage points.
- U.S. firms' principal competitors are Japanese firms NEC, Fujitsu, and Matsushita. These firms are gaining global market share, principally because their sales in the Japanese market are growing rapidly. Outside of the home market, Japanese PC manufacturers have experienced modest commercial success.
- A number of industry analysts forecast a global shake-out of PC manufacturers in the future. Many firms have generated low returns or losses in recent years. Compaq, AST Research, and Apple stand out as the market's most profitable firms. On average, these companies have generated annual return on sales exceeding 10 percent since 1985.
- The PC market increasingly resembles a price-sensitive consumer electronics market. Standardized architecture and mass production of components have reduced product differentiation, technology-based barriers to entry, and PC prices.
- Sales of PCs are expected to remain strong in all major markets, mainly due to platform downsizing by large customers.

- PC manufacturers principally compete in terms of price and time-to-market. Key factors affecting firms' abilities to compete are R&D, cost management, and marketing and distribution.

With respect to workstation manufacturers:

- U.S. manufacturers dominate the $10 billion global workstation market, which is projected to grow by up to 30 percent per year for the foreseeable future. U.S. workstation manufacturers account for more than 80 percent of the global workstation market.

- Principal U.S. workstation manufacturers include Sun Microsystems, Hewlett-Packard, IBM, DEC, Silicon Graphics, and Intergraph. Sun Microsystems, which has accounted for around 33 percent of global workstation revenues since 1990, is the market leader of this segment.

- U.S. firms' principal foreign competitors are Fujitsu, Toshiba, Hitachi, NEC, and Acer (Taiwan). These firms have received licenses from U.S. firms to use proprietary microprocessing and operating system technologies, and have entered the global market with low-end workstations.

- Firms that specialize in workstation manufacturing (Sun Microsystems, Silicon Graphics, and Intergraph) generally have been profitable in recent years. On average, Sun Microsystems and Intergraph have posted 10 percent return on sales since 1985.

- Much of the growth in the workstation segment can be attributed to the improved performance of these systems. Improved performance stems from the use of increasingly powerful microprocessors designed around reduced instruction set computing (RISC) architecture developed by U.S. companies.

- Workstation suppliers have benefited from computer platform downsizing as corporations have migrated from mainframes and minicomputers to networks supported by workstations.

- Workstation manufacturers principally compete in terms of price, processing power, and networking capabilities. Key factors affecting firms' ability to compete in such terms are research and development and alliances (i.e., microprocessor alliances and operating systems alliances).

With respect to mainframe and minicomputer manufacturers:

- U.S. firms account for 64 percent of revenues in the $56 billion global market for mainframes and minicomputers. Principal U.S. firms include IBM, DEC, Unisys, and Hewlett-Packard.

- The largest producer of mainframes and minicomputers is IBM, which alone accounts for 34 percent of the global market for these products. IBM's share of this market has declined by 11 percentage points since 1985. Hewlett-Packard has registered a small gain in global market share in recent years, whereas DEC and Unisys have registered small losses of market share.

- U.S. firms' principal competitors in this market segment are the Japanese firms Fujitsu and Hitachi. Both have gained global market share since 1985.

- Many large manufacturers in this segment have posted significant financial losses, ranging up to $9 billion by IBM, in recent years. Hewlett-Packard and Hitachi stand out as the most consistently profitable firms in this segment.

- Mainframes and minicomputers currently are being displaced by workstations and PCs as a result of technological evolution and changes in consumer preferences. Large customers continue to downsize computing platforms, replacing mainframes and minicomputers with networks of workstations and PCs.

- Employment and manufacturing capacity in this segment have been reduced as U.S. and foreign manufacturers restructure to stem financial losses. Some firms, notably DEC, are changing their primary focus, becoming computer software and service providers.

- Mainframe and minicomputer manufacturers principally compete in terms of price and processing power. Key factors affecting firms' abilities to compete in these terms are R&D and cost management.

With respect to supercomputer manufacturers:

- Five U.S. firms account for 69 percent of revenues in the $2 billion global supercomputer market: Cray Research, IBM, Convex, Thinking Machines, and Intel.
- Cray Research is the world's predominant and most profitable supercomputer manufacturer, accounting for 36 percent of the segment's global revenues in 1992. However, Cray was unprofitable in 1992, and its market share has declined by 13 percentage points since 1987. These problems are due in most part to market share gains among other U.S. firms.
- Japanese firms, namely Fujitsu, NEC, and Hitachi, are U.S. firms' principal competitors in the global supercomputer market. Since 1987, NEC is the only Japanese firm that has increased its global market share appreciably, by 3 percentage points.
- Traditional vector supercomputers presently face a challenge from new massively parallel processing (MPP) supercomputers. MPP supercomputers are cheaper than vector supercomputers because they incorporate mass-produced microprocessors and other standardized components. Two U.S. firms, Intel and Thinking Machines, are the principal manufacturers of MPP supercomputers while traditional supercomputer firms, such as Cray Research, are just beginning to enter the market.
- Supercomputer manufacturers principally compete in terms of price, processing power, and technical support. The most important aspect of technical support is the ability to develop software tailored to supercomputer users' unique requirements. Key factors affecting competitiveness are R&D and software-writing assistance.

Government Policy

The most significant government policies affecting competitiveness in the global computer hardware market pertain to R&D funding, export control, procurement, intellectual property protection, tariffs, and tax incentives.

- Government funding, ranging into the billions of dollars, helped establish computer industries in the United States, Japan, and Europe. However, government funding of computer-related research in the United States was directed toward defense and aerospace applications, whereas foreign programs emphasized civilian applications.
- Restricting exports of advanced U.S. computing technologies for national security interests appears to have hampered U.S. firms' participation in overseas markets. The President's Commission on Industrial Competitiveness estimated that U.S. computer hardware manufacturers lose over $11 billion in sales annually due to especially rigid unilateral export controls. Targeted countries, such as China, are gaining access to controlled technology from manufacturers in other countries. Proposals to relax U.S. export controls presently are under consideration.
- Domestic firms in Silicon Valley have stated that U.S. Government procurement policies that emphasize local content penalize U.S. computer manufacturers that source components globally.
- Increased globalization of the computer hardware industry and market pressures favoring open systems are raising potential problems associated with intellectual property protection. U.S. firms are divided with respect to preferred intellectual property policies, although there is a growing consensus that these policies must carefully balance producers' interest in assuring returns on investment with consumers' interest in open systems.
- It is increasingly difficult to protect U.S. computer hardware manufacturers from unfair trade practices. For example, in combination with wage and tax differentials, the

imposition of antidumping duties to protect domestic component producers allegedly has led certain U.S. computer manufacturers to move some production offshore.

- The U.S. R&D tax credit was renewed in August 1993. U.S. industry officials overwhelmingly have asked that the R&D tax credit be extended permanently, thus facilitating long-term planning and giving U.S. firms legislative stability similar to that of Japanese competitors.

Panel Discussion

Nine industry experts convened at the USITC on July 21, 1993 for a panel discussion on the future of the computer industry. Participants included representatives from two leading U.S. computer firms, one European firm, four U.S. economists, one analyst based in Japan, and an end user representing a financial services firm. The following opinions were expressed by the panel:

- Multimedia and object-oriented software will play increasingly important roles in the computer industry. Some believed that the new "multimedia" industry, centered around the computer industry, would primarily benefit small, flexible companies. Others suggested that large, vertically-integrated firms were best positioned to profit from multimedia.
- Portability and user-friendliness were identified as critical characteristics for future computer products.
- The panel believed that object-oriented software would become an important aspect of the software industry. It would allow common lines of software code to be duplicated and used as building blocks for new applications.
- The future role of government was described as twofold: (1) to help support pre-competitive R&D, and (2) to improve global market access opportunities.
- The participants disagreed on the relative role of the United States, Japan, and Europe in the future computer market. Some believed that U.S. dominance in the network, telecommunications, and software industries foreshadows U.S. dominance in the multimedia market. Others conjectured that the Japanese and European industries will take advantage of the changing market to increase their stake in the global computer industry.

Abbreviations

ACE	Advanced Computing Environment
CMOS	complementary metal oxide silicon
COSE	Common Open Software Environment
CPU	central processing unit
DOS	disk operating system
FLOPS	floating point operations per second
FPD	flat panel display
MIPS	millions of instructions per second
MPP	massively parallel processing
OSF	Open Software Foundation
PC	personal computer
PCB	printed circuit board
RISC	reduced instruction set computing

CHAPTER 1
Introduction

Purpose of Study

This study is part of an ongoing series of reports assessing the competitiveness of U.S. advanced-technology industries.[1] The series of reports, requested by the Senate Committee on Finance, attempts to provide policy-makers and other interested groups with a thorough and methodical analysis of the ability of firms to compete in certain high-technology industries.[2] This study assesses competition in the global computer hardware industry, an industry that both incorporates advanced technology and contributes to the technological progress of other industries. This report also examines government policy, industry trends, and technological developments to provide the proper context for this assessment.

Approach

Analysis of the computer hardware industry is conducted by examining four distinct market segments: personal computers (PCs), workstations, mainframes and minicomputers, and supercomputers (see Scope of Study). The approach of the study is to identify and analyze firm-specific factors as well as factors external to the firm that influence competitiveness in these market segments. Some of the firm-specific factors examined are research and development programs, cost management skills, and marketing efforts. Government policies are identified as key external factors. A firm's share of the global market for each type of computer system is referenced to reflect its competitiveness.

[1] The series is described in the United States International Trade Commission (USITC), *Identification of U.S. Advanced-Technology Manufacturing Industries for Monitoring and Possible Comprehensive Study (investigation No. 332-294)*, USITC publication 2319, Sept. 1990, pp. 15-16.

[2] On June 11, 1992, the Senate Committee on Finance requested that the USITC prepare studies on the cellular communication, large civil aircraft, and computer hardware industries as part of the series of competitive assessment studies, begun in 1990. See appendices A and B for more detail on this request.

Competitiveness Defined

Competitiveness has been defined in a variety of ways, but one common element runs through most definitions: competitiveness is the ability of a nation, national industry, or firm to produce goods and services that consumers choose over competing alternatives.[3] Some add the caveat that competitors also must produce goods and services on a profitable basis.[4] Several indicators commonly are used to assess competitiveness. Such indicators include global market share, profitability, product innovation, productivity, exports, trade balances, shipments, and employment. None of these indicators is perfect; all have certain strengths and weaknesses.

This report assesses the competitiveness of firms, rather than nations or industries. As mentioned above, global market share is employed as an indicator of competitiveness for firms in the computer hardware industry. Market share reflects computer hardware manufacturers' abilities to compete in terms of price, processing power,[5] and other factors that are important to computer users. This report assesses firms' competitiveness by identifying and analyzing the skills and strategies that firms have developed to increase or defend market share.

There are acknowledged weaknesses in using market share as an indicator of competitiveness. First, firms may focus on maximizing profits, rather than market share. Second, assessing competitiveness in terms of market share, calculated on the basis of sales revenue rather than units, may understate the market share of firms that reduce prices more aggressively than competitors. Third, market entry by new firms may reduce the market share of established firms without necessarily reflecting declining competitiveness among the latter.

[3] President's Commission on Industrial Competitiveness, *Global Competition—The New Reality*, vol. 1 (Washington, DC, Jan. 1985), p. 6; and Competitiveness Policy Council, *Building A Competitive America: First Annual Report to the President and Congress* (Washington, DC: GPO, Mar. 1992), p. 1.

[4] Theodore W. Schlie, *Analysis of Studies of the International Competitiveness of Specific Sectors of U.S. Industry*, draft prepared for Competitiveness Policy Council (Bethlehem, PA, Jan. 26, 1993), p. 8.

[5] Computer power is typically assessed by processing speed.

Given these limitations, however, market share is the most suitable indicator of firms' performance in the global computer hardware market, in large part due to the availability of relatively good data pertaining to market share. Unlike other available indicators, market share data provide for the analysis of distinct segments of the computer hardware market. Differences in firm structure and accounting procedures, among other factors, render other potential indicators of competitiveness less comparable than market share.[6] A number of studies that address the issue of competitiveness suggest or use market share as a measure of firm performance.[7] Moreover, certain industry representatives have supported the use of market share as an indicator of competitiveness. Participants in the Computer Futures Seminar, hosted by the Commission on July 21, 1993, were asked to name their preferred measure of competitiveness. Three of four participants who addressed the question, during or after the seminar, favored the use of market share.[8]

Whereas the report assesses firms' performance in terms of market share, it also examines profitability. Profitability is not used to assess firms' performance, but to gauge firms' abilities to participate in markets over the long run.[9] In the absence of external assistance, firms experiencing losses on a sustained basis must exit the market eventually, according to economic theory.[10]

Data Sources

Information for this analysis has been collected from a wide variety of sources. Commission staff conducted in-person or telephone interviews in the United States, Europe, and the Far East with principal computer manufacturers, component producers, research consortia, and government officials.[11] Information also was gathered from an extensive review of industry literature.[12] In addition, the Commission held a hearing pertaining to the computer industry on March 17, 1993,[13] and, as noted above, sponsored a seminar on the future of the computer industry.[14] This report incorporates information presented at these proceedings.

Scope of Study

The computer industry is comprised principally of three components: the computer hardware industry, the computer software industry, and the computer service industry (figure 1-1).[15] As stated previously, the focus of this study is the computer hardware industry. Trends and developments within the computer software and computer service industries receive treatment only insofar as they affect competition in the computer hardware market.

This study assesses the performance of computer hardware manufacturers in four separate discussions. Each discussion pertains to one distinct market segment: personal computers (PCs), workstations, mainframes and minicomputers, and supercomputers. Figure 1-2 lists the largest firms in each market segment. The computer hardware industry is commonly divided in this manner, or similar manners, to facilitate the analysis of firms that are affected by prevailing industry trends in largely different ways (see chapter 2), and that compete for global market share in significantly different terms (see chapter 4). In addition, computers in these segments differ markedly in terms of price, processing speed, and principal function (figure 1-3).

Personal computers are the least powerful and least expensive computers of the four market segments. They are most often used for wordprocessing and spreadsheet applications. PCs were the first products to use standardized components, resulting in rapid sales growth and, in recent years, intense price competition. During 1988-92, the global personal computer market grew by an average annual rate of 12 percent, to $46 billion.[16]

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[6] Similar conclusions are reached in Franklin M. Fisher, Joen E. Greenwood, and John J. McGowan, *Folded, Spindled, and Mutilated: An Economic Analysis of U.S. vs. IBM* (Cambridge, MA: MIT Press, 1983).

[7] For instance, see U.S. Department of Commerce, *The Competitive Status of the U.S. Electronics Sector* (Washington, DC: GPO, 1990); and Gary L. Guenther, "Industrial Competitiveness: Definitions, Measures, and Key Determinants" (Washington, DC: Congressional Research Service, 1986).

[8] U.S. International Trade Commission, *In the Matter of: Computer Futures Seminar*, July 21, 1993, pp. 187-188; and U.S. industry representative, telephone interview with USITC staff, Washington, DC, Aug. 11, 1993. Those in support of measuring competitiveness in terms of market share were Dr. Gene Gregory, Professor of International Business, Sophia University; Mr. Peter Schavoir, Director of Strategy, International Business Machines; and Mr. David House, Senior Vice President for Corporate Strategy, Intel Corp.

[9] In this report, profitability is measured in terms of gross return on sales in order to exclude the effects of special charges and international differences in tax policy. Data on profitability are not available for all firms.

[10] See, for instance, Paul A. Samuelson, *Economics*, 9th ed. (New York: McGraw-Hill Book Company, 1973), p. 470.

[11] See appendix C for the list of firms, associations, and government agencies interviewed by Commission staff during the course of this investigation.

[12] See appendix D for a detailed literature review.

[13] See appendix E for a list of witnesses participating in the public hearing on the computer industry.

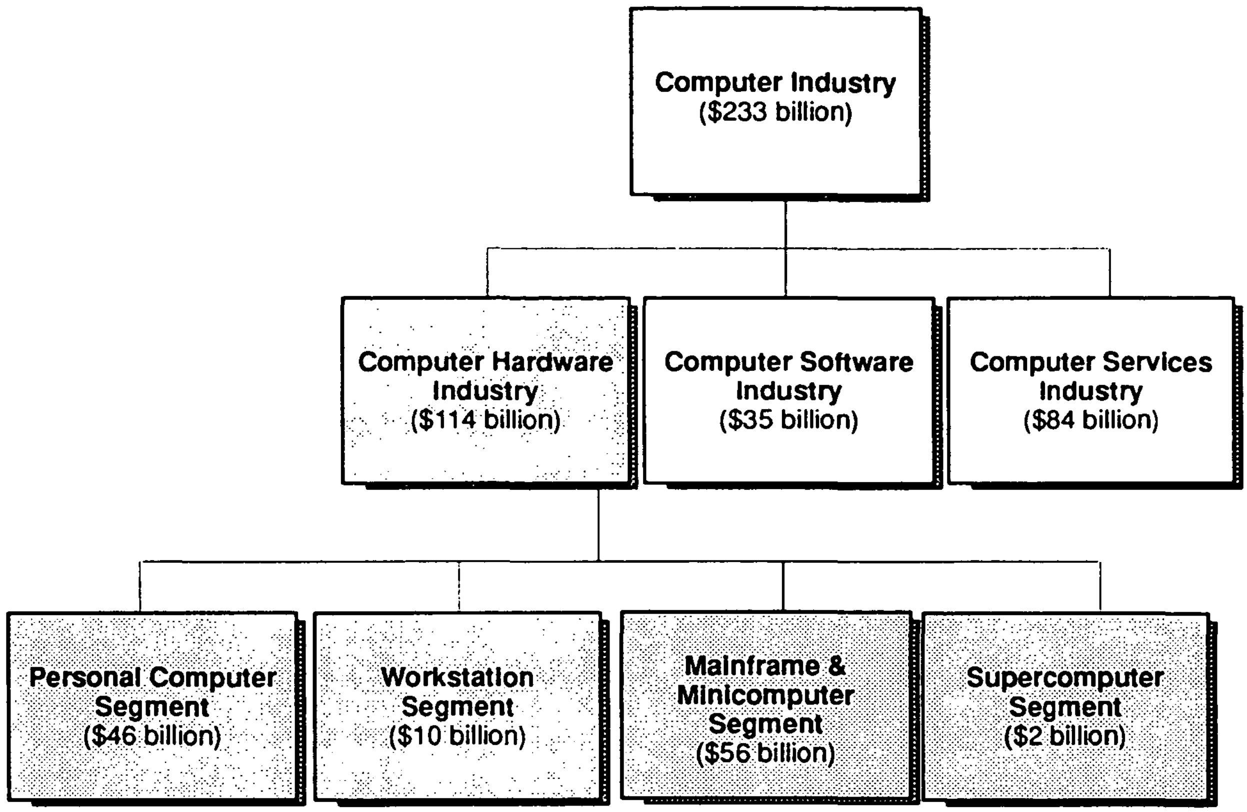
[14] See appendix F for a list of participants in the Commission's roundtable discussion on the future of the computer industry.

[15] A brief discussion of the evolution of the computer industry and interrelationships among computer hardware manufacturers, computer software manufacturers, and computer service providers is presented in chapter 2.

[16] All figures cited in this report are in current dollars, unless otherwise noted.

Figure 1–1
Structure of the computer industry and size of the global market by segment, 1992

(Current dollars)



Source: USITC staff and Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

Workstations are the newest market segment and are characterized by high-performance microprocessors, high-resolution monitors, and sophisticated graphics capabilities.[17] Workstations often are used for designing and manufacturing operations that require superior graphic displays. Workstations, used independently and in networks, compete with some low-end supercomputers, nearly all mainframes and minicomputers, and high-end personal computers. As shown in figure 1-2, U.S. firms dominate this market segment. This is because all key workstation technologies were developed, and are presently controlled, by U.S. firms. The global workstation market grew by an average annual rate of 13 percent during 1988-92, to $10 billion.

Mainframe computers and minicomputers comprise the most mature market segment, and feature a wide range of prices depending on processing power. The previously distinct mainframe and minicomputer markets have converged, in part because consumers increasingly use minicomputers as servers, a function once performed only by mainframes. Mainframes and minicomputers face a long-term competitive challenge from networked workstations and personal computers as these smaller systems become cheaper and more powerful. The global mainframe and minicomputer market contracted by 10 percent during 1990-92, to $56 billion.

Supercomputers incorporate the most sophisticated technology and feature the highest market prices of the four segments. They are used in applications requiring the manipulation of vast quantities of data, such as weather forecasting. The expense of supercomputers essentially limits usage to government entities and well-funded research institutions or consortia. The global supercomputer market grew by an annual growth rate of 6 percent during 1988-92, to $2 billion.

[17] See appendix G for a glossary of selected technical terms used in this report.

Figure 1-2
Revenues[1] of key global competitors in major computer hardware market segments, 1992

Computer Hardware Industry
1992

Personal Computers

Key firms	*Revenue* $ million
IBM (U.S.)	5,941
NEC (Japan)	5,849
Apple (U.S.)	5,599
Compaq (U.S.)	3,784
Fujitsu (Japan)	2,330
Matsushita Electric (Japan)	2,029
Dell (U.S.)	1,752
Toshiba (Japan)	1,558
Hewlett-Packard (U.S.)	1,324
Olivetti (Italy)	1,122
Groupe Bull (France)	966

Workstations

Key firms	*Revenue* $ million
Sun Microsystems (U.S.)	3,112
Hewlett-Packard (U.S.)	1,712
IBM (U.S.)	937
DEC (U.S.)	937
Silicon Graphics (U.S.)	814
Intergraph (U.S.)	568

Mainframes & Minicomputers

Key firms	*Revenue* $ million
IBM (U.S.)	20,823
Fujitsu (Japan)	8,036
Hewlett-Packard (U.S.)	4,496
Hitachi (Japan)	4,418
DEC (U.S.)	3,413
NEC (Japan)	3,026
Unisys (U.S.)	2,442
Siemens (Germany)	2,075
Groupe Bull (France)	1,654
Amdahl (U.S.)	1,080
AT&T (U.S.)	1,080

Supercomputers

Key firms	*Revenue* $ million
Cray Research (U.S.)	649
IBM (U.S.)	263
Fujitsu (Japan)	261
Convex (U.S.)	163
NEC (Japan)	134
Intel (U.S.)	94
Thinking Machines (U.S.)	88
Hitachi (Japan)	49

[1] Revenue is reported in current dollars.

Source: USITC staff and data as presented in Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

Figure 1-3
Characteristics of computer market segments, ranked by price[1]

Market segment	Price range	Processing speed	Principal function
Personal Computers	$700–$10,000	20–50 Millions of instructions per second (MIPS)	Desktop applications such as word-processing, spread-sheets, and small data bases.
Workstations	$5,000–$60,000	20–350 MIPS	Desktop applications such as high resolution graphics, simulations, and computations.
Mainframes and Mini-computers	$25,000–$500,000	50–375 MIPS	Central processors for data from linked terminals.
Super-computers	$500,000 and up	up to 26,000 MIPS	Numerical processing for problems involving massive amounts of data.

[1] Price ranges are reported in current dollars.
Source: USITC staff.

Organization of Study

Chapter 2 lays the groundwork for exploring government policy (chapter 3), competitiveness (chapter 4), and the industry outlook (chapter 5) by providing a brief history of the industry and examining prevailing industry trends. This chapter also provides a baseline analysis of the global industry, lending perspective on the size, growth, and competitive position of U.S. firms.

Chapter 3 examines the nature and results of government policies affecting the computer hardware industry in key computer-manufacturing countries and regions. These policies pertain to research and development, export controls, procurement, intellectual property, tariffs, and taxes.

Chapter 4 analyzes the performance of U.S. computer hardware manufacturers. The assessment identifies the terms of competition in each computer hardware market segment, then reviews the actions taken by firms to enhance their abilities to compete.

Chapter 5 notes the report's principal findings concerning the present competitive position of U.S. firms and provides a forward-looking section that offers insight regarding the possible future course of industry developments. In part, the substance of this final section was gathered during the roundtable conference sponsored by the Commission on July 21, 1993. Participants in the roundtable discussion included acknowledged experts from academia, the consulting industry, and the computer hardware industry.

CHAPTER 2
The Computer Hardware Industry

Introduction

This chapter has a three-fold purpose. First, the chapter provides a brief overview of the historical evolution of the computer hardware industry. Second, it offers a "snapshot" of the current global competitive position of U.S. firms. Finally, the chapter examines prevailing industry trends and their influence on the performance of computer hardware manufacturers.

Industry Evolution

While the computer hardware industry traces its origin to the 1930s, when the first analog computing machines were developed, the modern industry was essentially launched in the 1950s with the commercialization of early computers by firms such as IBM and Remington Rand (figure 2-1).[1] Although European and Japanese companies worked diligently to gain a foothold in what immediately became a fast-growing market, U.S. companies thoroughly dominated the industry in the early years. IBM controlled an estimated 85 percent of the global market during the late 1950s. IBM's major competitors were Remington Rand (later Sperry Rand), Burroughs, National Cash Register (NCR), Control Data, Honeywell, General Electric, and RCA.[2]

After the mainframe market was established, several U.S. companies perceived opportunities to use existing technology to create other types of computers. This led to the introduction of the first commercially successful minicomputers in 1963[3] and supercomputers in 1976. Digital Equipment Corp.'s (DEC) minicomputer was simpler and less expensive than most mainframes, yet was powerful enough for many scientific and engineering tasks. Later, Cray Research established a lucrative niche market for computers that surpassed the power of traditional mainframes. The power and capabilities of supercomputers have increased dramatically since their introduction in the mid-1970s. Today supercomputers are routinely used for computational modeling, complex simulations, and intricate scientific and industrial problem-solving.[4]

Shortly after the emergence of the supercomputer, the extraordinarily popular personal computer (PC) entered the market. Incorporating microprocessor technology (see figure 2-2 for definition) that Intel Corp. had developed several years earlier, Apple Computer commercialized personal computers in 1977.[5] Personal computers rapidly gained popularity in businesses, schools, and homes (see figure 2-3).[6] Apple's monopoly, based on proprietary technology, ended when IBM entered the PC market in 1981. Rather than manufacture proprietary components for its PC design, IBM incorporated off-the-shelf components such as Intel's microprocessor and Microsoft's disk operating system, MS-DOS. IBM's

[1] IBM and Remington Rand commercialized the technology that emerged from government-funded research on computers during World War II and the Korean conflict. For more information on the history of the industry, see Gerald W. Brock, "The Computer Industry," ch. in *The Structure of American Industry*, ed. Walter Adams (New York: Macmillan, 1990), p. 161; and Kenneth Flamm, *Targeting the Computer: Government Support and International Competition* (Washington, DC: Brookings Institution, 1987).

[2] See Flamm, *Targeting the Computer*.

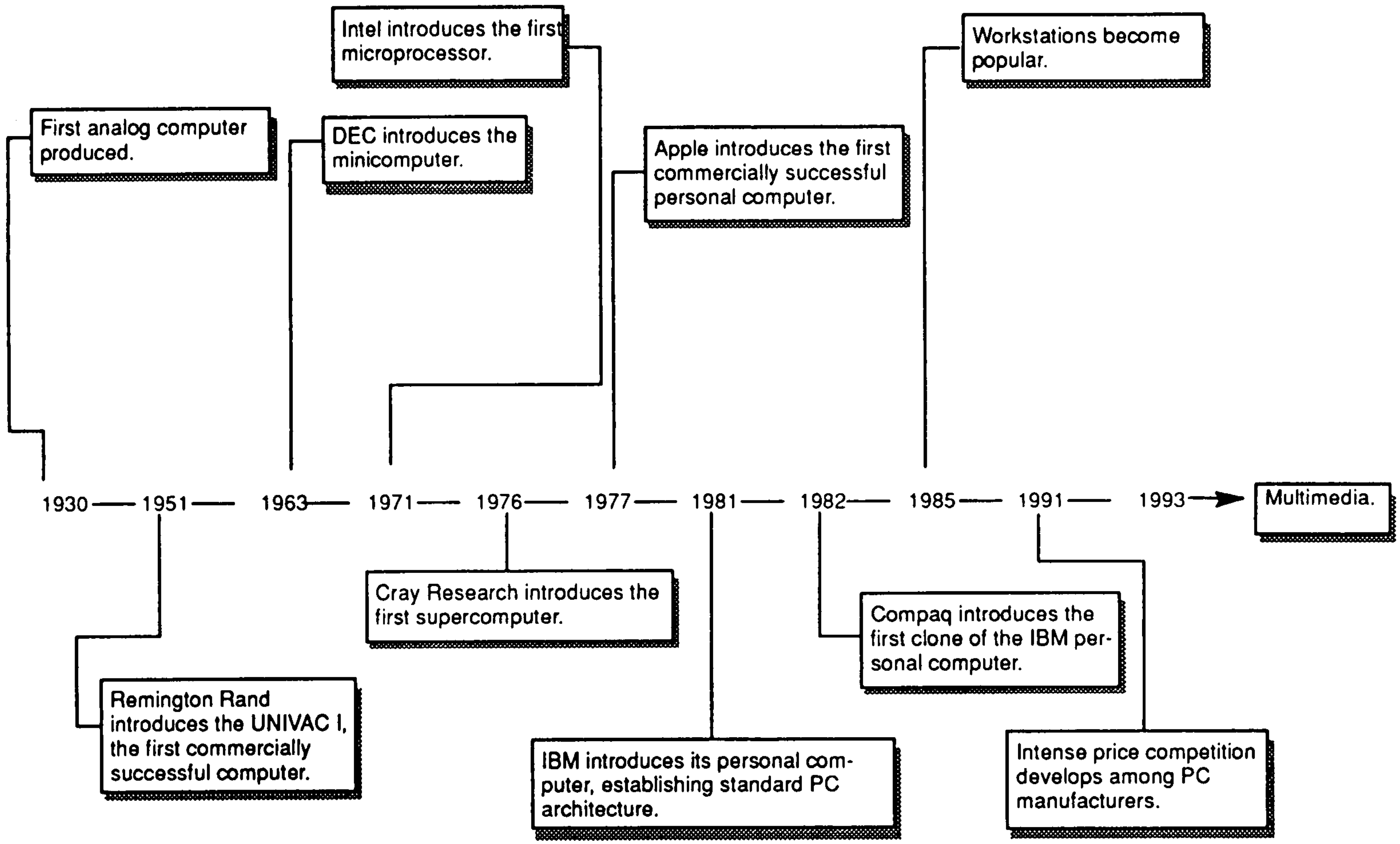
[3] Although it is widely held that the minicomputer industry began with DEC's introduction of the PDP-5 in 1963, other companies were also involved in early minicomputer research. For more information, see Nancy S. Dorfman, "Minicomputers," ch. in *Innovation and Market Structure: Lessons from the Computer & Semiconductor Industries* (Cambridge, MA: Ballinger Publishing Co., 1987), p. 103.

[4] Supercomputers are widely used by the aerospace, automotive, chemical, environmental, and petroleum industries, as well as by university and government entities.

[5] Technically, the first personal computer was the Altair, which had no keyboard or display screen and was programmable only through switches. However, Apple's model was the first machine that was widely available for commercial use.

[6] New companies such as Apple, Tandy, and Commodore were among the first to take advantage of the microprocessor's power. Established companies in the industry were initially hesitant to develop new products for fear of cannibalizing existing systems. For more information on the tendency of start-up firms to develop new technologies and product niches, see Kenneth Flamm, *Creating the Computer: Government, Industry, and High Technology* (Washington, DC: Brookings Institution, 1987); Flamm, *Targeting the Computer*; and Kenneth Flamm, "Globalization in the Computer Industry: Cooperation and Competition in the Global Computer Industry," background paper for the Organization for Economic Co-operation and Development, Directorate for Science, Technology and Industry (Dec. 1990).

Figure 2–1
Evolution of the computer industry



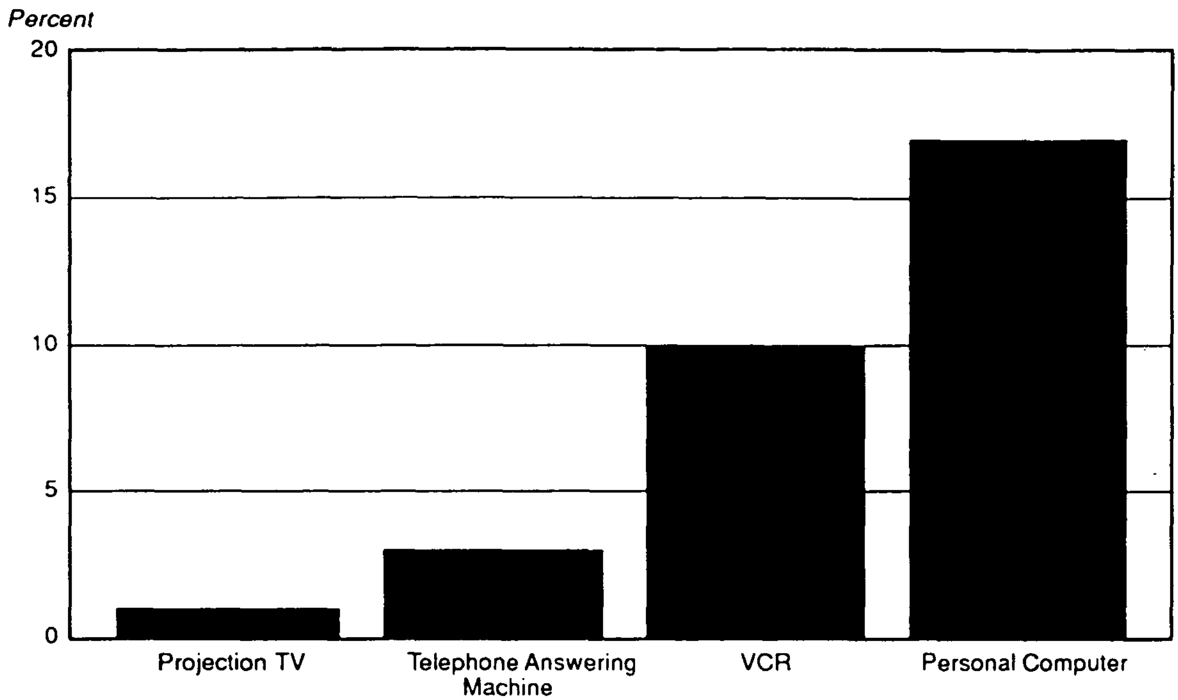
Source: USITC staff.

Figure 2-2
Component definitions

Printed Circuit Boards (PCBs):	PCBs are flat boards that hold chips and other electronic components, allowing them to communicate through circuitry printed on the board. The PCB that holds the microprocessor of a PC is called the "motherboard." PCBs are manufactured by many companies in the United States and overseas.
Microprocessors:	Microprocessors are semiconductor devices that form the central processing unit, or "brain," of the computer. Located on the motherboard, microprocessors process instructions and manipulate data. Advances in microprocessor technology have been largely responsible for increases in computer power. Intel, Motorola, AMD, Chips and Technologies, Cyrix, and Hewlett-Packard—all U.S.-based companies—are the world's foremost microprocessor producers.
Memory Chips:	Memory chips are semiconductor devices that provide the storage capacity of a computer. There are two kinds of memory chips: read-only memory, or ROM; and random access memory, or RAM. Dynamic RAM chips, or DRAMS, are the most common type of computer memory. The production of memory chips, which have become commodity items, largely has moved from the United States to East Asian countries.
Disk Drives:	Disk drives, either magnetic or optical, allow users to store information between computer uses. A disk drive may be a receptacle for removable disk cartridges ("floppy disk drive") or it may contain non-removable disks ("hard disk drive"). Although the disk drive industry is dominated by several firms based in the United States, over 90 percent of production is performed overseas. Primary firms include Seagate, Conner, Maxtor, and Quantum.
Operating Systems:	Operating systems, also referred to as systems software, serve as the bridge between computer hardware and application software programs. Examples include Microsoft's MS-DOS, Apple's and NEC's proprietary operating systems, and UNIX for workstations. Most operating systems are produced by U.S.-based companies.
Application Software:	Application software consists of operational programs for activities such as word processing, spreadsheets, and graphics. It allows businesses to process data without having to write their own unique programs. U.S. firms dominate the applications software industry.
Network Software:	Network software links a number of systems together (usually PCs or workstations) to allow file sharing, enhanced communication, and increased power capabilities. Primary suppliers of network software are located in the United States and include Microsoft, Novell, and Banyan.
Computer Architecture:	Computer architectures are the standards that govern the interaction of computer components and software. Computer architectures determine how components communicate with programs, and how data is exchanged between application software and operating systems. Architectures can be open (e.g., IBM's PC architecture) or proprietary (e.g., Apple's PC system). As software is written for established architectures, early or widely-available architectures can become de facto industry standards.

Source: USITC staff.

Figure 2-3
U.S. household penetration rates of selected consumer electronic products 10 years after their commercial introduction



Source: *Consumer Electronics U.S. Sales*, Electronic Industries Association (EIA), various issues.

use of mass-produced components, combined with widespread dissemination of its PC technology, led to the emergence of IBM-compatible machines and clone makers.[7]

Workstations, which also developed around microprocessor technology, were introduced in the computer market soon after the personal computer. Developed by U.S. companies such as Sun Microsystems and Apollo, workstations initially were designed to serve a special niche in the computer market. Engineers and other technical specialists who required large amounts of desktop processing power to perform complex calculations and graphic imaging quickly adopted the product. These stand-alone computers became more widely popular in the mid-1980s as a more powerful alternative to PCs and as a significantly cheaper alternative to minicomputers and mainframes.

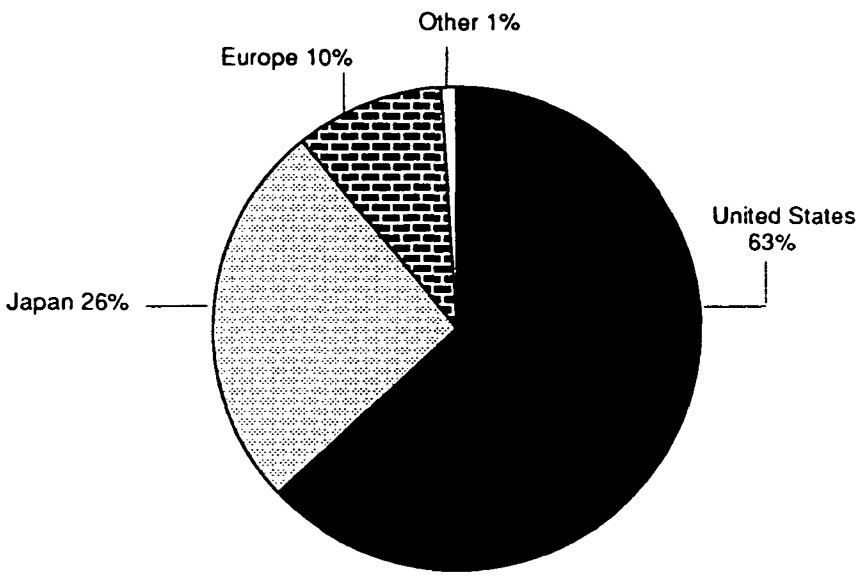
Competitive Position of U.S. Companies

Competition in the global computer hardware industry has intensified over the past four decades as computer technology has diffused, spawning new manufacturers abroad. Despite notable advances by a number of foreign computer companies, particularly Fujitsu, NEC, and Hitachi of Japan, U.S. firms still hold a dominant global market share position. U.S. firms accounted for 61 percent of the $114 billion global market for computer hardware in 1992, showing a slight decline from 63 percent in 1988. Likewise, European firms' share of the global market declined from 10 percent to 8 percent during 1988-92. By contrast, Japanese firms' share of the global market increased from 26 percent to 30 percent (see figures 2-4 and 2-5).[8]

[7] Widespread use of the IBM PC architecture resulted in high profits for Microsoft and Intel. For more information on the importance of controlling system architectures, see Charles H. Ferguson and Charles R. Morris, *Computer Wars: How the West Can Win in a Post-IBM World* (New York: Random House, 1993). Similar information also is presented in Charles R. Morris and Charles H. Ferguson, "How Architecture Wins Technology Wars," *Harvard Business Review*, vol. 71 (Mar./Apr. 1993), pp. 86-96.

[8] Gartner Group, *Yardstick: Top 100 Worldwide*, (Stamford, CT: Gartner Group, Inc., 1993), pp. II-4, II-5, II-14, II-16.

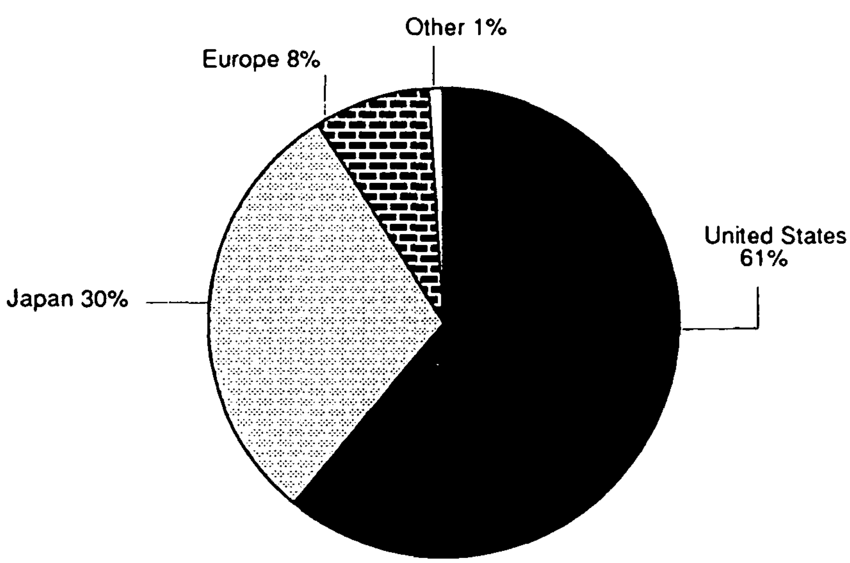
Figure 2-4
Market shares of U.S., European, and Japanese computer firms in the global hardware market, 1988



Total Market: $98 billion

Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

Figure 2-5
Market shares of U.S., European, and Japanese computer firms in the global hardware market, 1992



Total Market: $114 billion

Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

Figures 2-6 through 2-9 show the global market shares of leading companies by market segment. Despite Japanese firms' increasing market share, U.S. firms enjoy a strong competitive position. U.S. firms' share of each market segment exceeds 50 percent. Foreign competition is most intense in the PC segment and the mainframe and minicomputer segment. In these segments, the largest Japanese firms account for slightly more than 20 percent of global revenues. By contrast, U.S. leadership in both the workstation and supercomputer market segments is striking, with U.S. firms accounting for no less than two-thirds of the global market in each. European companies, meanwhile, account for no more than 10 percent of any computer hardware market.

Globalization of the U.S. Industry

In today's global industry, U.S. computer hardware manufacturers rely increasingly on internationally sourced components, foreign production and sales facilities, and strategic joint ventures to enhance their competitive positions.

Component Sourcing

As the price-sensitivity of computer components has increased, a large share of component[9] production has shifted to low-wage regions, particularly East Asia. U.S. imports of computer components, totalling $17.6 billion in 1992, increased by an average annual rate of 24 percent during 1986-92. Component imports by U.S.-based computer manufacturers are nearly four times greater than U.S. imports of finished computers, which totalled $4.6 billion in 1992.[10] U.S. imports of computer components and peripherals[11] are so large, in fact, that by 1991 the United States began registering deficits in overall computer trade (figure 2-10) despite the existence of a healthy U.S. trade surplus in finished computers.[12]

It appears that rapidly expanding imports of computer components have increased the foreign content of most computers manufactured in the United States.[13] U.S. firms do not record import and production data in sufficient detail to calculate foreign content precisely.[14] However, estimates place the overall foreign content of U.S. computer hardware at 30 percent in 1992, an increase from roughly 10 percent in 1986.[15] The foreign content of U.S. computers is likely to increase as finished computers become more price-sensitive. However, U.S. industry representatives suggest that the production of high value-added components and software, such as microprocessors and operating systems, will likely remain on-shore. This is largely due to the enormous investment required to construct appropriate production facilities and the need for access to leading edge research and development laboratories.

Foreign Facilities

The globalization of the industry also is reflected by generally increasing foreign direct investment by all U.S. computer hardware manufacturers (figure 2-11) except supercomputer firms, which remain firmly placed in the United States.[16] U.S firms' cumulative foreign direct investment in computer-related facilities stood at $20.6 billion in 1991. By positioning facilities near foreign customers, companies improve customer service and reduce transportation costs on increasingly price-sensitive goods.

U.S. foreign direct investment likely will continue to expand in the future because some foreign markets are growing more rapidly than the U.S. market. Between 1988 and 1991, for example, the average annual growth rates of Asian and European computer markets consistently exceeded 10 percent, compared with average annual growth rates of less than 5 percent over the same period in the United States. Customers outside the United States now account for 65 percent of global computer purchases.[17]

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[9] Computer components include such items as disk drives, circuit boards, and power supplies.

[10] Compiled from official statistics of the U.S. Department of Commerce.

[11] Peripherals include monitors, keyboards, printers, and other input/output devices.

[12] Favorable duty treatment of computer components may provide incentive to import components rather than finished computers. Computer components enter the United States duty-free, whereas imports of finished computers are subject to a 3.9 percent duty.

[13] Most vector supercomputers produced in the United States still contain over 75 percent U.S. content. The unique, long-term relationships developed between

[13]—*Continued*

supercomputer manufacturers and parts suppliers makes it possible for firms to determine more readily the U.S. content of these high-performance systems.

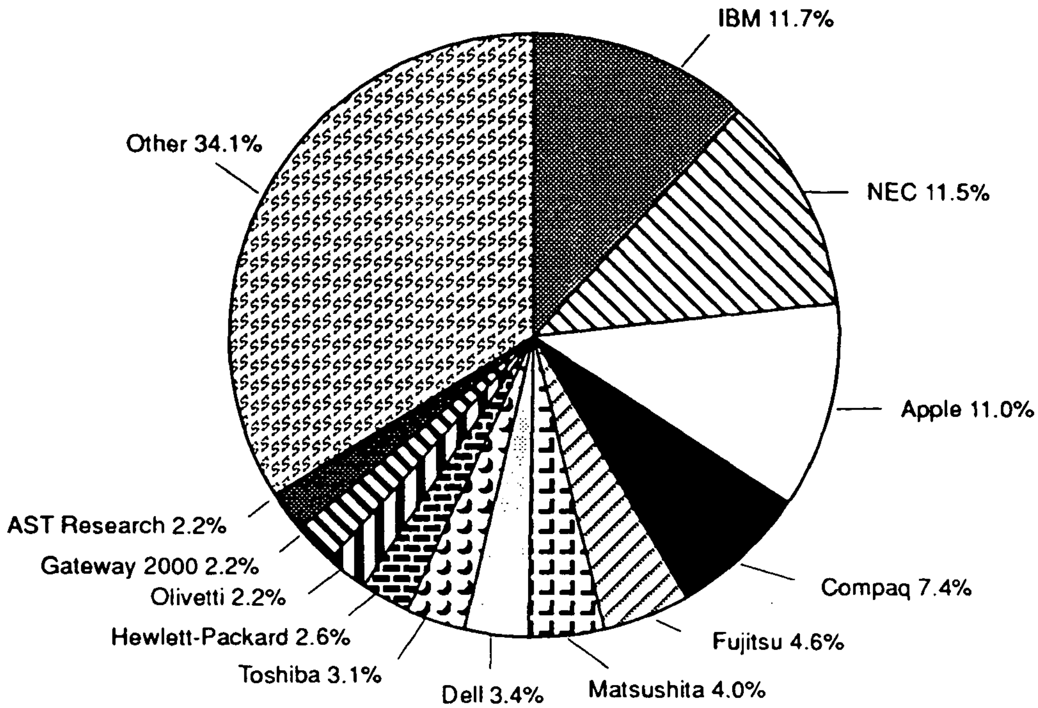
[14] Hardware manufacturers may rely on both domestic and foreign suppliers for the same component. Monthly purchasing patterns vary according to price quotes, as well as freight and duty costs. U.S. industry representatives, interviews with USITC staff, Houston and Austin, TX, June 8-11, 1993.

[15] Estimates have been calculated by dividing the value of imported computer components by the value of computers produced by all firms in the United States. Imported computer components include those manufactured at foreign-owned facilities as well as those manufactured at offshore U.S.-owned facilities, and those reentering the United States under provision 9802 of the Harmonized Tariff Schedule.

[16] Supercomputer firms stress the importance of access to technology and highly skilled labor as factors influencing the decision to keep R&D and production in the United States.

[17] The Gartner Group, *Yardstick: Top 100 Worldwide*, 1993, p. IV-2.

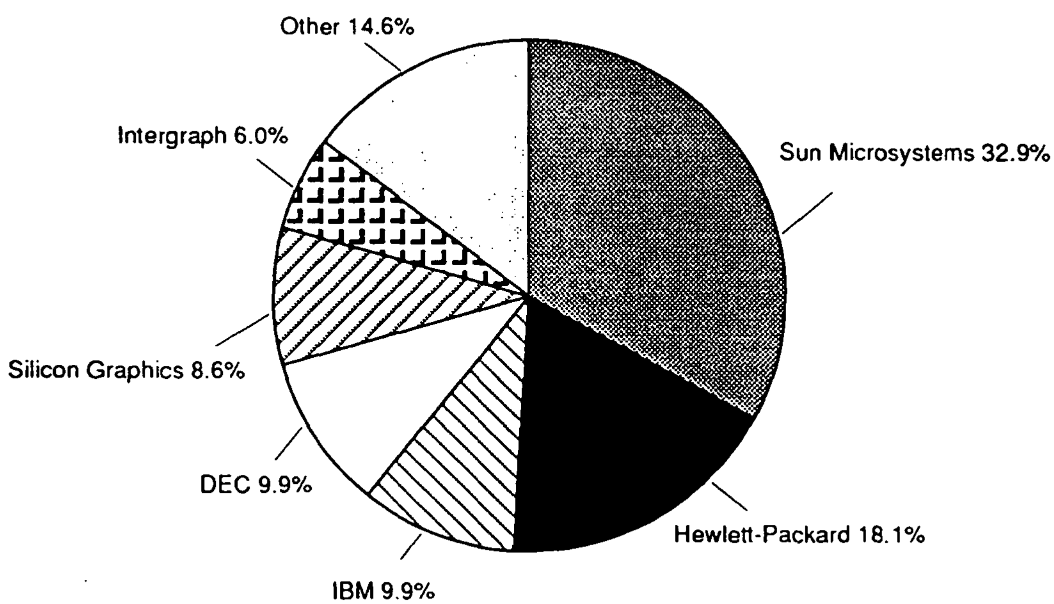
Figure 2-6
Global market share in the personal computer segment, 1992



Total Market: $46 billion

Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

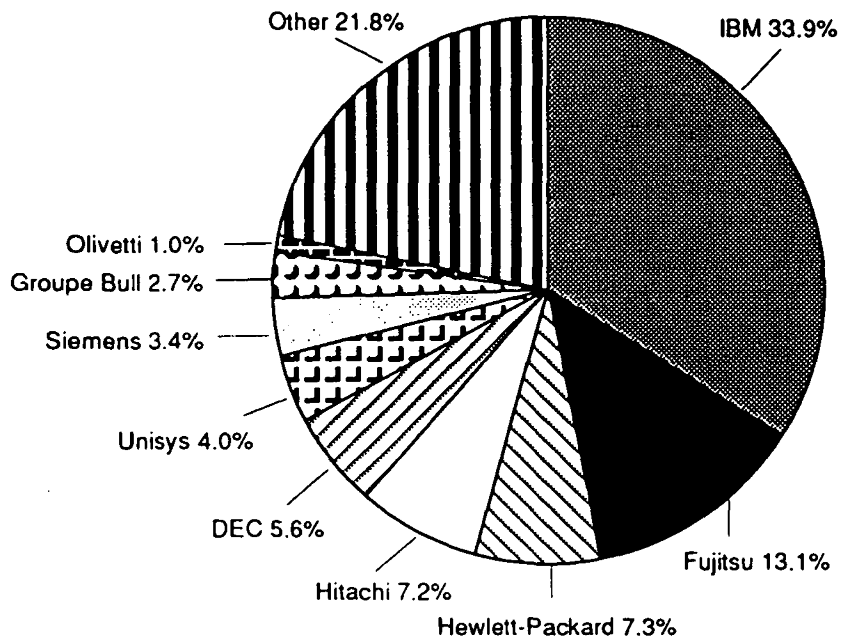
Figure 2-7
Global market share in the workstation segment, 1992



Total Market: $10 billion

Source: International Data Corporation as presented in "Last Year's Model," *The Economist*, May 29, 1993.

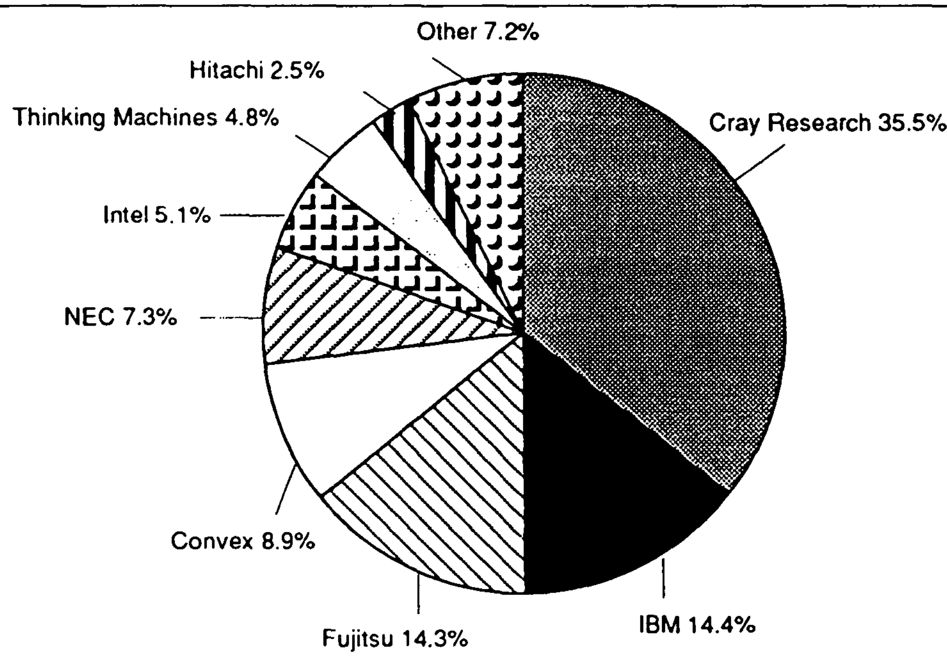
Figure 2-8
Global market share in the mainframe and minicomputer segment, 1992



Total Market: $56 billion

Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

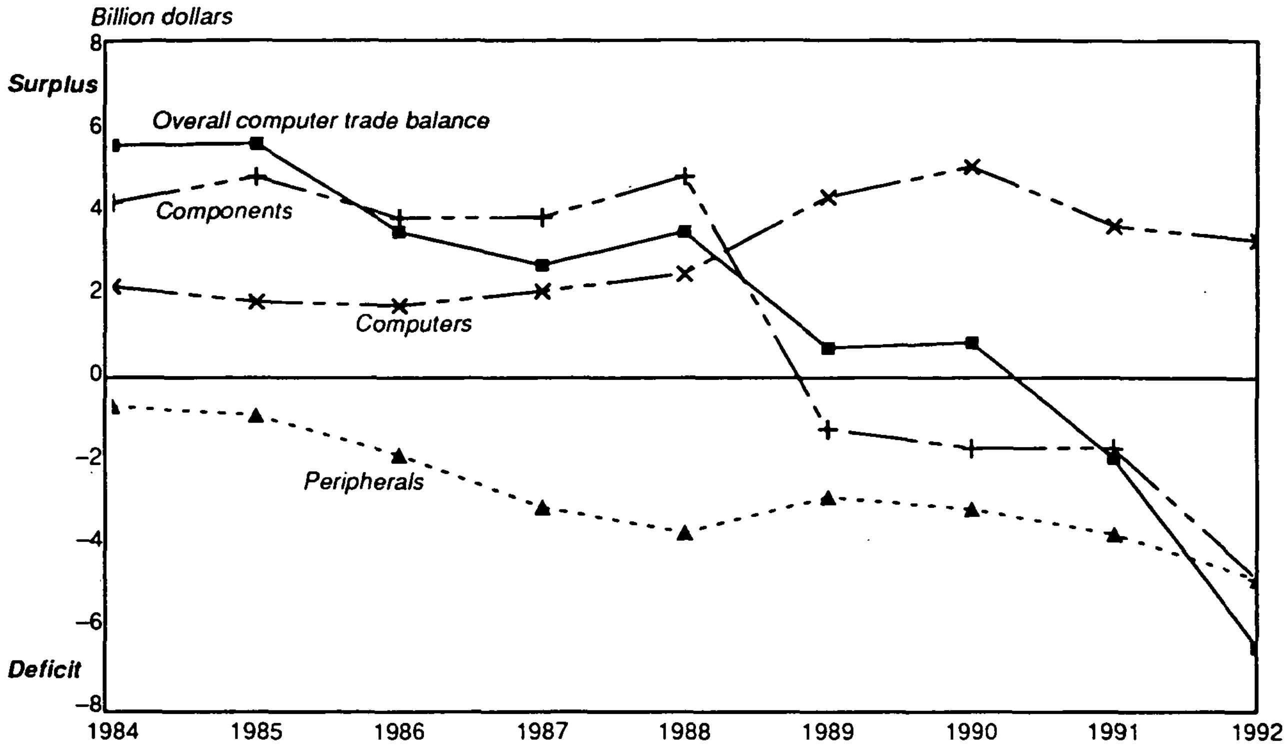
Figure 2-9
Global market share in the supercomputer segment, 1992



Total Market: $2 billion

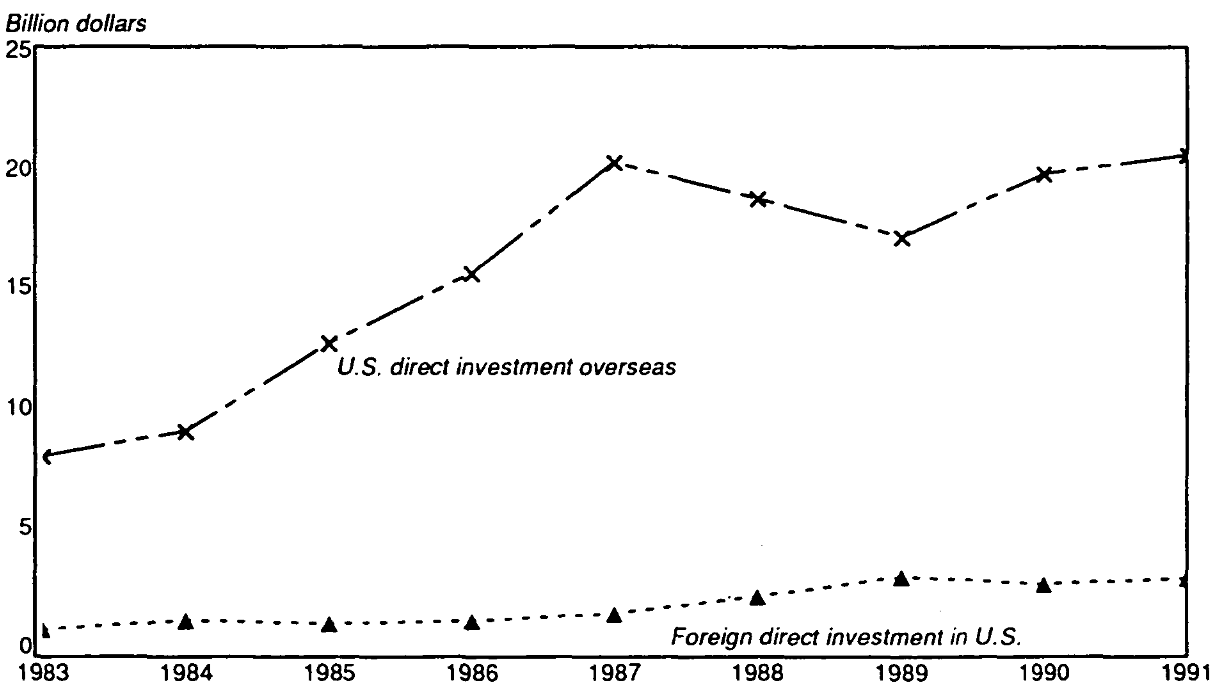
Source: USITC staff.

Figure 2-10
U.S. trade balance in computers, peripherals, and components



Source: U.S. Department of Commerce.

Figure 2-11
Cumulative U.S. and foreign direct investments in computer-related facilities, 1983-91



Source: U.S. Department of Commerce.

Although small by comparison, foreign firms' direct investment in the United States has been growing at a relatively steady pace as these companies pursue advanced technologies and research facilities in this country.[18] Foreign firms' cumulative direct investment in the U.S. computer industry totalled $2.9 billion in 1991. Table 2-1 provides information regarding foreign investment in the U.S. computer industry.

Strategic Alliances

Joint ventures, collaborative research programs, and formal technological alliances involving U.S. and foreign computer hardware manufacturers have proliferated in recent years. In many instances, U.S. firms have allied themselves with foreign competitors (table 2-2). One of the primary reasons for establishing a cooperative alliance is to share the costs and risks associated with research and product development. Companies competing within the same product segment occasionally form alliances to conduct pre-competitive research. For example, IBM has formed a joint research venture with Toshiba and Siemens-Nixdorf to develop a new generation of memory chips. In other cases, companies look beyond their immediate competitors and cooperate with firms capable of supplying complementary technology. For example, Apple Computer combined its considerable computer design skills with Sony's expertise in manufacturing and miniaturization to produce the 3-pound PowerBook notebook computer.[19]

Strategic alliances are also used to increase a company's involvement in and knowledge of a foreign market. Because consumer demands and expectations may vary in different markets, many firms prefer to enter new geographic markets by forming alliances with companies having a long-standing regional presence. IBM, for instance, has entered a marketing alliance with Hitachi to distribute IBM notebook computers in Japan, a country in which long-standing distributor contacts are reportedly essential.[20]

Finally, the number of strategic alliances has increased in direct proportion with company cost-cutting and streamlining efforts. Some companies have narrowed their business focus to manage costs more effectively, and consequently have formed partnerships that allow them to rely on other firms to perform important production, sales, and delivery tasks. Sun Microsystems' alliance with Fujitsu in the development and production of workstation microprocessors typifies such alliances.

Key Industry Trends

The competitive environment is changing rapidly in response to ongoing technological innovation and evolving consumer expectations. New innovations and consumer preferences are driving two key trends: commoditization of computer hardware and computer platform downsizing. In addition to these trends, many computer hardware firms are finding it necessary to seize opportunities in related industries. A number of companies, especially those in the mainframe and minicomputer segment, are focusing on the computer software and service industries.

Commoditization

The origin of commoditization can be traced to 1981, when IBM launched its personal computer. As stated earlier, IBM purchased standardized microprocessors and operating system software from Intel and Microsoft, respectively, and freely shared its PC technology with other computer hardware manufacturers. These were strategic decisions, designed to end Apple's effective monopoly on the personal computer market. The wide availability of IBM technology invited a host of firms to enter the PC market. Barriers to entry collapsed as new entrants were freed from the need to construct a huge, vertically-structured firm capable of supplying computer components internally. Nor was it necessary for these firms to conduct the pre-competitive research normally required to launch an advanced-technology product.[21] The mass entry of IBM clone makers into the market enticed software houses to create a plethora of user-friendly application programs conforming to IBM's architecture. These word processing, spreadsheet, and graphic applications packages were essential in promoting the widespread use of personal computers.

The growing popularity of personal computing generated vast economies of scale. This, in turn, brought down the average unit cost and, eventually, the price of personal computers, computer

[18] For more information on the positive correlation between the availability of scientists and engineers, the level of R&D spending, and the level of a country's computer exports, see Caroline H. Beetz, *Determinants of International Comparative Advantage: A Case Study of the Computer Hardware Industry*, Ph.D. dissertation, Department of Economics, Northeastern University, Boston, 1991.

[19] This PowerBook manufacturing alliance between Apple and Sony is no longer in force. Apple computer representative, telephone interview with USITC staff, Nov. 8, 1993.

[20] This alliance focuses on systems software, printers, and the distribution of IBM notebook computers in Japan. Gene Gregory, "The Irresistible Case for Strategic R&D Alliances," *Asia Management Journal*, June/July 1993, p. 20.

[21] Some analysts note that the flexibility of new companies constitutes an important competitive advantage over incumbent firms, despite the economies of scale and scope enjoyed by established firms. For more information on the creative energies of new market entrants in the PC market, see Richard N. Langlois, "External Economics and Economic Progress: The Case of the Microcomputer Industry," *Business History Review*, vol. 66 (Spring 1992), pp. 1–50.

Table 2–1
Foreign investment in U.S. computer-related facilities

Country	Parent	Facility	Product	State	Year	Percent ownership
France	Groupe Bull	Zenith Data Systems	PCs	IL	1989	100.0
		Honeywell IS	n.a.	MN	1988	65.1
		Packard Bell	PCs	CA	1993	19.9
Germany	Siemens Nixdorf AG	Siemens Nixdorf Information Systems	Computers and printers	MA	n.a.	92.0
Japan	Canon	Southtech	Printer parts	VA	1989	100.0
	Fujitsu	Amdahl	Mainframes	CA	1972	44.3
		Fujitsu America	High–capacity disk drives,	OR	1990	100.0
			semiconductors, and	OR	n.a.	100.0
			modems	FL	n.a.	100.0
		Poqet Computers	Palmtop computers	CA	1992	100.0
		HaL Computer Systems	Workstations and minis	CA	1991	44.0
		Fujitsu Microelectronics	Semiconductors	CA	n.a.	100.0
		Intellistor	Memory devices	CO	1987	100.0
		Ross Technology	Chip technology	CA	1993	100.0
	Hitachi	Hitachi Data Systems	n.a.	n.a.	n.a.	80.0
	Mitsui	Unisys	Mainframes	MN	n.a.	5.0
	NEC	Control Data	Systems integration	MN	1992	5.0
		NEC America	Network and modem software	CA	1987	100.0
		NEC Electronics	PCs	CA	1984	100.0
		NEC Technologies	PCs, printers, and hard disk drives	MA	1984	100.0
		NEC Technologies	Color displays	GA	1985	100.0
	Sony	Sony Engineering and Manufacturing of America	Monitors and storage devices	CA	1972	100.0
		Sony Semiconductor & Systems Laboratory	Semiconductors	CA	n.a.	100.0
		Sony Engineering and Manufacturing of America	Monitors and storage devices	CA	1972	100.0
	Toshiba	Toshiba America Information Systems	Printed circuit boards	CA	1990	100.0
		Vertex Semiconductors	Semiconductors	CA	1991	100.0
Korea	Daewoo	Leading Edge Products	PCs	MA	1989	100.0
	Hyundai	Hyundai America	PCs	CA	1992	100.0
	Samsung	Samsung IS America	PCs	NJ	n.a.	100.0
		Life and Culture Research Centers	Consumer research	CA	1992	100.0
		Harris Microwave Semiconductor	Semiconductors	CA	1993	100.0
Netherlands	Memorex Telex	Memorex Telex	PCs, controllers, and servers	NC	n.a.	100.0
Taiwan	Acer	Acer America and Altos	PCs	CA	1990	100.0

Source: USITC staff.
n.a. = not available.

Table 2–2
Selected manufacturing and R&D joint ventures and alliances

U.S. firm	Allied firm	Headquarters	Product	Year
Apple	General Magic	U.S.	Networking	1993
	IBM	U.S.	Software	1991
	Motorola & IBM	U.S.	PowerPC chip	1991
	Sharp	Japan	Palmtop computers	1992
	Sony	Japan	Notebook computers	1991
AT&T/NCR	General Magic	U.S.	Networking	1993
	Mitsubishi	Japan	Memory chips	n.a.
	NEC	Japan	Memory chips	n.a.
	Sierra On–Line	U.S.	On-line services	1993
Cadense Design Systems	Fujitsu and NEC	Japan	IC technology for CAD	1992
Chips & Technologies	Summit Systems	C.I.S.	PCs	1990
Control Data (Ceridian)	Intergraph	U.S.	CAD/CAM/CAE	1992
	Structural Dynamics Research	U.S.	Software	1992
Convex	Hewlett–Packard	U.S.	Workstations and MPP computers	1992
Cray Research	Bolt Beranek	U.S.	MPP computers	1991
	Motorola	U.S.	Application specific ICs	1992
	Sun	U.S.	Software	1992
	Yokogawa	Japan	Supercomputers	1992
Data General	Dun and Bradstreet Software	U.S.	Mainframe software	n.a.
DEC	Alcatel	France	Display terminals	n.a.
	Apple	U.S.	Network interfaces	n.a.
	Cray Research	U.S.	Supercomputer/ minicomputer interfaces	1992
	Escom	Germany	Network services	1992
	Fluent	U.S.	Video networking hardware and software	1992
	MasPar	U.S.	MPP computers	1991
	Mitsubishi	Japan	Alpha AXP processors	1993
	Motorola	U.S.	Data interface chip sets	n.a.
	Olivetti	Italy	Network interfaces	1992
	Siemens Nixdorf	Germany	Semiconductors	n.a.
Hewlett–Packard	Analog Devices	U.S.	Mixed digital and analog chips	1992
	Convex	U.S.	Workstations and MPP computers	1992
	TV Answer	U.S.	Interactive TV systems	1992
	Oki Electric Industry	Japan	PA–RISC chips and mobile communications	1992
	Hitachi	Japan	PA–RISC chips	1992
	Samsung	Korea	PA–RISC chips	1990
IBM	Apple	U.S.	Software	1991
	Canon	Japan	Printers	1992
	Digital	U.S.	Disaster recovery	1992
	Groupe Bull	France	Workstations	1992
	Hewlett–Packard	U.S.	Fiber optic components	n.a.
	Intel	U.S.	Microprocessors	1991
	Motorola	U.S.	Phoneless modems	1990
	Motorola & Apple	U.S.	Power PC chip	1991
	Motorola &	U.S.	Semiconductors	1989
	National Semiconductor	U.S.	LAN products	1992

Table 2-2—Continued
Selected manufacturing and R&D joint ventures and alliances

U.S. Company	Allied Firm	Headquarters	Product	Year
IBM—Continued	Picturetel	U.S.	Video conferencing	1991
	Siemens Nixdorf	Germany	Semiconductors	1991
	Thinking Machines	U.S.	Supercomputers	1991
	Toshiba	Japan	Flat panel displays	1991
			Memory chips	1992
INTEL	IBM	U.S.	Microprocessors	1991
	Sharp	Japan	Flash memory chips	1992
Motorola	Cray	U.S.	Integrated circuits	1992
	IBM	U.S.	Phoneless modems	1990
	IBM & Apple	U.S.	PowerPC chips	1991
	Samsung	Korea	Wireless pen PC	1992
	Toshiba	Japan	Memory chips	1987
	Unisys	U.S.	Semiconductors	1992
Silicon Graphics/ MIPS	Daewoo	Korea	RISC architecture	1990
	NEC and Toshiba	Japan	RISC architecture	1993
Sun Microsystems	Fujitsu	Japan	SPARC chips	1986
	Intergraph	U.S.	64-bit microprocessor	n.a.
	Kalpana	U.S.	LAN technology	1992
	Moscow Center of SPARC Technology	Russia	Workstation software	1992
	Texas Instruments	U.S.	Super-SPARC chip	n.a.
	Toshiba	Japan	RISC technology	n.a.
Tandy	Casio Computer, Geoworks, & Palm Computing	Japan U.S. U.S.	Hand-held computers	1992
Texas Instruments	Acer	Taiwan	Memory chips	1991
	Hitachi	Japan	Memory chips	1988
			Memory chip design	1991
Unisys	KPMG Peat Marwick	U.S.	Software	1991
	Motorola	U.S.	Semiconductors	1992

Source: USITC staff.
n.a. = not available.

components, and applications software (figure 2-12).[22] Prices continued to edge downward as the number of new firms multiplied. Virtually all new firms built largely undifferentiated products around IBM's personal computer architecture, leaving them to compete almost exclusively on the basis of price. Economic rents, the large profits captured by innovators that successfully protect their intellectual property, remained in the possession of microprocessor and operating systems software manufacturers.[23] Profit margins for PC manufacturers narrowed dramatically.

In addition to reducing prices, commoditization of the personal computer market changed the expectations of consumers in other computer hardware markets. Computer hardware typically has been built around proprietary technologies, complicating the task of networking machines that are manufactured by different firms. The ease of constructing PC-based networks from IBM-compatible machines has led purchasers of all types of computers to demand more compatible "open systems," wherein computers manufactured by different firms are more easily interconnected. In response, manufacturers are developing joint ventures to coordinate product development strategies and develop more open architectures. Workstation manufacturers have made significant progress in terms of establishing open operating systems. Minicomputer manufacturers have also charted a course toward open systems, with an estimated one-quarter of the minicomputers sold during 1992 incorporating nonproprietary architecture. Mainframe manufacturers, although heavily dependent on proprietary architectures, are making similar efforts to design and market open systems.

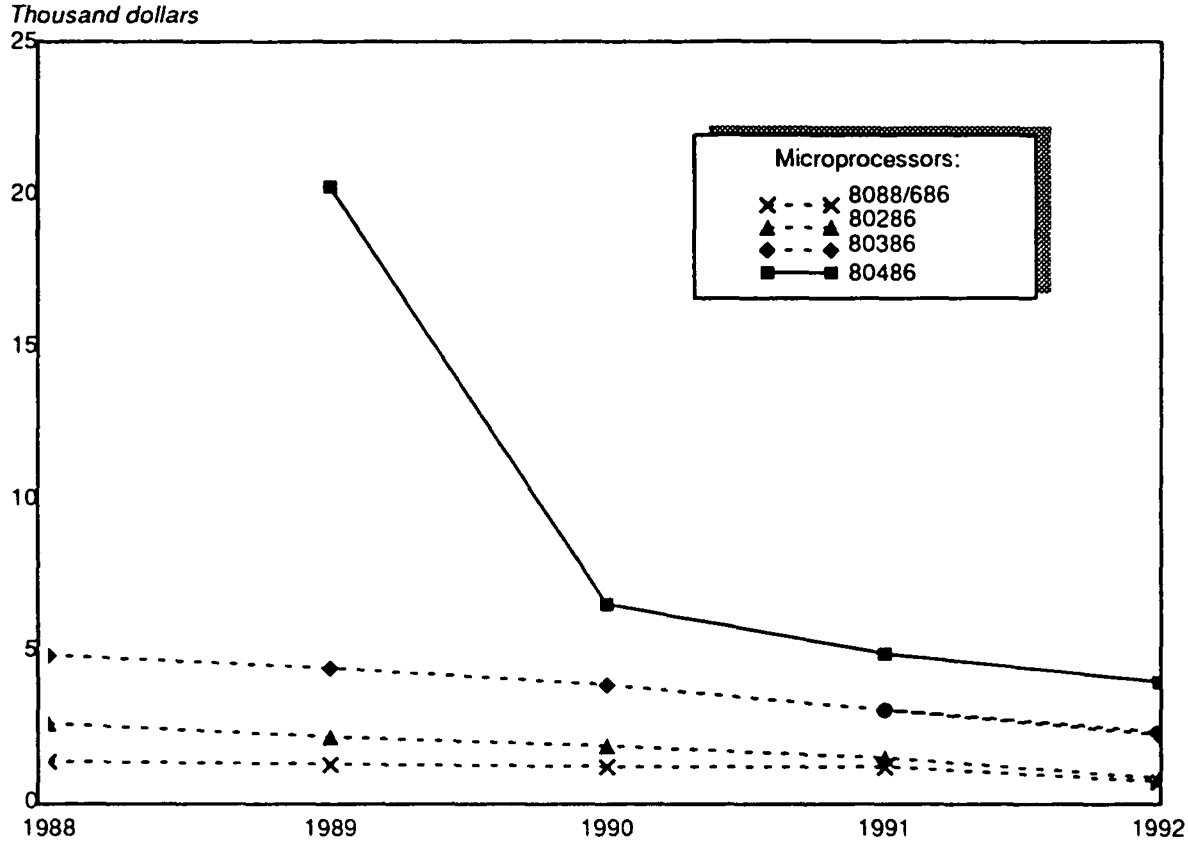
Computer Platform Downsizing

The commoditization of PCs has affected minicomputer and mainframe markets in several ways. Previous consumers of large-scale systems have begun to "downsize" computer platforms, replacing traditional mainframes and minicomputers with

[22] New market entrants, more flexible in structure than established manufacturers, also cut costs through innovative sales and distribution techniques. Dell's mail-order strategy is a good example of this.

[23] For more information on the shift of profits to the software and service industries, see Andrew S. Rappaport and Shmuel Halevi, "The Computerless Computer Company," *Harvard Business Review*, vol. 69 (July/Aug. 1991), pp. 69-80.

Figure 2-12
U.S. average selling price for PCs by microprocessor type



Source: International Data Corporation data as presented in European Association of Manufacturers of Business Machines and Information Technology (EUROBIT), *European Information Technology Observatory 93* (Frankfurt, Germany, 1993).

client-server networks[24] of less expensive workstations and PCs. Platform downsizing is the mechanism by which price competition in the PC market has spread to the markets for minicomputers and mainframes.

Platform downsizing became feasible as the processing capabilities of PCs and workstations expanded. PC and workstation performance levels have increased due to technological leaps in microprocessor technology. Each new version of the Intel X86 microprocessor (e.g., 386, 486, etc.),[25] the standard PC processor, has resulted in ever more powerful desktop computers. Today's 486-based personal computers offer the same amount of computing power as a 1960s-vintage mainframe, at a fraction of the cost. In 1993 Intel released its new Pentium chip, which is estimated to be 100 times more powerful than the chip inside the first IBM PC.[26] Workstations, meanwhile, are built around increasingly powerful reduced instruction set computing (RISC) microprocessors.[27] RISC processors are even more powerful than Intel's Pentium microprocessor. The increasing capabilities of these smaller, microprocessor-based computers are enabling many firms to downsize computer platforms without reducing processing power.

In addition to greater computing power within personal computers and workstations, the development of advanced network software has facilitated platform downsizing. Network software is critical to

[24] Client-server networks link a number of "clients" (usually PCs or workstations) to a central "server" computer. The server is responsible for storing and supplying data and applications for the client stations.

[25] Intel is the leading producer of microprocessors worldwide, accounting for over 60 percent of the global market. Its principal competitors include Advanced Micro Devices (United States), Cyrix (United States), and Motorola (United States).

[26] Tom R. Halfhill, "Intel Launches Rocket in a Socket," *Byte* (May 1993), p. 94.

[27] Current R&D related to the use of RISC chips in PCs will further blur the boundary between workstations and PCs.

communication between desktop computers and the file server. The server acts as a "traffic cop" by disseminating data and applications to some users while collecting or storing information for others.[28] Without network software, individual computers, regardless of their power, could not access data and applications stored on the main server. Companies are also developing software that will capture the combined power of several networked workstations by separating large problems into several parts for simultaneous, or "parallel," processing. When linked in closely interconnected "clusters," workstations may even compete with low-end supercomputers.

Pressure to downsize computer platforms also has come from users that no longer want to depend entirely on a central computer to run programs and store data. PCs linked to a network, unlike "dumb terminals" attached to mainframes, have their own memory and processing capabilities, and can function without the assistance of servers.[29] Independence from a central computer provides users with added flexibility and control.

The end result of downsizing computer platforms is that price-sensitive PCs and relatively inexpensive workstations are competing directly with mainframes and minicomputers. Eight of the world's 10 largest computer hardware manufacturers — IBM, DEC, Hewlett-Packard, Unisys, Fujitsu, Hitachi, Groupe Bull, and Siemens-Nixdorf — derive 25 to 40 percent of total hardware revenues from mainframes and minicomputers.[30] As a result of weaker demand and lower prices stemming from platform downsizing, the financial position of many of these firms has deteriorated (see chapter 4). The effect of downsizing on the hardware industry is illustrated in figure 2-13, which contrasts the declining revenues in the mainframe and minicomputer market with the increasing revenues in the PC and workstation markets.

Software and Services

Many computer hardware manufacturers derive a significant share of total revenue by providing computer software and services to hardware customers (table 2-3). Six of the largest 10 computer software vendors are IBM, Fujitsu, DEC, NEC, Hitachi, and Siemens-Nixdorf. IBM sells more software than Microsoft. Three of the largest 10 computer service providers are IBM, DEC, and Unisys. DEC's service revenues are larger than the firm's hardware revenues.

While the software and service industries presently are smaller than the computer hardware industry, the former are growing more rapidly. Figure 2-14, which shows the growth of certain U.S. industries in relation to gross domestic product (GDP) during 1987-91, reveals that revenues in the computer hardware industry grew less rapidly than those in either the computer software or service industries. Moreover, in stark contrast to rapid job creation in the computer software and service industries, employment in the U.S. computer hardware industry shrank. In terms of their contribution to aggregate U.S. economic activity, the computer software and service industries ranked among other rapidly growing technology industries, including the electromedical equipment and pharmaceutical industries.

Given the rapid growth and future potential of the software and service industries, many computer hardware companies are turning to the high value-added returns of software and services to supplement declining hardware revenues. A number of mainframe and minicomputer vendors, for example, are supplementing firm revenue by offering business consulting and solutions services.[31] Prominent U.S. companies such as Wang Laboratories, Prime, and Next Computer, all of which have failed to sustain profitable hardware operations, have shifted to a "software-first" strategy.[32] Moreover, successful hardware firms such as Sun Microsystems have recognized the importance of software development as a key component of the company's hardware business. Hardware engineers from these firms are working closely with in-house and independent software writers to ensure the development of computer hardware products that conform to users' evolving needs.

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[28] For a discussion of networks and their power in the workplace, see Ferguson and Morris, "Competing in a Radically Decentralized System," ch. in *Computer Wars*, p. 115.

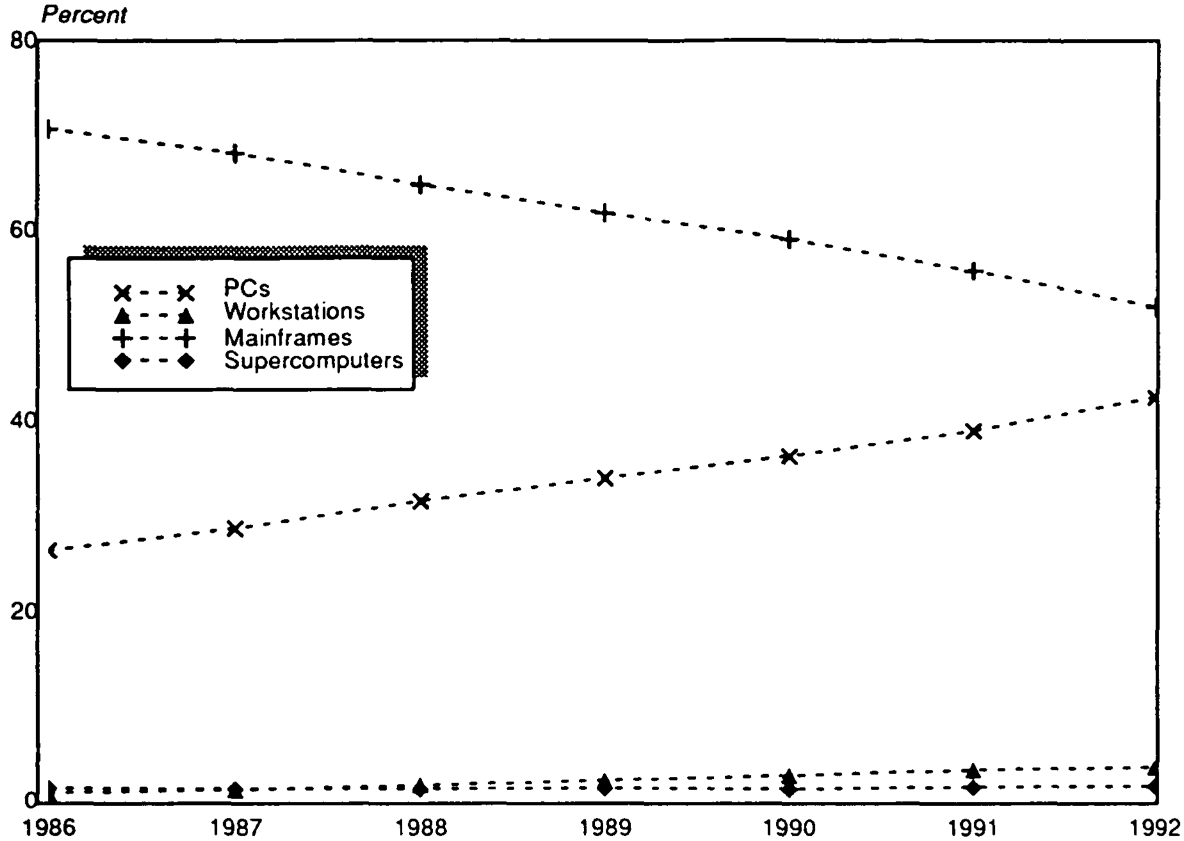
[29] Programs that are stored locally in the desktop computer's internal drive run independently of the file server.

[30] Gartner Group, *Yardstick: Top 100 Worldwide*, 1993, p. II-12.

[31] IBM's new "Solutions" division reportedly will function as an independent solutions provider, recommending computer products that best meet clients' needs, regardless of manufacturer. Other firms, such as DEC and Unisys, have made similar commitments. These newly created entities will compete with firms such as Andersen Consulting and EDS, both of which specialize in computer services and systems integration. IBM officials, interviews with USITC staff, Armonk, NY, Apr. 13, 1993.

[32] Cate Corcoran and Mark Stephens, "Next Nixes Hardware for Software," *Info World*, Feb. 8, 1993, p. 1.

Figure 2-13
Percent of world revenues by market segment



Source: USITC staff estimates and Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

Table 2–3
Revenues of the top 20 providers of computer hardware, software, and services, 1992

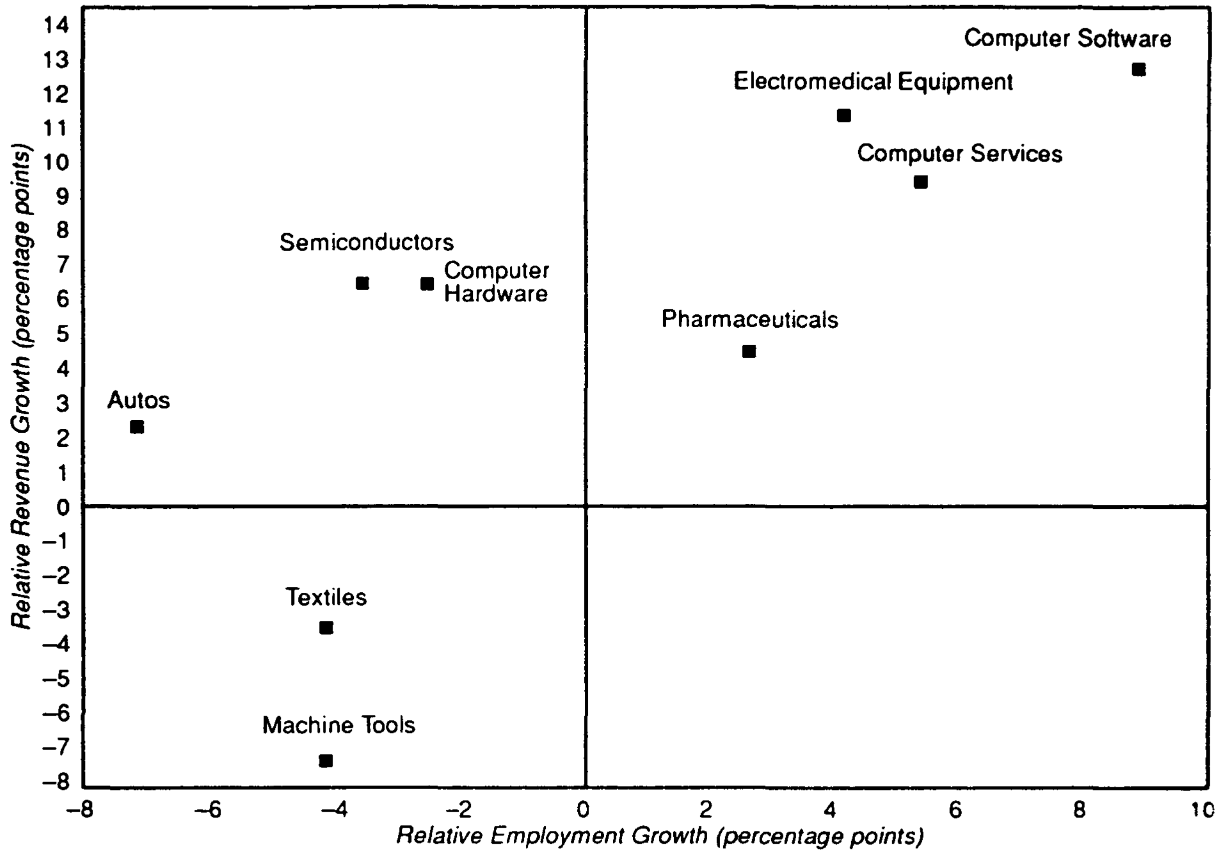
Companies	Country	Hardware revenues	Software revenues	Service revenues[1]	Other revenues[2]	Total firm revenues
		Percent				*(Million dollars)*
IBM	United States	43.7	18.1	24.6	13.6	61,245
Fujitsu	Japan	51.6	10.7	14.1	23.6	20,090
NEC	Japan	61.0	8.6	5.7	24.7	14,550
DEC	United States	32.0	11.8	43.3	13.0	14,162
Hitachi	Japan	38.5	9.0	10.5	42.0	13,306
Hewlett-Packard	United States	46.6	4.1	23.6	25.7	12,488
Unisys	United States	37.7	8.5	40.7	13.1	8,422
Siemens-Nixdorf	Germany	36.8	12.7	27.0	23.5	8,202
Electronic Data Systems	United States	0	0	100.0	0	8,155
Apple Computer	United States	77.3	3.6	0	18.8	7,224
American Telephone and Telegraph	United States	33.0	8.0	43.7	15.3	6,100
Groupe Bull	France	46.4	10.1	34.4	9.1	5,646
Olivetti	Italy	32.1	11.6	22.6	33.7	5,342
Canon	Japan	6.1	0	7.0	86.9	4,204
Toshiba	Japan	52.2	7.8	9.0	31.0	4,177
Compaq	United States	92.3	4.3	0	3.4	4,100
Sun Microsystems	United States	73.7	6.0	10.7	9.6	3,832
Matsushita Electric	Japan	58.0	0	9.2	32.8	3,528
Nippon Telephone and Telegraph	Japan	0	0	48.0	52.0	3,396
Mitsubishi Electric	Japan	48.7	4.3	11.6	35.4	3,295
Total *(million dollars)*		92,315	22,436	52,231	44,482	211,464

[1] Includes maintenance.

[2] Principally includes peripheral and data communications equipment.

Source: USITC staff estimates and data as presented in Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

Figure 2-14
Recent growth of selected industries[1], 1987–91



[1] Relative revenue growth is the difference between the average annual revenue growth rates of selected industries during 1987-91 and the average annual growth rate of U.S. gross domestic product. Relative employment growth is the difference between the average annual employment growth rate of selected industries and the average annual growth of U.S. private sector employment.

Source: USITC staff and U.S. Department of Commerce, *1993 U.S. Industrial Outlook* (Washington, DC: GPO, 1993).

CHAPTER 3
Government Policy

Introduction

This chapter principally examines government policies affecting the competitiveness of the computer hardware industries in the United States, Europe, and Japan. Policies in other countries are discussed where applicable.

All segments of the computer hardware industry appear to be affected by export controls and tax incentives (figure 3-1). In addition, policies pertaining to research and development (R&D), government procurement, and intellectual property rights (IPR) significantly influence the markets for supercomputers and mainframes and minicomputers. Tariffs, meanwhile, have the greatest effect on the price-sensitive personal computer (PC) market.[1]

Although governments continue to use such policies to enhance industry performance, their ultimate impact on competitiveness is unclear. This is because rapidly changing technology and market practices, in combination with globalization, are making it more difficult for countries to develop policies that can be easily targeted to help their own firms.[2]

Government Support for R&D

Although governments in the United States, Europe, and Japan all have been intimately involved in initiating and supporting R&D programs related to computer technology (table 3-1), their approaches have differed markedly in both content and effectiveness.[3] In the United States, government support for R&D in computers has been extensive; however, such support has traditionally focused on defense-related applications. Some industry analysts believe this emphasis has prevented U.S. firms from fully utilizing government-sponsored R&D for civilian product development.[4] European and Japanese support for R&D, meanwhile, has placed more emphasis on civilian applications.

As policymakers consider reorienting U.S. Government R&D efforts in computer technology to emphasize civilian applications, some industry analysts suggest that they may first wish to consider the relative successes and failures of policies in Europe and Japan.[5] Although certain aspects of European and Japanese R&D programs have been similar, it appears that Japanese reliance on market signals and inter-company competition was more successful than the European methods.[6] However, even in Japan, success in technology and R&D policies has been mixed in recent years. As Japanese firms have reached the "technology frontier," they no longer have a clear path to follow in establishing their future technology plans.

As the computer industry has globalized in recent years, alliances between firms from different countries have increased. As a result, government-sponsored R&D efforts targeted at specific firms and technologies have become much less effective in helping a nation's own firms. For this reason, a number of governments are refocusing their R&D efforts to support broad infrastructure and network capabilities, rather than particular firms or technologies. This section will describe several of the most important R&D policies and programs affecting the computer industries in the United States, Europe, and Asia, and will analyze the reasons for the success or failure of such policies.

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[1] USITC staff also examined the effects of antitrust, health, standards-setting, and environmental policies. These policies do not appear to affect competitiveness significantly, and therefore are omitted from the present discussion.

[2] Robert B. Reich, *The Work of Nations* (New York: Knopf, 1991), p. 1; U.S. industry representatives, interviews with USITC staff, Silicon Valley, CA, Apr. 15-23, 1993; and European industry representatives, Munich, Ivrea, Paris, and London, May 6-24, 1993.

[3] Charles H. Ferguson and Charles R. Morris, *Computer Wars: How the West Can Win in a Post-IBM World* (New York: Random House, 1993), pp. 233-239; National Academy of Sciences (NAS), *The Government Role in Civilian Technology: Building a New Alliance* (Washington, DC: The National Academy Press, 1992), pp. 37-38; and Kenneth Flamm, *Creating the Computer: Government, Industry, and High Technology* (Washington, DC: Brookings Institution, 1987), p. 29.

[4] David C. Mowery and Nathan Rosenberg, "The U.S. National Innovation System," ch. in *National Innovation Systems*, ed. Richard R. Nelson (Oxford: Oxford University Press, 1993), pp. 58-59.

[5] U.S. computer industry analysts, interviews with USITC staff, Silicon Valley, CA, Apr. 15-23, 1993.

[6] Ferguson and Morris, *Computer Wars*, pp. 233-239; NAS, *The Government Role in Civilian Technology*, pp. 37-38; and Flamm, *Creating the Computer*, p. 29.

Figure 3-1
Computer segments affected most by various government policies

	Personal computers	Workstations	Mainframes and minicomputers	Supercomputers
Research and development			x	x
Export controls	x	x	x	x
Procurement			x	x
Intellectual property rights		x	x	x
Tariffs	x			
Taxes	x	x	x	x

Source: Compiled by USITC staff.

United States

U.S. Government R&D support for computer technology was instrumental in establishing the U.S. computer industry.[7] However, the U.S. Government directed early R&D investments in this area almost entirely to military projects.[8] By the 1980s, U.S. industry officials began to express concern about strategic R&D programs initiated by the Japanese and European governments (figure 3-2), which focused on civilian applications of computer technology. In response to some of these concerns, Congress sought to promote more collaborative civilian R&D in high-technology industries by eliminating antitrust barriers to such efforts.[9] However, as figure 3-3 shows, U.S. Government support for R&D continued to focus on defense applications through the latter part of the 1980s.[10]

A recent U.S. initiative stemming from greater interest in civilian-oriented R&D is the Federal High-Performance Computing and Communications (HPCC) Initiative (table 3-1).[11] This is a 5-year, Federally-funded program to support R&D on advanced computing technologies. The program does not support any one firm or technology, but encourages improvements in high-performance computing that may benefit a wide range of industries.[12] Some industry officials believe that the U.S. Congress should build on the HPCC program by enacting a more comprehensive cooperative R&D policy to establish a nation-wide information

[7] See Ferguson and Morris, *Computer Wars;* and Flamm, *Creating the Computer.*

[8] Kenneth Flamm, *Globalization in the Computer Industry,* background paper for experts meeting, OECD, Directorate for Science, Technology and Industry, Paris, France, Dec. 17, 1990, p. 20.

[9] In 1984, Congress enacted the National Cooperative Research Act (NCRA) to eliminate the threat of treble damages in private antitrust suits for cooperative ventures that register with the Justice Department. The law stated that cooperative R&D, if challenged, should be evaluated on a rule of reason basis.

[10] One exception to this is the Semiconductor Manufacturing Technology Research Corporation (Sematech), established in 1988 by the U.S. Congress to increase joint research in the semiconductor and

[10]—*Continued*
semiconductor equipment sector (table 3-1). Some economists believe Sematech represents an important break with past trends in military R&D support with few commercial spillover possibilities. Although experts disagree on the extent of Sematech's success in improving the competitiveness of the semiconductor and semiconductor manufacturing equipment industries, many computer makers report that the program has benefited their industry by decreasing their reliance on Japanese and other foreign semiconductor equipment suppliers.

[11] High-Performance Computing Act of 1991, Public Law 102-194.

[12] Laura D'Andrea Tyson, *Who's Bashing Whom?: Trade Conflict in High-Technology Industries* (Washington, DC: Institute for International Economics, Nov. 1992), p. 82.

Table 3–1
International comparison of computer R&D organizations and programs

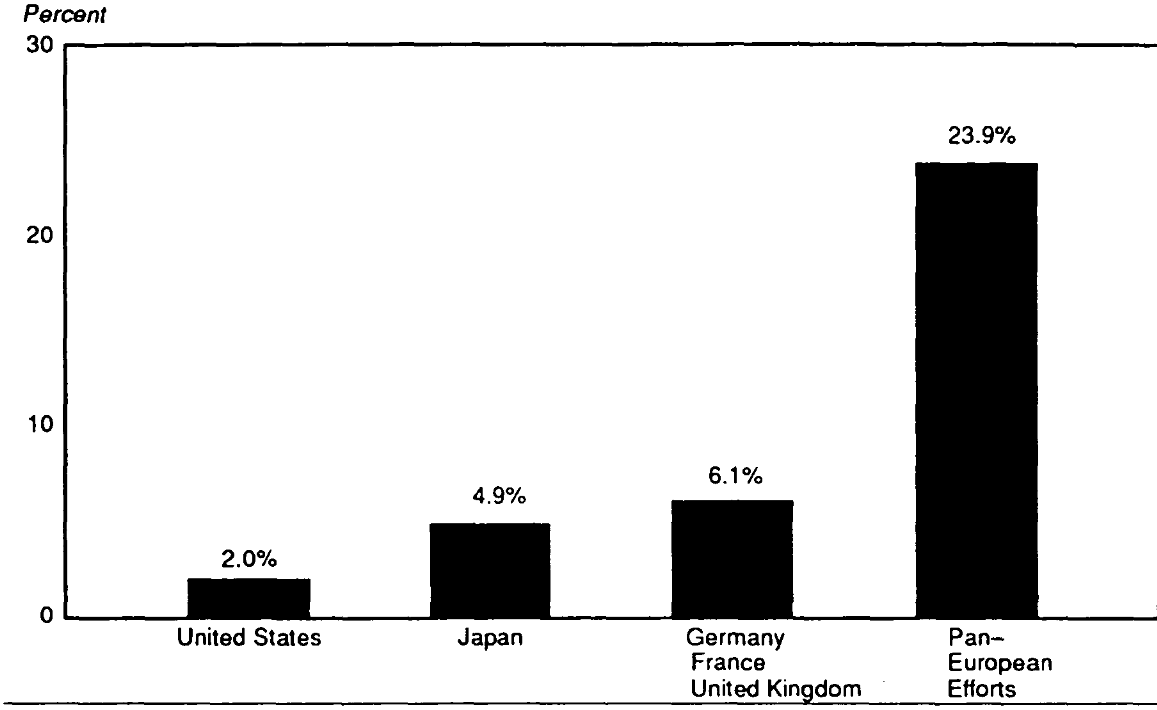
Country Region	Computer R&D Organizations & Programs	Size	Research Focus	Notes
United States	*High Performance Computing and Communications Initiative.* Established by Congress in 1991.	Received $657 million in Federal funds during fiscal 1992.	Develop generic U.S. software technology for scientific applications, scalable parallel computer systems, and national high–performance computer network.	Has become the center–piece of the Government's computer research effort.
	Sematech. Established by Congress in 1988.	Funded at $200 million annually, of which $100 million are federal funds.	Semiconductor manufacturing equipment technology.	R&D consortium of semiconductor and computer manufacturers, and Dept. of Defense.
	Microelectronics and Computer Technology Corporation (MCC). Founded in 1982 by leaders of computer industry. Next 10–year strategy announced in 1992.	450 employees. $45 million in annual funding.	R&D programs are application driven toward advanced computer technology, software technology, and superconductivity.	A private R&D consortium of semiconductor and computer firms. Government agencies have increased contracts with MCC in recent years.
Europe	*European Community Framework Programs.* Established in 1984.	$8.4 billion allocated for 1990–94.	R&D programs established in information processing, microelectronics, office automation, and software.	Collaborative R&D to create strong computer and information technology industry and infrastructure in the EC.
	EUREKA & JESSI Programs. Non–Framework programs of European countries as a response to U.S. Strategic Defense Initiative. Established in 1985.	$6.5 billion budget that funds 300 projects.	Supports R&D in microelectronics, computer technologies, telecommunications, and other technologies.	Collaborative R&D among firms, universities, and government laboratories.
Germany	*Informationstechnik programme.* Federal program in expert systems technology.	Funded by BMFT, German Government's research institute.	Electronic and computer technology, including parallel processing technology.	Research results transferred to major firms.
United Kingdom	*Alvey Program.* Established in 1982.	Expended $350 million from 1983–88, of which $200 million came from public funds.	Pre–competitive R&D in information technology.	Cooperative R&D involving computer and telecom firms, universities, and government researchers.

Table 3–1 *(Continued)*
International comparison of computer R&D organizations and programs

Country Region	Computer R&D Organizations & Programs	Size	Research Focus	Notes
France	*French Filiere Electronique.* Established in 1982.	Ended in 1987.	R&D in computers, software, telecommunications, micro-electronics, and other electronic technology.	Technology policy initiative by the French Government, including cooperative R&D in computer and electronics technology.
Japan	*Real World Computing Project.* Launched in 1992 by Japanese Government as follow-on to *Fifth Generation Computer Project* which ended in that same year.	Funded at $450 million for 10 years.	Research on massively parallel processing, optical computing, virtual reality, and "fuzzy" logic.	Expects to bring together 10 Japanese computer firms and several foreign research institutes to conduct joint R&D.
	Institute for New Generation Computer Technology (ICOT). Created by the government in 1981.	$200 million budget funded and managed by Ministry of Trade and Industry (MITI). 200 researchers.	R&D in electronic devices, software, and advanced computer technology.	Promotes cooperative R&D and technology transfer from ICOT labs to industry participants.
	Key Technology Center. Established in 1985 from sales of Nippon Telegraph and Telephone stock.	70 employees. $250 million budget in 1992.	Fundamental technologies, including computer technologies.	Provides up to 70 percent of capital investment for joint R&D ventures. Only principal must be repaid if project fails.
Korea	*Information–Industry Development Plan.* Established in 1992. Administered by Ministry of Trade and Industry.	Funded at $1.9 billion through the year 2000.	Development of technology in areas of computers, software, communications, and semiconductors.	Supports government and industry R&D and technology transfer.
Singapore	*National Science and Technology Board.* Established in 1991. Builds on work of *National Computer Board* (1980).	Funded at $1.2 billion from 1992–97 by Singapore Government.	To foster a world–class computer and information technology industry.	Encourages domestic and foreign investment in R&D, including collaborative projects.
Taiwan	*Industrial Technology Research Institute.* (ITRI) Established in 1973.	4,000 employees, 60 percent with science and engineering degrees.	Electronics research & service division engaged in computer research.	Multidisciplinary research institute.
Hong Kong	*Hong Kong Government.* Training Center for integrated circuit design. Established in 1984.	Training center for microelectronic circuit design. Funded by government.	Transfer of technology to Hong Kong computer and electronics firms.	Supports R&D in electronic components.

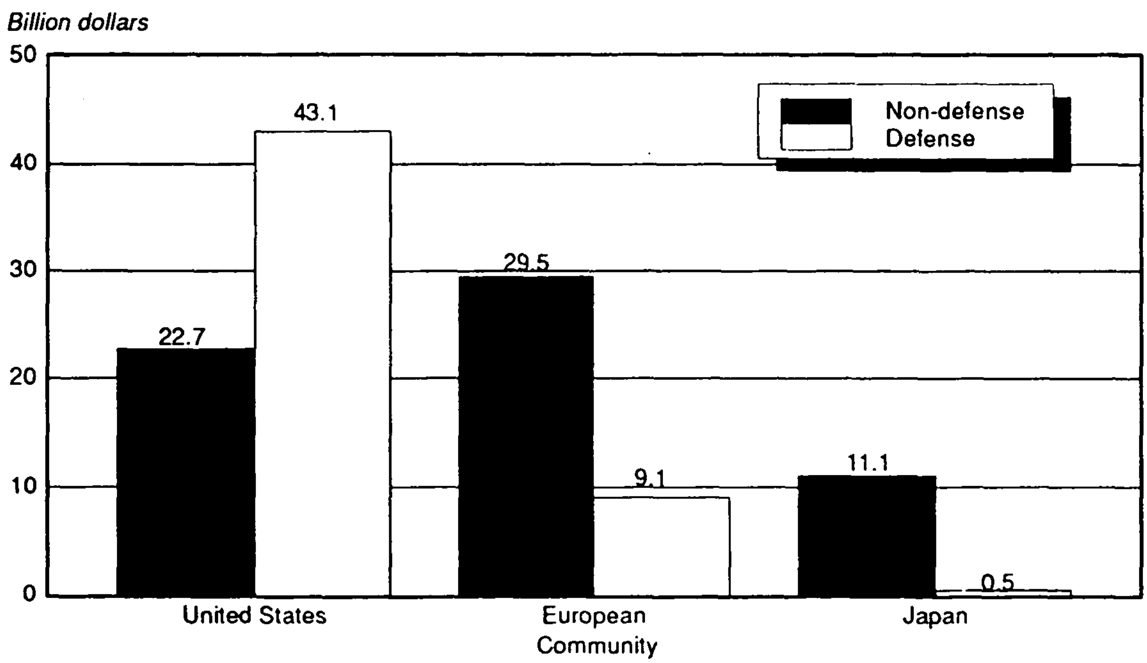
Source: Compiled by USITC staff.

Figure 3-2
Share of government-funded R&D related to the computer industry in the United States, Japan, and selected European countries, 1989



Source: Adapted by USITC staff based on information compiled by the Computer Systems Policy Project.

Figure 3-3
Total government defense and non-defense R&D expenditures in the United States, the European Community, and Japan, 1989



Source: Adapted by USITC staff from information compiled by the Computer Systems Policy Project.

infrastructure.[13] A digital information infrastructure would not only increase market demand for computers, software, and other related products, but reportedly would increase dynamism in other high-technology sectors that depend on developments in computer technology (e.g., consumer electronics).[14]

Europe

The European computer industry conducted very little cooperative R&D prior to the 1980s.[15] Instead of encouraging cooperation among a large number of companies on pre-competitive research, national policies of Germany, the United Kingdom, and France encouraged mergers.[16] These mergers created "national champion" firms that enjoyed considerable government support in their respective countries,[17] but only modest success in the global market.[18]

Some European countries initiated national collaborative R&D programs of their own in the early 1980s. These initiatives primarily responded to early successes of U.S. computer manufacturers and the emergence of Japanese cooperative R&D programs designed to achieve parity with the U.S. industry. The British Alvey and the French Filiere Electronique programs were notable examples of European collaborative efforts (table 3-1).[19] The British program achieved many of its goals. However, some experts believe that the government's failure to support civilian applications and technology transfer to participating firms may have hindered the Alvey program's effect.[20] According to European industry analysts, the French Filiere Electronique program experienced little success, principally because the government focused too heavily on supporting national champions and relied too little on market signals and industry input.[21]

In the past decade, the most significant collaborative R&D efforts in Europe have operated under the Framework R&D Programs of the European Community (EC) (table 3-1).[22] In all of the Framework programs, contributions from industry participants supplement government funds.[23] European industry officials suggest that the most important Framework program in computer technology is the European Strategic Programme for Research and Development in Information Technology (ESPRIT). The ESPRIT projects advance pre-competitive research and economic integration in information processing, microelectronics, office automation, software, and flexible manufacturing.[24]

Another European collaborative R&D program related to the computer industry is the EUREKA project, begun in 1985. EUREKA has increased communication between research institutes and private industry throughout Europe. Leading European computer manufacturers, including Siemens-Nixdorf, Olivetti, and Groupe Bull, participate in EUREKA's programs.[25]

[13] An advanced information infrastructure is needed, they say, to accommodate and facilitate use of digital information. Such infrastructure would make it easier to transform analog messages, including voice, text, or pictures, into the digital language of computers, which can then be transmitted, processed, and stored electronically.

[14] U.S. industry representatives, interviews with USITC staff, Washington, DC, Jan. 14, 1993; Silicon Valley, CA, Apr. 14-24, 1993; Redmond, WA, Apr. 20, 1993; Kenneth R. Kay, executive director, The Computer Systems Policy Project, testimony on *Implementation of the High Performance Computing and Communications Program and the Proposed Information Infrastructure and Technology Act*, before the U.S. House of Representatives, Committee on Science, Space, and Technology, Subcommittee on Science, Feb. 2, 1993; and Nathan P. Myhvold, Microsoft Corp., written statement on *The Importance of the Digital Information Future and a National Information Infrastructure to America's Industry*, in testimony on the National Competitiveness Act of 1993 (S.2937) before the U.S. Senate Committee on Commerce, Science, and Transportation, Mar. 25, 1993.

[15] EC officials, interviews by USITC staff, Brussels, May 13, 1993.

[16] Otto Keck, "The National System for Technical Innovation in Germany," William Walker, "National Innovation Systems: Britain," and Francois Chesnais, "The French National System of Innovation," ch. in *National Innovation Systems*, pp. 115-229.

[17] European industry representatives, interviews with USITC staff, Munich, Paris, Ivrea, and London, May 6-24, 1993.

[18] Flamm, *Globalization in the Computer Industry*, p. 19; European industry representatives, interviews with USITC staff, Munich, Ivrea, Paris, and London, May 6-24, 1993; and EC officials, interviews with USITC staff, Brussels, May 13, 1993.

[19] Though Alvey focused on pre-commercial R&D in the telecommunications sector, it involved computer manufacturers, universities, and electronics firms in multiple R&D consortia. The French Filiere project was initiated to promote French technological development in electronics, including computers. Brian Oakley and Kenneth Owen, *Alvey: Britain's Strategic Computing Initiative* (Cambridge, MA: MIT Press, 1989).

[20] NAS, *The Government Role in Civilian Technology*, p. 63.

[21] European industry analyst, interview with USITC staff, Frankfurt, May 19, 1993; and European industry representatives, interviews with USITC staff, Munich, Ivrea, and Paris, May 6-19, 1993.

[22] *Official Journal of the European Communities*, Council Decision of April 23, 1990, No. L 117/28; and Delegation of the Commission of the European Communities, *Important Progress for European Community Research* (May 18, 1990).

[23] U.S. and European industry representatives, interviews with USITC staff, Silicon Valley, CA, Apr. 15-23, 1993; Brussels, May 13, 1993; and Frankfurt, May 19, 1993.

[24] EC officials, interviews by USITC staff, Brussels, May 13, 1993.

[25] Some analysts believe the most significant initiative by EUREKA is its JESSI program, an 8-year, $4.4 billion project to manufacture 64-megabit semiconductors. European industry representatives, interviews by USITC staff, Paris, May 12, 1993, and Frankfurt, May 19, 1993.

Despite such efforts, many experts believe there is little evidence that the EC-Framework or EUREKA R&D programs are succeeding.[26] Overall government funding for EC-wide research represents less than 2 percent of what the 12 EC nations annually spend on total R&D.[27] Furthermore, some analysts believe that dispersion of technical and financial resources among many participants has diluted the effects of the support. Another criticism is that European collaborative programs often have required industry only to supplement, rather than match, public contributions.[28] Moreover, the complex administrative structure of EC programs has hindered coordination of program goals and clarity in technical agendas.[29] Due to these defects, some analysts believe that these programs have failed to enhance the ability of European firms to respond to market signals and to direct R&D funding to promising applications.[30]

Japan

Government organizations were responsible for leading Japanese firms into the computer business.[31] Japan's Ministry of International Trade and Industry (MITI) organized a research committee in the mid-1950s to determine how best to accelerate the development of a Japanese computer industry to compete with the rapidly emerging U.S. industry. The committee recommended more support for computer development, limits on foreign imports, and acceleration in introducing foreign technology by encouraging alliances with U.S.-based firms.[32]

Rather than direct financial subsidies, much of the early government support to the fledgling Japanese computer industry consisted of technical assistance from government laboratories and joint R&D efforts among major electronics companies and universities.[33] However, in spite of such close R&D cooperation, competition among Japanese firms in the domestic market remained fierce.[34]

When Japanese computer firms emerged as significant competitors in the international market, the effectiveness of government-led collaborative R&D waned. In the early 1980s, the Japanese Government encouraged its principal computer companies to cooperate in the Fifth Generation Computer Project, which attempted to further artificial intelligence. MITI invested over $370 million in the program. The project (table 3-1), which ended in 1992, left behind few tangible commercial technologies and is generally regarded as a failure.[35] Some analysts believe that the increasingly successful Japanese electronics firms felt less compelled to participate fully in MITI-sponsored projects, particularly in areas where their own interests diverged from those of government planners.[36] Thus, they often did not provide their best researchers or other corporate resources in many of the cooperative ventures in the project.

Some analysts suggest that more overt government direction in projects like the Fifth Generation Project may have been appropriate for Japan in the post-war "catch-up" period. They note, however, that such direction is less appropriate now that the Japanese economy and industry have matured and strengthened.[37] Japanese companies reportedly realize that to succeed in the future, they must develop their own technological and marketing strategies rather than focus on acquiring and improving on technology obtained from U.S. firms. For these reasons, a new emphasis of the Japanese Government involves financially supporting projects in new areas with few technology leaders. One of the most notable of these programs is the Key Technology

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26 Glenn J. McLoughlin, "European Research & Development," in *Europe and the United States: Competition and Cooperation in the 1990s*, study papers submitted to the Subcommittee on International Economic Policy and Trade and the Subcommittee on Europe and the Middle East of the Committee on Foreign Affairs, U.S. House of Representatives (Washington, DC: GPO, June 1992), p. 310; and NAS, *The Government Role in Civilian Technology*, p. 63.

27 EC officials, interviews by USITC staff, Brussels, May 13, 1993; and McLoughlin, "European Research & Development," p. 310.

28 NAS, *The Government Role in Civilian Technology*, p. 63.

29 The EC is presently completing plans for their next 5-year Framework program, which will begin in 1995. EC officials, interviews with USITC staff, Brussels, May 13, 1993.

30 McLoughlin, "European Research & Development," p. 310; and NAS, *The Government Role in Civilian Technology*, p. 63.

31 These Japanese Government organizations included the Japanese Ministry of International Trade and Industry's (MITI) Electrotechnical Laboratory (ETL) and the Electrical Communication Laboratory (ECL) of the Nippon Telephone and Telegraph Company (NTT). Although the NTT Corporation Law enacted by the Japanese Diet in 1985 set the stage for privatization of the old public corporation, the Japanese Government still retains shares in the company. Flamm, "Computers in Japan," ch. in *Creating the Computer*, (Washington, DC: Brookings Institution, 1988), pp. 172-202.

32 These alliances included Oki and Sperry, Hitachi and RCA, NEC and Honeywell, and Toshiba and General Electric. The Japanese Government also permitted selective exemption from the antimonopoly law, allowing MITI to establish research and production cartels. Flamm, "Computers in Japan," pp. 172-201. Also see Eugene J. Kaplan, *The Government-Business Relationship: A Guide for the American Businessman* (Washington, DC: U.S. Department of Commerce, 1972), p. 80.

33 Kaplan, *The Government-Business Relationship*, p. 82.

34 Ferguson and Morris, *Computer Wars*, pp. 233-239; NAS, *The Government Role in Civilian Technology*, pp. 37-38; and Flamm, *Creating the Computer*, p. 29.

35 Ibid.

36 Daniel Okimoto, Ph.D., Stanford University, interview with USITC staff, Stanford, CA, Apr. 21, 1993.

37 Okimoto interview and Gene Gregory, Sophia University, interview with USITC staff, Tokyo, Apr. 30, 1991.

Center (KTC) described in table 3-1. Other recent R&D initiatives by the Japanese Government have emphasized basic research, generic technologies, and broad infrastructural support for Japanese high-technology industries in general.

Unlike the European programs that encouraged "national champions," Japanese Government support has emphasized cooperation in basic and upstream technologies; this has allowed competition to determine success in the Japanese domestic market.[38] Thus, firms such as Hitachi, Fujitsu, NEC, and Toshiba, though encouraged to cooperate in upstream research, have competed fiercely in the Japanese market. Many observers believe that competition in the home market has enabled Japanese firms to compete more effectively than European firms in international markets.

Other countries

Other East Asian countries, including Hong Kong, Korea, Singapore, and Taiwan, have decided that new strategies are necessary for their computer hardware industries to continue their rapid growth of the last decade. These countries plan to move beyond past strategies that were based on attracting investment in low-wage commodity production, to strategies based on investment in advanced computer products.[39] Table 3-1 describes some recent R&D programs initiated by governments in these countries.

Singapore's recently established National Science and Technology Board issued a National Science and Technology Plan in September 1991.[40] The plan recommended doubling R&D expenditures to 2 percent of gross domestic product by 1995 and raising the number of scientists and engineers from 28 to 40 per 10,000 workers. It also advocated grants and tax incentives to encourage companies to conduct more R&D in Singapore, especially in computer hardware.

Similarly, the Governments of Taiwan and Korea have developed industrial strategies to encourage increased investments in R&D by their computer firms. However, these countries are moving toward more "generic" rather than "specific" industrial policies as their economies grow more complex and they move closer to the technological frontier. Taiwan, for example, recently replaced its system of providing targeted tax incentives to favored industries. It now has one overall tax incentive for R&D and other activities likely to promote "industrial upgrading."[41] Meanwhile, Korea's new government is moving away from targeted policies that support further growth of giant Korean industrial conglomerates.[42] Instead, it is providing new incentives to encourage its larger companies to downsize and restructure for greater flexibility. The government believes such efforts will enable Korean computer makers to compete more effectively in the rapidly changing global computer market.[43]

Export Controls

U.S. computer industry officials assert that U.S. export control policies have not kept pace with global technological developments and market conditions.[44] As a result, these officials believe that such policies hinder sales of U.S.-made computers. To address these concerns, the President proposed a plan on September 29, 1993 to ease controls on U.S. exports of computers.[45]

The U.S. Government imposed export controls after World War II to limit sales of high-technology goods to Communist countries.[46] Because of the need for comprehensive cooperation in imposing such controls, the United States encouraged its major allies to establish the Coordinating Committee for Multilateral Export Controls (COCOM).[47] The multilateral agreement seeks to ensure that allies maintain comparable export controls and that countries do not reexport controlled articles to restricted nations. COCOM operates based on the unanimous consent of its member nations, but actual implementation of the controls rests with individual members.

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38 NAS, *The Government Role in Civilian Technology*, p. 58; and Flamm, *Globalization in the Computer Industry*, p. 19.

39 Dieter Ernst and David O'Connor, *Competing in the Electronics Industry: The Experience of Newly Industrializing Economies* (Paris: OECD, 1992); Martin Bloom, *Technological Change in the Korean Electronics Industry* (Paris: OECD, 1992); and Robert Wade, "State-Led Industrialization," in *Governing the Market* (Princeton: Princeton University Press, 1990).

40 The board was established in January 1991. U.S. Department of Commerce, International Trade Administration (U.S. Embassy, Singapore), "Singapore-Economic Trends," *Market Research Reports*, June 29, 1992.

41 Okimoto interview.

42 Korean Government officials, in-person and telephone interviews with USITC staff, Seoul, Apr. 12-20, 1991, and Washington, DC, June 1993.

43 Ibid.

44 U.S. industry representatives, interviews with USITC staff, Silicon Valley, CA, Apr. 15-23, 1993.

45 Ronald H. Brown, Secretary of Commerce, "New Export Promotion Policy," *Press Briefing*, Washington, DC, Sept. 29, 1993; and Computer and Business Equipment Manufacturers Association (CBEMA), "CBEMA Praises Clinton Announcement," *CBEMA News Release*, Sept. 29, 1993.

46 U.S. export controls are administered under the Export Administration Acts of 1979 and 1988, as amended (50 U.S.C. app. 2401, et seq., 1988). The Export Administration Regulations implement the Export Administration Act (15 CFR 774.1).

47 COCOM is a non-treaty organization composed of NATO allies (except Iceland), Australia, and Japan.

In view of the collapse of the former Soviet bloc, a number of industry and policy analysts are criticizing the U.S. export control system for its detrimental effect on trade in critical technologies such as computers.[48] In theory, U.S. export controls should have little competitive effect on U.S. computer producers, since major competitors in Europe and Japan are also subject to COCOM regulations. However, many industry officials believe that U.S. computer firms incur higher costs than their foreign competitors in complying with the U.S. export controls.[49] U.S. implementation of export control regulations deviates markedly from that of other COCOM members. Key differences are (1) the greater breadth of U.S. controls, (2) the extraterritorial application of U.S. controls, and (3) the greater complexity of U.S. control procedures.[50]

Greater Breadth of U.S. Controls

The U.S. Government unilaterally controls several categories of so-called "dual use" products, which are capable of being used for both military and civilian purposes, that are not included on an international COCOM list. Computers are "dual use" goods since they have numerous applications, one of which is designing weapons.[51] However, many computers still on the U.S. critical commodities list are no longer considered high-technology items, and are widely available in the global market.[52]

Nowhere have Defense Department concerns over technology been greater than in the area of supercomputers. Supercomputer development was heavily subsidized by the U.S. Government, in large part to meet the needs of military weapons development laboratories.[53] Although supercomputers are used in the design of advanced nuclear weapons, they are also valuable in numerous civilian applications such as banking, biomedical research, weather mapping, and designing other complex systems.[54] However, because of the potential military uses, U.S. policy maintains tight controls on supercomputer exports. Such stringent controls reportedly have driven other countries to purchase supercomputers from competing Japanese companies, or to design their own.[55]

The technological standards used to define "supercomputers" for export control purposes reportedly are outdated. Captured within the existing definition are workstations with processing speeds that are one-hundredth as fast as those of current state-of-the-art supercomputers.[56] The additional expense incurred when exporting these controlled workstations can increase their cost by many times the original purchase price. Industry officials assert that such workstations are becoming price-sensitive commodities, with certain low-end versions now produced by several non-COCOM countries in East Asia.[57] With industry sales that are expected to double from $10 billion in 1992 to $20 billion by 1997, these officials claim that workstations are a key to maintaining U.S. competitiveness in the computer hardware industry.

The President's September 29, 1993 proposal for reducing controls on U.S. exports of computers includes new rules that would raise the supercomputer export control definition over tenfold, from 195 to 2000 million theoretical operations per second (MTOPs), thereby easing restrictions on many high-powered workstations.[58] The new proposal has been commended as a move in the right direction by some industry officials.[59] However, others have

[48] Richard Burke, Center for International Security and Arms Control, Stanford University, interview with USITC staff, Stanford, CA, Apr. 21, 1993; see also Robert Kuttner, *Export Controls: Industrial Policy in Reverse* (Washington, DC: Economic Policy Institute, 1991); and Paul Freedenberg, "The Commercial Perspective," ch. in *Export Controls in Transition: Perspectives, Problems, and Prospects*, eds. Gary K. Bertsch and Steven Elliott-Gower (Durham, NC: Duke University Press, 1992), pp. 37-58. Also see J. David Richardson, *Sizing Up U.S. Export Disincentives* (Washington, DC: Institute for International Economics, 1993).

[49] U.S. industry representatives, interviews with USITC staff, Munich, May 7, 1993; and Silicon Valley, CA, Apr. 15-23, 1993.

[50] Arvind Parkhe, "U.S. National Security Export Controls: Implications for Global Competitiveness of U.S. High-Tech Firms," *Strategic Management Journal*, vol. 13 (1992), pp. 47-66.

[51] Robert Kuttner, "How 'National Security' Hurts National Competitiveness," *Harvard Business Review*, vol. 69, No. 1 (Jan./Feb. 1991), pp. 140-149.

[52] U.S. industry representatives and arms control experts, interviews with USITC staff, San Jose and Palo Alto, CA, Apr. 15-23, 1993.

[53] Kuttner, "How 'National Security' Hurts National Competitiveness," pp. 140-149.

[54] U.S. industry representatives and trade association officials, interviews with USITC staff, Washington, DC, Apr. 8, 1993.

[55] Israel, for example, which was precluded by U.S. export controls from buying a U.S.-made supercomputer for its national technical university, is rapidly developing its own supercomputer; India and Brazil are following suit. Kuttner, *Export Controls*, p. 29.

[56] U.S. industry representatives, interviews with USITC staff, Silicon Valley, CA, Apr. 14-24, 1993; and Computer Systems Technical Advisory Committee meeting, U.S. Department of Commerce, Washington, DC, Apr. 21-22, 1993.

[57] U.S. industry representatives, interviews with USITC staff, Silicon Valley, CA, Apr. 15-23, 1993; and Computer Systems Technical Advisory Committee meeting, U.S. Department of Commerce, Washington, DC, Apr. 21-22, 1993.

[58] CBEMA, "CBEMA Praises Clinton Announcement," Sept. 29, 1993; and David T. Bottoms, "High-Tech Drives New U.S. Export Strategy," *Electronics*, Oct. 11, 1993, p. 1.

[59] Ibid.; and U.S. industry representatives, telephone interviews with USITC staff, Nov. 8, 1993.

expressed the opinion that the proposal falls short in key areas.[60] For instance, the proposal lacks an adjustment mechanism to ensure that control thresholds keep pace with technological advances.[61]

Extraterritorial Application of U.S. Controls

An additional problem of U.S. export controls is their extraterritorial application. Reexport provisions extend to products of U.S. foreign subsidiaries, products containing U.S.-origin components, and products manufactured using U.S.-origin technology.[62] No other COCOM country imposes reexport controls.[63] In 1985, the President's Commission on Industrial Competitiveness estimated that companies lose over $11 billion in U.S. sales annually due to extraterritorial application of U.S. controls. The National Academy of Sciences came to a similar conclusion in 1987.[64]

Greater Complexity of U.S. Procedures

U.S. manufacturers of computers also report that the relative complexity of U.S. export controls poses difficulties. In the United States, 11 different government agencies have jurisdiction over dual-use technologies.[65] In contrast, Japan's export controls are administered by only one entity, MITI, which requires only a fraction of the licenses required by the U.S. export administration. European members of COCOM also have more simplified export control procedures.[66]

Due to the fall of Communist governments throughout Eastern Europe and the end of the Soviet Union, and rapidly changing technological developments, COCOM significantly streamlined multilateral controls in 1991 by sharply reducing the list of controlled items.[67] Despite some reservations, the U.S. Government accepted the streamlined measures to prevent possible disintegration of COCOM.[68] The agreement led to an extensive relaxation of restrictions on computer sales to the former Soviet Union and Eastern Europe, but stopped short of allowing countries in those areas to buy the most advanced computer technology.[69] Restrictions were reduced by 50 percent, leaving controls on only a core list of the most strategic technology and products, or "higher walls around fewer products." Some product control reforms from the 1991 export control discussions are shown in table 3-2.

New U.S. export control rules permit the sale of most workstations, minicomputers, and PCs to the former Soviet bloc. Notwithstanding these changes, computer industry officials insist that the agreement does not go far enough in liberalizing the U.S. export controls.[70] They also assert that too much discretion is left to individual COCOM member nations in determining which products to restrict.

Despite numerous efforts by the Department of Commerce to streamline its controlled product list, both the National Security Agency and the Defense Technology Security Administration have blocked attempts to ease export restrictions on some widely available computer products.[71] As such, computer firms attest that these controls place U.S. manufacturers at a disadvantage with other competitors.[72]

In addition to easing controls on more powerful workstations and supercomputers, the President's September 29, 1993 proposal would eliminate licensing requirements for thousands of less-powerful computers.[73] This would be accomplished by raising the current U.S. license-free computer threshold from the current 12.5 MTOPs to 194 MTOPs, while seeking similar decontrol by U.S. allies for exports to the former Soviet Union and China. Some industry representatives predicted the changes could generate billions of dollars in new sales for computer companies and millions of dollars in savings on export licensing procedures.[74] However, others pointed out that decontrol of computer exports to the former Soviet Union and China would require unanimous support by COCOM allies, which might

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60 U.S. industry representatives, telephone interviews with USITC staff, Nov. 8, 1993.

61 Ibid.

62 U.S. industry representatives, interviews with USITC staff, Paris and Munich, May 6-19, 1993.

63 Parkhe, "U.S. National Security Export Controls," p. 54.

64 NAS, *Balancing the National Interest: U.S. National Security Export Controls and Global Economic Competition* (Washington, DC: National Academy Press, 1987).

65 Dwight B. Davis, "The Path to Exports: As Cold War-era Export Controls Slowly Abate, New U.S. Policies Burden Electronics Shippers," *Electronic Business*, Mar. 16, 1992, pp. 22-26; and Kuttner, "How 'National Security' Hurts National Competitiveness," p. 142.

66 European industry representatives, interviews with USITC staff, Munich, Paris, and London, May 6-24, 1993.

67 Parkhe, "U.S. National Security Export Controls," pp. 47-66.

68 Ibid.

69 U.S. industry officials, interviews with USITC staff, Silicon Valley, CA, Apr. 15-23, 1993.

70 U.S. industry representatives, interviews with USITC staff, Silicon Valley, CA, Apr. 15-23, 1993.

71 Willie Schatz, "Clinton Fails to Deliver on Export Relief," *Electronic Business*, Aug. 1993, pp. 22-24; and Kuttner, *Export Controls*, pp. 1-43.

72 U.S. industry analysts and representatives, interviews with USITC staff, Washington, DC, Jan. 14, 1993, and Silicon Valley, CA, Apr. 15-23, 1993.

73 U.S. industry representatives, telephone interviews with USITC staff, Nov. 8, 1993; and Bottoms, "High-Tech Drives New U.S. Export Strategy," p. 1.

74 U.S. industry representatives, telephone interviews with USITC staff, Nov. 8, 1993.

Table 3-2
High-technology 'priority sector' export control reform for computers: COCOM talking points, 1991

Products affected	Extent of decontrol	Nature of liberalization	Representative U.S. beneficiaries	Applications
Personal computers up to PDR[1] of 275 Mbps[2]	Full.	Four-fold rise in COCOM standard of Mbps.	IBM, Apple, Compaq, Motorola.	Word processing, spreadsheets, and communi-cations.
Small workstations and minicompu-ters up to PDR[1] of 275 Mbps[2]	Full.	Same as above.	IBM, DEC[3].	Engineering applications and graphic simula-tions.
Large mini-computers and mid-level main-frames up to PDR[1] of 550 Mbps[2]	Full.	Eight-fold rise in COCOM standard. Licensable at national dis-cretion.	IBM, DEC[3].	Scientific data processing and databases.
Large main-frames up to PDR[1] of 1000 Mbps[2]	Partial.	Fourteen-fold rise in COCOM standard. "Favorable considerations" approval to select countries.	IBM, DEC[3].	Seismic data analysis (oil and gas production)

[1] Processing data rate.
[2] Megabits per second.
[3] Digital Equipment Corporation.

Sources: U.S. Department of Commerce (Technology & Policy Analysis Division) white paper, "COCOM Talking Points," June 1990; Magnusson (1990a); Hudson (1990); and Arvind Parkhe, "U.S. National Security Export Controls," *Strategic Management Journal*, vol. 13, 1992, pp. 60-61.

not be forthcoming unless the United States is willing to support greater COCOM decontrol of telecommunications equipment and machine tools.[75] Thus, although most U.S. industry officials welcome the President's proposal, they recognize that extensive negotiations are required before the proposal can be adopted.[76]

Many policy analysts believe that the United States must drastically reform the process of regulating international technology transfer to achieve a desirable balance among the interrelated objectives of military security, economic vigor, and scientific and technological progress.[77] Losing sight of these interrelationships, they believe, has led to U.S. policies and rules that have emphasized U.S. military security at the expense of global economic leadership and competitiveness.[78]

Government Procurement

Government procurement remains an important factor affecting computer sales in the United States, as well as in foreign markets (table 3-3). Although the U.S. military and other government agencies are no

[75] Germany, France, and the United Kingdom, for example, have insisted that sales of almost all machine tool and telecommunications equipment be decontrolled before they will assent to even a modest easing on controls of computers, since telecommunications exports are so important to their economies. However, U.S. National Security Agency and Defense Department officials have reportedly resisted decontrols on exports of certain telecommunications equipment which could hurt their surveillance capabilities in China and in the former Soviet Union. U.S. industry representatives and arms control experts, interviews with USITC staff, Silicon Valley, CA, Apr. 15-23, 1993; and U.S. industry representatives, telephone interviews with USITC staff, Nov. 8, 1993.

[76] U.S. industry representatives, telephone interviews with USITC staff, Oct. 5, 1993.

[77] Parkhe, "U.S. National Security Export Controls," pp. 47-66; Kuttner, *Export Controls*, pp. 1-43; and Freedenberg, "The Commercial Perspective," pp. 37-58.

[78] U.S. industry representatives and arms control experts, interviews with USITC staff, Silicon Valley, CA, Apr. 15-23, 1993.

Table 3-3
Government procurement in the United States, Europe, and Japan

	United States	Europe	Japan
Principal government procuring entities	U.S. Department of Defense. General Services Administration. National laboratories.	National telecommunications authorities. Other public utilities.	Nippon Telephone & Telegraph[1]. Ministry of Posts and Telecommunications. National laboratories.
Legal provisions	Buy American Act of 1988. "Substantial Transformation" provisions of Trade Agreements Act of 1979.	EC 50-percent content rule. 3-percent price preference for EC firms. EC Public Service Directive Relating to Awards of Public Contracts. EC Utilities Remedies Directive.	Japanese laws and regulations relating to government procurement.
Trade agreements	Major supporter of strengthened GATT Procurement Code.	U.S.-EC agreements on procurement issues being conducted in context of GATT negotiations.	U.S.-Japan Super-Computer Agreement (1987). Revised U.S.-Japan Supercomputer Agreement (1990). U.S.-Japan Computer Agreement (1990).

[1] Although Nippon Telephone and Telegraph (NTT) was ostensibly privatized in 1985, the Japanese Government still maintains significant ownership shares in NTT. NTT is treated as a government entity by the United States for purposes of trade agreements with Japan on public procurement.

Source: Compiled by USITC staff.

longer dominant customers, they still account for a significant portion of total hardware sales. As such, computer firms compete vigorously for U.S. Government contracts.

Large government entities in Europe and Japan also represent significant markets for computer equipment. Some U.S. manufacturers have expressed concern that some foreign governments clearly have shown preference to national suppliers. Japanese government procurement practices with respect to supercomputers, for instance, have been a major focus of U.S. trade negotiations in recent years. However, as the computer industry becomes increasingly global in nature, industry officials state that biased government procurement policies mainly impede the competitiveness of nations' own firms.[79]

United States

With increased globalization of the computer industry, many industry analysts believe that current domestic-content legislation is adversely affecting the ability of U.S. firms to compete in the government procurement market.[80] For example, the "Buy American Act"[81] gives preference to U.S.-

[79] U.S. industry representatives, interviews with USITC staff, Silicon Valley, CA, Apr. 14-24, 1993.

[80] Ibid.

[81] 41 U.S.C. 10a et seq., 1988.

manufactured products that contain over 50-percent domestic content. This reduces potential sales of products with high foreign content to the Federal Government by U.S. firms that produce or source components globally. Although the Trade Agreements Act of 1979[82] established a more flexible domestic content law,[83] conflicting application of these two laws makes it very difficult to bid on government procurements.[84] U.S. industry officials recommend that there be a single rule of origin for government procurement purposes—that of substantial transformation—which involves a shift in tariff classification.[85] They have also urged the United States Trade Representative (USTR) to support the use of substantial transformation as a uniform rule of origin in the General Agreement on Tariffs and Trade (GATT).[86]

Computer manufacturers believe that the "Buy American Act" discourages sourcing decisions that allow U.S. computer hardware manufacturers to remain competitive globally.[87] In the increasingly price-sensitive computer market, a number of successful companies have found it necessary to outsource components that they cannot manufacture competitively themselves. Thus, domestic-content legislation, which hinders the ability of computer firms to obtain the highest quality components at the best possible global prices, impedes the global competitiveness of certain U.S. computer manufacturers.

Europe

European national governments have traditionally used procurement activities as a means to promote industrial development in the computer hardware industry. However, new EC-wide rules regarding public procurement went into effect on January 1, 1993.[88] These rules are expected to open procurement to nonnational suppliers, especially in large, state-owned utilities that are major computer purchasers.[89] The only concern of U.S. computer manufacturers is whether these new changes will primarily benefit other EC producers or will also open lucrative procurement markets to U.S. computer suppliers.[90]

If such changes do result in genuinely open European utility markets, especially those of the large telecommunications authorities in France and Germany, U.S. computer hardware manufacturers likely would win a significant number of new contracts from government entities.[91] European firms have been sheltered in their own national markets and consequently have developed few of the skills that appear to enhance competitiveness in open markets (see chapter 4).

Japan

U.S. industry and government officials allege that Japanese Government procurement policies over the past 20 years systematically denied foreign-based companies access to the Japanese supercomputer market.[92] In response, the U.S. Government negotiated a supercomputer procurement agreement with Japan in August 1987. Japan agreed to establish competitive bidding processes, including advance notification of procurement, publication of specifications, and establishment of procedures for lodging complaints and protests.[93]

The United States and Japan signed a revised supercomputer procurement agreement in June 1990. The revised agreement was more specific and detailed than the original and was intended to make Japanese Government procurement procedures more similar to

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[82] Trade Agreements Act of 1979, July 26, 1979 (93 STAT. 144, P.L. 96-39).

[83] This more flexible rule is based on determining domestic content on the basis of "substantial transformation," which determines whether the manufacturing processes applied to a product or products in a given country have resulted in a significant change in the classification or character of a particular good.

[84] U.S. industry representatives, interviews with USITC staff, Silicon Valley, CA, Apr. 14-24, 1993; CBEMA, "Government Procurement," *ISSUE Brief: Buy American Act/Rule of Origin*, May 29, 1990; and USITC, letter from CBEMA to USITC, Washington, DC, Jan. 19, 1993.

[85] As an alternative, U.S. computer industry officials believe that vendors should have the option of using a "total cost" method of accounting that allows producers to count not only U.S.-made components, but also U.S. labor, overhead, and R&D towards the total domestic costs of a product.

[86] U.S. industry representatives, interviews with USITC staff, Silicon Valley, CA, Apr. 14-24, 1993; CBEMA, "Government Procurement," *ISSUE Brief: Buy American Act/Rule of Origin*, May 29, 1990; and USITC, letter from CBEMA to USITC, Washington, DC, Jan. 19, 1993.

[87] Ibid.

[88] *EC Council Directive of 25 February 1992 Coordinating the Laws, Regulations and Administrative Provisions Relating to the Application of Community Rules on the Procurement Procedures of Entities Operating in the Water, Energy, Transport and Telecommunications Sectors, 92/13/EEC, OJ*, No. L 76 (Mar. 23, 1992), pp. 14-20.

[89] EC officials, interviews with USITC staff, Brussels, May 13, 1993.

[90] U.S. industry representatives and analysts, interviews with USITC staff, New York, NY, Apr. 1-2, 1993; Cambridge, MA, Apr. 13-16, 1993; and Silicon Valley, CA, Apr. 14-24, 1993.

[91] European industry representatives and government officials, interviews with USITC staff, Munich, Ivrea, Paris, and London, May 6-24, 1993; and EC officials, interviews with USITC staff, Brussels, May 13, 1993.

[92] U.S. Department of Commerce, Technology Administration, *Global Markets for Supercomputers: The Impact of the U.S.-Japan Supercomputer Procurement Agreement: A Report to Congress* (Washington, DC: GPO, Oct. 1992), p. ii.

[93] "Procedures to Introduce Supercomputers," attachment to letter from Ryohei Murata, Ambassador of Japan, to Ambassador Carla A. Hills, USTR, June 15, 1990.

U.S. Government procurement procedures. A 1992 report to Congress by the U.S. Department of Commerce shows that the revised agreement has been somewhat successful in opening the Japanese public-sector procurement process.[94] For example, Japanese procurement procedures now emphasize actual performance levels rather than theoretical performance levels, improving the competitive position of U.S. supercomputer manufacturers.[95] Nevertheless, the report also indicates a continued pattern of purchasing bias favoring Japanese producers.

The 1990 agreement was severely tested in late 1992. Japan's National Institute for Fusion Research decided to lease an NEC supercomputer system for $625,000 per month instead of one from U.S.-based Cray Research Inc.[96] Cray objected to the award, but a panel of Japanese experts, acting in accordance with provisions of the revised supercomputer agreement, endorsed the selection of the NEC supercomputer. Although there is no basis for appeal, on April 30, 1993, the USTR promised to review Japan's implementation of the 1990 supercomputer agreement.[97]

In addition to the supercomputer agreements, the Japanese government has promised to expand procurement of other types of foreign-manufactured computers, including mainframes, minicomputers, workstations, and personal computers.[98] For years, U.S. sales of mainframes and other computer hardware to private Japanese companies have greatly exceeded sales to public entities. This has reinforced concern among U.S. officials about the openness of Japanese procurement practices.

Despite the problems encountered by U.S. firms in Japan, some analysts believe it is difficult for U.S. industry and trade officials to persuade Japan to open public procurement when the U.S. Government historically buys U.S. supercomputers rather than Japanese brands. For example, none of the U.S. Government laboratories, the largest users of supercomputers, has yet bought a Japanese machine.[99] Reciprocity is likely to become a more important issue in the near future as Japanese companies continue to narrow the technological gap with U.S. competitors.[100]

Intellectual Property Protection

Divergent views on intellectual property rights (IPR) issues among computer companies, even those based in the same country, illustrate the difficulty governments have in establishing IPR laws that clearly benefit their own computer industries. Some analysts argue that since U.S. computer firms are generally more advanced technologically than their foreign competitors, the U.S. Government should favor stricter IPR rules (table 3-4).[101] On the other hand, a number of successful U.S. computer firms base their competitiveness on supplying open, distributed computer networks. These networks are able to connect with other companies' systems and, thus, could be harmed by intellectual property laws and policies that result in overprotection of computer interfaces.[102] Officials of these firms believe that in some instances companies should be allowed access to protected software interface code to determine necessary specifications for making products interoperable.[103]

Historical Perspective

Intellectual property protection has become a major issue in the U.S. computer industry only in recent years. Strong government support for computer research in the early days of the industry resulted in wide diffusion of many basic computer technologies. This minimized the influence of patents on the industry.[104] In addition, the rapid rate of technological advance in the industry, coupled with the slow pace of patent litigation, often made patent conflicts moot by the time legal proceedings were concluded.

Another influence minimizing the importance of patents on the computer hardware industry was the settlement of two antitrust cases. These cases were filed against two of the most important companies

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[94] U.S. Department of Commerce, *Global Markets for Supercomputers*, p. ii.

[95] Japanese supercomputers generally feature higher theoretical processing speeds than U.S. supercomputers, although U.S. supercomputers rank higher in terms of actual processing speeds. For a fuller discussion of this issue, see chapter 4.

[96] U.S. supercomputer industry representatives, interview by USITC staff, Washington, DC, Apr. 8, 1993.

[97] Office of the U.S. Trade Representative, "Section 306 Review of Japan's Implementation of the 1990 U.S.-Japan Supercomputer Agreement," fact sheet, Apr. 30, 1993.

[98] Ryohei Murata, Ambassador of Japan, letter to Ambassador Carla A. Hills, USTR, Jan. 22, 1992, Washington, DC; Office of the U.S. Trade Representative, "Measures Related to Japanese Public Sector Procurement of Computer Products and Services," fact sheet, Jan. 22, 1992; The White House, Office of the Press Secretary, "U.S.-Japan Computer Agreement," fact sheet, Jan. 22, 1992.

[99] Tyson, *Trade Conflict*, pp. 80-81.

[100] Tyson, *Trade Conflict*, pp. 76-84.

[101] Representative of the *Alliance to Promote Software Innovation*, interview with USITC staff, Washington, DC, June 9, 1993.

[102] U.S. and European industry representatives, interviews with USITC staff, Silicon Valley, CA, Apr. 14-24, 1993; Washington, DC, Jan. 14, 1993; Munich, Paris, and London, May 6-24, 1993.

[103] Hewlett-Packard Co., "Software Copyright Protection," *Public Policy Issue Brief*, July 2, 1992, pp. 36-37; and U.S. industry representatives, interviews with USITC staff, Washington, DC, Jan. 14, 1993.

[104] Flamm, *Creating the Computer*, pp. 212-224.

Table 3-4
Comparison of four types of intellectual property in the United States

	Patent	Copyright[1]	Trade Secret	Trademark
Term	17 years from date of grant.	Life of the author plus 50 years from date of creation of a work, or in the case of a "Work for Hire," 75 years from date of creation.	Perpetuity.	Pertpetuity so long as the mark does not become generic.
Matter that is protected	Invention or discovery must be a new and useful process, machine, manufacture or composition of matter or a new and useful improvement thereof.	Original works of authorship fixed in any tangible medium from which the work can be perceived, reproduced, or otherwise communicated, either directly or with the aid of a machine or device.	Information used in one's business that supports a competitive position.	Words or symbols.
Condition for protection	The invention must not (1) have been known or used by others in the U.S., (2) have been patented or described in a printed publication in the U.S. or any foreign country, (3) have been in public use or on sale in the U.S. for more than one year prior to the date of application, or (4) have been abandoned.	The work must be original.	Confidentiality.	Registration.

[1] In 1980, intellectual property protection afforded under U.S. copyright law was extended to computer programs.

Source: Nathan Rosenberg, Ralph Landau, and David C. Mowery (eds.), *Technology and the Wealth of Nations* (Stanford: Stanford University Press, 1992).

involved in early development of computers and computer-related technology, AT&T and IBM. Settlements of the two cases in 1956 required both companies to license patents to all interested applicants. Due to these judgments, a general pattern of cross-licensing developed among U.S. computer hardware manufacturers.[105]

However, as the growing impact of IPR issues on international trade became apparent in the past decade, concern about intellectual property protection grew among U.S. companies. U.S. firms were responsible for a major portion of new technological developments in the computer field. As such, they became increasingly concerned that reverse engineering and other IPR violations by Japanese computer manufacturers were enabling Japanese companies to use U.S. technology to gain competitive advantage.[106] More recently, U.S. firms have expressed concern regarding Taiwanese, Korean, and Brazilian firms, which are emerging as important suppliers in the global PC market.[107] A major U.S. objective in the current round of GATT negotiations is a provision requiring a minimum level of patent, copyright, and trademark protection in developed and emerging computer markets alike.[108] However, increased globalization of the computer industry, and market pressures favoring open standards and systems, promise to make IPR protection more problematic in the future.

IPR vs. Interoperability

In the U.S. market, the rapid movement to open systems has generated conflict among U.S. firms concerning the extent of protection that should be afforded to intellectual property. For example, computer companies that base their competitiveness on proprietary systems are concerned that the

[105] Ibid.

[106] U.S. industry representatives, interviews with USITC staff, Cambridge, MA, Apr. 13-16, 1993; Silicon Valley, CA, Apr. 14-24; Washington, DC, Jan. 14, 1993; and Houston, Austin, and Dallas, TX, June 8-16, 1993.

[107] "Daily Seoul Press Translations," *1993 Internal News*, Jan. 27, 1993; and U.S. industry representatives, interviews with USITC staff, Silicon Valley, CA, Apr. 15-23, 1993.

[108] Hewlett-Packard Co., "Software Copyright Protection," *Public Policy Issue Brief*, July 2, 1992, pp. 36-37; and U.S. industry representatives, interviews with USITC staff, Washington, DC, Jan. 14, 1993.

liberalization of copyright laws sought by other companies will lead to reverse engineering and product cloning.[109] These companies wish to preserve protection of their interface codes and specifications to assure adequate returns on R&D expenditures.

However, companies that emphasize open systems, including a number of successful U.S.-based hardware and software applications firms, are concerned that overprotection of IPR could impede further innovation and development in the computer industry.[110] They allege that overprotection of computer interfaces gives copyright holders monopoly power and deprives consumers of the benefits of freely available interface information.

European IPR

EC efforts to harmonize European IPR laws have caused similar conflicts between proprietary and open systems companies. The EC has decided that computer systems and software interfaces should be protected by copyright. However, the EC also has decided that under limited circumstances companies should be permitted to decompile software code to determine interface specifications necessary to make different computer products compatible.[111]

U.S. computer hardware manufacturers are split with respect to their opinion of the compromise EC policy.[112] U.S. firms that favor stringent protection of intellectual property have expressed concern regarding the extent to which decompilation will be permitted. U.S. firms that favor open systems generally support the EC policy. In between these two opposite ends of the spectrum, a large number of U.S. firms have expressed the opinion that the EC policy represents a reasonable compromise. While these companies support the protection of intellectual property, they recognize that consumer demand for open systems requires a mechanism that allows competitors to ascertain the interface information required to develop interoperable systems.[113]

Tariffs

Although tariffs on finished computers and systems (table 3-5) do not vary enough among the major computer-producing countries to have a significant effect on the competitiveness of computer firms, some tariffs on important components have been regarded as impediments to competitiveness. Ironically, in many of these cases, computer firms in the countries or regions imposing the tariffs appear to have suffered the most from such duties, which increase component costs.

Some U.S. computer producers assert that recent U.S. Government dumping decisions have raised costs considerably for them. For example, an August 1991 affirmative dumping determination[114] resulted in the imposition of antidumping duties in excess of 60 percent on U.S. imports of active-matrix flat panel displays (FPDs) from Japan. The dumping duties applied only to flat panel displays, not to the laptop computers that incorporate them. However, because of the additional duties on this key component, several computer companies reported that they were forced to move some of their laptop manufacturing to offshore locations to remain cost-competitive with foreign producers.[115] Although the U.S. Department of Commerce revoked the order authorizing the tariff in 1993, some industry observers indicated that the imposition of dumping duties had already damaged the competitiveness of the U.S. industry.[116]

In Europe, both U.S. and European computer manufacturers are increasingly vocalizing complaints against 14-percent EC tariffs on semiconductors and other electronic components. Such tariffs have been either eliminated or reduced significantly by other major developed countries, including the United

109 U.S. industry representatives, interviews with USITC staff, Silicon Valley, CA, Apr. 14-24, 1993; Redmond, WA, Apr. 20, 1993; and Washington, DC, Jan. 14, 1993; European government officials, interviews with USITC staff, Brussels, May 13, 1993, and London, May 23, 1993; and USITC, *The Effects of Greater Economic Integration Within the European Community on the United States: Fifth Followup Report* (investigation No. 332-267), USITC publication 2628, Apr. 1993, pp. 39-45.

110 American Committee for Interoperable Systems, "Fact Sheet," Aug. 3, 1992. Members of this organization include, among other firms, Sun Microsystems, Inc., Unisys Corp., Zenith Data Systems Corp., Amdahl Corp., Advanced Micro Devices, Inc., Fujitsu Systems Business of America, Inc., Software Entrepreneurs Forum, and Seagate Technology, Inc.

111 EC officials, interviews with USITC staff, Brussels, May 13, 1993; and European industry representatives, interviews with USITC staff, Munich, Ivrea, Paris, and London, May 6-24, 1993.

112 *OJ*, No. L 122 (May 17, 1991), p. 42. The original proposal (88/816) was discussed in USITC, *The Effects of Greater Economic Integration Within the European Community on the United States: First Follow-Up Report* (investigation No. 332-267), USITC publication 2268, Mar. 1990, pp. 12-4 to 12-7.

113 Hewlett-Packard Co., "Software Copyright Protection," pp. 36-37; and U.S. industry representatives, interviews with USITC staff, Washington, DC, Jan. 14, 1993.

114 USITC, *Certain High-Information Content Flat Panel Displays and Display Glass Therefor From Japan, Determination of the Commission* (investigation No. 731-TA-469 (final)), USITC publication 2413, Aug. 1991.

115 U.S. industry representatives, interviews with USITC staff, Silicon Valley, CA, Apr. 15-23, 1993; Houston, TX, June 8, 1993; and Munich and London, May 6-24, 1993.

116 Yvonne L. Lee, "Repeal of Active Matrix Display Tariff is Too Late: Manufacturers Who Moved Out of the Country Aren't Likely to Return," *Infoworld*, July 5, 1993; U.S. industry representatives and analysts, interviews with USITC staff, Silicon Valley, CA, Apr. 15-23, 1993.

Table 3-5
General tariffs on finished computers in the United States, Europe, Japan, and certain other East Asian countries, 1992[1]

Country	Tariff Rate
U.S.	3.9%
European Community	4.9%
Japan[2]	4.9%
Taiwan[3]	5.0%
Singapore[4]	0.0%
Korea	11.0%
Malaysia[5]	5.0%

[1] Based on Harmonized Tariff Classification numbers 8471.20 and 8471.91.
[2] 25% rate for countries which do not participate in GATT.
[3] Preferred rate.
[4] 1989 tariff rate.
[5] 1990 tariff rate does not include 10% sales tax.
Source: Compiled by USITC staff.

States and Japan.[117] Officials of European computer firms believe that such duties particularly place their companies at a disadvantage by increasing component and manufacturing costs in Europe.[118]

Some computer industry officials in the United States and Europe[119] blame government agencies and administrators for recent trade and tariff decisions that have resulted in higher component and manufacturing costs. However, a number of analysts believe many of the problems are due to outdated trade laws that are no longer relevant for fast-paced, complex, and highly globalized high-technology industries.[120]

Industry officials state that computer companies must be able to source low-cost, high-quality components and materials to compete with foreign rivals.[121] Decisions under present trade and tariff laws to protect one segment of a nation's industry often damage other segments of the industry, according to these officials. They believe that national governments must revise their laws and policies to reflect the changed economic conditions in high-technology industries.

Tax and Other Incentives

Many industry observers believe that tax policies and other incentives have had significant effects on the competitiveness of computer hardware manufacturers in Asia and Europe (table 3-6). Japanese and other East Asian electronics manufacturers, in particular, reportedly have benefited from tax policies. Certain European countries, such as France and Italy, also have been active in providing tax and other incentives to promote the competitiveness of computer and other high-technology firms. Although U.S. computer companies also have benefited from tax incentives, the often temporary basis of such measures reportedly has made it difficult for U.S. firms to establish long-term strategies.

United States

U.S. tax policies that appear to be most relevant for the competitiveness of the U.S. computer industry include R&D and investment tax credits. Because the computer industry is one of the most R&D-intensive industries in the United States, R&D tax credits may be particularly beneficial. In 1981, the U.S. Congress enacted a temporary R&D tax credit to increase innovation and U.S. competitiveness in global markets.[122] The credit began at 25 percent but was reduced to 20 percent in 1986. It was renewed several times prior to expiring on June 30, 1992. Although the R&D tax credit was renewed once again in the recently enacted Omnibus Budget Reconciliation Act of 1993,[123] it has still not been made permanent; it is scheduled to expire on July 1, 1995.

According to some economists, the R&D tax credit has been effective. For example, a study by the Brookings Institution estimates that the R&D tax credit increased private R&D spending by 7 percent a year.[124] It also shows that certain changes in computation of the credit could quadruple the initial effect of the credit. However, U.S. industry officials believe that the tax credit was less effective than it

[117] European industry and trade association officials, interviews with USITC staff, Frankfurt, Munich, Ivrea, Paris, and London, May 6-24, 1993; and EUROBIT, *European IT Competitiveness in a Distorted Market Environment: Consequences of EC - 14% - Tariff on Semiconductors for European Information Technology Manufacturers* (Frankfurt: EUROBIT, 1991).

[118] European Association of Manufacturers of Business Machines and Information Technology (EUROBIT), *European Information Technology Observatory 93* (Frankfurt, Germany, 1993), p. 22.

[119] U.S. and European industry representatives and trade association officials, interviews with USITC staff, Silicon Valley, CA, Apr. 14-24, 1993; and Munich, Frankfurt, Ivrea, Paris, and London, May 6-24, 1993.

[120] U.S. trade association officials, interviews with USITC staff, Washington, DC, Jan. 14, 1993; U.S. industry representatives and analysts, interviews with USITC staff, Silicon Valley, CA, Apr. 14-24, 1993; European industry representatives, interviews with USITC staff, Frankfurt, May 7, 1993, and Munich, May 17, 1993; and Tyson, *Trade Conflict*, pp. 141-43, 220, 273-74, 276, 286-88, and 296.

[121] U.S. and European industry representatives and trade association officials, interviews with USITC staff, Silicon Valley, CA, Apr. 14-24, 1993; and Munich, Frankfurt, Ivrea, Paris, and London, May 6-24, 1993.

[122] Economic Recovery Tax Act of 1981, 95 Stat. 172.

[123] Public Law 103-66.

[124] Martin N. Baily and Robert Z. Lawrence, *The Incentive Effects of the New R&D Tax Credit*, study commissioned by the Council on Research and Technology (Washington, DC: Brookings Institution, July 19, 1992).

Table 3-6
Tax policies and other incentives available in certain computer producing countries

Country	R&D tax credit	Preferential capital gains tax	Foreign direct investment incentives	Special incentives for high-tech	Accelerated depreciation
United States	X	X			
United Kingdom		X			
Germany	X				X
France	X	X		X	
Italy	X	X			X
Japan	X				X
Korea	X		X	X	
Singapore	X		X	X	X
Taiwan	X			X	
Hong Kong				X	

Source: USITC staff and Price Waterhouse, *Corporate Taxes - A Worldwide Summary, 1992.*

could have been because it required periodic reapproval. Given the temporary nature of the incentive, U.S. companies have ignored the potential benefit of the tax credit in their long-term economic planning.[125] Accordingly, U.S. industry officials have asked for a permanent extension of the R&D tax credit.[126] They maintain that permanent extension of the law would reduce uncertainty resulting from the temporary basis of the credit and thus encourage more R&D spending in long-range computer technology.

Some industry analysts maintain that the general investment tax credit that was proposed by the President[127] would have been particularly valuable to computer hardware manufacturers, since computers account for a growing portion of new capital investment by U.S. business.[128] However, critics maintain that past investment tax credits have not been effective, and have cost the government about 1 dollar in forgone tax revenues for each dollar of investment generated. A previous investment tax credit was repealed in 1986 after many economists argued that it distorted investment in favor of industries where credit was already available.[129]

Europe

Although various European countries have provided generous tax incentives (table 3-6) to promote competitiveness in the computer and other high-technology industries, there are few cases in which such measures have helped these industries demonstrably. Where such incentives have been used to subsidize or protect leading companies from international competition, targeted firms usually have experienced adverse consequences.

Industry analysts and officials point to Ireland and Scotland as two European countries that have used tax policies and other incentives effectively to attract foreign investment and technology.[130] Such incentives include tax holidays, tax credits, and relaxed labor laws. The principal advantage of Ireland's and Scotland's policies over traditional European policies is that they focus on attracting foreign investment in computer technology rather than protecting "national champion" firms from foreign competitors. As a result of their policies, Scotland and Ireland have some of the most productive computer manufacturing operations in Europe, including facilities established by IBM, DEC, Compaq, and Apple.

Japan

Although the Japanese Government has general tax policies aimed at stimulating overall industrial R&D, most Japanese incentives are directed toward specific industrial sectors.[131] MITI has dispensation from the Ministry of Finance to allocate incentives as it determines appropriate, often to high-technology industries that the Japanese Government wishes to

[125] U.S. computer industry officials, interviews with USITC staff, Silicon Valley, CA, Apr. 14-24, 1993.

[126] Computer and Business Equipment Manufacturers Association, interview with USITC staff, Washington, DC, Jan. 14, 1992; and Hewlett-Packard Co., "R&D Tax Credit," *Public Policy Issue Briefs*, Apr. 1993, pp. 21-22.

[127] The proposed investment tax credit was not included in the final version of the Omnibus Budget Reconciliation Act of 1993 (P.L. 103-66).

[128] U.S. industry analysts, telephone interviews with USITC staff, June 22, 1993.

[129] Ibid.

[130] U.S. industry representatives, interviews with USITC staff, London, May 21, 1993; and U.S. and European government officials, interviews with USITC staff, London, Edinburgh, and Munich, May 6-24, 1993.

[131] T. Howell and others, *The Microelectronics Race: The Impact of Government Policy on International Competition* (New York: Westview Press, 1988), pp. 67, and 132-33; and Martin Fransman, *The Market and Beyond: Cooperation and Competition in Information Technology Development in the Japanese System* (Cambridge, MA: Cambridge University Press, 1990).

encourage. Once established, such taxes and incentives remain in effect for long periods of time and are not subject to periodic revision or reapproval. Some sources report that Japan has approximately 20 different tax incentive arrangements to encourage technological innovations in the computer, communications, and related high-technology areas.[132]

[132] Japanese industry and government officials, interviews with USITC staff, Apr.-May, 1991.

Some industry analysts attribute the ability of the Japanese Government to target particular industries and technologies to the Ministry of Finance's inclusion of MITI and other relevant Japanese Government agencies in the development of tax policies. However, the difficulty of targeting particular industries in the increasingly globalized and complex high-technology sector has caused a recent shift in Japanese tax policies toward supporting broad infrastructural goals.

CHAPTER 4
Competitive Assessment

Introduction

This chapter assesses the performance of U.S. computer hardware manufacturers. The assessment is provided in four separate and distinct discussions, each pertaining to one computer hardware segment. Four separate discussions are merited since prevailing industry trends, such as computer platform downsizing and commoditization influence segments differently, and since the nature of competition varies noticeably across segments. These four discussions generally have a parallel structure, described below.

The Competitive Assessment Framework

Figure 4-1 delineates the USITC framework for assessing performance in each segment of the computer hardware market. Discussions begin with a summary of the recent performance of predominant firms in each segment. In this report, performance is measured by global market share. As noted, global market share is the most suitable indicator available for this analysis, in large part due to the availability of relatively good data pertaining to market share.[1]

[1] Market share and profitability are often proposed as measures of competitiveness. Market share was selected as the measure of competitiveness to be used in this analysis because profitability data were not available on a segment basis. In *Folded, Spindled, and Mutilated: An Economic Analysis of U.S. vs. IBM* (Cambridge: MIT Press, 1983), Franklin M. Fisher, John J. McGowan, and Joen E. Greenwood state that revenue is "...the best of the single measures..." that might be used for market share in the computer industry, given the available data (p. 110). With respect to profitability as a measure, they state that "...the problems involved [with using profitability] are so large as to make *any* inference from accounting rates of return as to the presence of economic profits, and *a fortiori* monopoly profits, totally impossible in practice." (p. 219). A further discussion of the measurement of competitiveness is found in USITC, *Global Competitiveness of U.S. Advanced-Technology Industries: Communications Technology and Equipment* (investigation No. 332-301), USITC publication 2439, Oct. 1991, pp. 3-1, 3-2; USITC, *Global Competitiveness of U.S. Advanced-Technology Industries: Semiconductor Manufacturing and Testing Equipment* (investigation No. 332-303), USITC publication 2434, Sept. 1991, pp. 2-1, 2-2; and USITC, *Global Competitiveness of U.S. Advanced-Technology Industries: Cellular Communications* (investigation No. 332-329), USITC publication 2646, June 1993, pp. 3-1 to 3-5.

Market share reflects a firm's ability to sell computers in competitive markets, irrespective of growth or decline in market size. Industry representatives and industry analysts widely cite market share estimates as indicative of competitive position. In addition, market share is the only measure of competitiveness available for all firms in all computer hardware market segments.

Each introduction concludes with a brief summary of the terms of competition in each market segment and the skills or strategies that most significantly affect firms' abilities to compete on those terms. Terms of competition, shown in the third column of figure 4-1, are the factors that are important to consumers. In each market segment, price is important to consumers, although PC consumers stress price more than consumers of other computer hardware. Price is significantly less important to supercomputer consumers, for instance, although the relative importance of price has increased for certain consumers in recent years. Processing power is also a deciding factor for all consumers except those of PCs. The standardization of PC architecture has resulted in far less variation in processing power among these computers, reducing the importance of this factor as a purchasing criterion. The importance of time-to-market,[2] networking capabilities, and technical support are unique to consumers of personal computers (PCs), workstations, and supercomputers, respectively.

Factors that influence firms' abilities to compete in each market segment are found in the fourth column of figure 4-1. This column, too, shows that there are certain similarities and differences across market segments. All computer hardware manufacturers have undertaken research and development (R&D) programs, although the focuses of these privately-funded R&D programs differ markedly. For instance, much of the R&D conducted by personal computer manufacturers focuses on motherboards, whereas much of the R&D conducted

[2] Time-to-market is defined as the time required by manufacturers to assemble personal computers, especially those incorporating new technology (e.g., a newly available microprocessor), and deliver the finished product to consumers.

Figure 4-1
Competitive assessment framework for computer hardware industry

Firms . . .	**compete for . . .**	**in terms of . . .**	**influenced by . . .**
Personal computer manufacturers	❑ Global market share	❑ Price ❑ Time-to-market	❑ Research and development ❑ Cost management skills ❑ Marketing and distribution
Workstation manufacturers	❑ Global market share	❑ Price ❑ Processing power ❑ Networking capabilities	❑ Research and development ❑ Alliances
Mainframe and minicomputer manufacturers	❑ Global market share	❑ Price ❑ Processing power	❑ Research and development ❑ Cost management skills
Supercomputer manufacturers	❑ Global market share	❑ Price ❑ Processing power ❑ Technical support	❑ Research and development ❑ Software-writing assistance

Source: USITC staff.

by supercomputer manufacturers focuses on massively parallel processing (MPP). In addition to R&D programs, firms in the personal computer market and the mainframe and minicomputer market have undertaken pronounced cost management programs, although these programs differ somewhat by type of manufacturer. The importance of marketing and distribution, alliances, and software-writing assistance are unique to manufacturers of personal computers, workstations, and supercomputers, respectively. Detailed discussions of R&D programs, cost management programs, and other key factors that are unique to specific market segments comprise the bulk of chapter 4.

An additional component of the discussion regarding PC manufacturers' performance summarizes a statistical analysis that assesses the relationship between the skills and strategies referenced in the discussion — research and development, cost management, and marketing and distribution — and global market share. Data required to perform similar assessments of the other three computer hardware segments are not available.[3] However, a broad statistical analysis of factors that appear to be important for all computer hardware manufacturers, including firms in the workstation, mainframe and minicomputer, and supercomputer segments, was performed. This analysis generally supports the significance of cost management programs, labor-saving techniques (a component of cost management), and marketing efforts.[4]

Each discussion concludes with an examination of long-term profitability, which is intended to complement the focus on global market share. Unprofitable firms, un-aided by external sources, must exit the market over the long-run, irrespective of market share. Unprofitable firms are those that fail to generate revenues that equal total costs, plus a minimally acceptable level of return for entrepreneurs or investors. Market exit may entail a complete discontinuation of all operations, but is most commonly manifested by refocusing businesses on different markets, either by reorganization or diversification. In certain instances, unprofitable firms have exited markets when they have been absorbed by profitable competitors and no longer function as independent entities.

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[3] Statistical analysis of the workstation and supercomputer segments was not possible due to insufficient observations; data were not available for enough firms to perform sound statistical analysis. Statistical analysis of the mainframe and minicomputer segment was not performed because relevant data were not available in sufficient detail.

[4] This statistical analysis does not support the importance of R&D and software-writing skills. These anomalous results may be due to imprecise measurement of these factors, or to the effects of unobserved factors. For more detail, see appendix H.

Personal Computer Manufacturers

Introduction

In terms of market share, three of the four largest firms in the global personal computer market are U.S. companies (figure 4-2). IBM, with $5.9 billion in PC revenues in 1992, is still the world's leading supplier of PCs. However, IBM's share of the PC market has fallen sharply, from an estimated 40 percent in 1985 to 12 percent in 1992.[5] In contrast, U.S. clone makers — particularly Compaq, Dell, and AST Research — posted significant gains in market share during 1985-92.

Japanese firms have benefitted immensely from Japan's rapidly growing personal computer market during recent years. Due to their experience in the large Japanese market, NEC, Fujitsu, Matsushita, and Toshiba now account for a significant share of the global PC market. However, their strength continues to lie almost exclusively within the Japanese domestic market. Outside of their home market, Japanese PC manufacturers have been largely unwilling or unable to compete in terms of price. In addition, PCs manufactured for sale in the Japanese market feature proprietary operating systems and therefore are incompatible with most PCs in the U.S. and European markets.[6] Consequently, the level of overseas PC sales for Japanese firms has been rather low in comparison with that of U.S. counterparts. For instance, NEC derives 87 percent of its PC sales from the Japanese market.[7] By contrast, Dell derives 64 percent of its sales from the U.S. market, Apple 55 percent; AST Research, 42 percent; and Compaq, 37 percent.[8]

Similar to Japanese firms, leading European PC makers such as Groupe Bull and Olivetti have developed sizable PC operations in their home markets, but performance in other regions has been poor.[9] Even in their home markets, however, aggressive price competition from U.S. companies has prevented European companies from maintaining a dominant market share. In particular, IBM and Compaq have been able to market very low-priced PCs, in part due to the economies of scale they have

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[5] Gartner Group, *Yardstick: Top 100 Worldwide*, 1993, p. XIV-25.

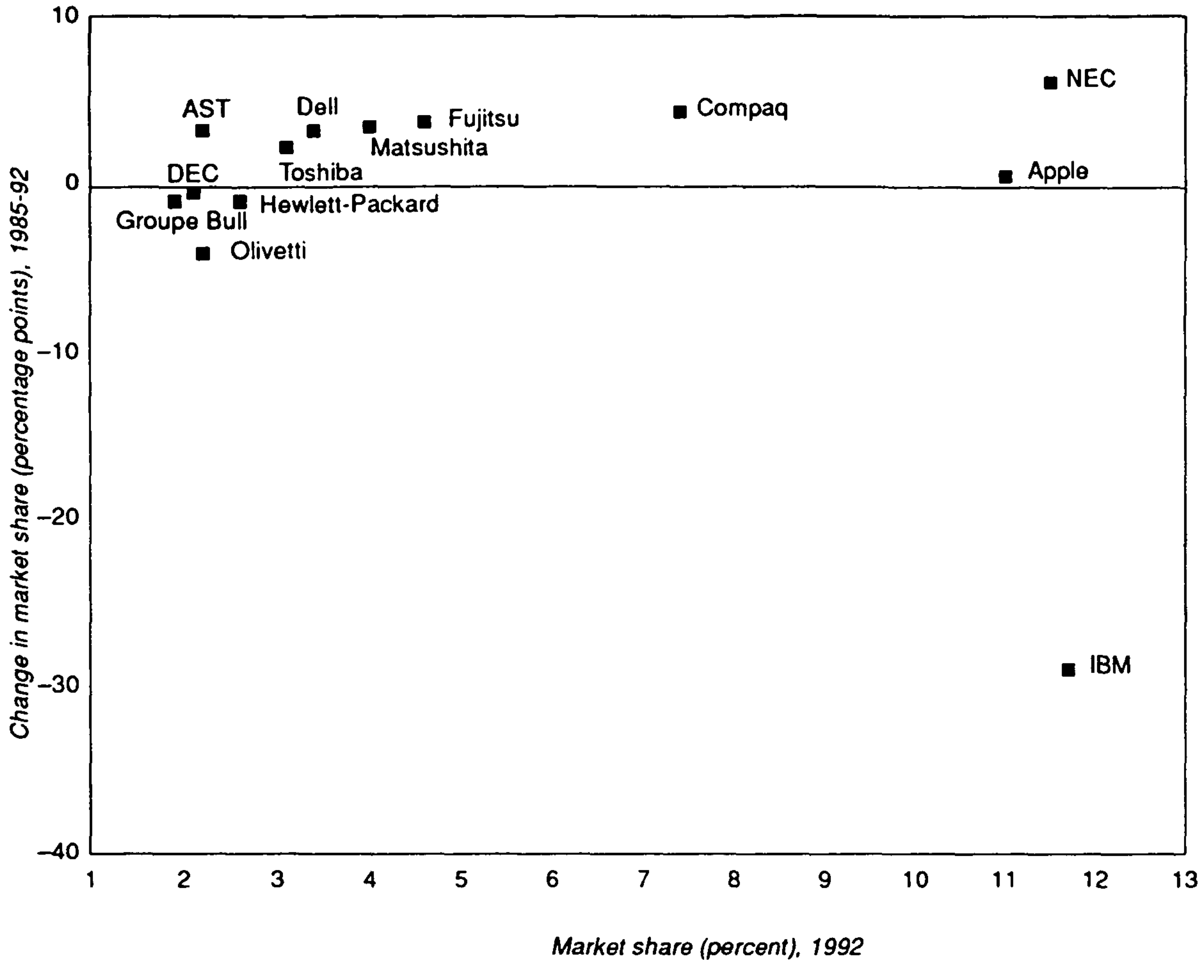
[6] NEC's proprietary operating system has become a *de facto* standard and dominates the Japanese PC market. This, in part, explains the difficulty U.S. firms have had in marketing traditional IBM-compatible PCs in the Japanese market.

[7] Domicity Ltd., *NEC, A Strategic Analysis* (Toronto: Domicity Ltd., 1993), p. 7-11.

[8] Gartner Group, *Yardstick: Top 100 Worldwide*, 1993, pp. XV-5, XV-21, XV-43, and XV-63.

[9] Siemens-Nixdorf and Olivetti, interviews with USITC staff, Munich and Ivrea, May 6 and May 10, 1993.

Figure 4-2
Global personal computer market share of selected firms, 1985-92



Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

achieved in European production and distribution facilities.[10]

Based upon interviews with the world's leading personal computer manufacturers, firms in this industry segment compete principally in terms of price and time-to-market. Consequently, PC manufacturers have undertaken R&D programs to reduce costs and improve efficiency. In addition, PC manufacturers have developed new cost management programs, including component outsourcing strategies to minimize component costs, and labor-saving manufacturing to reduce staffing. Lastly, PC manufacturers have developed innovative approaches to marketing and distribution, thereby reducing sales costs and time-to-market.

[10] Compaq Computer, interviews with USITC staff, Erskine, May 21, 1993.

Factors Influencing Competitiveness

Research and Development

Personal computer manufacturers have focused R&D programs on designing lower cost PCs. One of the most expensive PC components is the motherboard, which principally is composed of printed circuit boards (PCBs) and a microprocessor. Many PC manufacturers are reducing the number of PCBs in each motherboard from six to four, for a cost savings of 20 percent to 40 percent per motherboard. AST Research has taken this concept further, redesigning the usually rectangular motherboard in addition to eliminating 2 PCB layers. AST has designed an L-shaped motherboard, which allows the firm to fabricate two motherboards, instead of one, from each sheet of PCB material.[11]

Some R&D programs focus on streamlining the PC manufacturing process. A number of PC manufacturers are designing motherboards to accommodate many different types of microprocessors. Use of these so-called "universal" motherboards allows firms to manufacture and market computers incorporating newly-commercialized chips more rapidly.[12] Proceeding along a different avenue, Hewlett-Packard has designed a motherboard that is held in place by one screw, thereby reducing assembly costs. By contrast, a Dell motherboard reportedly is held in place by 25 screws.[13]

Other important R&D programs ultimately may alter the nature of competition in the PC market, adding portability and multimedia content to consumers' purchasing criterion. Laptop, notebook, and pen-based computers presently account for about 20 percent of all PC sales. These products have matured rapidly, and principally compete in terms of price and time-to-market, like desktop PCs. However, firms are racing to reduce the weight and increase the functionality of these products. For instance, IBM has announced that it will introduce miniature conversion units that enable IBM's Thinkpad laptops to access television programs. Manufacture of these conversion units, which will be commercialized in 1994, entailed research on constructing and miniaturizing the silicon circuitry that is required to turn analog wave-based television signals into digital signals used by computers.[14] NEC has designed a notebook computer with a conventional flat panel display on one side, and a pen-based display on the other.

Cost Management Skills

Component sourcing strategies

With few exceptions, personal computer makers rely on outside sources for supplies of key components such as microprocessors, operating systems, memory chips, and disk drives.[15] Only a few of the largest PC manufacturers, including IBM and the Japanese vendors, continue to depend heavily on internal sources of components. Relying on outside sources appears to enhance firms' abilities to reduce component costs.

[11] Andrew Reinhardt, "Penny-Pinching PCs: How They Did It," *Byte*, Nov. 1992, p. 131.

[12] Ibid., p. 130.

[13] Ibid., p. 131.

[14] "IBM ThinkPad 750, 750CS, 750C and 750P Systems and Related optional Features," *IBM Press Release*, Sept. 9, 1993, p. 1.

[15] Some U.S. producers still make these components in-house. For example, IBM still has substantial memory chip capacity. Others may produce printed circuit boards internally if high volumes can be used in the downstream manufacturing process.

Clone makers have reduced component costs most aggressively. Compaq overhauled its approach to component sourcing in the wake of severe price competition beginning in 1991. Compaq uses a component "benchmarking" strategy to identify continuously the low-cost supplier of all key PC components.[16] As a result of benchmarking, Compaq replaced some traditional component suppliers with lower cost suppliers, even in instances where Compaq held a financial stake in the traditional supplier. The company also has established close consultation procedures with component suppliers such as Intel; this allows the company to modify purchasing requirements and delivery schedules, thereby reducing production costs and delays.[17]

Other popular means to reduce component costs are demonstrated by AST Research. AST Research has eased technical specifications on memory expansion sockets and circuit boards, achieving substantial savings at the cost of marginally lower component quality.[18] AST also has reduced component costs in ways that are readily discernable to consumers, such as incorporating cheaper speakers and reducing the length of its PC keyboard cables by 6 inches.[19] AST's growing market share suggests that many PC customers are satisfied with marginally lower quality and minor inconveniences in return for substantially lower PC prices.

Labor-saving manufacturing techniques

Irrespective of firm size or location, personal computers are typically assembled with the use of simple conveyor belts and hand-held screwdrivers.[20] PC manufacturers have consolidated conveyor lines to increase labor productivity and reduce labor costs. Compaq, for instance, currently assembles PCs on single conveyor lines; this eliminates the expense of using several conveyor lines, usually housed in different facilities, to perform discrete tasks, such as assembling motherboards or chassis. Compaq also has discontinued testing every PC subassembly, opting instead to test only samples until the computer arrives at the end of the conveyor line, where each finished computer continues to be fully tested.[21]

[16] Compaq Computer, interviews with USITC staff, Houston, TX, June 8, 1993; and Reinhardt, "Penny-Pinching PCs," p. 128.

[17] Compaq Computer, interviews with USITC staff, Houston, TX, June 8, 1993.

[18] Similar steps to modify specifications have been taken by most U.S. PC vendors. Reinhardt, "Penny-Pinching PCs," p. 130.

[19] Ibid., p. 131.

[20] U.S. industry representatives, interviews with USITC staff, San Jose, CA, and Houston, TX, Apr. 14-24 and June 8-16, 1993.

[21] Barbara Dutton, "Quality in the Glen," *Manufacturing Systems*, Mar. 1992, p. 21.

Labor-saving techniques have facilitated labor productivity growth among U.S. clone makers during recent years. During 1990-92, annual company revenues per employee increased by $272,000 at Compaq, $952,000 at Packard Bell, and $1.2 million at Dell (figure 4-3). Japanese firms, by comparison, did not experience severe price competition in their home market and performed poorly in terms of labor productivity. During 1990-92, Matsushita increased revenues per employee by $55,000, whereas revenues per employee fell by $8,000 at NEC.[22]

More efficient production lines have allowed U.S. firms to reduce workforces. Clone makers, motivated by intense price competition, reduced global employment by 13 percent, or 12,500 workers, during 1990-92. Compaq was most aggressive in such efforts, initiating two separate layoffs during 1990-92.[23] Compaq's layoffs resulted in the displacement of nearly 2,000 workers.[24]

Innovations in Marketing and Distribution

Changes in marketing and distribution strategies have helped PC manufacturers reduce sales and administrative costs, as well as time-to-market. Mass production of largely undifferentiated PCs, in addition to the rising number of knowledgeable PC users, is motivating firms to discard expensive marketing and distribution methods. Personal computer manufacturers are exploiting new opportunities to sell PCs through high-volume mail and retail channels.[25] Companies such as Packard Bell and Gateway 2000 maintain low overhead expenses by selling PCs almost exclusively through direct mail, telephone orders, and high-volume retail chains such as Sears and Wal-Mart (figure 4-4).

To date, clone makers have been more aggressive than integrated manufacturers like IBM and Apple in terms of adopting new marketing and distribution techniques. Integrated firms typically have maintained large sales forces, stressing their ability to construct networks tailored to customers' unique needs. In light of recent staffing reductions in these firms' sales forces, however, it seems that integrated firms are revising marketing strategies. IBM has begun selling a low-priced PC through mail and telephone orders and is increasingly selling PCs in non-computer related retail stores. IBM's market share of PC sales by such stores increased to 19 percent in 1993, bolstered by sales of its new PS/1 line of computers.[26] Apple began selling Macintosh computers at Sears and Wal-Mart during summer 1992.

To a lesser extent, new mass-marketing methods have been adopted by European PC manufacturers, particularly those in Germany. Mass merchandising by firms such as Vobis and Escom has grown rapidly in the last 2 to 3 years.[27] It appears that European firms' efforts in this area largely have been motivated by intense price competition with U.S. firms, which have employed certain low-cost marketing methods in the European Community. Dell, for instance, has established toll-free telephone numbers for PC orders from European customers.

By contrast, marketing and distribution patterns are changing slowly in Japan, where low-volume retail stores account for the bulk of PC sales. In part, this is due to less intense price competition in Japan's PC market; there is less incentive to control marketing and distribution costs when price competition is subdued. However, certain Japanese firms have adopted new marketing tactics in competitive overseas markets. In the United States, NEC and Toshiba have been among the first Japanese firms to adopt new marketing and distribution techniques. For instance, NEC has begun to sell PCs through mass merchandisers like Lechmere and CompUSA.

Evidence from Statistical Analysis

Statistical analysis performed by USITC staff supports several themes identified in interviews with industry representatives.[28] Using data for eight manufacturers of PCs, staff evaluated the statistical relationship between factors highlighted in industry interviews and global market share.[29]

Proxies were available for three of the factors highlighted by the discussion above: cost management programs, as measured by gross return on sales;[30] labor-saving manufacturing techniques, as measured by revenues per employee; and innovative

[22] Gartner Group, *Yardstick: Top 100 Worldwide*, 1993, p. XIV-38.

[23] Compaq Computer, interviews with USITC staff, Houston, TX, June 8, 1993.

[24] Gartner Group, *Yardstick: Top 100 Worldwide*, 1993, p. XIV-38.

[25] U.S. and Asian industry representatives, interviews with USITC staff, San Jose, CA, Apr. 23, 1993, Maynard, MA, Apr. 15, 1993, and Austin and Houston, TX, June 8-16, 1993.

[26] IBM representative, telephone interview with USITC staff, Nov. 9, 1993.

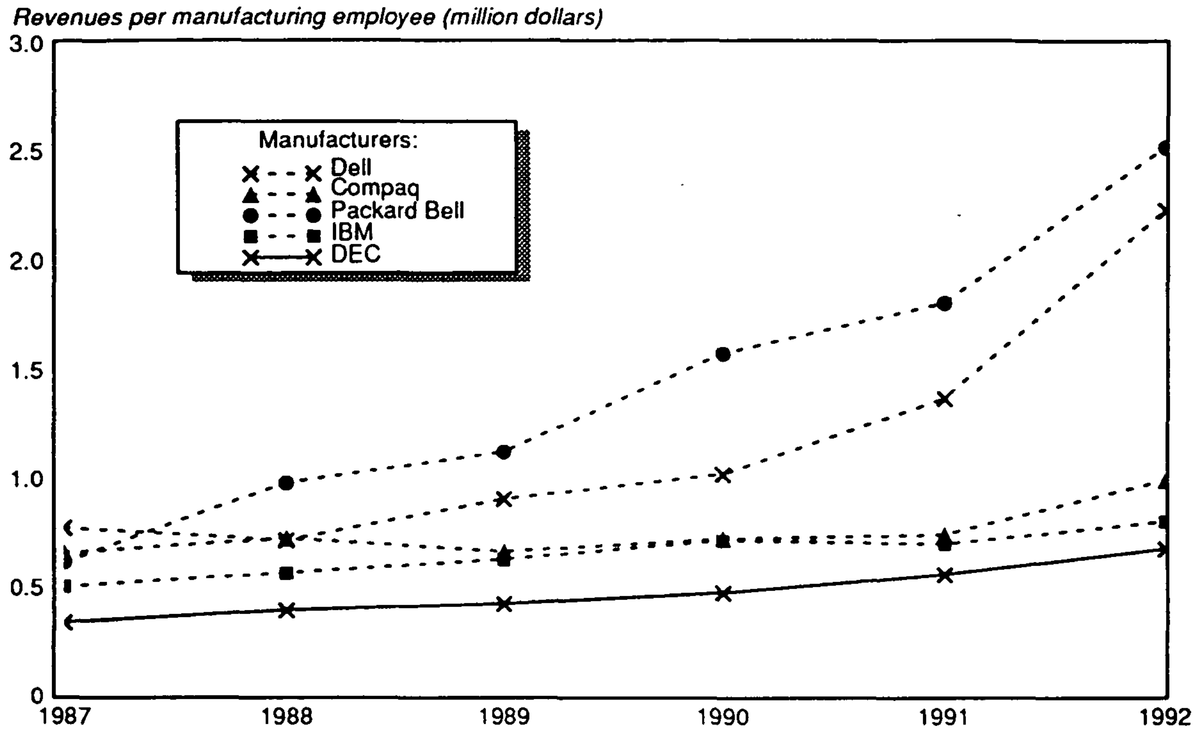
[27] Groupe Bull, interviews with USITC staff, Paris, May 12, 1993.

[28] Appendix H describes the methods employed and data used in the statistical analysis and gives a detailed presentation of the results.

[29] The statistical analysis that follows examines the correlation of the identified factors with market share. It does not address causality.

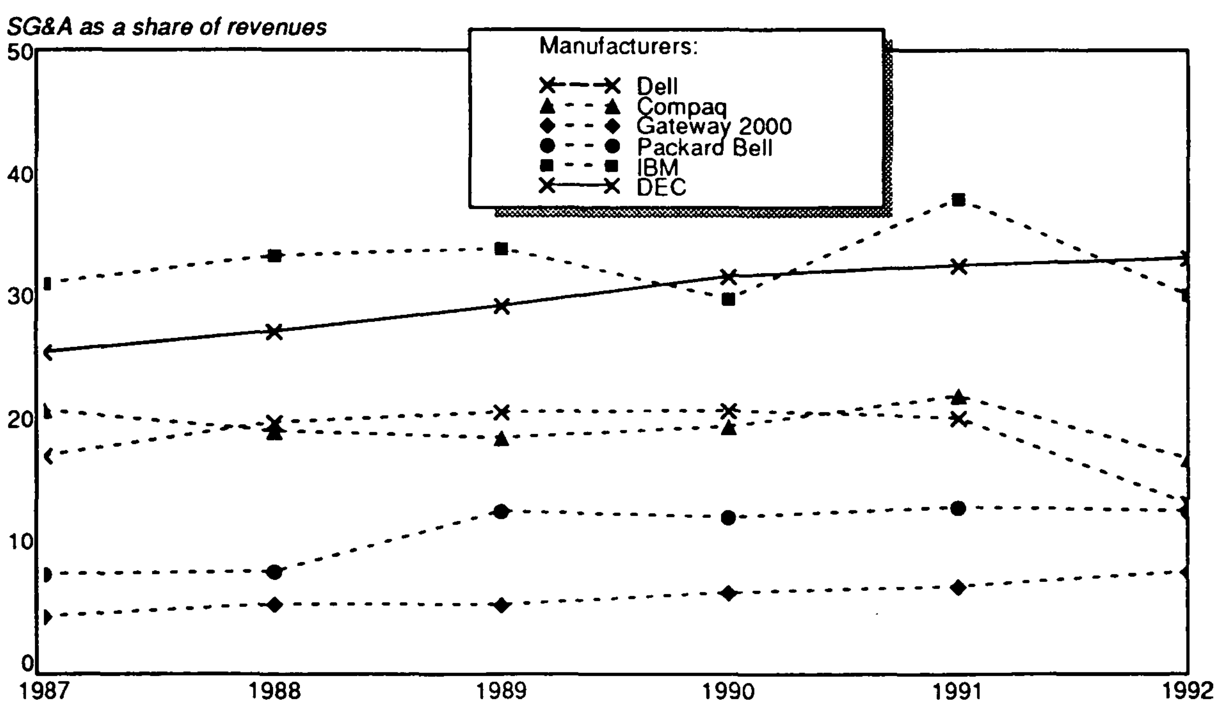
[30] The gross return on sales indicates the efficiency of operations as well as how products are priced. See James C. Van Horne, *Financial Management and Policy* (Englewood Cliffs, NJ: Prentice Hall, 1992), p. 737. Since pricing is very competitive in the PC market segment, gross profitability likely reflects efficiency to a greater extent in this market segment where PCs are becoming commodity products than it would in other market segments where products are less like commodities.

Figure 4–3
Labor productivity trends for personal computer manufacturers, 1987–92



Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

Figure 4–4
Selling, general, and administrative cost trends in the personal computer market, 1987–92



Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

marketing, as measured by the number of sales and marketing employees. In addition, a proxy was developed for R&D programs. This proxy expressed the number of R&D employees as a share of total employees. No proxy was developed to measure component sourcing strategies. However, the effect of component sourcing strategies likely is reflected in the proxy for cost control.[31]

Two of these factors were found to be statistically significant. Table 4-1[32] shows how these factors affected market share.

All the factors had the expected effect on market share, although not all were statistically significant. As shown in the tabulation, for example, cost management skills had a positive and significant effect on the market share. Large sales staffs had a negative and significant effect on market share, reflecting the importance of mail-order marketing and other techniques that do not depend on large sales forces. Labor-saving manufacturing techniques and research and development programs had the expected positive effect on market share, but were not statistically significant. Lack of significance may be due to imprecise measurement or unobserved factors.

Outlook

U.S. firms, accounting for over 55 percent of global PC revenues, continue to enjoy a strong competitive position in the global PC market. Despite a marked decline in IBM's market share since 1985, the firm continues to derive more revenue from the global PC market than any other PC manufacturer. Apple's share of the global market has remained steady in recent years, and Compaq, Dell, and AST continue to be among the most rapidly growing firms in the global industry. NEC, Fujitsu, Matsushita, and Toshiba jointly account for 23 percent of the global market, but continue to be reliant on the Japanese market for the vast majority of their sales.

Global PC sales are forecasted to grow by approximately 50 percent during 1993-97.[33] PC sales in the United States may grow more slowly than this due to the relatively advanced state of computer platform downsizing in this country. Growth in Europe and Japan may exceed the average as the popularity of computer platform downsizing grows in these markets.

The composition of the global industry likely will continue to change during the near term. Although price competition has resulted in a worldwide expansion in PC sales, overall profits in the segment have declined sharply in recent years. Many firms have failed to generate competitive rates of return for investors, which suggests that they will exit the market over the long run (figure 4-5).[34] Some industry analysts agree, forecasting a worldwide shake-out of PC suppliers.[35] However, no large firm appears likely to exit the market in the near term.

Commodore closed assembly plants in Germany and Hong Kong and consolidated operations in the Philippines in 1992, reducing its global workforce by 50 percent in the process.[36] Tandy sold its PC-manufacturing business to AST Research in June 1992, and Everex entered Chapter 11 bankruptcy in December 1992.[37] Everex is refocusing its business on high-end PCs and servers.[38] Corporate reorganizations continued in 1993. CompuAdd initiated a major restructuring, reducing its workforce by half.[39] In June, Zenith Data Systems, a subsidiary of Groupe Bull, purchased a 20 percent equity stake in Packard Bell.[40]

Workstation Manufacturers

Introduction

Six major U.S. workstation manufacturers, Sun Microsystems, Hewlett-Packard, IBM, DEC, Silicon Graphics, and Intergraph account for over 80 percent of the global workstation market. Sun Microsystems, Silicon Graphics, and Intergraph specialize in workstation manufacturing. These manufacturers have benefitted enormously from the downsizing of computer platforms.

Sun Microsystems is the leading supplier of workstations, consistently accounting for about one-third of global workstation sales since 1990 (figure 4-6). Hewlett-Packard is currently the second largest workstation manufacturer, accounting for

[31] The effect of publicly funded R&D and other government policies discussed in Chapter 3 were not tested statistically since these policies are not readily quantifiable.

[32] Four distinct regressions were performed on available data pertaining to personal computer manufacturers. Information presented in the tabulation reflects the results of the model that explained the most variation in the dependent variable, market share. See appendix H for more detail.

[33] Gartner Group, *Yardstick: Top 100 Worldwide*, 1993, p. III-10.

[34] IBM, DEC, Hewlett-Packard, Fujitsu, Matsushita, Toshiba, Groupe Bull, and Olivetti derive most revenue from other segments of the computer hardware business. For these firms, data on company-wide profitability are not believed to be an accurate indicator of long-term competitiveness in the personal computer market. Therefore, the long-term competitiveness of these firms is not addressed in the present discussion.

[35] Compaq Computer, interviews with USITC staff, Houston, TX, June 8, 1993; and Nomura Research Institute, interviews with USITC staff, New York, NY, Apr. 2, 1993.

[36] Mark Schlack, "The New IT Industry Takes Shape," *Datamation*, June 15, 1993, p. 85.

[37] Ibid., p. 83.

[38] Everex representative, telephone interview with USITC staff, Washington, DC, Aug. 8, 1993.

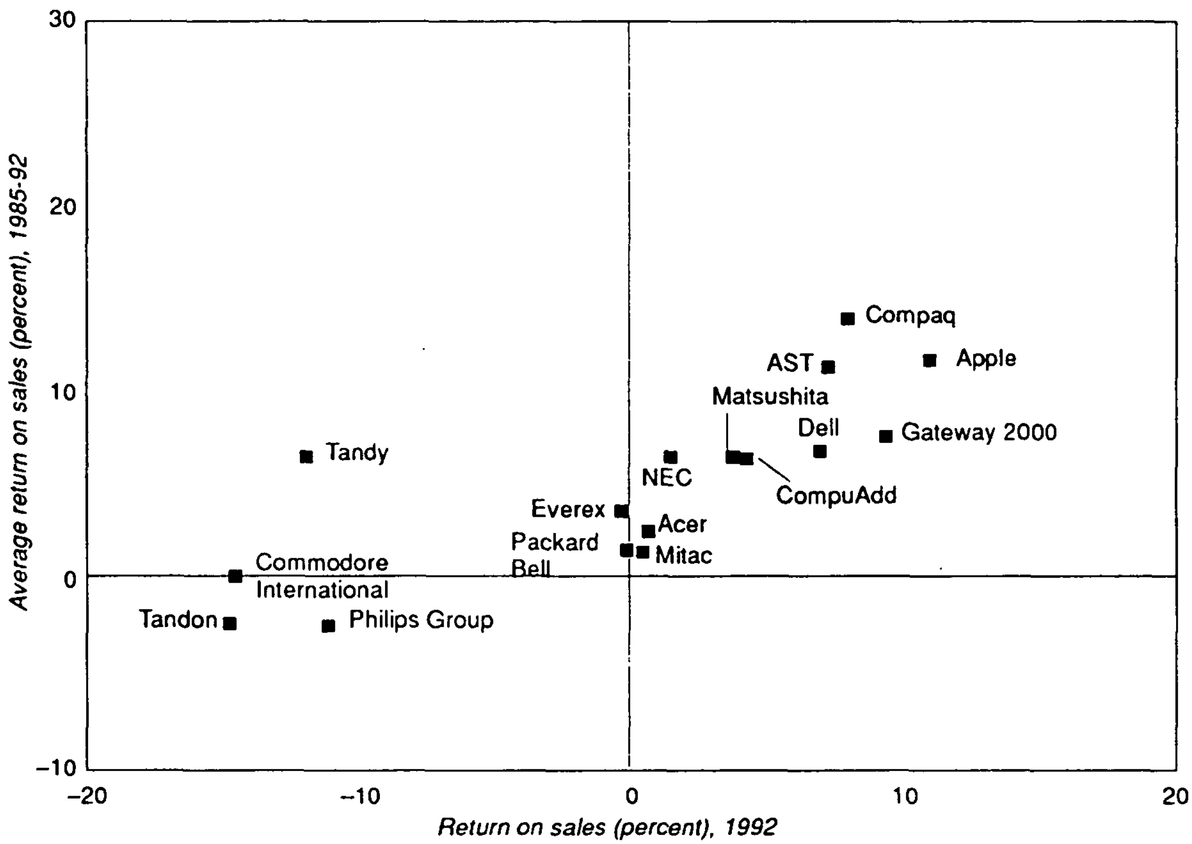
[39] Ibid.

[40] "Bull and Packard Bell Announce Strategic Alliance," *Press Release*, June 22, 1993, p. 1.

Table 4-1
Specific factors' effects on market share

Factor	Effect on market share	Statistical confidence level
Cost management programs	positive	99 percent
Marketing employees	negative	95 percent
Labor–saving manufacturing techniques	positive	not significant
Research and development programs	positive	not significant

Figure 4-5
Profitability of selected personal computer firms, 1985-92



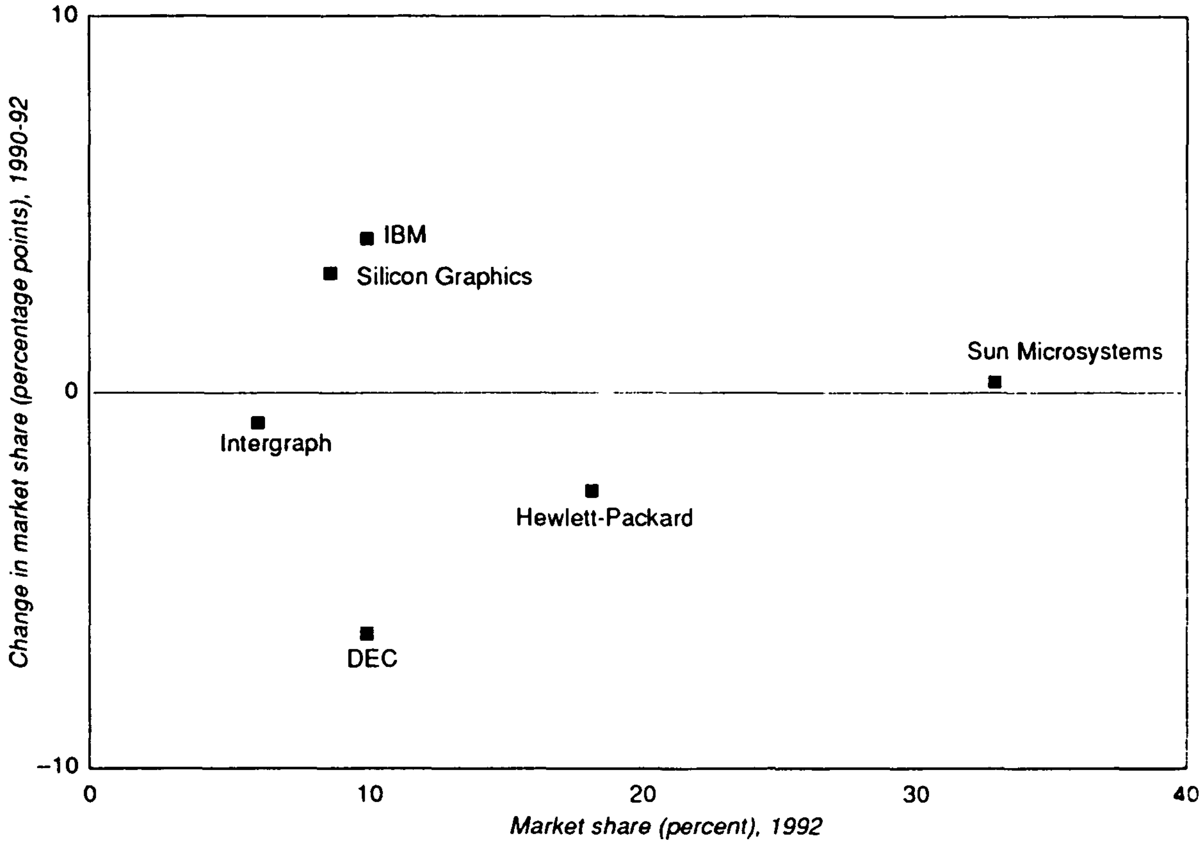
Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

18 percent of the global market. Its market share has declined slightly, by 2 percentage points, since 1990. Both DEC and IBM presently account for 10 percent of the global market, although the former has lost market share in recent years while the latter has increased its share.

A number of Japanese firms have attempted to compete in overseas markets, but have fared poorly. Oki and Sony exited the U.S. workstation market in 1992. Japanese firms reportedly lag behind U.S. counterparts in terms of microprocessor and operating system design. Japanese firms that appear most likely to compete successfully in the global workstation market are those acquiring or forming alliances with U.S. firms. Kubota acquired the hardware operations of U.S.-based Stardent in 1991,[41] while Fujitsu made

[41] Stardent, the result of a merger between Ardent Computer Corp. and Stellar Computer Corp., produces MIPS-based workstations.

Figure 4-6
Global workstation market share of selected firms, 1990-92



Source: International Data Corporation, as presented in "Last Year's model," *Economist*, May 29, 1993; and "Makers Plan More Powerful Machines," *Financial Times*, Apr. 23, 1991.

a 44 percent equity investment in Hal Computer Systems, a U.S. manufacturer of high-end workstations and minicomputers.[42] In the following year, Silicon Graphics agreed to exchange its three-dimensional graphics technology for NEC's mass-production technology.[43]

Workstation manufacturers compete principally in terms of price, processing power, and networking capabilities. Networking capabilities are enhanced by interoperable[44] or open systems[45] architecture. Factors that most significantly influence firms' ability to compete in these terms are R&D and alliances.

[42] "Fujitsu, Hal to Cooperate in Development of Commercial UNIX Systems," *Feedback From Fujitsu*, vol. 10, No. 4 (Autumn 1991), p. 6.

[43] U.S. Department of Commerce, *U.S. Industrial Outlook 1993*, p. 26-12.

[44] Interoperable systems are those that permit communication among computers with limited changes in hardware or software.

[45] Open systems permit communication among computers with essentially no changes in hardware or software, irrespective of the firms that manufactured the computers.

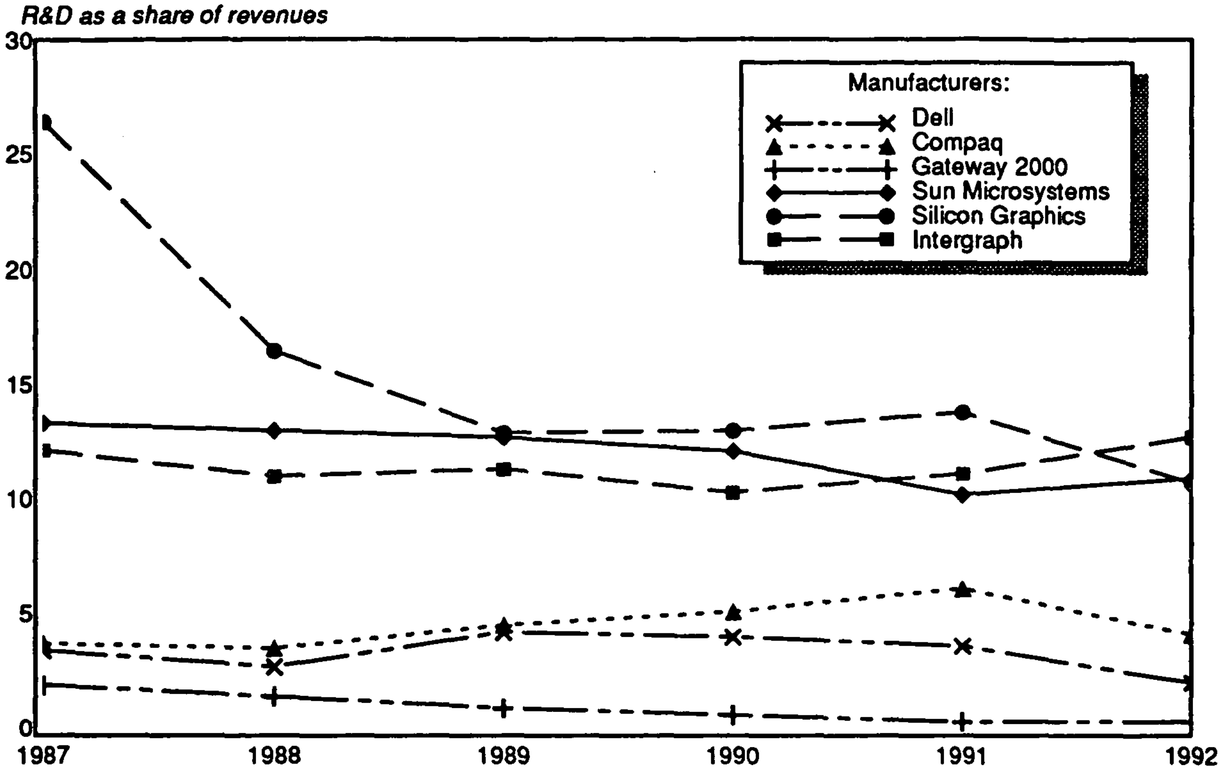
Alliances fall into two categories: those pertaining to designing and manufacturing RISC chips, and those pertaining to establishing open or interoperable operating systems.

Factors Influencing Competitiveness

Research and Development

Workstation specialists such as Sun Microsystems, Silicon Graphics, and Intergraph presently devote a much greater share of company revenues to R&D than do successful PC specialists such as Dell, Compaq, or Gateway 2000 (figure 4-7). Greater R&D spending among these firms and other workstation manufacturers is due, in part, to in-house development of RISC microprocessors and UNIX operating systems. In contrast to most PC manufacturers, which outsource microprocessors and operating systems,

Figure 4-7
Comparison of R&D spending by PC and workstation specialists, 1987–92



Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

workstation manufacturers have remained intimately involved in the design and production of these components. All predominant workstation manufacturers have developed proprietary RISC microprocessors and UNIX-based operating systems (table 4-2).

Table 4-2
Selected workstation microprocessor chips

Company	Chip
DEC	Alpha
Hewlett-Packard	Precision Architecture RISC (PA-RISC)
IBM	PowerPC
Silicon Graphics	MIPS
Sun	Scalable Processor Architecture (SPARC)

Source: Compiled by USITC staff.

Workstation manufacturers are competing vigorously to determine which microprocessors and operating systems will prevail. Noting the success of the firms that have maintained control over the most popular PC microprocessors and operating systems, Intel and Microsoft respectively, each workstation manufacturer appears to be determined to establish its proprietary components as the industry standard, or as one of a select few alternative standards. Firms that successfully establish their microprocessor or operating system as a predominant standard likely would be able to extract economic rents from competitors. The ability to collect such rents would bolster significantly the earnings of workstation manufacturers. It is expected that these firms ultimately will compete in a market that resembles the rapidly growing, but intensely competitive, PC market.

Workstation manufacturers' R&D programs have resulted in significant achievements, among the most notable of which is the development of RISC technology. U.S. workstation manufacturers' development and control of this technology underlie their strong competitive position in the global workstation market. RISC technology streamlines the instruction set interpreted by microprocessors, thereby increasing processing power. For instance, IBM and Motorola's RISC chip, named the PowerPC chip, reportedly processes information five times faster than does Intel's Pentium chip. RISC chips also are less expensive to produce than other microprocessors of comparable power, in part because they are smaller, allowing more chips to be fabricated from standard silicon wafers. The PowerPC chip sells for approximately $450,[46] less than half the price of Intel's Pentium chip, which sells for $965.

RISC technology has spillover benefits in all other computer hardware markets, helping firms like IBM, DEC, and Hewlett-Packard to compete in these markets. For instance, RISC microprocessors may be incorporated in PCs. IBM and Motorola have funded RISC R&D jointly to design and manufacture the PowerPC chip, which IBM and Apple will incorporate into workstations and PCs.[47] This alliance will enhance its participants' ability to compete against PCs based on Intel's new Pentium chip and Microsoft's new operating system, Windows NT. In addition, RISC microprocessors form the foundation of new parallel processing mainframes and new MPP supercomputers (see sections in this chapter on Mainframe and Minicomputer Manufacturers and Supercomputer Manufacturers).

Strategic Alliances

U.S. workstation manufacturers have formed strategic alliances among themselves and with other firms to enhance their competitive positions. There are two types of alliances, those formed around RISC microprocessors, and those formed around operating systems. Each firm has entered into these alliances to promote its microprocessors or operating systems as a predominant industry standard.

Microprocessor alliances

Workstation manufacturers have formed alliances with premier chip manufacturers to improve the design and production of RISC microprocessors, and to increase production volume (table 4-3). Sun Microsystems, for instance, has relied principally on Texas Instruments and Fujitsu for its SPARC chip.[48]

Table 4-3
Selected workstation microprocessor alliances

Companies	Product
DEC, MIPS Computer Systems	MIPS chip
Hewlett-Packard, Hitachi	PA-RISC chip
IBM, Apple, Motorola	PowerPC chip
Silicon Graphics, MIPS Computer Systems	MIPS chip
Sun Microsystems, Texas Instruments	Super-SPARC chip

Source: Compiled by USITC staff.

Silicon Graphics and DEC traditionally have relied on MIPS Computer Systems for their chips,[49] although DEC recently formed a partnership with Mitsubishi to produce the Alpha chip.[50] Recently, Hewlett-Packard entered an alliance with Hitachi to manufacture the PA-RISC chip,[51] and IBM formed a partnership with Motorola to manufacture the PowerPC chip.

U.S. workstation manufacturers have licensed RISC technology to allied firms to increase production volumes. In many cases, this technology has been licensed to foreign firms. Sun Microsystems has been most aggressive in terms of licensing its RISC chip. In 1991, 8 percent of all SPARC-based systems were produced by firms other than Sun Microsystems.[52] By 1992, SPARC technology had been licensed to over 40 clone manufacturers.[53] Asian firms have been some of the principal beneficiaries of this licensing strategy (figure 4-8). Fujitsu, Toshiba, Hitachi, NEC, and Acer (Taiwan) recently entered the global market with low-end workstations, designed primarily for commercial applications rather than design and engineering.[54]

Operating system alliances

Until recently, workstation manufacturers sold computers that featured largely incompatible, proprietary operating systems. Most or all of these were variants of the UNIX operating system commercialized by AT&T in the late 1970s, and purchased by Novell, Inc. in June 1993 (table 4-4).[55] Firms adopted proprietary versions of UNIX to differentiate their workstations and, consequently, increase profitability.

Table 4-4
Workstation manufacturers and Unix versions

Firms	Proprietary Unix version
DEC	Ultrix
Hewlett-Packard	HP-UX
IBM	AIX
Silicon Graphics	IRIX
Sun Microsystems	Solaris

Source: "Product Spotlight," *Computerworld*, Mar. 23, 1992.

[46] Tom Thompson, "PowerPC Performs for Less," *Byte*, Aug. 1993, p. 56.
[47] U.S. industry representatives, interviews with USITC staff, Mountain View, CA, and Austin, TX, Apr. 15, 1993 and June 10, 1993.
[48] Sun Microsystems, Inc. Securities and Exchange Commission Form 10-k, June 30, 1993, p. 7.
[49] Silicon Graphics purchased MIPS Computer Systems when MIPS fell into financial difficulties in 1992.
[50] Melinda-Carol Ballou, "DEC Names Second Source for Alpha," *Computerworld*, Mar. 22, 1993, p. 2.
[51] Bob Johnstone, "Take Your Partners," *Far Eastern Economic Review*, Dec. 17, 1992, p. 56.
[52] International Data Corp. information as presented in "Life Just Got Easier for Sparc Clone Makers," *Electronics*, July 13, 1993, p. 46.
[53] Maryfran Johnson, "Sun Sets Out to Rise Again," *Computerworld*, Apr. 13, 1992, p. 20.
[54] Ibid., p. 22.
[55] "Novell Completes USL Acquisition, Gains in Market," *Network World*, June 21, 1993, p. 23.

Figure 4-8
Competing RISC alliances

DEC	Hewlett-Packard	IBM	Silicon Graphics	Sun Microsystems
• Cray	• Convex	• Apple	• Acer	• Amdahl
• Kubota	• Hitachi	• Groupe Bull	• NEC	• Control Data
• Mitsubishi	• Mitsubishi	• Motorola	• Toshiba	• Cray
	• Oki			• Fujitsu
	• Prime			• NEC
	• Samsung			• Solbourne
	• Sequoia			• Toshiba
				• Unisys

Source: USITC staff and Jagannath Dubash and Robert Wrubel, "Do or Die," *Financial World*, May 12, 1992, p. 21.

Demand for interoperable and open systems has resulted in the formation of many operating system alliances, three of which appear to be the most resilient (figure 4-9). Some firms have joined more than one alliance to enhance their competitive position. DEC, Hewlett-Packard, and IBM formed the Open Software Foundation (OSF) in 1988. The OSF has successfully developed a unified version of UNIX, called OSF/1, which is compatible with the various RISC chips manufactured by its three founding firms (table 4-5). OSF was created to compete with UNIX International, an early alliance between Sun Microsystems and AT&T to develop a standard UNIX operating system around Sun Microsystems' RISC chip (SPARC).

The Advanced Computing Environment (ACE) initiative was established in 1991. DEC, Silicon Graphics, and Microsoft are the principal backers of the ACE initiative, but it includes approximately 200 other hardware and software vendors. The ACE initiative is developing two UNIX operating systems. These systems will feature nearly identical interfaces for applications software and will interoperate with Microsoft's Windows NT operating system for PCs. One of the UNIX operating systems supported by ACE is based on the Open Systems Foundation's OSF/1 standard. ACE operating systems function equally well on MIPS microprocessors and Intel 386 and 486 microprocessors. In addition, ACE operating systems require only limited hardware changes for installation on PCs, facilitating greater interoperability among all desktop machines.[56]

[56] Lee The, "Workstations: Choosing an ACE OS," *Datamation*, Apr. 1, 1992, pp. 40-41.

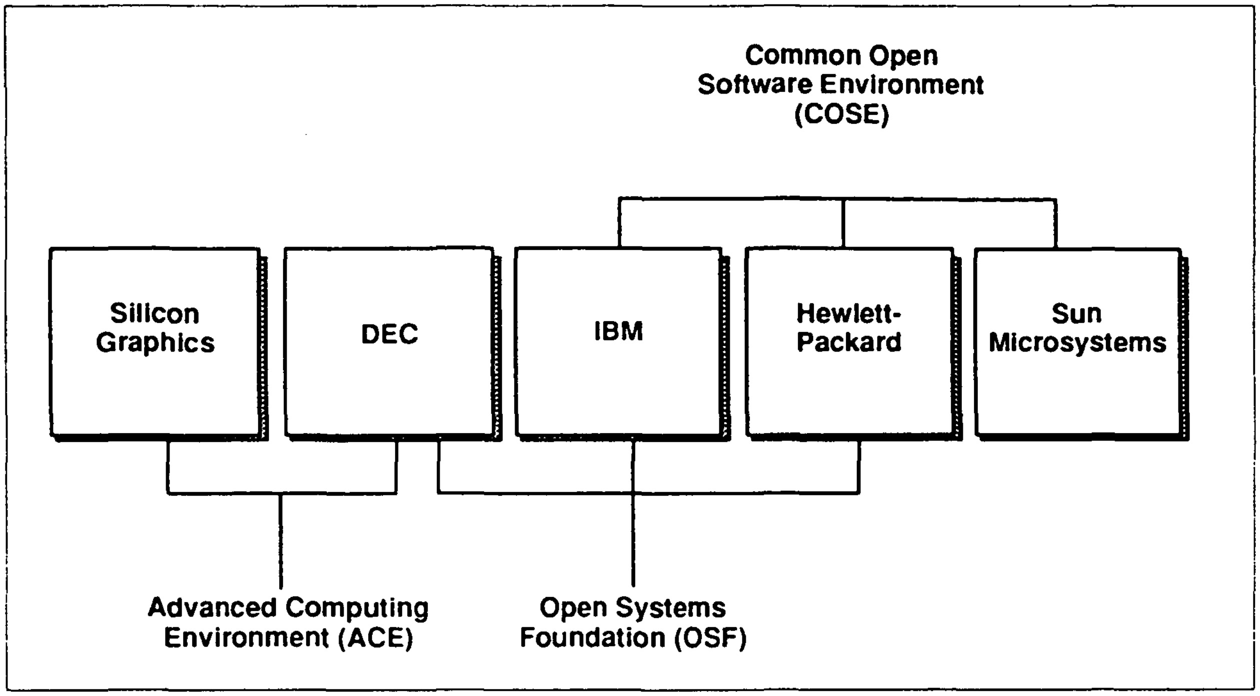
The Common Open Software Environment (COSE) emerged in March 1993. Its principal members are Sun Microsystems, Hewlett-Packard, and IBM, which are the three largest workstation manufacturers. COSE is attempting to design a single "look and feel" for these firms' proprietary versions of UNIX — Solaris, HP-UX, and AIX — by implementing common application programming interfaces (APIs), networking protocols, and object, graphics, and multimedia standards.

In October 1993, it appeared that COSE's adoption of common applications programming interfaces progressed when Novell initiated an agreement to transfer a common set of 1,170 APIs and the UNIX trademark to X/Open Co., a standards-setting body comprising COSE members and 11 other firms. Adoption of common APIs would allow consumers to operate the same applications software on workstations that are manufactured by different firms. However, the ultimate impact of the agreement is presently unclear. X/Open will not be able to certify compatibility with UNIX until late 1994. In addition, members of X/Open may continue to combine common interfaces with proprietary interfaces in order to boost sales of existing machines and applications software.[57]

Hewlett-Packard, IBM, and DEC presently appear to be most dependent on software alliances. Each firm is involved in two of the three open systems or

[57] Jean Bozman, "Novell Transfers Unix Trademark to X/Open," *Computerworld*, Oct. 18, 1993, p. 12; and Elisabeth Horwitt, "Novell to Move UnixWare to Fore," *Computerworld*, Sept. 27, 1993, p. 14.

Figure 4-9
Operating system alliances



Source: Compiled by USITC staff.

Table 4-5
Selected workstation operating systems software alliances

Firms	Alliance	Objective
Hewlett-Packard, IBM, and DEC	Open Software Foundation (OSF)	One unified UNIX version
DEC, Microsoft, and Silicon Graphics	Advanced Computing Environment Initiative	Two similar UNIX versions, interoperable with Windows NT
Sun Microsystems, Hewlett-Packard, and IBM	Common Open Software Environment (COSE)	Greater interoperability

Source: Compiled by USITC staff.

interoperability initiatives. These firms, which manufacture a broad range of computers, appear to be using alliances to develop workstation operating systems that closely resemble their mainframe and minicomputer operating systems. A close resemblance among operating systems would reduce the costs associated with moving from larger systems to workstations, providing large corporate customers with a natural migration path as they downsize computer platforms. DEC was the first firm able to ship workstations conforming to the open OSF/1 operating system.[58]

[58] "RISC Workstations Under $10,000," *Computerworld*, Mar. 23, 1992, p. 17.

Sun Microsystems and Silicon Graphics are least dependent on operating system alliances. These firms produce few or no mainframes and minicomputers, and therefore are not obligated to provide present customers with operating system migration paths. Moreover, Sun Microsystems' dominant market share position, and the wide use of Sun Microsystems' microprocessor and operating system by clone manufacturers, may present Sun Microsystems with the opportunity to establish a *de facto* standard designed around its SPARC microprocessor and its proprietary version of UNIX, Solaris. Sun Microsystems' architecture is most attractive to customers who value processing power over price and networking capabilities. Proprietary systems currently feature more rapid processing speeds than do open systems.

Outlook

Global workstation sales generally are forecasted to grow rapidly, by as much as 30 percent per annum, during the next 3-5 years. U.S. workstation manufacturers' sales are likely to expand both at home and abroad, although competition from Japanese clone manufacturers may reduce prices on low-end workstations.

The six largest workstation manufacturers are likely to remain in the workstation market. Larger firms such as IBM, DEC, and Hewlett-Packard will increasingly focus on the workstation market as they de-emphasize mainframe and minicomputer operations. Sun Microsystems, Silicon Graphics, and Intergraph appear equally committed to the workstation market, and their workstation businesses generally have been profitable, although Silicon Graphics posted a substantial loss in 1992 (figure 4-10). Sun Microsystems and Intergraph averaged return on sales of approximately 10 percent during 1985-92.[59]

A number of factors suggest that the workstation market ultimately will resemble the intensely competitive PC market. Workstations and PCs, which are increasingly close substitutes for one another in terms of price and performance, will compete more intensely in the future. In addition, product differentiation among workstations is likely to decrease as clones are introduced and interoperable or open systems are engineered. In this environment, it is likely that price competition will intensify, and that the importance of cost management will increase. Workstation specialists such as Sun Microsystems, Intergraph, and Silicon Graphics appear best positioned to compete in a price-sensitive market because they have overall lower cost structures than horizontally-integrated competitors.

Mainframe and Minicomputer Manufacturers

Introduction

The downsizing of computer platforms has severely challenged giant computer firms such as IBM, DEC, Unisys, Fujitsu, and Hitachi, for which mainframes and minicomputers traditionally have been the source of steady profit. The effects of computer platform downsizing are most apparent in the United States, where the transition to client-server technologies has proceeded most rapidly.

Although the installed base of mainframes and minicomputers is likely to decrease in the future, these machines will continue to serve a number of functions. Mainframes will continue to be used in so-called "mission critical" applications, which require high volume, on-line processing, security, and reliability. In addition, mainframes and minicomputers increasingly will be used as large file servers and database managers in client-server relationships.

Since the computer industry's inception, U.S. firms have held a favorable competitive position in the mainframe and minicomputer segment. In large part, this is due to IBM's predominance. IBM's success is inextricably linked with its control of proprietary mainframe architectures, on which many other firms like Amdahl (United States), Fujitsu, and Hitachi have based their computers.[60] Since the introduction of IBM's System 360 and its successors in the 1960s and 1970s, IBM has controlled an overwhelming share of the global mainframe market. Despite falling by 11 percentage points during 1985-92, IBM's share of the global mainframe and minicomputer market stood at an estimated 34 percent in 1992. This is more than twice the market share of its leading competitor, Fujitsu (figure 4-11).

IBM's declining market share largely reflects the increasing global competitiveness of firms making IBM-compatible machines, particularly Fujitsu and Hitachi.[61] The market position of Japanese mainframe and minicomputer suppliers improved appreciably between 1985 and 1992. Fujitsu increased its share of the global mainframe and minicomputer market to an estimated 13 percent by 1992, an increase of almost 8 percentage points over the corresponding 1985 figure. Other firms experiencing growth during 1985-92 were Hewlett-Packard, which contends vigorously with Hitachi to remain the third largest firm in this market, and Siemens-Nixdorf. Siemens-Nixdorf is the only European firm that has increased its share of the global mainframe and minicomputer market in recent years.

Manufacturers of mainframes and minicomputers compete principally in terms of processing power and price. Manufacturers of these computers are under immense pressure to increase processing power while

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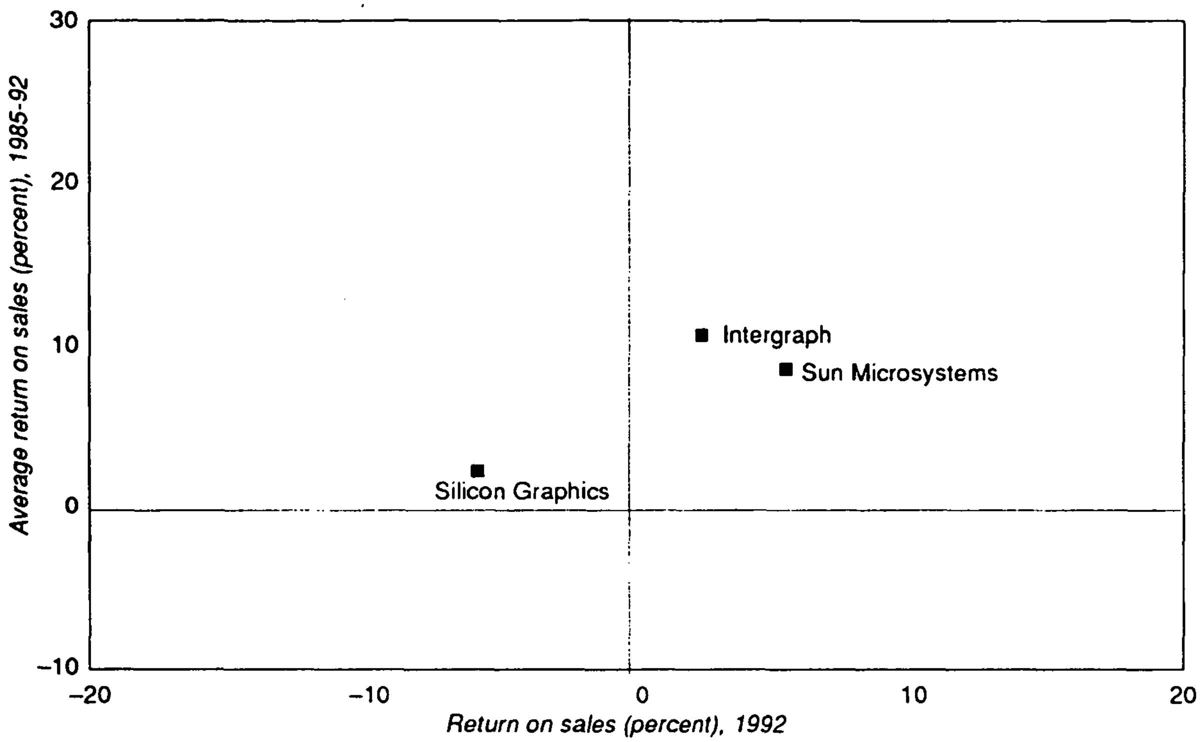
[59] IBM, DEC, and Hewlett-Packard derive most hardware revenue from sales of mainframes and minicomputers. Data on company-wide profitability is not a useful indicator of these firms' long-term competitiveness in the global workstation market.

[60] Charles H. Ferguson and Charles R. Morris, *Computer Wars* (New York: Random House, 1993), pp. 3-29.

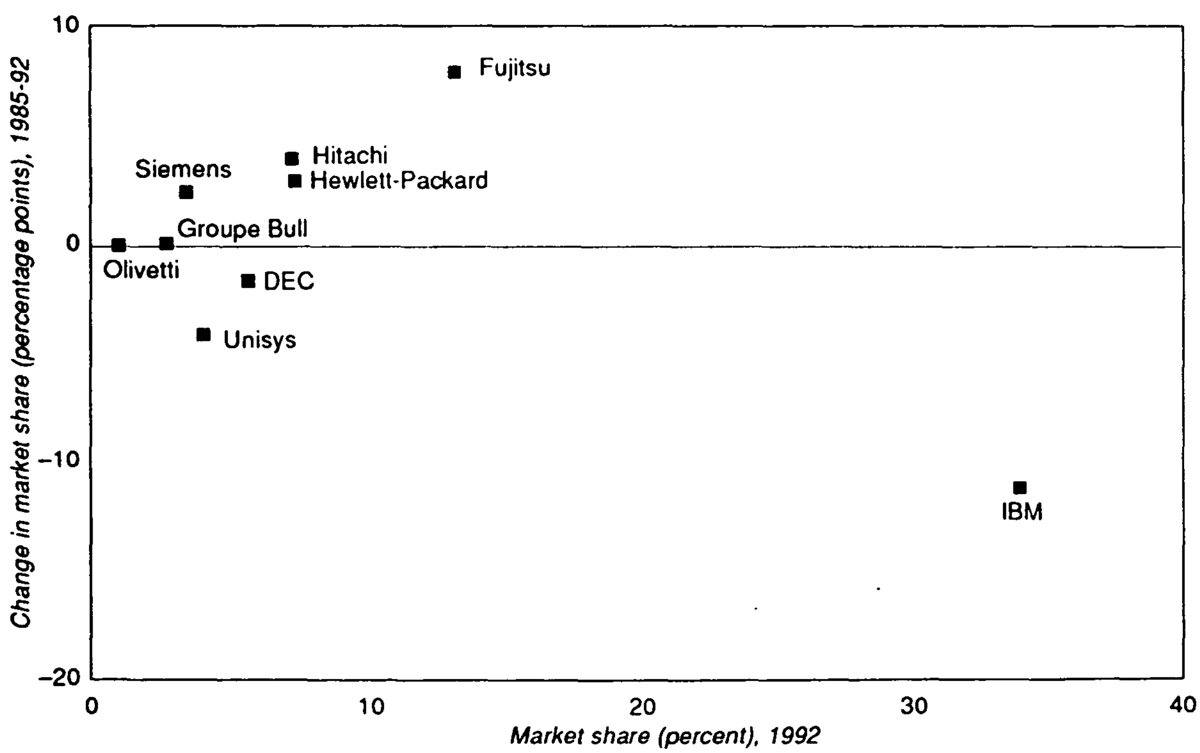
[61] Most of the decline in IBM's segment market share actually occurred between 1985 and 1987, when global mainframe and minicomputer revenues grew rapidly. IBM's share of the global mainframe and minicomputer market declined by about 1 percentage point between 1987 and 1992.

Figure 4-10
Profitability of selected workstation firms, 1985-92



Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

Figure 4-11
Global mainframe and minicomputer market share of selected firms, 1985-92



Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

reducing price, both to compete with one another and to differentiate mainframes and minicomputers from increasingly powerful networks of PCs and workstations. Factors that most significantly influence firms' ability to compete in terms of processing power and price are R&D programs and cost management programs.

Factors Influencing Competitiveness

Research and Development

In 1992, the 10 largest mainframe and minicomputer suppliers each directed between $500 million and $6.2 billion toward research and development, representing about 10 percent of revenues on average.[62] Significant improvements in processing power and price have resulted from R&D expenditures. The least expensive mainframes available today feature processing speeds of 50 million instructions per second (MIPS), nearly three times as powerful as mainframes on the market 5 years ago.[63] Table 4-6 shows the declining price of processing power available on IBM's largest mainframes.

Parallel processing

To increase processing power and reduce prices, manufacturers are developing advanced parallel processing technology. This technology will be used with RISC microprocessors, which originally were designed for workstations. Mainframes and minicomputers designed around RISC chips are less expensive than traditional machines because RISC microprocessors are produced in far greater volumes at lower cost than typical computer processors.

Several U.S. firms currently are designing and commercializing product lines of parallel processing computers around proprietary RISC chips, hundreds of which may be incorporated into a single mainframe. DEC, for example, has responded to lagging demand for its VAX minicomputers by designing a broad range of computers around the newly released Alpha RISC microprocessor.[64] IBM, on the other hand, is designing a new family of mainframes and minicomputers around the PowerPC RISC chip.[65]

[62] Gartner Group, *Yardstick: Top 100 Worldwide*, 1993, p. XIV-18.

[63] U.S. Department of Commerce, *U.S. Industrial Outlook 1993*, p. 26-9.

[64] Industry analyst, interviews with USITC staff, New York, NY, Aug. 27, 1992.

[65] Robert Scheier, "IBM Fine-Tunes Mainframe Strategy," *PC Week*, Feb. 15, 1993.

Fujitsu, too, is designing new products around the RISC chip technology licensed to it by Sun Microsystems. Fujitsu owns 44 percent of both Amdahl and Hal Computer Systems, and 80 percent of the United Kingdom's International Computers Limited (ICL). These firms are developing computers based on the SPARC chip for the U.S. and European markets. ICL currently sells SPARC-based mainframes and minicomputers as servers in Europe, and Fujitsu has set up a global marketing group to sell ICL machines under its own name.[66]

R&D programs to design RISC-based parallel processing mainframes and minicomputers are complemented by programs designed to increase the power of RISC chips. Currently employed complementary metal oxide silicon (CMOS) technology allows firms to manufacture chips with elements that measure about 3 microns (millionths of a meter) wide.[67] Ongoing research on bipolar CMOS would allow manufacturers to produce more powerful chips with elements that measure less than one micron across. In 1991, IBM demonstrated a technology that in the distant future would allow firms to manufacture chips with elements measured in nanometers (billionths of a meter), more than 1,000 times smaller than today's circuits.

In addition, firms are currently investigating the feasibility of producing chips out of gallium arsenide and indium phosphide, materials that have better electronic properties than silicon.[68] Due to its longstanding presence in the semiconductor market, Fujitsu may be well ahead of U.S. firms in terms of its ability to produce gallium arsenide chips. Fujitsu already uses gallium arsenide chips in certain computer peripherals, and reportedly has several research programs that focus on the eventual transition from silicon to gallium arsenide.[69]

Open systems

Manufacturers of mainframes and minicomputers also are conducting research to develop new operating systems. These operating systems will need to be sufficiently advanced to control parallel processing mainframes and minicomputers. Furthermore, new operating systems must be open if mainframes and minicomputers are to act as servers in client-server networks.

[66] Bob Johnstone, "A Moment to Seize," *Far Eastern Economic Review*, Jan. 1992, p. 38.

[67] Amdahl, interviews with USITC staff, Sunnyvale, CA, Apr. 16, 1993.

[68] U.S. Department of Commerce, *U.S. Industrial Outlook 1992*, p. 16-3.

[69] Although Fujitsu is optimistic about the future use of gallium arsenide (GaAs), many experts do not expect GaAs to replace silicon as the leading semiconductor material. GaAs is much faster than silicon, but much more expensive. Peter Van Zant, *Microchip Fabrication* (New York: McGraw-Hill, 1990), p. 33; and David K. Kahaner and Ulrich Wattenberg, "Japan: A Competitive Assessment," *IEEE Spectrum*, Sept. 1992, p. 43.

Table 4-6
Estimated sales price, processing power, and price per MIPS of IBM's largest mainframes, 1985-92

Year	Estimated sales price	Processing power	Estimated price per MIPS
	(Thousand dollars)	*(MIPS)*	*(Thousand dollars)*
1985	4,887	27	181
1986	5,608	36	156
1987	6,435	49	131
1988	7,384	66	112
1989	8,473	90	94
1990	9,723	121	80
1991	11,158	163	68
1992	12,803	221	58

Source: Xephon Mainframe Market Monitor, as presented in Ned Snell, "Making the Best Mainframe Deal," *Datamation*, Sept. 1, 1992.

Although the transition to open operating systems is widely expected to take 5-10 years, a number of firms have made significant strides. DEC and Hitachi have developed OSF/1 operating systems, based on UNIX, for recent product lines.[70] DEC also has modified its proprietary VMS operating system to conform to POSIX and Motif, internationally recognized open systems standards. DEC calls this system Open VMS.[71] Likewise, IBM has modified the AIX operating system, its proprietary version of UNIX, to facilitate interconnection with other UNIX systems. IBM's UNIX-compatible system is called the Advanced Interactive Executive/Enterprise System Architecture (AIX/ESA).[72] In fact, IBM has made on-line transaction processing available on AIX/ESA to enable interoperability and source code compatibility with IBM's proprietary mainframe operating systems, creating a channel through which its mainframe customers can downsize their computer platforms.[73]

Cost Management Skills

Price competition from increasingly powerful networks of PCs and workstations has reduced profit margins for the leading mainframe and minicomputer makers, forcing all of these firms to find new means to control costs. For high-end hardware suppliers worldwide, aggregate gross profit margins fell from 47 percent in 1987 to 41 percent in 1992. For certain firms, the deterioration of profit margins has been striking. At DEC, for example, gross profit margins fell from an estimated 53 percent in 1987 to 40 percent in 1992.[74] To protect existing margins, many firms in the segment have been forced to reduce production costs significantly.[75] To date, firms principally have reduced costs by trimming workforces.

Sales and marketing employment

In particular, firms have focused on trimming sales, general, and administrative (SG&A) expenses. At IBM, DEC, Groupe Bull, and Siemens-Nixdorf, SG&A expenses as a percentage of total revenues consistently have run higher than the industry average, rising to more than 35 percent of revenue in some cases. At IBM, SG&A expenses increased dramatically during 1987-91, from $15.9 billion to $20.4 billion, but declined to $18.5 billion in 1992.[76] SG&A expenses at Fujitsu, NEC, and Hitachi increased between 1987 and 1992, although SG&A expenses accounted for less than 25 percent of revenues at each firm. Stubbornly high SG&A costs are principally the result of reliance on large direct sales forces.

To reduce SG&A costs, many companies have devised restructuring plans to decrease employment in sales and marketing (figure 4-12). IBM and Unisys began to reduce sales and marketing employment in 1988, and were followed by DEC in 1992.[77] During 1988-92, IBM and Unisys reduced sales and marketing employment by 25 percent and 39 percent, respectively.

[70] Jean S. Bozman, "HDS Users Ponder Plans for Unix Server, Host Links," *Computerworld*, May 3, 1993, p. 89.

[71] Nomura Research Institute America, Inc. (NRI), *Digital Equipment Corp.: Still A Rocky Road to Recovery*, Sept. 22, 1992, p. 11.

[72] NRI, *IBM Corporation: Is There a Light at the End of the Restructuring Tunnel*, Aug. 27, 1992, pp. 10-11.

[73] On-line transaction processing has historically required mainframes and is just recently beginning to move toward smaller hardware platforms. "Vendors Scramble to Support Open OLTP," *Datamation*, Sept. 15, 1993, p. 67.

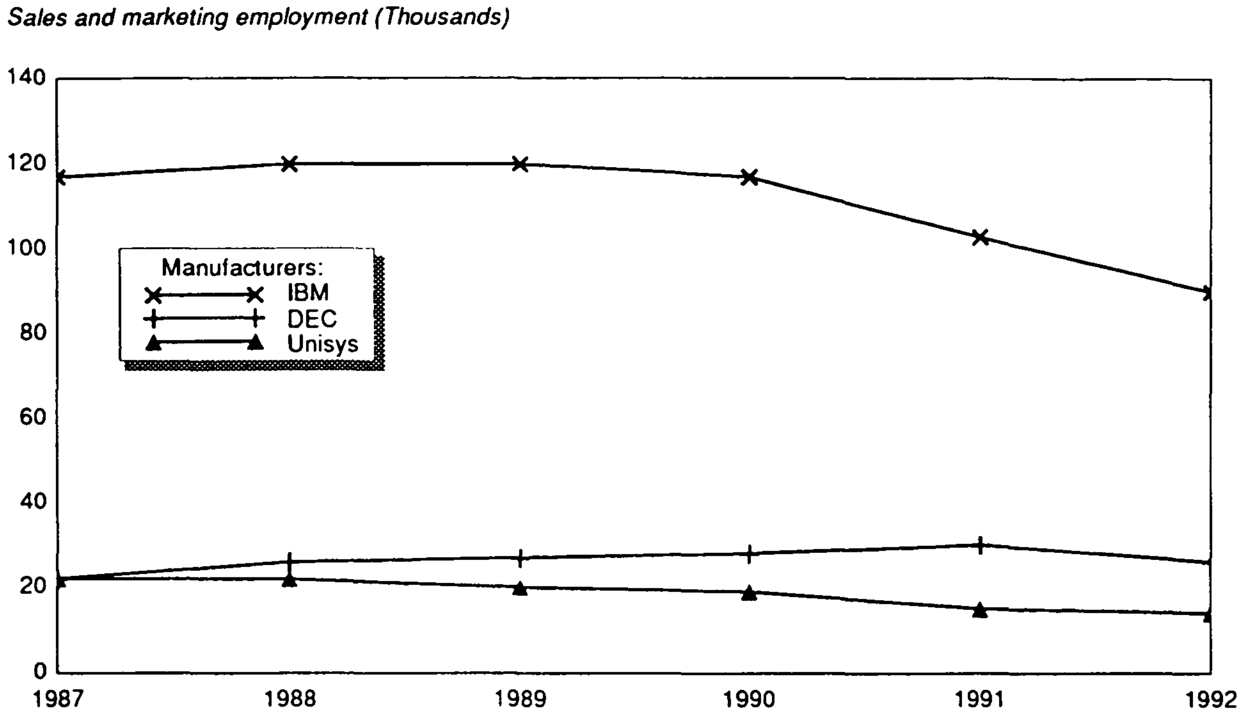
[74] Gartner Group, *Yardstick: Top 100 Worldwide*, 1993, p. V-8; and Gartner Group, *Yardstick: Top 100 Worldwide*, 1992, p. V-8.

[75] NRI, interviews with USITC staff, New York, NY, Apr. 2, 1993.

[76] Gartner Group, *Yardstick: Top 100 Worldwide*, 1993, p. VI-4; and Gartner Group, *Yardstick: Top 100 Worldwide*, 1992, p. VI-4.

[77] Industry analyst, interview with USITC staff, New York, NY, Apr. 2, 1993.

Figure 4–12
Sales and marketing employment of selected U.S. firms, 1987–92



Source: Gartner Group, *Yardstick: Top 100 Worldwide,* 1993.

In contrast to U.S. and most European firms, Japanese firms are continuing to increase sales and marketing employment (figure 4-13). This is largely due to the lag in computer platform downsizing in the Japanese market, where Japanese firms derive the majority of their sales. Fujitsu, Hitachi, and NEC have not had to reduce staffing because they only recently have experienced competition from low-priced, high-performance networks in their home market.[78]

Production employment

Similar trends are evident with respect to manufacturing employment. IBM reduced manufacturing employment by 22 percent during 1987-92 (figure 4-14). DEC and Unisys initiated similar restructuring a year later. By 1992, DEC and Unisys had eliminated 34 percent and 51 percent of manufacturing jobs, respectively. In contrast, Japanese firms have yet to reduce their manufacturing workforces, although employment at Fujitsu seemed to reach a plateau in 1992 (figure 4-15).[79]

Outlook

U.S. firms, accounting for 64 percent of global mainframe and minicomputer revenues, continue to enjoy a strong competitive position in the global market. Despite a decline in IBM's market share since 1985, the firm accounts for approximately one-third of all mainframe and minicomputer sales. The next largest competitor, Fujitsu, accounts for only 13 percent of global sales in the market segment. In addition, other U.S. firms such as Hewlett-Packard, DEC, and Unisys rank among the largest firms in this market.

Global sales of mainframes and minicomputers are forecasted to decline by another 2 percent in 1994.[80] Thereafter, sales may level off as these systems increasingly perform as file servers for large computer networks. Sales of mainframes and minicomputers likely will remain strongest in Japan over the short term, due to the relatively recent appearance of computer platform downsizing in that country.

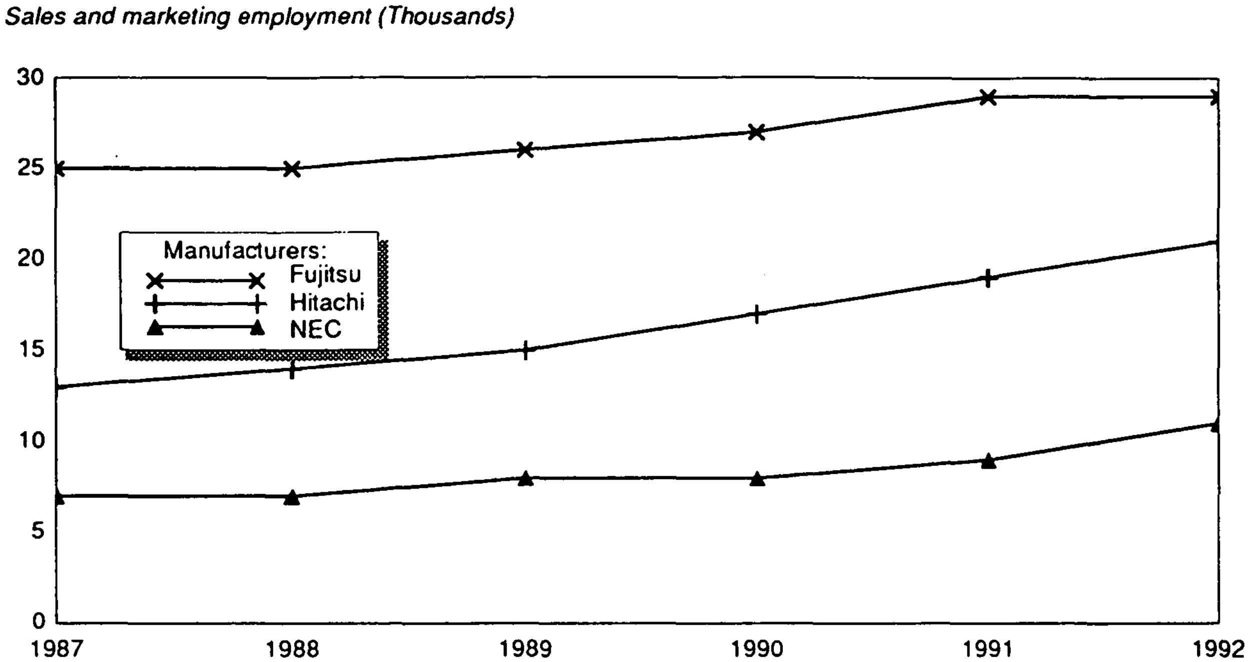
Almost all firms that compete in the global mainframe and minicomputer market presumably will depend less on this segment over the long term. Profit margins likely will continue to narrow, and revenues

[78] Gartner Group, *Yardstick: Top 100 Worldwide,* 1993, p. XII-6.

[79] Fujitsu says it plans to hire only 300 new college graduates in 1994, down from a record 4,000 in 1991. Comtex Scientific Corp., NewsEDGE/LAN, Mar. 9, 1993.

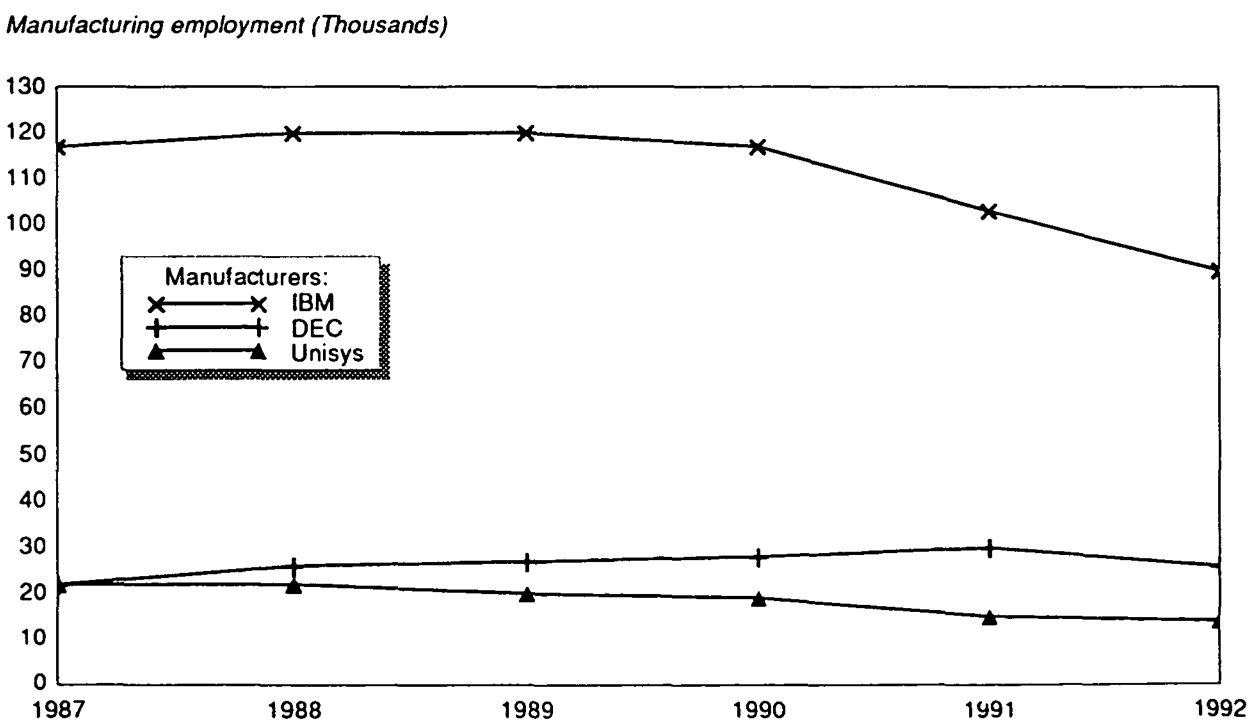
[80] Gartner Group, *Yardstick: Top 100 Worldwide,* 1993, p. III-10.

Figure 4–13
Sales and marketing employment of selected Japanese firms, 1987–92



Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

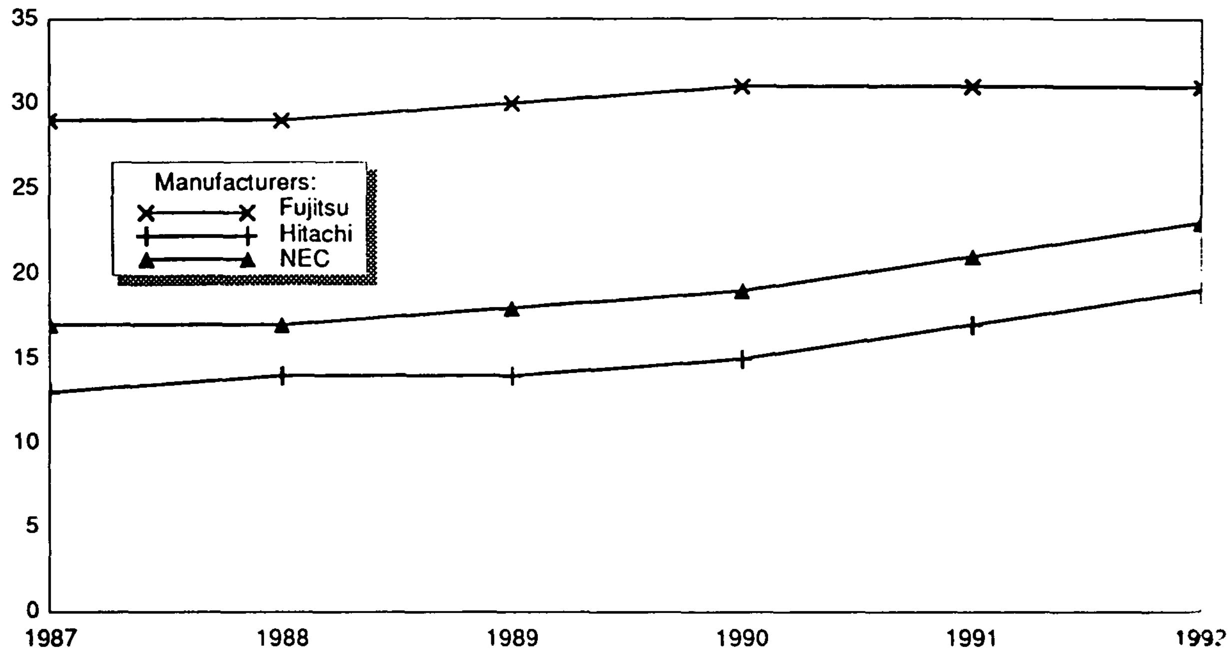
Figure 4–14
Manufacturing employment of selected U.S. firms, 1987–92



Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

Figure 4–15
Manufacturing employment of selected Japanese firms, 1987–92

Manufacturing employment (Thousands)



Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

likely will decline. Groupe Bull may exit this market altogether in the long term (figure 4-16) since it has generated little or no profit in this market for 8 years.

Whether or not other predominant manufacturers will continue to participate in this market over the long run is more difficult to assess on the basis of profitability. Despite IBM's losses in 1992, its average profitability during the 1985-92 period is unsurpassed by comparable firms. Hewlett-Packard also has performed well on average. High average profitability suggests that these two firms are best capable of sustaining a long-term presence in the mainframe and minicomputer market.

Supercomputer Manufacturers

Introduction

Five of the eight largest global supercomputer producers are U.S. firms (figure 4-17). Cray Research currently holds the largest share of the global market with 1991 revenues of $649 million. However, increased competition has caused Cray Research's market share to decline sharply in recent years, from an estimated 48 percent in 1987 to 37 percent in 1991.[81]

A significant share of the global market has been lost to other U.S. firms, namely Intel and Thinking Machines; these companies are innovators in MPP supercomputers. The advent of MPP supercomputing is intensifying price competition in the global market and challenging traditional vector supercomputer manufacturers, such as Cray Research, Convex, IBM, Fujitsu, NEC, and Hitachi, to alter competitive strategies. In fact, in September 1993, Cray introduced its first MPP machine, the Cray T3D, which is designed to work with its traditional vector supercomputers to achieve higher theoretical processing speeds than other, stand-alone MPP machines. Although MPP manufacturers currently account for a small percentage of the total market, they are expected to grow more quickly than established supercomputer manufacturers. It has been estimated that sales of MPP systems grew by nearly 20 percent during 1993.[82]

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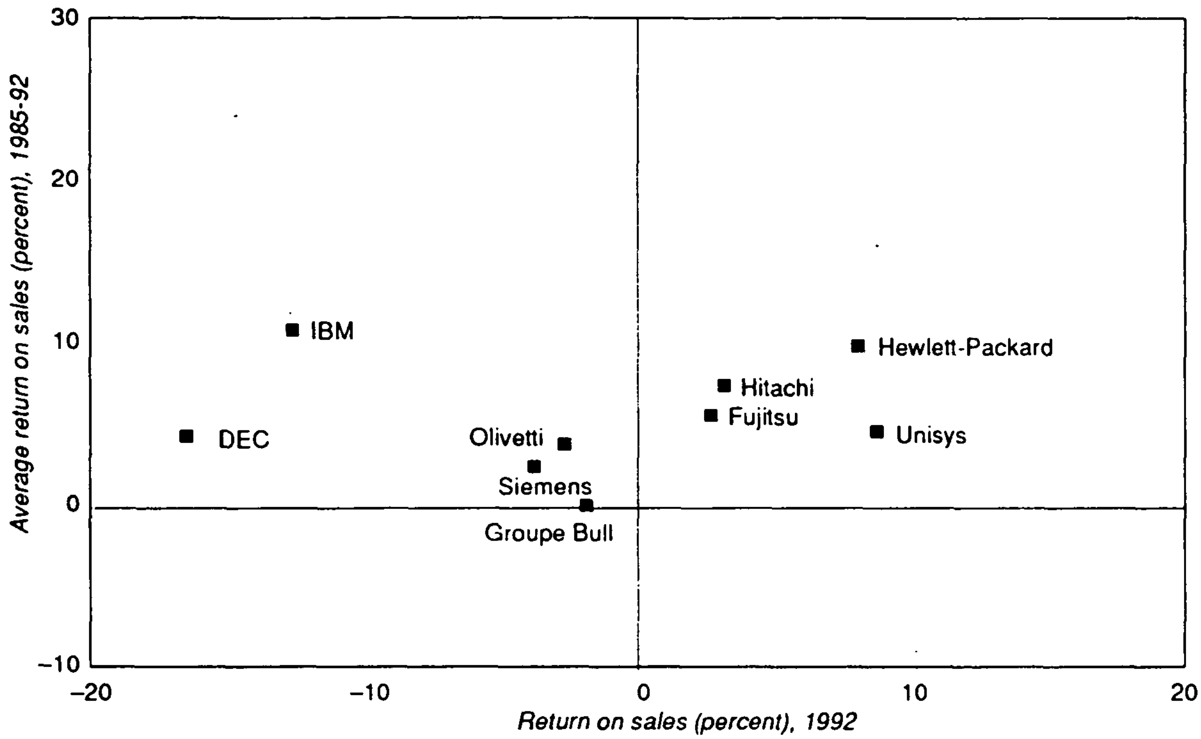
[81] USITC staff estimates.

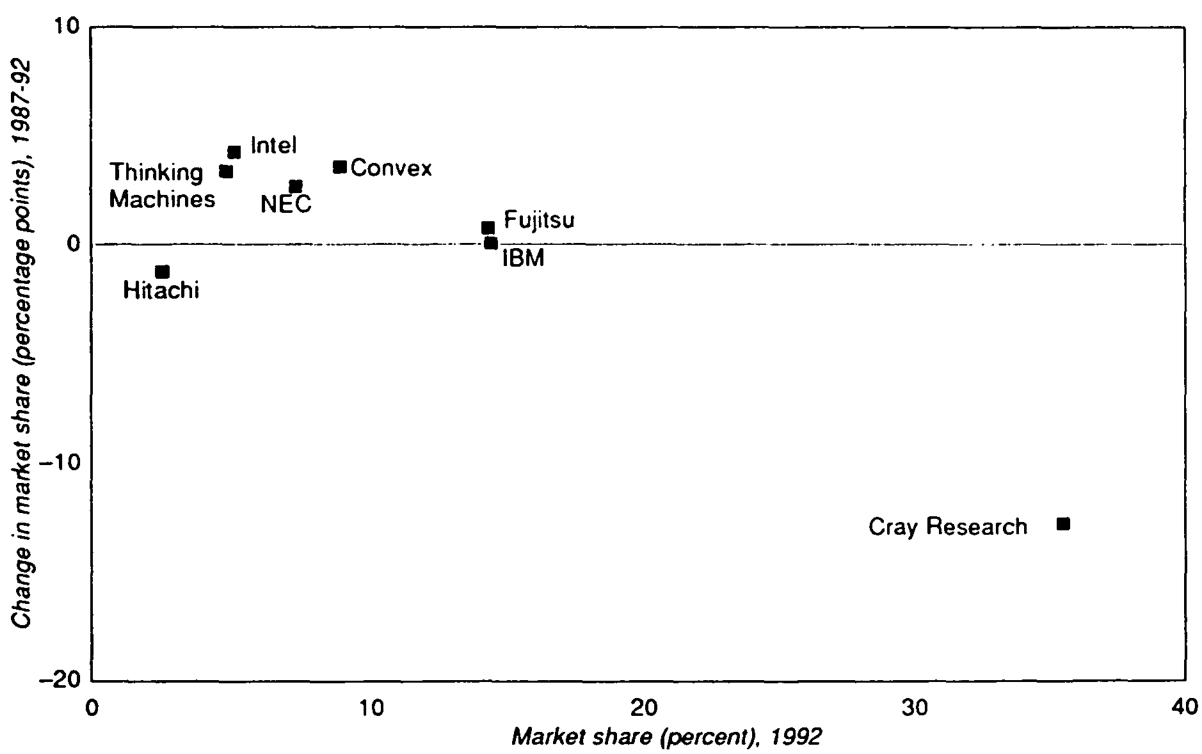
[82] U.S. Department of Commerce.

Figure 4-16
Profitability of selected mainframe and minicomputer firms, 1985-92



Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

Figure 4-17
Global supercomputer market share of selected firms, 1987-92



Source: USITC staff estimates.

Japanese firms Fujitsu, NEC, and Hitachi all have relatively strong positions in the market and present the most serious competitive challenge to U.S. firms. All three companies have relied heavily on sales in the Japanese market, which Cray Research and others believe is effectively closed to foreign competition (see chapter 3).[83] No European manufacturer has a significant share of the global supercomputer market.

Supercomputer manufacturers compete primarily in terms of price, processing power, and technical support. While processing power traditionally has been the focus of competition in this market, price and technical support are becoming increasingly important as supercomputers make inroads in the private sector. A firm's ability to compete in terms of price, processing power, and technical support is most significantly influenced by R&D and software-writing skills.

Factors Influencing Competitiveness

Research and Development

Supercomputer manufacturers invest a relatively large share of annual revenues in research and development (figure 4-18).[84] In 1992, Cray Research spent 20 percent of revenues on R&D, while Convex invested 14 percent.[85] MPP producers, in particular, invest heavily in research. Thinking Machines, for example, spends 30 percent of revenues on R&D. Supercomputer research has increased processing power and reduced prices for supercomputers.

R&D programs traditionally have focused on enhancing performance, often measured in terms of processing speed. Supercomputers currently are capable of processing tens of billions of floating-point operations per second (gigaflops), and rates of a trillion such operations (teraflops) are envisioned for the near future.

Hitachi and NEC have created vector supercomputers that theoretically surpass the processing speed of any vector supercomputer manufactured in the United States. Hitachi's fastest supercomputer performs 32 billion floating-point operations per second (32 gigaflops), and NEC's has a peak of 26 gigaflops. By comparison, Cray Research's fastest vector supercomputer has a theoretical peak of 16 gigaflops.[86] Japanese firms have been able to produce supercomputers with very high theoretical processing speeds because they have focused R&D programs almost solely on hardware.[87] Fujitsu, NEC, and Hitachi have developed very fast central processing units and basic processor chips, in part due to intensive efforts to increase feature densities on integrated circuits.

However, U.S. firms still lead Japanese firms in terms of actual processing speeds. To achieve faster processing speeds, U.S. firms have taken a more balanced approach to R&D, focusing equally on hardware and operating systems. Cray Research currently spends half of its total R&D budget on software, and Kendall Square Research, a producer of MPP supercomputers, employs twice as many software engineers as hardware engineers.[88] U.S. firms' R&D programs have enabled them to design and build multiprocessor vector supercomputers, which tie as many as 16 customized processors together with cutting edge operating systems. Japanese firms' sole focus on hardware has left them unable to build successful multiprocessing systems. As of 1992, NEC was the only Japanese firm that had succeeded in installing a multiprocessing system outside of its own facilities.[89]

As a result of conducting extensive R&D on operating systems software, it appears that U.S. firms are several years ahead of Japanese firms in terms of their ability to build MPP supercomputers, which require software capable of tying together hundreds or thousands of processors. No Japanese manufacturer has commercialized MPP supercomputers.[90] In contrast, Intel has sold approximately 325 MPP systems, and Thinking Machines has sold approximately 90 such systems.[91] Cray Research has received nine orders for its new MPP system, ranging from 32 to 256 processors, with theoretical peak performances from 4.8 to 38.4 gigaflops.[92] Ultimately, U.S. firms' abilities to design and construct MPP systems could significantly enhance their competitive positions, better enabling them to compete in terms of both processing power and price.

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[83] Cray Research, interviews with USITC staff, Eagan, MN, Apr. 28-29, 1993.

[84] Data for supercomputer R&D spending by Fujitsu, NEC, Hitachi, and IBM are not available.

[85] Gartner Group, *Yardstick: Top 100 U.S.*, 1993, p. VII-8. According to company officials, Cray's R&D spending typically equals or exceeds 15 percent of revenues.

[86] Kahaner and Wattenberg, "Japan: A Competitive Assessment," p. 42.

[87] Theoretical peak performance is derived simply by multiplying the peak rate of performance for each processor by the number processors in the supercomputer. Actual peak performance reflects the processing speed during benchmark testing. "Japan: A Competitive Assessment," *IEEE Spectrum*, Sept. 1992, p. 42.

[88] Richard Comerford, "Software On the Brink," *IEEE Spectrum*, Sept. 1992, p. 34.

[89] Kahaner and Wattenberg, "Japan: A Competitive Assessment," p. 42.

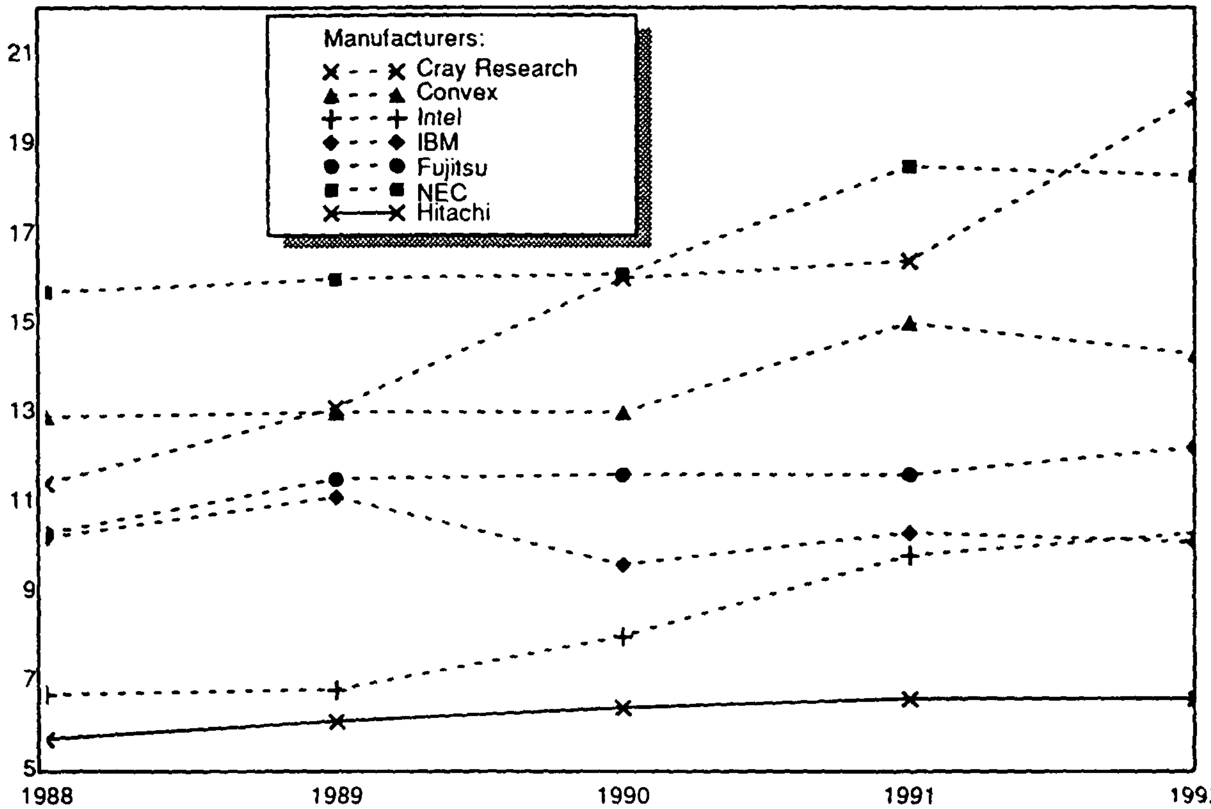
[90] Ibid., p. 44.

[91] Glenn Zorpette, "The Power of Parallelism," *IEEE Spectrum*, Sept. 1992, p. 32.

[92] Cray affirms that it has the capability to build a 2,048 processor, 307.2 gigaflop machine, but production is dependent upon customer orders. Cray Research, telephone interview with USITC staff, Oct. 6, 1993.

Figure 4–18
R&D expenditures of selected supercomputer producers, 1988–92

R&D as a share of revenues



Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

Software-Writing Assistance

U.S. firms have developed and used their software-writing skills to assist supercomputer users, many of whom must design customized applications software. U.S. firms were first to establish open operating systems, which facilitate the development of applications software and improve the portability of such software. Cray Research was the first firm to do so. It adopted UNIX System V Release 4 (SVR4), developed by Unix Systems Laboratories, in 1986. Since then, Thinking Machines has joined Cray Research in using this operating system. Intel and Kendall Square Research, on the other hand, have deployed systems using the OSF/1 operating system, developed by the Open Software Foundation (OSF). Furthermore, OSF and Unix Systems Laboratories announced in June 1992 that they would collaborate to develop more similarities between these two dominant UNIX versions.[93]

By contrast, Japanese firms Hitachi and Fujitsu have begun offering UNIX operating systems only recently. These firms also continue to offer supercomputers that employ proprietary operating systems. NEC, on the other hand, has jettisoned proprietary systems altogether on its current generation of supercomputers, and has marketed these UNIX-based systems in the United States aggressively.[94]

Due in part to their delayed adoption of open operating systems, Japanese firms were somewhat slower than U.S. firms to market supercomputer applications software successfully. Japanese firms have created little original software over the years. Until recently, Japan's software development programs focused principally on designing Japanese-language interfaces for software originally designed in the United States. Applications software packages for Japanese multiprocessing supercomputers are still in a nascent state. As MPP supercomputers grow to account for a greater share of the total supercomputer market, the principal challenge before NEC, Hitachi, and Fujitsu will be to develop the skills required to design software to accompany MPP architecture, which is much more

[93] Comerford, "Software on the Brink," p. 36.

[94] Kahaner and Wattenberg, "Japan: A Competitive Assessment," p. 44.

complex than the software that accompanies vector supercomputers. Japanese firms have formed cooperative research programs with groups in the United States, Australia, and Europe to enhance their abilities to create future generations of supercomputer software.[95]

It is reported that Cray Research possesses a clear advantage over other U.S. and foreign firms in developing applications software.[96] Cray Research uses partnerships with independent software vendors and customers to develop key applications. For example, the company recently entered a consortium with pharmaceutical and chemical firms, such as E.I. Du Pont de Nemours and Co. and Eli Lilly and Co., to develop molecular modeling software. Cray Research also has helped to develop engine-combustion analysis software for automotive firms.

The lack of a developed base of applications software is a major obstacle for all manufacturers of MPP supercomputers, adversely affecting the global competitive position of Intel and Thinking Machines. At present, because the MPP platform accounts for only a small share of the supercomputer market, independent software companies have been reluctant to invest heavily in software development for MPP machines. Efforts are currently underway to form standards for MPP systems, which are a necessary first step toward addressing these difficulties.[97]

Outlook

U.S. firms, accounting for 69 percent of global supercomputer revenues, continue to enjoy a strong competitive position in the global supercomputer market. Despite a decline in Cray Research's market share since 1987, the firm accounts for approximately 36 percent of all supercomputer sales. Cray Research's loss of market share is principally the result of market share gains by other U.S. firms such as Convex, Intel, and Thinking Machines. Fujitsu, NEC, and Hitachi are U.S. firms' principal competitors, yet they jointly account for only 24 percent of global revenues.

Global sales of supercomputers are forecasted to increase by an average of 12 percent per annum during 1993-96. U.S. firms' sales likely will continue to be concentrated in the United States and Europe. U.S. firms' principal competitors will continue to be Fujitsu, Hitachi, and NEC, although the competitiveness of these firms may decrease slightly as MPP supercomputers become more popular.

Available data on profitability suggest that Cray Research and Convex are likely to remain active in the global supercomputer market (figure 4-19).[98] During 1988-92, both firms posted rates of return that compared favorably with those posted by most firms in the computer hardware industry. In spite of a loss amounting to 2 percent of sales in 1992, Cray Research posted an average return on sales of about 25 percent during 1985-92.

Fujitsu, Hitachi, and NEC reportedly will remain in the supercomputer business regardless of the profitability of competing in this particular market segment. Profits generated in other lines of business may compensate for losses in the supercomputer segment. According to Watanabe Tadashi, a chief designer at NEC, Japanese manufacturers focus principally on the technological advances stemming from participation in the supercomputer segment.[99] Profitability is a secondary consideration.

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95 Ibid.

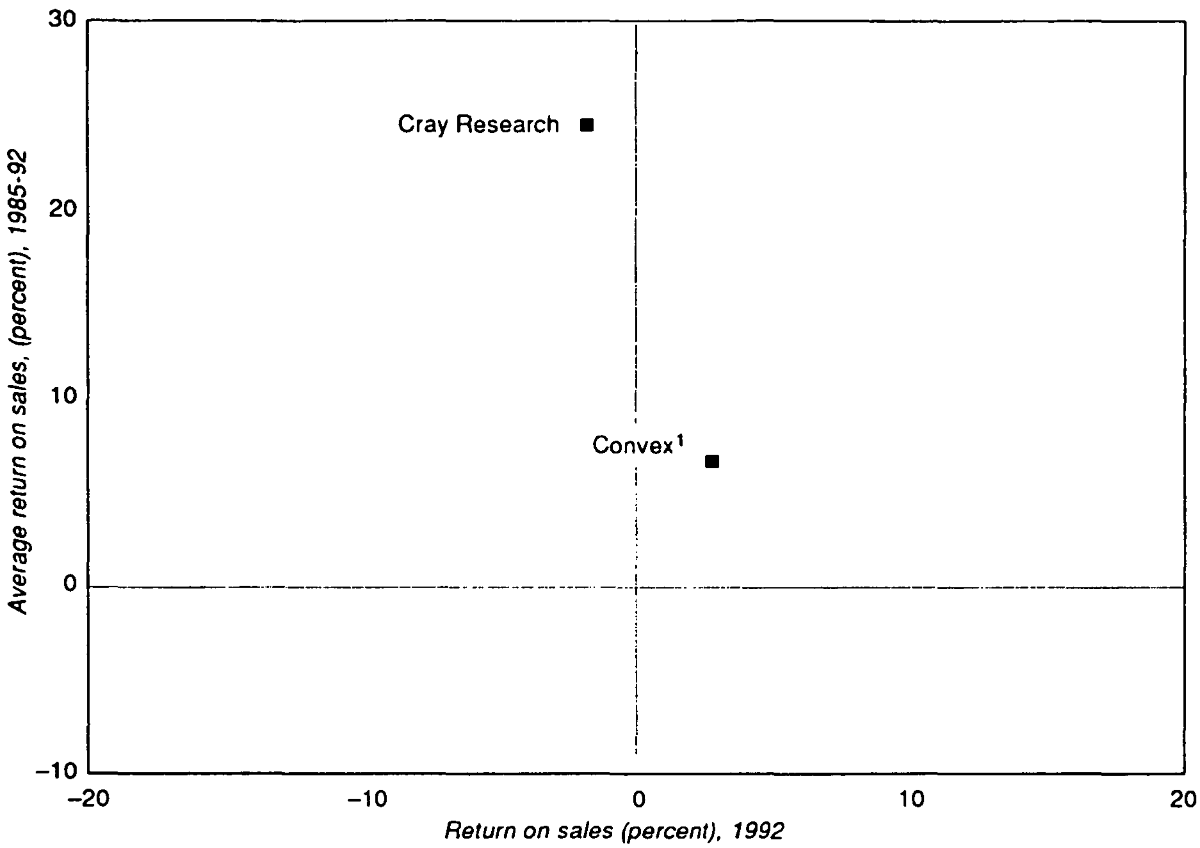
96 Ibid., p. 42.

97 Comerford, "Software on the Brink," pp. 34-38.

98 IBM, Intel, Fujitsu, and Hitachi derive most revenue from other segments of the computer hardware and computer component business. For these firms, data on company-wide profitability are not believed to be an accurate indicator of long-term competitiveness in the supercomputer market. Therefore, the long-term competitiveness of these firms, as indicated by profitability, is not addressed in the present discussion.

99 "Supercomputer Bout," *Business Tokyo*, Apr. 1990, p. 34.

Figure 4-19
Profitability of selected supercomputer firms, 1985-92



[1] Convex data begin in 1987.
Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

CHAPTER 5
Findings and Future Developments

Introduction

This chapter summarizes the preceding four chapters, offering insights regarding the competitive position of U.S. firms and the effects of certain government policies. First, the chapter reviews the U.S. industry's performance, addresses the implications of ongoing technological and industry trends, and considers the likely future course of the industry. The latter draws on analysis performed by Commission staff and on insights offered by industry experts attending the Commission's computer futures seminar, held July 21, 1993. Second, the chapter summarizes key government policies and their effect on U.S. competitiveness, and communicates policy proposals offered at the seminar.

Overall U.S. Competitive Position

The overall competitive position of the U.S. computer hardware industry remains very favorable. Certain U.S. firms have experienced a loss of market share in specific market segments, yet this has often occurred as a result of market entry by other firms as computer technology diffused. With respect to the personal computer and supercomputer markets, predominant firms like IBM and Cray Research principally lost market share to other U.S. firms in possession of less expensive machines and newer technologies. U.S. firms account for approximately 60 percent of the revenues generated by the global computer hardware industry, and account for no less than 50 percent of the revenues generated in each industry segment.

Five of the industry's largest firms, measured in terms of global market share, are from the United States (figure 5-1). IBM is indisputably the industry's predominant firm, accounting for about 20 percent of global computer hardware revenues. IBM prevailed in defining the most popular architectures in the computer hardware industry's two largest segments, the personal computer (PC) segment and the mainframe and minicomputer segment. The firm's gradual loss of market share is, in part, due to other firms' adoption and acceptance of these architectures.

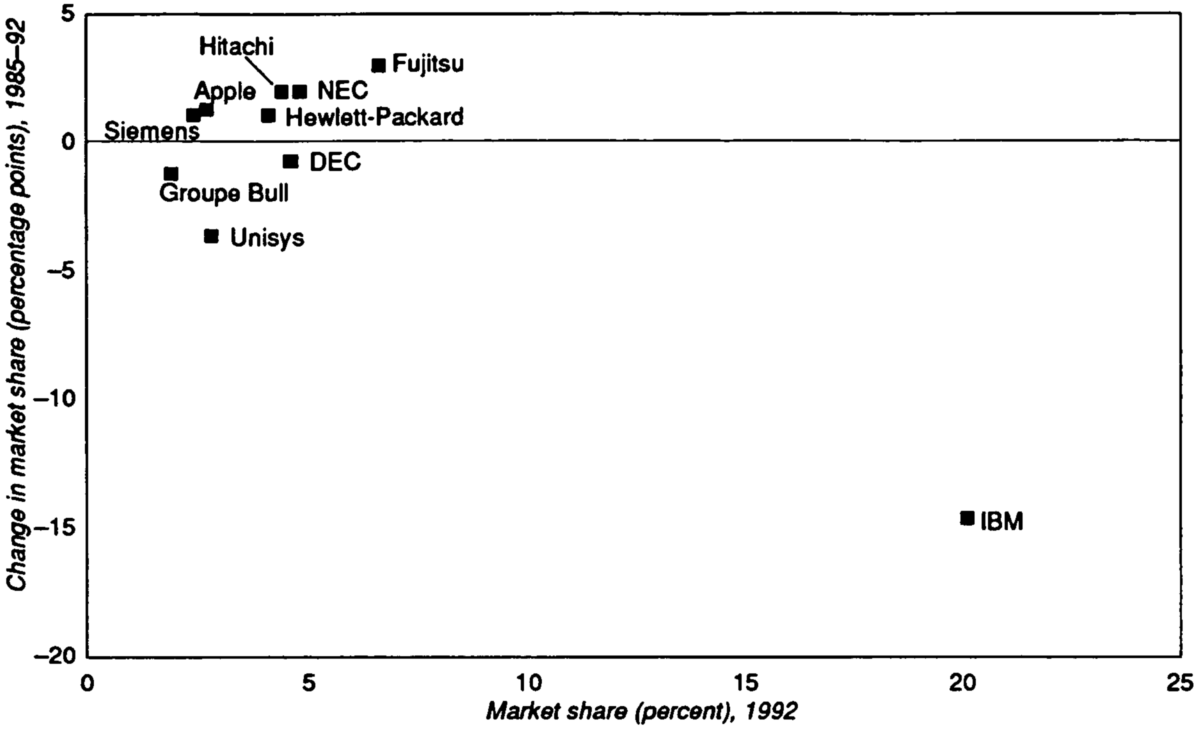
Other U.S. firms that are among the industry's largest 10 firms include DEC, Hewlett-Packard, Unisys, and Apple. Apple and Hewlett-Packard have gained market share since 1985, whereas the remaining two have lost market share. Apple was the first firm to enter the PC market and won many adherents to its proprietary, user-friendly architecture. Hewlett-Packard, on the other hand, has proved to be a successful designer and builder of mid-size computers, primarily minicomputers and workstations. Hewlett-Packard has been able to compensate for declining sales of minicomputers by increasing sales of workstations. DEC and Unisys, principally dependent on mainframe and minicomputer sales, have lost shares of the total computer hardware market as a result of declining demand for these machines.

Japanese firms are the principal competitors of U.S. firms. Fujitsu, NEC, and Hitachi all have gained market share since 1985, owing to rapid economic growth in Asia and expertise in hardware manufacturing. All three firms produce a broad range of computer hardware, although they have not competed successfully in the rapidly growing workstation market. Fujitsu and Hitachi, prime adherents to IBM mainframe architecture, have grown with the mainframe and minicomputer market over the past 10 to 20 years. These firms remain overly dependent on mainframe sales, but have escaped the rigors of computer platform downsizing because user preferences are changing slowly in Japan. NEC, on the other hand, is Japan's largest manufacturer of PCs, and is beginning to be an aggressive participant in overseas PC markets.

Firms' continued participation in the computer hardware market is contingent on profitability, according to economic theory. Except for DEC and Unisys, predominant U.S. firms are among the most profitable firms in the global computer hardware industry (figure 5-2). Since 1985, Apple, Hewlett-Packard, Sun Microsystems, Intergraph, and IBM have generated average gross return on sales of about 10 percent. Cray Research and Compaq have done considerably better.

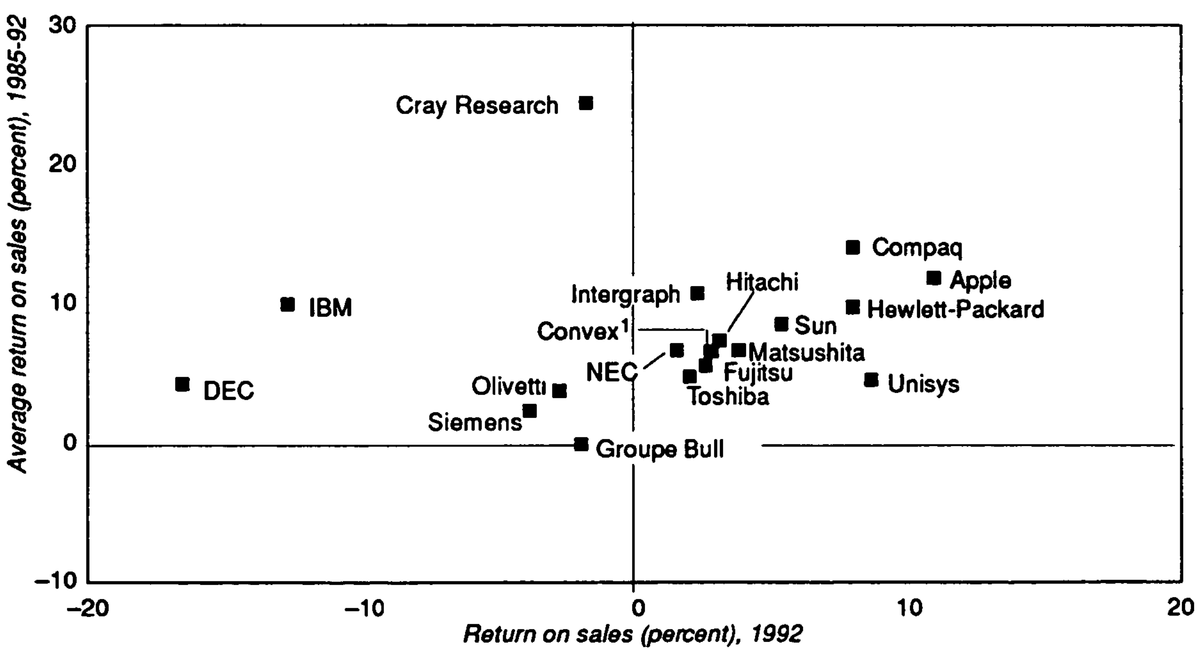
Key Japanese firms, too, generally have performed well in terms of profitability. However, predominant European firms have recorded relatively low profitability or losses. If such trends prevail in the

Figure 5-1
Global market share of selected firms, 1985-92



Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993.

Figure 5-2
Profitability of selected firms, 1985-92



[1] Convex data begin in 1988.

Source: Gartner Group, *Yardstick: Top 100 Worldwide*, 1993; and electronic database developed and maintained by Gartner Group.

long run, Groupe Bull might exit the industry, although industry experts suggest that the firm's eventual exit may take the form of a shift in focus to computer software and services. Siemens-Nixdorf has remained only slightly profitable as assessed by gross return on sales, and has registered net losses in each of the past 4 years. Siemens-Nixdorf, too, may ultimately refocus its future operations, de-emphasizing computer hardware manufacturing.

Competitive Position by Segment

Personal Computers

U.S. firms account for between 55 and 60 percent of global personal computer sales. Market leaders include IBM, NEC, Apple, and Compaq. U.S. personal computer manufacturers are active globally, dominating both the U.S. and the European markets. By contrast, NEC and other Japanese firms focus principally on the Asian market.

Other key players in the global personal computer market are clone makers such as AST Research, Dell, Gateway 2000, and Packard Bell. These U.S. firms have competed very successfully in terms of price and time-to-market. They also have pioneered low-cost component sourcing and innovative marketing strategies that foreign competitors are beginning to emulate.

The personal computer market increasingly resembles a price-sensitive consumer electronics market. Standardized architecture and mass production of PC components have reduced product differentiation, technology-based barriers to entry, and PC prices. Firms that have not responded to changing market conditions by aggressively reducing costs have experienced financial hardship. Some firms have exited the market, and others may follow.

Nevertheless, the personal computer market presents some unique opportunities. The global market for personal computers will grow as the downsizing of computer platforms continues. Technological leaps in microprocessing technology may blur the distinction between personal computers and workstations, creating new growth opportunities for aggressive PC manufacturers. Last, the development of a multimedia[1] industry likely will create demand for new products, offering significant new opportunities to established PC manufacturers and new entrants alike (see "Future Developments").

[1] The concept of multimedia involves the communication of information in more than one form, such as text, audio, graphics, animated graphics, and full-motion video.

Workstations

U.S. firms account for over 80 percent of global workstation sales. Market leaders include Sun Microsystems, Hewlett-Packard, IBM, DEC, Silicon Graphics, and Intergraph. Like PC manufacturers, workstation manufacturers have benefitted enormously from the downsizing of computer platforms. The appeal of workstations also has grown because of technological leaps in their processing power. In particular, U.S. workstation manufacturers' development of reduced instruction set computing (RISC) microprocessors has resulted in the development of machines that rival minicomputers, mainframes, and even low-end supercomputers in terms of processing capabilities.

Workstation manufacturers are now competing to establish one standard workstation architecture, just as IBM established the predominant PC architecture in the early 1980s. To increase economies of scale in workstation component and applications software manufacturing, U.S. firms are leasing RISC technology to other domestic and foreign firms, and are creating common interfaces with new PC operating systems. These efforts ultimately will make workstation manufacturing another commodity business, enhancing the competitive position of those firms with lean cost structures and advanced marketing skills.

Mainframes and Minicomputers

U.S. firms account for nearly two-thirds of global mainframe and minicomputer sales. IBM, DEC, Fujitsu, Hitachi, and Hewlett-Packard are the predominant manufacturers in this market. The latter three have gained market share at the expense of IBM and DEC during the past 10 years. IBM, Hewlett-Packard, and Hitachi stand out as the most profitable firms in this segment, although IBM's financial performance has suffered in recent years.

The trend toward smaller computer platforms has reduced demand for mainframes and minicomputers, and consequently has driven prices downward. This has affected severely the financial experiences of some of the world's largest computer manufacturers, which traditionally have relied on mainframe and minicomputer sales for revenue growth and profitability. Many of these firms, including IBM and DEC, have posted record losses in recent years, prompting them to restructure operations. Restructuring is most evident in the United States, where downsizing of computer platforms is furthest along. The phenomenon is only beginning in Europe and Japan.

As noted, a principal component of restructuring has been workforce reduction. However, restructuring also has led firms to spin off certain business segments and to terminate longstanding management practices. IBM, for instance, has created separate companies to manufacture and market personal computers and computer printers, IBM Personal Computer Co. and Lexmark International, Inc., respectively. Other units have remained integral parts of the IBM parent company, but have been separated into distinct profit centers, improving their focus and agility. IBM's Integrated Systems Solutions Corp., for instance, has been tasked with pursuing data processing contracts outside IBM in order to offset the firm's waning computer hardware revenues. Industry analysts generally have commented favorably on restructuring, although all have noted that the ultimate impact of restructuring on firms' competitiveness may not be evident for many years.[2]

In addition, mainframe and minicomputer manufacturers are enhancing their position in the global market by turning to parallel processing technology. Parallel processing increases computer power and reduces production costs. These firms also are engineering open operating systems to facilitate file serving and data management in large networks. In addition, these firms are increasingly seeking alternate sources of revenue. As noted earlier, IBM, Hewlett-Packard, and DEC have introduced popular workstations. The provision of software and service has increased revenues significantly. IBM sells nearly four times as much software as Microsoft, and Fujitsu's software sales rival those of Microsoft. DEC, on the other hand, now generates more revenue from service provision than from hardware sales.

Supercomputers

U.S. firms account for nearly 70 percent of worldwide supercomputer sales. Key U.S. firms include Cray Research, IBM, Convex, Thinking Machines, and Intel. U.S. firms' principal competitors are Fujitsu, NEC, and Hitachi, which account for 24 percent of the global market.

The supercomputer industry is changing as standard vector processing systems experience competition from massively parallel processing (MPP) supercomputers, which may employ over 1,000 mass-produced processors to work on different portions of one problem simultaneously. Because the processors used by MPP supercomputers are mass-produced, they are much less expensive than typical supercomputer processors. As the performance of MPP supercomputers improves and MPP-compatible software becomes more readily available, firms such as Intel and Thinking Machines, which specialize in manufacturing MPP supercomputers, may increase their global market share significantly.

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[2] Representatives of Goldman, Sachs, & Co., McKinsey & Co., Nomura Research Institute, and Dean Witter, interviews with USITC staff, New York, Apr. 1-2, 1993; and representatives of Amdahl Computer Corp., interviews with USITC staff, Sunnyvale, CA, Apr. 14-24, 1993.

The introduction of MPP supercomputers has made the supercomputer market much more price sensitive than it once was. Price sensitivity has been compounded by the incorporation of parallel processing technology among high-end mainframes and workstation clusters, which compete with low-end supercomputers at present. Further downward pressure on supercomputer prices has resulted from increasing private sector purchases. Private sector consumers have proved to be more price-conscious than traditional public sector purchasers, which typically emphasized only performance.

Implications

Prevailing industry trends — commoditization of computer hardware, downsizing of computer platforms, and increasing importance of computer software and services — are very likely to continue in the future. These trends may actually accelerate, calling for tremendous flexibility on the part of firms wishing to remain focused on the computer hardware market. Company restructuring, including workforce reduction, will likely continue in the United States and Europe, and eventually spread to Japan. Industry experts anticipate that revenues generated by the computer hardware industry will continue to grow, even as profit margins narrow for most firms.

Commoditization began with PCs and spread to mainframes and minicomputers. The advent of parallel processing and open operating systems may accelerate commoditization, and spread into the workstation and supercomputer segments. Parallel processing will increase computer power and reduce computing prices by replacing a small number of expensive, customized processors with many inexpensive, mass-produced processors. Over time, proprietary operating systems will be replaced by open operating systems as a result of consumer demand. As these trends proceed, workstations, mainframes and minicomputers, and MPP supercomputers will increasingly look and perform similarly. Competition within computer segments, competition between computer segments, and decreasing consumer reliance on one manufacturer likely will drive most computer prices downward.

In addition, the gradual adoption of open operating systems will promote computer platform downsizing by reducing the costs associated with downsizing. Firms like IBM and DEC are facilitating the migration to workstation networks. They are doing so by providing migration paths from currently popular mainframe and minicomputer operating systems to evolving workstation operating systems. These migration paths will allow firms to interface with downsized computer platforms in familiar ways, and to use familiar applications software.

Opportunities in the computer software and service industries will proliferate. Firms may offer traditional services, such as patching together networks customized for each user's needs, as well as new services, such as familiarizing private sector firms with supercomputing. As standard computer architectures emerge, many new application software packages will be created. This will greatly enhance the popularity of workstations and, perhaps, supercomputers, for which there are few presently available commercial applications packages.

Future Developments

On July 21, 1993, the U.S. International Trade Commission convened a panel of nine computer industry participants and analysts to discuss the future of the global computer industry. Seminar participants included representatives from two leading U.S. computer firms and one European firm, four U.S. economists who follow the industry, one industry analyst based in Japan, and a representative of a financial services firm that uses leading-edge computer systems (see appendix F).

Although there was consensus within the group that forecasts for the fast-paced computer industry are speculative at best, several insightful predictions surfaced during the discussion. Participants identified three principal trends that they expect to change the shape of the computer hardware industry during the next few years. First, the convergence of information technology industries will result in the creation and rapid growth of a "multimedia" industry in the near future. Second, computer hardware will become increasingly portable and easier to use, allowing for a greater diffusion of technology among users. Finally, tomorrow's software will be revolutionized by the commercialization of object-oriented designs. Besides identifying these trends, participants provided significant input on the future division of labor among regions and countries.

Multimedia

Participants noted that the computer industry will play an important role in the expected convergence of information technology companies. As envisioned, the new "multimedia" industry will encompass computers, telecommunications, consumer electronics, content (e.g., television, newspaper, and other media), and all the services associated with each. Analysts speculate that the multimedia industry will generate global revenues of $2 trillion by 1997.

An important facet of the new industry will be the emergence of a national information infrastructure capable of transmitting educational, health, and financial material across the continent. In order for such a network to succeed, seminar experts cited the need for standards among telecommunication bodies and scalability among computer systems. Although there was a strong appreciation for the potential profits offered by proprietary systems, most participants recognized that some degree of standardization, similar to that in the PC industry, would be necessary for an effective national infrastructure.

The anticipated structure of companies within the new multimedia industry evoked considerable discussion. Seminar participants recognized that computer companies are already rejecting traditional, vertically-integrated organizations in favor of smaller, more flexible structures. Most agreed that the new industry would continue on this path. This type of structure likely will encourage agility within companies and intense competition among producers. Temporary alliances will bring together the best chip design, the best hardware, the best content, etc. Some participants suggested that the regional telephone companies are likely to lose their monopoly position as competition from cable and cellular companies intensifies. On the other hand, several experts suggested that there might be some movement back toward temporary monopolies or monopolies through alliances as the communications and computer industries merge. Already individual companies are entering multimedia alliances simply to hedge against uncertainty.

Portability and User-Friendliness

On another level, industry experts predict that computer products will become increasingly portable and considerably easier to use in the near future. Already available on the market are notebook computers and personal digital devices, such as palmtop computers, pen-based computers, and personal digital assistants. Industry representatives expect that consumer demand for these products will increase rapidly. Seminar participants noted that large businesses will continue to purchase and test these new products, but small companies and individual users will account for a growing share of overall sales and revenues in the industry. Participants also suggested that growing access to portable products will encourage a vast diffusion of information technology across the globe.

The projected diffusion of products and information will accelerate as computers become easier to use. One panelist noted that new technology, including that associated with the multimedia industry, will radically improve the ability of users to interact with machines. Computers, which currently communicate through keyboards, flow charts, and character strings, will ultimately respond to the preferred communication methods of users, including voice and touch.

Object-Oriented Software

Participating panelists noted that the software industry, also a key component of the projected multimedia industry, will see considerable improvements over the next few years. One of the most significant developments anticipated by industry experts is the commercialization of object-oriented software. This calls for the creation of a library of reusable, self-defined software modules that can be strung together rapidly to provide software packages for new applications. In other words, software modules will be building blocks made up of common lines of software code; they will eliminate time-consuming and redundant software-writing.

Although research on this concept has been underway for many years, limitations in the memory and processing power of computers have prevented the creation of object-oriented software. However, recent advancements in computer hardware technology have increased the likelihood that firms will begin the production of object-oriented software in the near future.

International Division of Labor

There was considerable discussion surrounding the future division of labor in the multimedia industry. Most participants agreed that the United States would play a significant role in the new multimedia industry, largely due to its strengths in networks, telecommunications, and software technology. The United States also has the advantage of being a prime innovator, with one of the largest and most receptive test markets for new products.

An expert on Japanese firms suggested that Japan's ability to compete in the multimedia industry as an innovator is too often understated. This expert indicated that Japanese companies currently are improving their global competitive position through complementary global alliances and increased R&D spending. Other participants also noted Japan's expertise in consumer electronics and the growing software mass-marketing expertise of companies like Nintendo and Sega.

The European industry representative, meanwhile, held out some hope for Europe in the future. This representative cited Europe's proximity to emerging markets in the Middle East, Eastern Europe, the former Soviet Union, and Africa as an important advantage. However, others suggested that the European industry's slow reaction to the changing competitive environment, combined with a highly regulated telecommunications industry, would adversely affect its future competitive position in the multimedia industry.

Key Government Policies

This report examines government policies pertaining to research and development funding, export control, procurement, intellectual property protection, tariffs, and tax incentives. Industry representatives have reported that some of these policies are adversely affecting U.S. competitiveness, or favoring the interests of some U.S. firms over the interests of others. Such policies include those regarding export controls, procurement, and intellectual property.

Despite proposals for major reforms, U.S. export controls remain more stringent and extensive than those of other countries, and thus hamper the ability of U.S. firms to compete globally. While the competitive position of the U.S. industry remains favorable, the globalization of computer manufacturing is leading to the availability of computers with advanced processing power from a multitude of sources not subject to export controls. However, the President recently has proposed a revision of export controls to reflect significant technological developments and thereby expand opportunities for U.S. producers to market state-of-the-art hardware. Many in the U.S. industry have expressed support for such a revision, although others have withheld support because the proposal does not provide for future liberalization as new technologies develop.

Procurement policies also have adversely affected the competitiveness of U.S. firms. To remain competitive as computer hardware prices fall, companies must control costs. One facet of cost control is sourcing the lowest-cost computer components, regardless of the country of origin. However, the 1933 Buy American Act, in tandem with the 1979 Trade Agreements Act, reportedly has complicated bidding on Federal Government contracts when U.S. firms have sourced low-cost foreign components. Government attempts to help U.S. computer component manufacturers have adversely affected the ability of U.S. computer manufacturers to win contracts from the Federal Government.

The optimal level of protection afforded to intellectual property also is an area of debate among computer manufacturers. While some U.S. firms have prospered by developing proprietary hardware and software, others have prospered by developing open, or non-proprietary, systems. Companies deriving competitive advantage from proprietary technology are advocating stronger efforts to protect intellectual property, and thereby spur innovation by assuring adequate returns on R&D expenditures. Companies emphasizing open systems, however, express concern that overprotection of proprietary systems could impede innovation and reduce consumer welfare. U.S. industry representatives stress that future efforts to protect intellectual property should take into consideration the interests of these opposing camps.

Industry Experts' Policy Proposals

To maximize the global benefits derived from innovation and alliances in the computer industry, participants in the Commission's computer futures seminar proposed several very specific roles for government, including R&D funding and global deregulation. Most panelists, remarking on the general success of Sematech, recommended that the government continue to invest in industry research. They suggested that government should provide funding for some of the more visionary research projects, which companies may have to terminate as they restructure and reduce costs. Few firms can justify research that does not have immediate commercial potential. Specifically, analysts agreed that government should provide financial support for the development of a national information superhighway.

Other roles recommended for government included deregulation and the elimination of protectionism. A European expert expressed the desire to see industries reduce all barriers, including the preferences extended to regional telecommunication structures. This expert also advocated the removal of protectionist duties and tariffs that hinder competition. Finally, industry representatives proposed that governments encourage capital formation in the computer industry, with tax incentives if necessary.

APPENDIX A
LETTERS FROM THE COMMITTEE ON FINANCE, UNITED STATES SENATE, REQUESTING THE INVESTIGATION

Rec'd 6/11/92 Chairman's Office DV/7??

United States Senate

COMMITTEE ON FINANCE

WASHINGTON DC 20510-6200

CL

June 11, 1992

1700

The Honorable
Don E. Newquist
Chairman
U.S. International Trade Commission
500 "E" Street, S.W.
Washington, D.C. 20436

Dear Mr. Chairman:

Global competitiveness of key U.S. industries continues to be of concern and interest to the U.S. Congress. Therefore, the Senate Committee on Finance requests the U.S. International Trade Commission to undertake three additional studies assessing the global competitiveness of advanced technology industries as follow-on studies to the three competitive assessments provided to the Committee during September-October 1991. As noted in the Committee's initial request, providing to the Senate on an ongoing basis impartial and detailed information on the competitiveness of advanced technology industries is a logical extension of the Commission's investigatory role in trade matters.

We approve the Commission's recommendation that the next three studies focus on the U.S. cellular communication, aircraft, and computer industries, and that they be carried out pursuant to sections 332(b), 332(d), and 332(g) of the Tariff Act of 1930. The reports on these three industries should include factors found by the Commission to be relevant to the global competitiveness of these industries as they are considered singly. Such factors may include, but are not limited to, government policies, regulatory and trade impediments, and research and development financing and expenditures. In the aircraft study, the Committee expects the Commission to address the issues of competition in civil aircraft from the Airbus consortium and the proposed acquisition of U.S aerospace technologies and manufacturers by foreign interests.

The Commission is requested to complete the first of these three studies within 12 months, and to conclude the remaining two at three-month intervals thereafter.

Sincerely,

Lloyd Bentsen
Chairman

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United States Senate

COMMITTEE ON FINANCE

WASHINGTON, DC 20510-6200

June 21, 1990

DOCKET

1569

The Honorable
Anne Brunsdale
Chairman
United States International
Trade Commission
500 "E" Street, S.W.
Washington, D.C. 20436

Dear Madam Chairman:

As part of its policymaking process, the Senate Committee on Finance anticipates a need for impartial and detailed information on the competitiveness of advanced technology manufacturing industries in the United States. As an independent Federal agency with the authority to investigate the impact of international trade upon domestic industry, it would be a logical extension of the Commission's responsibility to expand and enhance its capacity to provide information on an ongoing basis concerning the relative global competitiveness of American industry.

Accordingly, the Committee hereby requests the Commission to expand its collection of, and ability to analyze, information on the competitiveness of such industries pursuant to sections 332(b), 332(d), and 332(g) of the Tariff Act of 1930.

While the Committee wants the Commission to develop a long-term capacity on a broad range of industries, it recognizes that this expertise must evolve in stages. Thus, the Committee requests initially a two-step investigation. Within three months of the receipt of this letter, the Commission is requested to provide to the Committee a list of industries about which the Commission will develop and maintain up-to-date information. In identifying these industries, the Commission should consider the following criteria, as well as any other criteria it may choose to establish:

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U.S. INTL TRADE COMMISSION

-- Those industries producing a product that:

(1) involves use or development of new or advanced technology, involves high value-added, involves research and development expenditures that, as a percentage of sales, are substantially above the national average, and is expected to experience above-average growth of demand in both domestic and international markets; and

(2) benefits in foreign markets from coordinated -- though not necessarily sector-specific -- policies that include, but are not limited to, protection of the home market, tax policies, export promotion policies, antitrust exemptions, regulatory policies, patent and other intellectual property policies, assistance in developing technology and bringing it to market, technical or extension services, performance requirements that mandate either certain levels of investment or exports or transfers of technology in order to gain access to that country's market, and other forms of Government assistance.

At the time the Commission provides this list of industries, the Commission is requested to recommend to the Committee three industries for comprehensive study. In selecting these industries, the Commission should consider, among any other factors it considers relevant, the importance of the industries producing these products to future U.S. global competitiveness; and the extent of foreign government benefits to industries producing competing products.

The Commission's report on these three industries should include, but is not limited to, the following information:

-- Existing or proposed foreign government policies that assist or encourage these industries to remain or to become globally competitive, existing or proposed U.S. Government policies that assist or encourage these industries to remain or become globally competitive, and impediments in the U.S. economy that inhibit increased competitiveness of these U.S. industries.

The Commission should complete the study of these three industries within 12 months of the Committee's approval of the list of recommended industries.

It would be the Committee's intention to review the report carefully in order to determine how to expand, extend, or otherwise modify this request, if necessary, to ensure that future reports continue to yield worthwhile results.

Sincerely,

Lloyd Bentsen
Chairman

APPENDIX B
THE COMMISSION'S NOTICE OF INVESTIGATION

UNITED STATES INTERNATIONAL TRADE COMMISSION
Washington, DC 20436

Investigation No. 332-339

Global Competitiveness of U.S. Advanced-Technology Industries: Computers

AGENCY: United States International Trade Commission

ACTION: Institution of investigation and scheduling of public hearing.

EFFECTIVE DATE: November 13, 1992

SUMMARY: Following receipt of a request on June 11, 1992 from the Senate Committee on Finance, the Commission instituted investigation No. 332-339, Global Competitiveness of U.S. Advanced-Technology Industries: Computers, under section 332(g) of the Tariff Act of 1930 (19 U.S.C. 1332(g)).

FOR FURTHER INFORMATION: For information on industry-specific aspects of this investigation contact Mr. John Kitzmiller (202-205-3387) or Ms. Sylvia McDonough (202-205-3393). For information on the legal aspects of this investigation contact Mr. William Gearhart of the Commission's Office of the General Counsel (202-205-3091). Hearing impaired individuals are advised that information on this matter can be obtained by contacting the TDD terminal (202-205-1810).

BACKGROUND: This is one of three competitiveness studies requested by the Committee on Finance in its letter of June 11, 1992. The other two studies concern the aircraft and cellular communications industries. These three studies are part of a series begun in 1990 at the request of the Committee. In a letter dated June 21, 1990, the Committee asked that the Commission, pursuant to sections 332(b), (d), and (g) of the Tariff Act of 1930, expand its collection of and ability to analyze information on the competitiveness of advanced-technology manufacturing industries in the United States. It also asked the Commission to undertake a two-part process under which it would (1) within 3 months of receipt of the letter, identify the U.S. advanced-technology industries to be monitored (using the criteria set out by the Committee) and recommend three of those industries as subjects for comprehensive Commission studies; and (2) within 12 months of receipt of a subsequent Committee letter either agreeing with or modifying the Commission's recommendations, submit its reports on the three industries.

In response, the Commission instituted investigation No. 332-294 for the purpose of identifying industries to be monitored and recommending three for comprehensive study. In its report to the Committee in September 1990, the Commission identified ten advanced-technology industries and recommended the following three for comprehensive study: communications technology and equipment, pharmaceuticals, and semiconductor manufacturing and testing equipment. The Committee by letter of September 27, 1990, approved the Commission's recommendations, and the Commission furnished its reports on the three investigations (investigation Nos. 332-301, 332-302, and 332-303) in late September 1991. Notice of the institution of investigation No. 332-294 was published in the Federal Register of July 26, 1990 (55 F.R. 3053), and notice of the institution of the three comprehensive-study investigations was published in the Federal Register of November 15, 1990.

In the three new studies, the Commission will, as requested by the Committee in its June 11, 1992 letter, seek to examine all factors found by the Commission to be relevant to the global competitiveness of the subject industries, including but not limited to, government policies, regulatory and trade impediments, and research and development financing and expenditures. The Commission will also seek the views of experts on the implications of these factors for U.S. trade interests and policy. As requested, the Commission will submit its industry report on computers by December 7, 1993.

PUBLIC HEARING: A public hearing in connection with the computer investigation will be held in the Commission Hearing Room, 500 E Street, SW, Washington, DC, beginning at 9:30 a.m. on March 17, 1993. All persons will have the right to appear by counsel or in person, to present information, and to be heard. Requests to appear at the public hearing should be filed with the Secretary, United States International Trade Commission, 500 E Street, SW, Washington, DC 20436, no later than noon, March 3, 1993. Any prehearing briefs (original and 14 copies) should be filed not later than noon, March 3, 1993 and any posthearing briefs should be filed by March 28, 1993.

WRITTEN SUBMISSIONS: In lieu of or in addition to appearing at the hearing, interested persons are invited to submit written statements concerning the matters to be addressed by the Commission in its report on this investigation. Commercial or financial information that a submitter desires the Commission to treat as confidential must be submitted on separate sheets of paper, each clearly marked "Confidential Business Information" at the top. All submissions requesting confidential treatment must conform with the requirements of section 201.6 of the Commission's Rules of Practice and Procedure (19 CFR 201.6). All written submissions, except for confidential business information, will be made available for inspection by interested persons in the Office of the Secretary to the Commission. To be assured of consideration by the Commission, written statements relating to the Commission's report should be submitted at the earliest practical date and should be received no later than July 28, 1993. All submissions should be addressed to the Secretary of the Commission at the Commission's office, 500 E Street, SW., Washington, DC 20436.

Persons with mobility impairments who will need special assistance in gaining access to the Commission should contact the Office of the Secretary at 202-205-2000.

By order of the Commission.

Paul R. Bardos

Paul Bardos
Acting Secretary

Issued: November 18, 1992

APPENDIX C
LIST OF CONTRIBUTING COMPANIES, AGENCIES, ASSOCIATIONS, AND CONSULTANTS

Companies
Acer America Corp.
Advanced Micro Devices (AMD)
Amdahl Corp.
American Management Systems Deutschland GmbH
Apple Computer, Inc.
Borland International, Inc.
Compagnie IBM France
Compagnie Des Machines Bull
Compaq Manufacturing Ltd. (Bishopton, Scotland)
Compaq Computer Europe (Munich)
Compaq Computer Corp.
Control Data Corp.
Convex Computer Corp.
Cray Research, Inc.
Cyrix Corp.
Dell Computer Corp.
Digital Equipment Co. Ltd. (London)
Digital Equipment Corp. (DEC)
Everex Systems, Inc.
Hewlett-Packard Co.
International Computers Ltd. (ICL)
Intel Corp.
International Business Machines Corp. (IBM)
Lotus Development Corp.
Microsoft Corp.
Motorola and PowerPC Alliance
Ing. C. Olivetti & C., A.p.A.
Siemens Nixdorf Informationssysteme AG
Silicon Graphics, Inc.
Software AG
Sun Microsystems, Inc.
Tandem Computers, Inc.
Thinking Machines Corp.

Government Agencies
Commission of the European Communities
U.S. Embassy, Bonn
U.S. Consulate General, Munich (FCS)
U.S. Department of Commerce, International Trade Administration
U.S. Mission to the European Communities
U.S. Embassy, Paris
United Kingdom Department of Trade and Industry

Associations
Business Software Alliance (BSA)
Computer and Business Equipment Manufacturers Association (CBEMA)
European Association of Manufacturers of Business Machines and Data Processing Equipment (Eurobit)
German Electrical and Electronic Manufacturers Association (ZVEI)
Microelectronics and Computer Tech. Co (MCC)
Organization for Economic Co-operation and Development (OECD)
Sematech

Consultants/stockbrokers

Alex. Brown & Sons, Inc.
Dean Witter
Gartner Group
Goldman, Sachs, & Co.
Hambrecht and Quist
International Data Corp. (IDC)
McKinsey & Co.
Nomura Research Institute
Rauscher Pierce Refsnes
SAP
Smaby Group
Stanford University
Technology Research Group

APPENDIX D
REVIEW OF LITERATURE PERTAINING TO THE COMPUTER INDUSTRY

Review of Literature[1] Pertaining to the Computer Industry

The computer industry has drawn considerable attention from analysts seeking to explain the fast pace of change in technology, the adoption of new products, and the relative competitive position of different firms in the industry. Although analysts have differed in their interpretation of events and the factors that affect competitiveness, they have generally focused on the roles of industry structure, government policy, and technology.

Economist Kenneth Flamm of the Brookings Institution and the Pentagon has treated the computer industry extensively in recent writings.[2] Flamm argues that the fundamental strategy for entry into the industry has been to target new market niches. According to Flamm, market leaders, particularly IBM, have enjoyed a substantial advantage in established market niches due to economies of scale and scope, that is, the ability to spread large, fixed product development costs over a large volume of sales and a broad range of products. However, he maintains that new product niches, such as minicomputers in the late 1960s and personal computers in the 1970s, tend to be exploited by new firms, because incumbent firms seek to prevent new products from cannibalizing old ones. According to Flamm, IBM and other leading firms used internal company standards to maintain customer loyalty in the past, but other firms and the user community have pursued the development of open systems, or non-proprietary standards, since the 1970s as a means to reduce the advantage of leading firms. Flamm also stresses the importance of government funding for the development of major computer firms in the United States, Europe, and Japan. In the United States, military research programs led to a wide range of new computer technologies with commercial spinoffs, according to Flamm, whereas government funding in Europe and Japan was used directly for commercial development.

Charles H. Ferguson and Charles R. Morris recently have argued that the primary factor in competitive success in the computer industry is proprietary control over system "architectures."[3] They attribute much of IBM's past success to its control over the standards for the System 360/370 series of mainframe computers. According to Ferguson and Morris, IBM's recent decline in competitiveness has been due largely to its failure to keep proprietary control over system standards in such recently emerging technologies as personal computers and RISC workstations. Ferguson and Morris said that Microsoft Corp. has built a strong competitive position on its control over MS/DOS and Windows operating system software.

In a similar line of thinking, Andrew Rappaport and Shmuel Halevi argue that due to the "commoditization" of computer hardware production, the primary future areas of growth and profits in computing will be in software and information services, where products can satisfy computer users' desires to make maximum use of hardware capabilities.[4] By contrast, a report by the MIT Commission on Industrial Productivity argues that the U.S. computer industry is losing ground to Asian producers largely as a result of inferior manufacturing practices in such

[1] A review of empirical literature is available in appendix H.

[2] Kenneth Flamm, *Creating the Computer: Government, Industry, and High Technology* (Washington, DC: Brookings Institution, 1987); Kenneth Flamm, *Targeting the Computer: Government Support and International Competition* (Washington, DC: Brookings Institution, 1987); Kenneth Flamm, "Globalization in the Computer Industry: Cooperation and Competition in the Global Computer Industry," background paper for the Organization for Economic Co-operation and Development, Directorate for Science, Technology and Industry, Dec. 1990.

[3] Charles H. Ferguson and Charles R. Morris, *Computer Wars: How the West Can Win in a Post-IBM World* (New York: Random House, 1993). Much of the same material is presented in Charles R. Morris and Charles H. Ferguson, "How Architecture Wins Technology Wars," *Harvard Business Review*, vol. 71 (Mar.-Apr. 1993), pp. 86-96.

[4] Andrew S. Rappaport and Shmuel Halevi, "The Computerless Computer Company," *Harvard Business Review*, vol. 69 (July-Aug. 1991), pp. 69-80.

areas as quality, inventory control, and design for assembly.[5] This report also maintains that the U.S. industry has been adversely affected by strategic failures in investment spending and in the commercialization of the results of basic research.

The importance of technological factors for the competitiveness of national computer industries is supported by a recent dissertation by economist Caroline H. Beetz.[6] Beetz undertook a statistical analysis of factors related to the volume of computer exports from different countries. She found that larger exports are associated with, among other things, the number of scientists and engineers and private-sector expenditures on research and development.

Economist Richard Langlois argues in a recent article that the history of the personal computer industry presents a strong contrast to the view that large firms gain an advantage due to economies of scale and scope.[7] Noting the important roles of a series of small firms in the industry's evolution, Langlois maintains that the mobility of key personnel and the modularity of PCs enabled the decentralized market network to focus creative energies on emerging technical problems in microcomputing. This, he argues, facilitated the rapid development of PC technology and markets.

A 1990 report from the Computer Science and Technology Board of the National Research Council summarizes the views of a broad range of U.S. computer industry participants and analysts on factors affecting the industry's competitiveness.[8] Most of those quoted agreed that competitiveness depends on such factors as cooperation among firms, government, and universities; efficient and high-quality manufacturing; strategic exploitation of changing technology; and good education and training programs. A 1992 follow-up report focuses on U.S. firms' unique advantage in systems integration skills as a factor in global competitiveness.[9] The report attributes this advantage to U.S. firms' large world market share in software, international acceptance of standards developed in the United States, and U.S. engineers' skills in flexible thinking and the management of complexity.

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[5] "The U.S. Semiconductor, Computer, and Copier Industries," MIT Commission on Industrial Productivity working paper (Massachusetts Institute of Technology (MIT), 1989). Some of the material from this paper appears in Michael L. Dertouzos, Richard K. Lester, and Robert M. Solow, eds., *Made in America: Regaining the Productive Edge* (Cambridge, MA: MIT Press, 1989).

[6] Caroline H. Beetz, *Determinants of International Comparative Advantage: A Case Study of the Computer Hardware Industry*, Ph.D. dissertation, Department of Economics, Northeastern University, Boston, 1991.

[7] Richard N. Langlois, "External Economies and Economic Progress: The Case of the Microcomputer Industry," *Business History Review*, vol. 66 (Spring 1992), pp. 1-50.

[8] Computer Science and Technology Board, National Research Council, *Keeping the U.S. Computer Industry Competitive: Defining the Agenda* (Washington, DC: National Academy Press, 1990).

[9] Computer Science and Technology Board, National Research Council, *Keeping the U.S. Computer Industry Competitive: Systems Integration* (Washington, DC: National Academy Press, 1992).

APPENDIX E
CALENDAR OF WITNESSES APPEARING AT THE PUBLIC HEARING

CALENDAR OF PUBLIC HEARING

Those listed below appeared as witnesses at the United States International Trade Commission's hearing:

Subject	:	GLOBAL COMPETITIVESS OF U.S. ADVANCED-TECHNOLOGY INDUSTRIES: COMPUTERS
Inv. No.	:	332-339
Date and Time	:	March 17, 1993 - 9:30 a.m.

Sessions were held in connection with the investigation in the Main Hearing Room 101 of the United States International Trade Commission, 500 E Street, S.W., Washington, D.C.

ORGANIZATION AND WITNESS:

Computer and Business Equipment
Manufacturing Association
Washington, D.C.

John L. Pickitt, President

Department of Commerce, International
Trade Adminstration, Washington, D.C.

John McPhee, Director, Office of
Computers and Business Equipment

Tim Miles, Director, Computer Systems
Division, Office of Computers

Heidi Hijikata, Director, Software
Division, Office of Computers

ORGANIZATION AND WITNESS:

Swidler and Berlin
Washington, D.C.
on behalf of

Business Software Alliance (BSA)

Robert Holleyman, President

Members include:

Apple Computer, Incorporated
Autodesk, Incorporated
Borland International, Incorporated
Go Corporation
Lotus Development Corporation
Novell Incorporated
Aldus Corporation
WordPerfect Corporation
Microsoft Corporation

Brian W. Fitzgerald—OF COUNSEL

APPENDIX F
PARTICIPANTS IN COMPUTER FUTURES SEMINAR

Participants in Computer Futures Seminar, July 21, 1993

Dr. Caroline Beetz, Economist, Inter-American Development Bank.

Dr. Charles Ferguson, Cambridge, MA. Consultant, formerly at MIT.

Dr. Kenneth Flamm, The Pentagon, formerly at Brookings Institution.

Dr. Gene Gregory, Professor of International Business, Sofia University, Tokyo, Japan.

Mr. David House, Senior VP, Intel Corp.

Ms. Elizabeth Kaufman, VP, Citibank NA.

Dr. Bruno Lamborghini, Vice President for Strategic Studies, Olivetti Corp., Italy.

Dr. Richard Langlois, Professor, University of Connecticut.

Mr. Peter Schavoir, IBM Director of Strategy, IBM Corp.

APPENDIX G
GLOSSARY OF SELECTED TECHNICAL TERMS

Glossary of Selected Technical Terms

Advanced Computer Environment (ACE): This consortium of workstation and software firms is developing two Unix-based operating systems that can run on various workstation architectures. ACE is one of three workstation consortia competing to set the workstation operating system standard. See Common Open Software Environment and Open System Foundation.

application software: Computer programs that enable activities such as word processing, spreadsheet analysis and database creation/updates. Computer firms conform to many hardware and software standards to insure that available application software are compatible with their products and operating systems.

binary digit (BIT): A zero (0) or a one (1) in the binary language of computers. It represents a physical memory cell, a magnetic spot on disk or tape, or a pulse of high or low voltage travelling through a circuit.

bipolar: One of two types of digital integrated circuits (ICs). Although more difficult to produce, they are faster than the other type of IC, the MOS device.

byte: Made up of eight bits, it is the common unit of computer storage in all computers. The memory in most computers is now measured by megabytes, or millions of bytes.

central processing unit (CPU): The part of the computer that computes information. A single microprocessor is the CPU in a PC while a CPU in a minicomputer or mainframe is contained on one or several printed circuit boards.

centralized processing: Processing performed by one or more computers at a principal location that receives and disperses information to dumb terminals. The computer industry is moving away from centralized processing toward distributive processing, where computations are performed both at a central location and at the PC or workstation on the desktop.

chip: See integrated circuit.

client-server: See distributive processing.

clone: A computer that is compatible with a particular machine and is designed to be as similar to the original as legally possible. Clones of the IBM PC revolutionized the computer industry by cultivating a mass market based on price competition.

Common Open Software Environment (COSE): A consortium of workstation firms working to achieve interoperability between proprietary workstation operating systems. COSE is one of three workstation consortia competing to set the workstation standard for operating systems. See Advanced Computing Environment and Open System Foundation.

complementary metal oxide silicon (CMOS): One of the newest versions of MOS, CMOS processes information very quickly without using lots of power. CMOS is being used to increase the computing power in certain RISC chips. See metal oxide silicon.

component: Any hardware part that is contained within a computer, such as disk drives, power supplies, or printed circuit boards.

computer: Usually an electronic digital machine capable of processing data using temporary or permanent internal instructions. The definition of a computer changes as the industry evolves and new technology emerges.

computer architecture: The basic design of a computer system based on the type of applications needed and the desired level of interoperability; it determines available memory, computing power, processing speed, and type of operating system. As users begin to demand interoperability and standardized products, computer architectures are starting to become more compatible.

computer platform: The hardware architecture on which computer systems are based, often defined by the processing power available at each terminal. Computer users are moving from mainframe-based computer platforms that process all information at a central location, to client-server platforms, which distribute processing capabilities to individual users.

disk drive: An internal or external storage device that allows users to extract and store information between computer uses on removable magnetic or optical disk cartridges, or on non-removable disk platters. Computer firms are constantly searching for smaller and faster disk drives to speed up the read/write process.

disk operating system (DOS): A single user operating system used in IBM and IBM-compatible PCs. Although several companies have developed operating systems to compete with DOS, over 50 percent of PCs now use DOS.

display: A video screen that shows a computer's output. Displays differ depending on the computer size and the required graphics capabilities.

distributive processing: A type of computer platform in which each computer handles its own workload while the server, which connects all of the computers, provides application programs, communication between computers, and limited memory; this is often referred to as a client-server network. Distributive processing is becoming a popular alternative to centralized processing and is the impetus behind the platform downsizing trend.

dumb terminal: An input/output unit that has no processing capability; it is attached to a central processor, usually a mainframe. Dumb terminals are becoming obsolete as mainframe systems begin to use PCs and workstations as their terminals to battle the platform downsizing trend.

flat panel display (FPD): A thin display screen that uses technologies other than cathode ray tubes. Flat panel displays are relatively new and are essential in the development of lightweight portable computers. See USITC Certain High-Information Content Flat Panel Displays and Display Glass Therefor from Japan (investigation No. 731-TA-469 (F)) and Views on Remand in investigation No. 731-TA-469 (F).

floating point: A method for storing and calculating numbers in which the decimal points do not line up. Floating point operations are used in the large numerical calculations executed by supercomputers.

floating point operations per second (FLOPS): The unit of measurement of floating point calculations.

floppy disk: A removable storage medium, also called a diskette; it is a single round disk of flexible, tape-like material that is housed in a square envelope or cartridge. The disk drive grabs the disk at its center and spins it inside its envelope.

gigaflop: One billion FLOPS. Most supercomputers have peak processing speeds between 3 and 16 gigaflops.

hardware: The physical equipment in a computer system. Computer hardware is the focus of this study.

integrated circuit (IC): A collection of transistors, diodes, capacitors, and resistors attached to a silicon chip in a precise format to perform specific electronic functions. There are several types of integrated circuits, often called chips, including memory chips and microprocessors.

interface: An interface is the connection in all aspects of computing. There are interfaces for hardware components, software, and user/computer communications. See software interface.

interoperable: Two computers are interoperable when, through manipulation of operating systems and software interfaces, they reach a certain level of compatibility. Customers are starting to demand interoperability among different computers as they expand their computer systems and want existing software to run on various types of hardware.

laptop computer: A portable computer that weighs between 7 and 12 pounds.

mainframe computers: Mainframe computers support a large number of users at one time and are primarily used by large organizations for general-purpose applications such as payroll, accounting, and decision support. Because users are moving away from centralized processing, mainframe producers are attempting to incorporate distributive processing in upcoming models.

massively parallel processing (MPP): Parallel processing that uses hundreds or thousands of processors. MPP is an emerging field, said to be competitive with traditional vector supercomputers despite a lack of software to coordinate communication between processors.

memory: The working storage of a computer, memory determines the size and number of programs that can be run simultaneously as well as the amount of data that can be processed instantly. As chip technology improves, computer memories expand.

metal oxide silicon (MOS): One of two types of digital integrated circuits (ICs); it is used in the computer industry because of its significantly lower power requirements than bipolar ICs. See bipolar and complementary metal oxide silicon.

microcomputers: See personal computer.

microprocessor: A type of processor that is used in PCs and workstations as the CPU. Advances in microprocessors are often catalysts to new models of PCs.

million instructions per second (MIPS): A unit of measure for the processing speed of computers. MIPS is usually used to describe the speed of PCs and workstations, while FLOPS are often used when discussing supercomputers.

minicomputers: Similar to mainframes, they serve as the central processor for multiple terminals, but generally have less processing power and memory and are available at a lower price. The market for minicomputers is shrinking as high-end workstations and low-end mainframes continue to encroach upon their market.

modulator/demodulator (MODEM): A device that allows communications between computers by converting digital pulses into telephone line frequencies and then back into digital pulses for the receiving computer. Modems are popular among those that wish to communicate with other computer users not located in the same building.

monitor: See display.

motherboard: The main printed circuit board in computers. It contains sockets to accept additional boards, a microprocessor, and other components. Motherboards are critical to the performance of a computer and many firms design the layout of their boards in order to incorporate the maximum amount of components on the board.

network: A system of interconnected computers, usually PCs attached to a server (local area network), or multiple computer systems connected through phone lines to a central server and information distributor (wide area network). Many new networks are being installed to replace aging mainframes, and they are contributing to the shift toward smaller computer systems.

notebook computer: A portable computer that weighs less than 7 pounds and usually incorporates a flat panel display. Notebooks are making up a larger portion of total PC sales as users begin to buy these small machines for home, office, and travel use.

object-oriented software: Building blocks made up of common lines of software code that will eliminate time-consuming and redundant software writing. Object-oriented software is not currently used extensively but is expected to play a major role in future software developments.

Open Software Foundation (OSF): A consortium of workstation and supercomputer firms that has developed a unified version of Unix called OSF/1. See Advanced Computing Environment and Common Open Software Environment.

open systems: Computer platforms that are designed to be fully compatible with other platforms so that companies may easily use the same software on various machines throughout their institutions. Users are encouraging the development of open systems, especially in workstations, which currently have a variety of proprietary architectures.

operating system: This software serves as the bridge between computer hardware and application software programs. While there are two standard operating systems for PCs, there are still several proprietary operating systems for workstations, mainframes, and supercomputers, making interoperability between different computers difficult. See disk operating system and UNIX.

parallel processing: Parallel processing divides a problem into several parts and distributes the work among processors or computers. This often increases the speed at which the problem is solved when compared with sequential processing. See massively parallel processing.

peripheral: Any hardware device connected to a computer, such as a monitor, keyboard, or printer. Peripherals are needed in order to input information and receive feedback from computers.

personal computer (PC): The least powerful of all computers, PCs are also called microcomputers. PCs, which include desktop computers, laptop computers, and notebook computers can run applications software such as word processing, financial analysis, and computer programming software. The popularity of PCs, especially attached to networks, is a major reason for the current platform downsizing trend.

platform downsizing: The replacement of mainframes, minicomputers, or supercomputers with smaller, often less powerful machines, that are attached to a server through a network. The platform downsizing trend has caused a shift in demand from mainframes and minicomputers to PCs and workstations.

portable computer: PCs that weigh less than 12 pounds and usually incorporate flat panel displays so that users can carry their computers wherever they go.

printed circuit board (PCB): Flat boards that contain chips and other electronic components that necessary for computers. PCB design is essential to manufacturers because the number and size of PCBs in a computer determine the size of the computer.

processing: A computer's manipulation of data to solve a problem. See centralized processing, distributive processing, and parallel processing.

processor: See central processing unit.

program: Software that contains instructions to perform a particular task.

reduced instruction set computing (RISC): A type of microprocessor that, because of its streamlined instruction set, performs at a rate 15 to 50 percent higher than traditional PC microprocessors, which are usually based on more complex instructions.

semiconductor: A solid state substance that can be electrically altered; silicon is the semiconductor used in the computer industry. Semiconductors are the building blocks used in computer design and are part of the PCBs that make up a computer.

server: One of the central computers in a network that distributes information to and from hundreds of users, many times acting as a "traffic cop" by directing information from one user to another. Any computer can act as a server as long as it has the required processing and memory capabilities to fill the needs of its network.

software: The instructions that tell a computer what to do. See applications software and operating system.

software code: The basic instructions that comprise a software program.

software interface: Software interfaces contain languages and codes for communications between applications, operating systems, and networks. While proprietary software interfaces are closely guarded by their developers, many computer firms encourage standard software interfaces as a step toward open systems.

standards: A widely accepted architecture, hardware, or software that facilitates interoperability between different brands of computers. As an unregulated industry, most standards are "de facto" standards that have evolved from consumer preferences and market conditions. Companies attempt to influence new de facto standards for emerging products.

supercomputers: Large-scale computers that are distinguished from mainframe computers by their faster execution, larger memory, and generally higher prices. Historically, they have been used for scientific research and in applications requiring the processing of massive amounts of data, such as weather forecasting.

system software: See operating system.

teraflop: One trillion flops. This processing speed has not yet been reached by supercomputers.

terminal: An input/output device for a computer that usually has a keyboard for input and a video screen or printer for output. Terminals are usually attached to mainframes.

Unix: An operating system used mainly in workstations and supercomputers that allows multi-tasking. There are several versions of Unix, and different consortia of workstation producers are attempting to establish an industry standard based on one, non-proprietary version of Unix.

vector processing: The traditional approach to solving problems with computers; this method performs multiple calculations on vectors (one-dimensional arrays) simultaneously. Vector processing is the basis on which most computers are designed, although new massively parallel supercomputers are attempting to achieve higher processing speeds by dividing a problem among several processors for simultaneous computation.

workstations: Similar in appearance to PCs and often attached to networks, these computers have greater technical analysis and computing capabilities. Although workstations were first developed for use in the engineering profession, they are now used in all industries. Workstations are also used as servers in networks as well as in attempts at parallel processing.

APPENDIX H
RESULTS OF STATISTICAL TESTS

Introduction

This appendix reports the results of statistical tests performed to evaluate how selected factors affect performance in the computer industry. Efforts were made to quantify the factors identified in chapter 4 as determinants of competitiveness. Two separate analyses were conducted for personal computer (PC) manufacturers and for computer firms that derive 75 percent of revenues from hardware sales (to be referred to as the hardware analysis). Necessary data were not available to conduct a separate statistical analysis for each of the segments. Regression analysis was used to test the hypothesis that global market share is influenced by key factors identified in industry interviews.[1]

For the PC analysis, the dependent variable was the share of global PC revenues accounted for by each of the selected PC manufacturers. For the hardware analysis, the dependent variable was the share of global sales of hardware accounted for by each of the selected firms. Hardware revenue included sales of mainframes, minicomputers, and personal computers plus other related, data processing equipment.[2] The data used in the regression analysis are taken from the Gartner Group's *Yardstick: Top 100 Worldwide*, 1993. The data cover the 1987-92 time period. All value data have been deflated by the GDP deflator[3] to obtain revenues or expenditures in real terms. Estimation was done using a pooled time-series, cross-section method[4] that corrected for autocorrelation[5] within each cross section and for heteroskedasticity[6] between

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[1] Market share and profitability are often proposed as measures of competitiveness. Market share was selected as the measure of competitiveness to be used in this analysis because profitability data were not available on a segment basis. In *Folded, Spindled, and Mutilated: An Economic Analysis of U.S. vs. IBM* (Cambridge, MA: MIT Press, 1983), Franklin M. Fisher, John J. McGowan, and Joen E. Greenwood state that revenue is "...the best of the single measures..." that might be used for market share in the computer industry, given the available data (p. 110). With respect to profitability as a measure, they state that "...the problems involved [with using profitability] are so large as to make *any* inference from accounting rates of return as to the presence of economic profits, and *a fortiori* monopoly profits, totally impossible in practice." (p. 219). A further discussion of the measurement of competitiveness is found in USITC, *Global Competitiveness of U.S. Advanced-Technology Industries: Communications Technology and Equipment*, (investigation No. 332-301), USITC publication 2439, Oct. 1991, pp. 3-1 to 3-2; USITC, *Global Competitiveness of U.S. Advanced-Technology Industries: Semiconductor Manufacturing and Testing Equipment*, (investigation No. 332-303), USITC publication 2434, Sept. 1991, pp. 2-1 to 2-2, and USITC, *Global Competitiveness of U.S. Advanced-Technology Industries: Cellular Communications*, (investigation No. 332-329), USITC publication 2646, June 1993, pp. 3-1 to 3-5.

[2] Other data processing equipment includes data communications equipment and peripherals for computers. This aggregation of revenues makes the hardware revenue figure comparable to the labor productivity figure, which includes revenue from all data-processing hardware manufacture.

[3] The GNP deflator comes from table B-3 in the *Economic Report of the President* (Washington DC: U.S. Government Printing Office, 1993), p. 352.

[4] The specific method used is detailed in Jan Kmenta, *Elements of Econometrics 2nd ed.* (New York: Macmillan, 1986), pp. 616-625. Additionally, the autoregressive parameter was constrained to be the same for all cross sections.

[5] Autocorrelation exists when the disturbance terms between successive observations are related. The disturbance terms in time series data are frequently autocorrelated. Autocorrelation causes problems in determining the level of statistical significance when estimating by ordinary least squares. Accordingly, a technique that corrects for autocorrelation needs to be used when working with data that have this problem. The pooled time-series, cross-section method employed here corrects for the problem. See Jan Kmenta, *Elements of Econometrics, 2nd ed.* (New York: Macmillan, 1986), pp. 298-334, for a discussion of this problem.

[6] Heteroskedasticity exists when the variance of the disturbance terms is not constant. Heteroskedasticity causes problems in determining the level of statistical significance when estimating by ordinary least squares. Accordingly, a technique that corrects for heteroskedasticity needs to be used when working with data that have this problem. The pooled time-series, cross-section method employed here corrects for the problem. See Jan Kmenta, *Elements of Econometrics, 2nd ed.* (New York: Macmillan, 1986), pp. 269-98, for a discussion of this problem.

cross sections after preliminary runs using ordinary least squares indicated that these problems were present.

PC Analysis

Tested Hypothesis and Variables

The regression equation for the PC analysis attempts to explain the success of PC manufacturers in increasing and maintaining market share as a function of cost control efforts, labor productivity, marketing effort, and research and development (R&D) effort. The regression equation takes the following form:

$$\text{Market share} = a + b_1\,(\text{cost control}) + b_2(\text{labor productivity}) + b_3\,(\text{marketing effort}) + b_4(\text{R\&D effort})$$

Cost control was selected because firms that are better able to control costs are likely to be those that have better component-sourcing strategies (4-3 and 4-4), and components are a major portion of the total cost of a PC. Cost control is measured by gross return on sales.[7] The expected impact of cost control on market share is positive. Labor productivity was selected because PC manufacturers have focused on ways of increasing productivity to reduce costs (4-5). Labor productivity is measured as hardware output, in dollars, per manufacturing employee. The expected impact of labor productivity on market share is positive. Marketing effort was selected because newer, specialized PC manufacturers have succeeded in gaining market share through the use of innovative marketing techniques, such as direct mail and telephone order, at the expense of the integrated firms that maintain large sales forces (4-6 and 4-7). The expected impact of marketing effort on market share is negative, reflecting the shift away from direct sales forces in the PC market segment. Two measures of marketing effort are used, selling, general, and administrative expenses (SG&A) as a percent of total firm revenue and sales employees as a percent of total firm employment. The data are normalized by either total revenues or total employment, as appropriate, so that large firms are not simply associated with large market shares without some attempt to control for the quality of expenditures or a relatively more efficient allocation of employees.

Research and development effort was selected because PC manufacturers are redesigning products to reduce manufacturing costs, thereby enhancing the competitive positions of these firms. In addition, R&D effort was selected because work by other researchers has indicated that it is important for international competitiveness in high-technology products. F. M. Scherer notes that "international comparative advantage in the production and sale of high-technology goods is not something obtained and sustained by historical birthright," but "must be struggled for and earned through superior technological innovativeness."[8] Further, there is "a high correlation between tallies of scientists and engineers as a proportion of the American work force and U.S. industries' share of exports originating from ten leading nations."[9] More specifically, in her dissertation on international comparative advantage in the computer industry, Caroline Beetz found that the number of scientists and engineers was significantly and positively related to a net

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[7] The gross return on sales indicates the efficiency of operations as well as how products are priced. See James C. Van Horne, *Financial Management and Policy* (Englewood Cliffs, NJ: Prentice Hall, 1992), p. 737. Since pricing is very competitive in the PC market segment, gross profitability likely reflects efficiency to a greater extent in this market segment where PCs are becoming commodity products than it would in other market segments where products are less like commodities.

[8] F. M. Scherer, *International High-Technology Competition* (Cambridge: Harvard University Press, 1992), p. 5.

[9] Scherer, *International High-Technology Competition*, p. 11.

export measure of comparative advantage in the computer industry for a sample of 31 countries.[10] The expected impact of R&D effort on market share is positive. Two measures of R&D effort were used, R&D expenditures as a percent of total revenues and R&D employees as a percent of total employment. The R&D variables were normalized in the same way and for the same reason as the marketing variables were normalized. The R&D variables were lagged because R&D takes time to appear in a product, but R&D was lagged only once since the product cycle in PCs is quite short.

Results

Table H-1 presents the results of four regressions run on the data for the PC segment. Eight firms specializing in the PC segment were selected. Data reflected operations during 1987-92. The 1987-92 data were used in regressions 1 and 2. However, in regressions 3 and 4, data for 1988-92 were used since R&D effort was lagged 1 year. Gross return on sales and labor productivity have the expected signs and are statistically significant at the 90 percent level or better in three of the four regressions. Of the remaining variables, only that of sales employees is significant and has the expected sign in regression 4. The regressions explained between 19 and 33 percent of the variation in the dependent variable.

Table H–1
Estimates for the personal computer manufacturers data

Determinant	Proxy		1	2	3	4
Cost management:	Gross return on sales	est	3.91	6.96	4.74	10.38
		t–ratio	1.76*	3.11***	1.46	3.79***
		beta weight	0.15	0.26	0.17	0.38
Labor saving manufacturing techniques:	Labor productivity	est	98.59	98.3	86.48	69.71
		t–ratio	2.37**	1.9*	2.16**	1.15
		beta weight	0.11	0.11	0.1	0.08
Marketing effort:	SG&A	est	2.08		–0.3	
		t–ratio	0.6		–0.07	
		beta weight	0.05		–0.007	
	Sales employees	est		–2.92		–6.36
		t–ratio		–1.36		–2.37**
		beta weight		0.09		–0.2
R&D effort:	R&D expenditures lagged once	est			24.41	
		t–ratio			1.65	
		beta weight			0.2	
	R&D employees lagged once	est				5.8
		t–ratio				1.25
		beta weight				0.08
number of observations			48.0	48.0	40.0	40.0
Buse R2			0.1879	0.2303	0.2963	0.3334

* Significant at the 90 percent confidence level in a two–tailed test.
** Significant at the 95 percent confidence level in a two–tailed test.
*** Significant at the 99 percent confidence level in a two–tailed test.

Source: USITC staff.

[10] Caroline Beetz, p. 107. Beetz notes in a footnote that private R&D expenditures were also significantly related to net exports of computer equipment, but she does not report the actual coefficient.

The regression results indicate that at least some of the selected determinants of competitiveness have a systematic impact on market share. Of the variables that were significant, gross profitability appears to have the most influence, as measured by the beta weight,[11] on market share.

Hardware Analysis

Tested Hypothesis and Variables

The regression equation for the hardware analysis attempts to explain the success of computer firms that are primarily engaged in manufacturing hardware. The regression equation takes the following form:

$$\text{Market share} = a + b_1\,(\text{cost control}) + b_2(\text{labor productivity}) + b_3\,(\text{marketing effort}) + b_4(\text{R\&D effort}) + b_5\,(\text{software skill})$$

All of the independent variables used in the PC segment analysis are also used in this analysis. Additionally, software skill was identified as being an important determinant of competitiveness in the supercomputer segment (4-29) and the workstation segment (4-15) because of, inter alia, the complexity of writing applications software for both systems. Software skill is measured as the percent of total revenue that a firm derives from the sale of software. The expected impact of software skill is positive.

Results

Table H-2 presents the results of four regressions run on the data for the hardware analysis. Data for 49 firms were used in the regression analysis. The data covered 1987-92. In regressions 1 and 2, 1 year was dropped in order to lag R&D effort, and the regressions used data for 1988-92. In regressions 3 and 4, 2 years were dropped in order to lag R&D effort 2 years. Since R&D for some segments of the computer industry may take up to 5 years before it is incorporated into a product, R&D effort was lagged an additional year in the hardware analysis to see if the longer lead time associated with these segments might be evident in the data.

Labor productivity had the expected sign and was statistically significant in all four regressions. Gross return on sales had the expected sign in all four regressions but was only significant in two of them. When SG&A expense was used to measure marketing effort, it had the expected sign and was significant; however, when sales employees were used, it did not have the expected sign and was not significant. R&D effort only had the expected sign in regression 1; however, it was not significant in any of the four regressions. Software skills had the expected sign but was not significant in any regression. The regressions explained between 7 and 13 percent of the variation in the dependent variable.

Although the regression results for the hardware analysis do not explain as much of the variation in the dependent variable as those for the PC segment, they still indicate that some of the selected determinants of competitiveness do have a systematic impact on market share. For example, labor productivity was significant in all four regressions and had the largest beta weight

[11] Beta weights indicate how many standard deviations an independent variable will move the dependent variable. Since beta weights are in standard deviation units, they allow the independent variables to be compared to see which has the most influence on the dependent variable. For a discussion of beta weights, see G. S. Maddala, *Econometrics* (New York: McGraw-Hill, 1977), p. 119.

Table H-2
Estimates for computer manufacturers with 75 percent or more of their revenues accounted for by sales of hardware

Determinant	Proxy		1	2	3	4
Cost management:	Gross return on sales	est	0.26	0.22	0.27	0.17
		t-ratio	1.92*	1.43	1.81*	0.98
		beta weight	0.02	0.02	0.02	0.01
Labor saving manufacturing techniques:	Labor productivity	est	16.78	19.6	14.96	20.26
		t-ratio	3.27***	3.74***	2.61***	3.53***
		beta weight	0.03	0.04	0.03	0.05
Marketing efforts:	SG&A	est	-1.09		-1.37	
		t-ratio	-3.32***		-3.69***	
		beta weight	-0.05		-0.07	
	Sales employees	est		0.2		0.3
		t-ratio		0.77		1.02
		beta weight		0.01		0.02
R&D efforts:	R&D expenditures lagged once	est	0.2			
		t-ratio	0.47			
		beta weight	0.005			
	R&D employees lagged once	est		-0.33		
		t-ratio		-0.93		
		beta weight		-0.01		
	R&D expenditures lagged twice	est			-0.17	
		t-ratio			-0.38	
		beta weight			-0.004	
	R&D employees lagged twice	est				-0.21
		t-ratio				-0.52
		beta weight				-0.008
Software skills	Percent software revenue of total revenue	est	0.16	0.09	0.53	0.2
		t-ratio	0.39	0.23	0.85	0.32
		beta weight	0.004	0.002	0.01	0.005
number of observations			245.0	245.0	196.0	196.0
Buse R2			0.1164	0.0722	0.1298	0.0828

* Significant at the 90 percent confidence level in a two-tailed test.
** Significant at the 95 percent confidence level in a two-tailed test.
*** Significant at the 99 percent confidence level in a two-tailed test.

Source: USITC staff.

in two of them. SG&A expense had the largest beta weight in those regressions where it was used to measure marketing effort. And gross profitability was significant in two of the regressions. One possible reason for the statistical significance of cost control, labor productivity, and marketing effort is that these variables are important in all four segments of the computer industry. R&D is clearly important in the supercomputer and mainframe segments of the industry but not so important in the PC segment. Similarly, software writing skills are important in the workstation and supercomputer segments but not in the other segments. By aggregating the data on all segments, some of the possible relationships between market share and the independent variables R&D effort and software skills could have been masked. Also, there may be measurement problems with the proxies used in the analysis, especially the proxies for R&D effort. Finally, given that only about 13 percent of the variation in the dependent variable was explained, other, unobserved factors likely influence competitiveness in this industry.

Empirical Literature

Much of the empirical work done on computers has dealt with estimating hedonic price indexes. A hedonic price index attempts to account for price changes that are the result of a quality change in a product.[12] Hedonic price index work on computers started with mainframe computers and has recently been applied to personal computers as well. Gregory Chow did one of the first studies on hedonic price indexes for computers.[13] In that study, Chow estimated the rental rate for a general-purpose digital computer as a function of multiplication time, memory size, and memory access time.[14] Chow's results indicated that the relative price of computers declined 20 percent per year, on average, during 1954-65. In 1985, the Bureau of Economic Analysis (BEA) of the Department of Commerce introduced hedonic price indexes for computing equipment into the National Income and Product Accounts (NIPA).[15] The BEA looked at computer processors, disk drives, printers, and general purpose displays in their work to obtain a deflator for computing equipment for use with the NIPA. The BEA developed three quality-adjusted price indexes for computer processors, the item that corresponds to Chow's general-purpose digital computer. The three price indexes showed an average fall in the price of processors of 17.6 to 19.2 percent per year for 1972-84. These figures correspond closely to Chow's estimate of price decline for the 1954-65 period. The average annual price declines for disk drives (12.6 to 16.9 percent), printers (10.4 to 15.5 percent), and general-purpose displays (7.3 to 7.5 percent) were less than the declines for processors but still indicated a substantial fall in price during 1972-84. In his survey of research done on hedonic price indexes of computers, Jack Triplett states that "by 1984, computer processor prices had fallen to *one-tenth of one percent* of their introductory level in 1953..." [italics in original].[16] Similarly, Robert Gordon's research indicates that the annual price decline for mainframe and minicomputer processors averaged 21.8 percent for the 1951-84 period.[17]

Research on hedonic price indexes for PCs is now being conducted. Randy Nelson, Tim Tanguay, and Christopher Patterson examined PC prices over 1984-91 and found that prices of PCs supplied by mail-order firms fell by 24.6 percent per year and that prices of PCs supplied by major manufacturers fell by 17.5 percent per year.[18] Ernst Berndt, Zvi Griliches, and Neal

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[12] For a detailed explanation of hedonic methods see Zvi Griliches, *Price Indexes and Quality Change: Studies in New Methods of Measurement* (Cambridge: Harvard University Press, 1971), and Jack Triplett, "The Economic Interpretation of Hedonic Methods," *Survey of Current Business*, vol. 66 (Jan. 1986), pp. 36-40.

[13] Gregory Chow, "Technological Change and the Demand for Computers," *American Economic Review*, vol. 57 (Dec. 1967), pp. 1117-1130.

[14] Subsequent research on hedonic price indexes for computer equipment follows Chow in using a measure of machine speed and a measure of main memory as major characteristics in explaining the quality-adjusted price declines in computer processors.

[15] This research is detailed in Rosanne Cole, et.al., "Quality-Adjusted Price Indexes for Computer Processors and Selected Peripheral Equipment," *Survey of Current Business*, vol. 66 (Jan. 1986), pp. 41-50.

[16] Jack E. Triplett, "Price and Technological Change in a Capital Good: A Survey of Research on Computers," in Dale W. Jorgenson and Ralph Landau, eds., *Technology and Capital Formation* (Cambridge: MIT Press, 1989), p. 127.

[17] Robert J. Gordon, *The Measurement of Durable Goods Prices* (Chicago: University of Chicago Press, 1990), p. 189.

[18] Randy A. Nelson, Tim L. Tanguay, and Christopher D. Patterson, *A Quality-Adjusted Price Index for Personal Computers*, unpublished manuscript (Colby College, Department of Economics, Waterville, ME), Feb. 1993. The authors also note that the implied price of four important PC attributes fell substantially during 1984-91. The implied price of an additional megabyte of RAM fell by 81 percent, an additional megabyte of hard disk space fell by 90 percent, an additional megahertz of processor speed fell by 58 percent, and an additional port fell by 61 percent.

Rappaport examined PC prices over 1989-92 and developed several hedonic price indexes.[19] They found that their quality-adjusted price indexes decline at about 20 percent per year on average.

Brian Ratchford and Gary Ford use hedonic analysis to control for differences in hardware in their study of prices and market shares in the mainframe computer industry for 1964-71.[20] They use speed and capacity measures as their attributes in their estimation. They found that IBM machines are priced above competing machines of equal performance and inferred that IBM offers its customers better services, such as superior after-sales service or greater product reliability, than its competitors, accounting for the price premium of the IBM machines. Gerald Brock noted that Ratchford and Ford made errors in their measurement of some of their variables and expressed doubt that Ratchford's and Ford's two-characteristic model could distinguish between manufacturers.[21] Ratchford and Ford corrected the clerical errors in the data and re-estimated their model.[22] In doing so, they obtained essentially the same results as they had previously, and they reaffirmed their conclusion that the prices on IBM machines were at a premium during 1964-71. Robert Michaels conducted a study similar to Ratchford's and Ford's and found no significant price premium for IBM machines.[23] However, Michaels used a more elaborate model in his estimation, employed a different data set, and used data on computer systems that included peripherals rather than on central processing units alone. These factors could account for the difference in the results.

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[19] Ernst R. Berndt, Zvi Griliches, and Neal Rappaport, *Econometric Estimates of Price Indexes for Personal Computers in the 1980's and the 1990's*, unpublished manuscript (MIT Sloan School of Management, Cambridge), Feb. 19, 1993.

[20] Brain T. Ratchford and Gary T. Ford, "A Study of Prices and Market Shares in the Computer Mainframe Industry," *Journal of Business*, vol. 49 (April 1976), pp. 194-218.

[21] Gerald W. Brock, "A Study of Prices and Market Shares in the Computer Mainframe Industry: Comment," *Journal of Business*, vol. 52 (Apr. 1979), pp. 119-124.

[22] Brain T. Ratchford and Gary T. Ford, "A Study of Prices and Market Shares in the Computer Mainframe Industry: Reply," *Journal of Business*, vol. 52 (Apr. 1976), pp. 125-134.

[23] Robert Michaels, "Hedonic Prices and the Structure of the Digital Computer Industry," *Journal of Industrial Economics*, vol. 27 (March 1979), pp. 263-275.