Globalization and Increasing Returns: Implications for the U.S. Computer Industry

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Over the last twenty years, the computer industry has become global with respect to computer production as well as computer use, a trend which has raised concerns among U.S. policymakers of hollowing out the industry and exporting employment. This paper uses the framework of increasing returns to analyze the issue. It classifies market segments within the computer industry, shows how the advent of the personal computer created these segments, examines how this change in the structure of the industry led to the evolution of an Asia-Pacific production network, identifies company and country leadership in this network, and evaluates the implications for the United States. It shows that some manufacturing employment, mainly in the decreasing returns segments of the industry, has shifted to the Asia-Pacific region. However, it also shows that employment in some manufacturing segments and in software and services, which are increasing returns or hybrid markets, has increased dramatically in the United States. It concludes that the global division of labor between the United States and both companies and countries in the Asia-Pacific region has been largely positive in that it has supported the continuing U.S. leadership position in the global computer industry.

(*Increasing and Decreasing Returns*; *Globalization*; *Computer Industry*; *Industrial Policy*; *Industry Structure*; *Competition*; *Asia-Pacific Region*)

Introduction

The computer industry was dominated from its inception until the 1980s by U.S. companies that developed most of the important innovations, set key technical standards, and controlled over two-thirds of the world's market for hardware, software, and services. Periodic technology shifts such as the introduction of the minicomputer and personal computer changed the structure of the industry, but in each case it was American companies who were the industry leaders. And since most computer production was done in the United States, the success of U.S. companies translated into corresponding benefits for the U.S. economy in the form of jobs, value added, and a positive trade balance.

The personal computer revolution of the early 1980s led to a new phenomenon in the industry, however. PC makers turned to outside suppliers for most of their inputs and moved some of their own production activities offshore. So while U.S. *companies* remained the leaders in most segments of the computer industry, the actual *production* of computer equipment began shifting away from United States, mostly to Asia. These trends have raised concerns that in the new global division of labor, company and country success are no longer synonymous.

The rapid globalization of the computer industry also raised concerns that U.S. companies are at risk of losing their industry leadership. Former U.S. Trade

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Representative Clyde Prestowitz predicted in 1989 that the Japanese would take over the computer industry as they had with televisions and other electronics products (*Business Week*, 1989). The next year, Intel CEO Andrew Grove forecast that Japanese companies would control the majority of the PC market by 1992 (*New York Times*, 1990). These predictions failed to materialize because Japan's computer industry was slow to respond to the personal computer era, but the concerns have not gone away. While some in the United States celebrate the triumph of Silicon Valley, others worry that the tables will be turned each time Japanese companies launch a new drive into the U.S. computer market.

The purpose of this paper is to provide a deeper understanding of the implications of globalization in the computer industry for the United States. We seek to develop a clearer picture of the computer industry's global production network, the concentration of that network in Asia, the global division of labor within that network, and the factors shaping the global industry structure. Thus, the paper looks at a key question raised by the globalization of the industry: What are the implications of so much production concentrated in the Asian countries for U.S. computer companies and for the U.S. economy as a whole?

We hypothesize that globalization of production has been based on a division of labor whereby U.S. computer companies focus on increasing-returns market segments and activities, and East Asian companies focus on decreasing-returns market segments and activities. A central question for future research is whether the current balance of competition and cooperation between the United States and East Asia is sustainable, or whether the industry's own dynamics and the ambition of East Asian companies and countries will upset the balance with negative implications for the United States. In order to assess this hypothesis, we must analyze the structure of the computer industry, the division of labor within the industry, and the resulting competitive position of companies and counties.

We begin by setting up a conceptual model of increasing- and decreasing-returns businesses. We use this model to characterize the computer industry in the mainframe era and show IBM as a classic increasing-returns business during its heyday. We then show how the PC changed the structure of the industry from large-scale, vertically-integrated firms to smaller firms that are focused on products in horizontal industry segments from microprocessors to operating systems to end user applications. Using the conceptual model, we show that this shift in industry structure created a new alignment of increasing- and decreasing-returns businesses based on those that were able to achieve a monopoly in new industry segments through control over standards versus those that were not able to do so.

Within the framework of increasing versus decreasing returns, we also identify several hybrid segments in which U.S. companies have succeeded by concentrating on increasing-returns activities and outsourcing decreasing-returns activities to Asian suppliers. These corporate decisions helped create an East Asian computer industry that both competes and cooperates with U.S. multinationals in various markets. We look at the impacts of Asia's success in computers on the U.S. computer industry and on employment in the United States.

In addition, we move beyond theory and description to develop a set of metrics for identifying increasing- and decreasing-returns markets, based on commonly available measures of corporate performance. These measures could serve as the basis for future research to quantify the nature of different segments of the computer industry. Finally, we look at how both companies and countries can position themselves to participate in the increasing-returns industry segments in the emerging network computing era.

Theoretical Framework

In order to analyze the structure of the computer industry, the division of labor within the industry, and the competitive position of companies and countries, we employ a framework that distinguishes between increasing- and decreasing-returns markets and activities. The argument for increasing returns is that under certain conditions, higher levels of production can result in lower unit costs, and hence, in increasing returns to producers. The possibility of increasing returns to scale has been posited as far back as Adam

Smith's *Wealth of Nations* (1776). Smith and later economists such as Alfred Marshall (1890) and Allyn Young (1928) noted that factors such as labor specialization and economies of scale could lead to increasing returns to scale in manufacturing industries.

The idea that increasing returns were not only common but important in determining economic outcomes was revived in the 1980s by economists such as Nicholas Kaldor, Paul Romer, and W. Brian Arthur. Kaldor (1985) argues that scale and specialization in manufacturing can lead to increasing returns for the largest and most advanced companies or regions, allowing them to gain competitive advantage over time at the expense of more backward competitors. Romer (1990) points to technological progress as a key force driving economic growth because it allows higher levels of output for a given combination of labor and capital inputs. Technology can be codified as a set of instructions (e.g., recipes, designs, blueprints, software) that can be used over and over at little additional cost.

The notion of increasing returns becomes much more powerful when the element of time is introduced. Rather than being dependent on a static production function and a given level of technology diffusion, returns to scale and economic outcomes in general are seen as resulting from a dynamic path dependent process. In the case of increasing-returns markets, we find the tendency for "that which is ahead to get further ahead, for that which loses advantage to lose further advantage." (Arthur 1994, p. 100). Success begets success as the leaders expand their market and achieve lower costs relative to competitors, enabling them to expand their market share even further.

Increasing returns can also apply at the country or regional level in explaining geographic concentration and division of labor in an industry. Arthur (1994) and Kaldor (1985) argue that industrial location decisions depend not only on traditional economic factors such as the presence of natural resources or the cost of labor. Rather, they are also path dependent in that once one company chooses a particular location, others will be more likely to follow. As more companies gather in one location, they tend to attract or create industry-specific assets such as parts suppliers, specialized services, and workers with specialized skills. Michael Porter (1990) reviews a number of such industry clusters, such as Silicon Valley, arguing that the presence of such clusters are key sources of national economic competitiveness.

Arthur (1994, 1996) argues that while decreasing returns still apply to traditional bulk processing industries such as agriculture, mining, and most manufacturing, increasing returns are the norm in knowledge-based industries such as computers, software, pharmaceuticals, and aircraft. He points to three conditions that account for increasing returns, each of which applies particularly well to the computer industry. The first is up-front costs—such products have high R&D costs relative to their unit production costs, e.g., the first disk of a new software program costs a million dollars to produce, subsequent copies cost a few dollars or less. The second is network effects—products are more valuable when they are used by large numbers of users and when they have a large base of complementary assets. So as more people adopt Windows, and more software vendors write programs for the Windows platform, the value of being a Windows user increases. The third is customer "groove-in," sometimes referred to as "switching costs" or "lock-in." Here, customer training and organizational adaptation to a particular product makes it costly to switch to another, even superior product. This was a key to IBM's decades-long dominance of the mainframe industry; once companies adopted IBM's proprietary hardware and software, it was very expensive and risky to switch.

In standards-based competition, which characterizes important parts of the computer industry, path dependence and increasing returns lead to a winner-take-all (or most) outcome, rather than the more balanced competitive equilibrium that would be expected in traditional industries. In the cases of VCRs and PCs, one standard has come to achieve a monopoly position after competition among two or more technically similar standards. Once a standard (such as VHS) or product architecture (such as the IBM PC) got ahead in the market, either due to chance or clever strategy, its lead was magnified as users and creators of complementary assets (e.g., video tapes or application software) gravitated toward that standard (Cusumano 1992, Morris and Ferguson 1993).

The computer industry has all three characteristics

of an increasing-returns industry, involving high up-front costs, customer groove-in, and network externalities. Yet unlike the mainframe industry, in which IBM reaped the benefits of increasing returns from its dominant proprietary standards, the PC industry is much more complex (Table 1). Specialization within the industry has divided it into numerous horizontal segments, with different competitive characteristics. Knowledge-based products such as software and microprocessors tend to demonstrate increasing returns, with near monopolies for Microsoft and Intel. Most hardware production is more of a traditional bulk processing industry, in which diminishing returns apply. Some product categories such as PCs, printers, and hard drives are hybrids that involve bulk processing but include knowledge processing in the form of technology integration, branding, marketing, and logistics.

When we analyze the strengths and weaknesses of both companies and countries in the context of increasing and decreasing returns, competition in the computer industry can be understood in a different way. We find that some companies have succeeded by being highly efficient manufacturers of commodity hardware, while others compete in the increasing-returns world through innovation, market positioning, and the ability to define new markets. A few have been good at both. Likewise, some countries have become major producers of commodity hardware, while others are strong in software and services. The present position and future competitiveness of both companies and countries depend partly on their ability to develop and enhance their capabilities in either or both those worlds. However, because of the path-dependent nature of the industry's development, the possibilities for both companies and countries at any time are shaped and bound by what has gone before.

In this paper, we use the framework of increasing versus decreasing returns to understand the historical development and current structure of the computer industry and to analyze the nature of competition within the industry.

Methodology

The methodology for conducting the research in this paper included gathering primary and secondary data from a variety of sources, reviewing academic and popular books and journal articles, collecting news reports, and conducting field interviews with over 600 people, mostly in the United States, Japan, Korea, Taiwan, Singapore, and Hong Kong, but also in China,

Table 1 Comparison of Increasing and Decreasing Returns Businesses

Dimensions	Increasing Returns	Decreasing Returns
Firm characteristics	Knowledge-based assets	Bulk-processing assets, plant & equipment
	High risk, high cost R&D relative to production costs	High process engineering costs
	High margin	Low margin
Market structure	Monopoly	Oligopoly to "open" markets
Competitive success factors	Control of technology standards	Cost efficiency throughout the value
	Definition of new markets	Product and process technology
	Brand recognition	Speed to market
	Quality	
	Product features	
Entry barriers	Established standards	Money—capital for large plant and equipment investments
	Customer lock-in	Technology—access to new process and product technologies
Determinants of location	Lead markets, with sophisticated users	Low cost labor
	Innovation-favorable environment	Skilled workers
	Availability of venture capital	Government incentives
		Good infrastructure
Illustrative computer industry sectors	Operating systems, microprocessors	Floppy disk drives, CD-ROMs, motherboards, DRAM

Malaysia, Thailand, the Philippines, India, Australia, and New Zealand. This research has been published in country case studies (Gurbaxani et al. 1990, Dedrick and Kraemer 1993a and 1993b, Kraemer and Dedrick 1993 and 1995, Kraemer et al. 1994, Dedrick et al. 1995), cross-country comparisons of computer production and use (Dedrick and Kraemer 1994, Kraemer and Dedrick 1994), and a book (Dedrick and Kraemer 1998). This extensive research has led to a number of conclusions about the nature of the computer industry and the use of information technology throughout the Asia-Pacific region. This paper builds on that research to focus on the critical issue of how U.S. companies have developed an Asian production network as a basis of competitive advantage and how they have maintained their competitiveness in the face of growing competition from Asia.

The structure of the paper is as follows. First, we review the changing of the computer industry from the mainframe era to the PC era and show how the horizontally segmented structure of the PC industry encouraged globalization and made possible the growth of an Asian production network. Next, we segment the PC industry along the lines of increasing and decreasing returns to scale, characterizing the nature of competition and identifying market leaders in each segment. We summarize the performance of U.S. and Asian companies and countries in the computer industry and locate them along the dimensions of increasing and decreasing returns. Finally, we analyze the implications of the Asian production network and consider possible competitive threats and opportunities that are arising from Asia for the U.S. computer industry.

Increasing Returns and Computer Industry Evolution

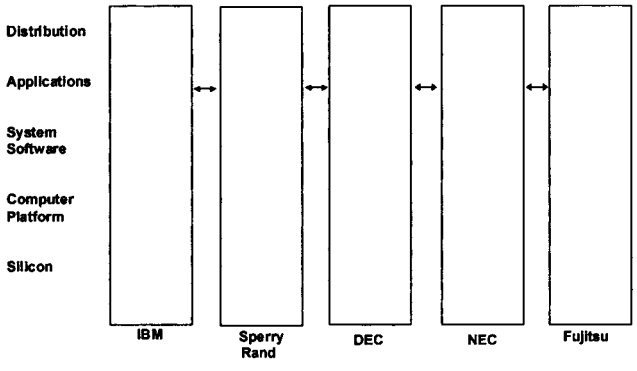
Increasing returns have been a feature of the computer industry since its early days because one or two companies have been able to control key standards and translate that control into market dominance. During the mainframe era, IBM enjoyed increasing returns as a result of its market share and control of key standards, but in the PC era, IBM inadvertently ceded control over the key standards to Microsoft and Intel, who have enjoyed the benefits of increasing returns ever since.

Increasing Returns in the Mainframe Computing Era

From the time of its inception in the 1940s until the early 1980s, the computer industry was dominated by IBM, which controlled nearly half the world market for computers. This era of the centralized mainframe and minicomputer was marked by a few large vertically-integrated companies that produced many of their own components, developed their own software, and sold their computers through their own sales force (Figure 1). IBM's System/360 and System/370 became the dominant platforms of the central computing era and created an increasing-returns business for IBM. IBM's standard drove competing platforms to the fringes of the market and became the safe choice for computer users, as illustrated by the saying that "No one ever got fired for buying IBM." IBM was able to develop its own peripherals and software for the System/360 and 370, and other companies developed complementary assets in the form of plug-compatible peripherals and application software that increased the value of adopting the IBM standard. IBM enjoyed a high level of customer lock-in as users invested millions of dollars in hardware and software, trained their staff in IBM systems, and built entire business processes around IBM standards. IBM's solid growth and

Figure 1 Computer Industry Structure: The Mainframe Era

Source: Jason Dedrick and Kenneth L. Kraemer, 1998, *Asia's Computer Challenge: Threat or Opportunity for the United States and the World?* New York: Oxford University Press. Adapted from Andrew S. Grove, 1996, *Only the Paranoid Survive*, New York: Doubleday.



high-profit margins in the 1960s and 1970s were the by-products of its ability to create and sustain increasing returns in its business.

Although the U.S. government worried about IBM's dominant position, the company's market dominance carried with it a corresponding national advantage for the United States. While IBM was an international company—with marketing, production, and even R&D operations around the world—the bulk of its high-value activities remained in the United States. Much of the market not controlled by IBM was in the hands of other U.S. companies. With strong government support, Japan's computer makers came to control most of their domestic market, and Europe's national champions remained competitive in their home markets. But none of these companies could compete with IBM outside their domestic markets.

Division of Labor in the PC Era: Increasing and Decreasing Returns

The comfortable equilibrium enjoyed by IBM was punctuated by the introduction of the personal computer in the 1970s. The mainstream computer companies scoffed at the PC as an underpowered toy for people who couldn't afford a real computer. However, when Apple Computer began selling PCs by the hundreds of thousands, IBM responded quickly by developing its own PC.

Rather than build its PC entirely in-house, IBM followed the lead of Apple, Commodore, and others by assembling components from outside suppliers. The de facto standards that allowed standardization of components were set when IBM introduced its PC in 1981, which had an open architecture for which other companies could develop complementary products such as software and peripherals.

IBM made a critical strategic error, however, when it contracted with Microsoft and Intel to develop the operating system and microprocessors for the IBM-PC and allowed them to license their technologies to other companies. IBM soon faced hundreds of competitors making IBM clones and selling them at cut-rate prices, while Microsoft and Intel garnered the huge profit margins that IBM had been accustomed to in the mainframe business. While IBM had given away control of its own creation, the open standards of the IBM-PC architecture also lowered barriers to entry, allowing literally thousands of new companies to get into the computer business, making everything from chips to systems to software.

The computer industry in the mainframe era had been dominated by 10 giants who controlled 65% of the market in 1975, with another 40 companies controlling 32%. The category "all others" accounted for just 3% of the market. By the 1990s, the industry was populated by thousands of firms, including PC newcomers such as Compaq, Apple, Dell, Microsoft, Novell, and Acer. IBM, which accounted for 37% of the world computer market in 1975, had only 15% by 1994. The "all others" category now accounted for 23% of the market, its growth mirroring IBM's declining market share (Table 2).

The personal computer revolution led to a dramatic change in the structure of the computer industry. Whereas the mainframe computer industry consisted of a few large, vertically-integrated firms such as IBM, NCR, Fujitsu, and Hitachi, the PC industry was a horizontally segmented industry with thousands of firms competing at the different levels of the value chain (Figure 2). Most companies specialize in one market segment such as disk drives, PCs, or software, and even the smallest companies could find niches producing anything from cables and connectors to software and services.

The shift from vertical integration to horizontal segmentation in the computer industry had a profound effect on the nature of competition in the industry. The microprocessor and operating systems markets became new increasing-returns businesses, with near-monopoly industry structures. The application software market has increasing-returns characteristics, but

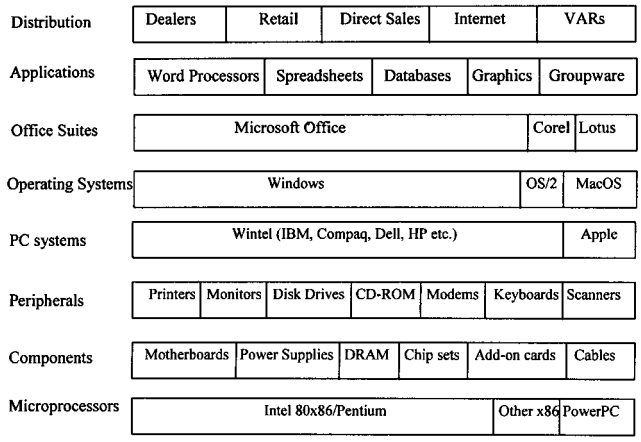
Table 2 Worldwide Market Share (%)

	1975	1985	1990	1995
IBM	37	30	21	14
Companies 2–10	28	29	28	32
Companies 11–50	32	29	28	31
All others	3	18	23	23

Source: McKinsey & Company, Inc., *The 1996 Report on the Computer Industry* (New York, NY: McKinsey & Company, Inc., 1996).

Figure 2 Computer Industry Structure: The PC Era

Source: Dedrick and Kraemer, 1998. Adapted from Grove, 1996.



most segments are more competitive because of limited customer lock-in and network effects, or they are specialized markets in which increasing returns are limited by the scale of the market. Most hardware segments of the industry have evolved into highly competitive decreasing-returns businesses. A few segments, such as printers, PC systems, and services, are hybrids that fall between purely increasing- and decreasing-returns markets. Within the three categories, there were important distinctions among the types of companies that succeeded, as well as among which countries played important roles.

Before discussing the roles of different companies and countries in the various segments of the industry, it is valuable to provide some basic quantitative metrics that help distinguish among the categories. The difficulty in quantifying increasing returns is that there are very few markets that exhibit such pure increasing-returns characteristics that the outcome is a monopoly or near-monopoly market structure. In the PC industry, only the operating system and microprocessor markets have the near-monopoly structure expected in increasing-returns markets.

Most segments of the industry fall somewhere between pure increasing and decreasing returns, and some measure or set of measures is needed to place them on that continuum. Market share is good initial indicator of increasing or decreasing returns, but looking at the competitive structure of a market segment alone will not necessarily distinguish whether it has increasing-returns characteristics. However, there are measures of company and sector performance that point to the presence of increasing returns. We propose the following three metrics as indicators of returns to scale in the computer industry:

• *Market share of top company:* This is an obvious choice, as it indicates the degree to which "That which is ahead tends to get further ahead," in Brian Arthur's terms. If a dominant standard gains strong customer lock-in and network externality effects, the company controlling the standard is likely to have a very large share of the market. Both Microsoft and Intel have over 80% of the operating system and microprocessor markets, respectively (Table 3). In PCs, market leader Compaq has just 12% of the market, while in floppy disk drives Mitsumi has an 18% share; yet we have identified PCs as a hybrid market and floppy drives as a decreasing-returns market based on the ability of PC makers to achieve competitive edge through branding and other increasing-returns activities. How, then, can we distinguish more clearly where increasing returns exist? To do so, we use a pair of financial indicators.

• *Profit margins* are highest in increasing-returns markets. For instance, net income as percent of sales of leading software and networking companies range from 10% to as high as 25%, compared to PC and hard disk drive makers, which rarely top 5%. Also, software and datacommunications (networking companies such as Cisco and Cabletron) earn a share of total computer industry profits that is much higher than their share of revenues. (Table 4 and 5).

• *Return on equity:* ROE is a measure of the ability of firms to put capital to productive use, and the best way to do so is by achieving increasing returns. One way is obviously through dominating an increasing-returns market, as in the case of Intel, Microsoft, and Cisco. However, some companies are able to succeed even in highly competitive markets by focusing on increasing-returns activities. Thus, even in a low margin business such as PCs, a company can earn a high return on investment by focusing on high value knowledge activities and leaving capital intensive bulk processing to its suppliers. This is the case with Dell, whose net margins are only 5% to 6%, but whose ROE in the 1990s

Table 3 Competition in the Computer Industry, 1996 (% Share of World Market)

1. Micro-processors*		2. Operating systems (1995)**		3. PC systems (1997)*		4. Printers**		5. Hard disk drives*		6. DRAM*		7. Floppy disk drives**		8. CD-ROM drives**		9. Monitors (1995)**	
Intel	83.4	Microsoft	80.1	Compaq	12.4	Hewlett Packard	49.4	Seagate	26.	Samsung	16.	Mitsumi	18.6	Matsushit	20.5	Samsung	14.0
IBM	4.1	Apple	8.2	IBM	8.8	Canon	17.2	IBM	24.	NEC	13.	Teac	17.5	Mitsumi	14.0	Acer	6.3
AMD	8.5	IBM	6.7	Dell	5.6	Epson	8.7	Quantum	15.	Hitachi	11.	Sony	14.3	Toshiba	9.8	Philips	6.2
Motorola	1.9	n.a.		Hewlett-Packard	5.4	Lexmark	6.6	Western Digital	12.	Hyundai	9.2	Matsushita	9.4	Sony	9.4	LG (Goldstar)	6.1
Texas Instruments	1.1	n.a.		Packard Bell-NEC	4.8	Okidata	4.9	Toshiba	5.7	Toshiba	8.9	Mitsubishi	7.7	NEC	8.5	ADI	4.8
Top 5	92.5	Top 3	95.0	Top 5	37.0	Top 5	79.	Top 5	84.	Top 5	59.	Top 5	67.5	Top 5	62.2	Top 5	37.4
Increasing returns						Hybrid						Decreasing returns					

* Share of *revenues* ** Share of unit *shipments*

Sources:

1. Calculated from *Electronic Buyers' News,* "MPUs: MPU Makers Expect Lucrative Year," http://techweb.cmp.com/ebn/semicon/mpu.html
2. International Data Corporation (IDC), "Worldwide Market Share of New PCs Shipped 1995," *The Gray Sheet 30*(1995): 19–20.
3. Dataquest, "Worldwide PC Market Posts Nearly 16% Growth in 1997, According to Dataquest," Press Release, January 26, 1998.
4. U.S. Shipments only, Computer Intelligence InfoCorp, 1997, data provided to authors.
5. Includes captive and noncaptive shipments. *1997 Disk/Trend Report: Rigid Disk Drives,* Mountain View, CA: Disk/Trend, Inc.
6. Calculated from *Electronic Buyers' News,* "DRAM: DRAM Leaders Gird for a Tough 1997," http://techweb.cmp.com/ebn/semicon/dram.html
7. *1997 Disk/Trend Report: Removable Data Storage,* Mountain view, CA: Disk/Trend, Inc.
8. *1997 Disk/Trend Report: Optical Disk Drives,* Mountain View, CA: Disk/Trend, Inc.
9. MIC/III, "Taiwan's Major Monitor Producers," *Asia IT Report,* Special Edition: Taiwan 1995: 44.

Table 4 Profit Margins and Return on Equity of Companies by Industry Segments

Industry Segment	Net Income as % of Revenues, 1993–1996 Average	Return on Equity
Increasing Returns		
Microsoft	25.3	28.5
Intel	23.2	28.8
Cisco	22.6	34.1
Oracle	13.7	35.6
Adobe	12.0	14.2
Hybrid		
Compaq	6.7	19.9
Dell	3.5	26.4
Gateway	4.8	35.3
EDS	6.8	16.8
Computer Sciences Corp.	3.5	10.8
Decreasing Returns		
Samsung Display Devices (Korea)	5.3	n.a.
Acer (Taiwan)	4.4	8.7 (1996)
Mitac (Taiwan)	1.5	n.a.
FIC (Taiwan)	4.1	n.a.

Sources: McKinsey & Company, *Report on the Computer Industry*, 1993 and 1996.

Table 5 Share of Total Industry Revenue vs. Profits for Industry Segments, 1995

Industry Segment	Share of Revenues	Share of Profits
Hardware	61.8	29.6
Software	13.7	38.6
Services	19.6	15.6
Datacomm	5.0	16.3

Source: McKinsey & Company, *The 1996 Report on the Computer Industry.*

has matched that of monopolists Intel and Microsoft (Table 4).

The following sections provide more detail on the character of decreasing-returns, increasing-returns, and hybrid markets, and the role of the United States and Asia in those markets.

Decreasing-Returns Markets

Most hardware markets operate on the basis of decreasing returns to scale. The differences among the various market segments are important, however, as they greatly influence what types of companies and countries are most competitive in each segment. For instance, some industries, such as DRAMs (Table 3, column 5) and flat-panel displays (column 6) are very capital-intensive, high-volume commodity industries, with little differentiation among products. These industries tend to favor large diversified companies who can have the financial resources to make large investments in R&D and production facilities, and who can weather temporary downturns in the market. Not surprisingly, the DRAM and flat-panel industries are dominated by large Japanese and Korea electronics conglomerates such as Toshiba, NEC, Fujitsu, Samsung, Hyundai, and LG Electronics. Most U.S. semiconductor makers have abandoned the DRAM market, although Micron and IBM remain active. The flat-panel display market, built on LCD technology developed in the United States, has been almost completely ceded to Japanese companies, with Korean companies just recently entering the market in large scale. Now a few Taiwanese companies are entering the DRAM and LCD markets as well.

Other segments of the hardware industry follow different rules, however. Some—such as motherboards, add-on cards, and a variety of peripherals and components—are highly price sensitive and place a premium on speed-to-market of new product generations. They require flexibility rather than scale in production. These segments favor the many small- and medium-sized Taiwanese companies, who compete on the basis of speed, flexibility, the ability to squeeze costs to the bone, and close ties to global markets via the overseas Chinese network.[1] While data are not available on motherboard market share by company, most of the major motherboard producers supplying the global PC

[1]Large numbers of Taiwanese engineers work for U.S. companies. These "human resources on deposit" serve as sources of market and technology information for Taiwanese companies who are linked by family or alumni networks. Some are also lured back to work for Taiwanese companies, bringing their knowledge and connections with them.

industry are Taiwanese companies such as Asustek and FIC.

There are also market segments based on more stable technologies in which price is the determining factor, such as monitors, floppy disk drives, CD-ROM drives (columns 7–9), keyboards, cables, and connectors. Most of these are made by Japanese, Korean, and Taiwanese companies, but production is often done in low-cost locations such as China or Southeast Asia. Japanese companies still produce most of the key high-value components for products such as large monitors and CD-ROMs and either produce the final products offshore or sell the components to Korean and Taiwanese companies that produce the end product. U.S. companies are again virtually absent in these segments of the market.

While the various hardware markets have quite different industry structures, and have favored different companies and countries, they all are marked by the characteristics of diminishing returns. Competition is intense, margins are thin, and if one company starts to get ahead, it attracts even more aggressive attacks by its competitors. For example, the Japanese giants who had driven most of their American competitors out of the DRAM industry in the 1980s were unable to enjoy the fruits of their victory as the Koreans soon entered the market with huge volumes of production. Prices for DRAM are now so low that it is questionable if anyone is making a profit in the industry. The same pattern may be repeated in flat-panel displays as Korean companies ramp up production, followed by Taiwanese companies in the near future. As we have seen, U.S. companies have abandoned most of these decreasing-return markets altogether, finding them not profitable enough to justify continued participation.

Increasing-Returns Markets

In contrast to the world of decreasing returns, which is dominated by Asian companies, the increasing-returns segments of the industry are completely under the control of U.S. companies. The classic case of an increasing-returns business is the operating systems market (Table 3, column 1). Microsoft gained a critical first-mover advantage when IBM chose MS-DOS as the operating system for the original IBM-PC. Ensuing Windows operating systems cost millions each to develop, but the marginal cost of each new copy was just a few dollars. Meanwhile, as more users adopted Windows and more software developers wrote applications for Windows, the marginal value of each new copy of Windows actually grew, due to the external economies provided by a larger user base and a larger pool of complementary assets (third-party software, add-on hardware, distribution channels, user experience).

Application software also functions as an increasing-returns business, but with much greater competition in most market segments than is seen in the operating systems business. While the cost structure of application software is similar in terms of high up-front costs and low marginal costs, the customer lock-in effect is less pronounced. It is easier and cheaper to switch from WordPerfect to Word than it is to switch from Macintosh to Windows. However, Microsoft has been quite successful in extending its dominant market position into the critical office application market by bundling its software into the Microsoft Office suite. This application suite costs less than buying separate applications and offers some product integration among the component applications.

The other industry segment clearly characterized by increasing returns is the microprocessor market (column 2), where Intel has enjoyed a market share of over 70% since IBM selected its processors for the original IBM-PC. Through its ability to control many hardware standards for the PC (and aggressive protection of its intellectual property), Intel has created a counterpart to the Windows franchise in operating systems. While it does have competitors in the x86 microprocessor market, Intel has actually been able to increase its share of that market over time, topping 80% in 1996. Thanks to the huge profits garnered in this increasing-returns market, Intel can afford to make heavy investments in R&D and production capacity in order to stay ahead of competitors technologically and lower its production costs. It has also spent heavily on its "Intel Inside" campaign to create a franchise based on branding as well as architectural standards.

Hybrid Markets

In between the clearly defined increasing- and decreasing-returns markets, there are a few market

segments that show characteristics of both worlds. These "hybrid" industries might start out as increasing-returns businesses and mature into decreasing-returns businesses, as was the case with the original IBM-PC. Or they can start out as decreasing-returns businesses, but be transformed into increasing-returns by a change in the market or by management strategies that recast a company's role in the market. For instance, Microsoft initially developed separate custom versions of DOS for different PC makers before realizing the power of creating (and controlling) one common version which would run on all IBM-compatible PCs. Likewise, Intel's original 4004 microprocessor was developed as a custom product for a Japanese calculator company, Busicom, and then was transformed into a general purpose microprocessor.

Within the computer industry there are several markets that currently can be classified as hybrids. One is the information services business, which includes custom programming, systems integration, outsourcing, network services, and maintenance. The information services business has been dominated by domestic companies in most countries. The need for close interaction with customers, local language skills, and intimate knowledge of local business culture has put even large companies such as EDS and Computer Sciences Corporation at a disadvantage outside the U.S market. No matter how good they are in the United States, these companies have to hire and train local people in each market and compete against local companies who have access to the same talent. The main advantage of U.S. companies is their size and ability to serve the global needs of large multinationals. For instance, IBM has marketed information services around the world by utilizing its global data network and has taken advantage of local capabilities developed over the years to support its hardware business. Still, there are limited network externalities available in the services industry, because the business is based mainly on providing custom solutions for each client's needs.

Some of the most interesting hybrid industries, and the most competitive for U.S. companies, are found in the hardware industry. Here, U.S. companies face direct competition from powerful Japanese firms, many of whom are successful in a variety of consumer electronics and components markets. Most notable among these are the PC systems, printer, and hard disk drive industries (Table 3, columns 3–5). PCs are seen by many to be the ultimate commodity product, with thousands of producers all making nearly indistinguishable products from the same array of components. Price competition is fierce, and market share success is measured in one- or two-percent gains. The PC industry would seem to be a perfect fit for the Japanese and other Asian companies that have come to dominate most of the commodity hardware industry, yet U.S. companies hold four of the top five positions in world markets.

Likewise, in spite of Japan's strong position in the printer market and its companies' strengths in related optoelectronics products such as cameras and copiers, it is the U.S. company Hewlett-Packard that controls nearly half the U.S. market (and data from earlier years show a similar picture for global markets). Finally, U.S. companies have maintained a dominant position in the hard disk drive (HDD) industry, in contrast to the near total control by Japanese companies in floppy disk drives and CD-ROM rives.

Strategies of U.S. Companies to Compete in Hybrid Markets

The ability of U.S. companies to succeed against the odds in a few key high volume hardware industries provides perhaps the most interesting story of the global PC industry. It also shows most clearly the complementary relationship between U.S. companies in hybrid markets and the Asian production network.

Based on the criteria presented in Table 1, the PC, printer, and HDD industries would appear to fall within the domain of decreasing returns. They are not marked by high up-front costs relative to unit production costs, they provide little or no opportunity to establish defensible standards, and they have no strong customer groove-in effects. A user can switch effortlessly from a Compaq to a Dell PC or from a Hewlett-Packard to an Epson printer. A PC maker likewise can change hard drive suppliers from one product generation to another with little difficulty. Yet in each of these products, U.S. companies have maintained their leadership in the face of supposedly superior Asian manufacturing prowess. How have they done so?

The answer is that U.S. companies have focused on

increasing-returns activities within these industries and turned over the decreasing-returns activities to other (usually Asian) companies. U.S. PC makers such as Dell, Compaq, and Hewlett-Packard have concentrated their own efforts on product design, marketing, brand development, distribution, and customer service. These are knowledge-based activities that enable them to distinguish themselves and gain a sustainable competitive advantage. They have been able to achieve tremendous leverage by focusing on their own strengths and integrating the capabilities of external resources to get the right products into the right markets at the right time. For some PC models, the U.S. company literally never takes possession of the PC. The Taiwanese supplier designs the product to meet specifications set by the U.S. vendor, builds the machines, ships them to the distributor, and sometimes even provides service and support. By integrating the capabilities of Asia with their own internal competencies, U.S. PC makers have kept an edge over their more vertically-integrated Japanese competitors, who until recently tried to keep most of their production in-house and had trouble keeping up with the rapid product cycles of the industry.

In some ways, PC makers add the least obvious value to the PC industry. They spend little on R&D and depend heavily on component suppliers to provide the continuous technological progress on which the industry depends. Rather than manufacturing or technology, the keys to success in the PC industry now involve mostly other forms of innovation, namely marketing, distribution, customer service, and logistics. Companies such as Dell, Micron, and Gateway 2000 have grown rapidly with a build-to-order direct sales mode that offers additional value to customers in the form of customized products. This strategy, when implemented effectively, also reduces costs by eliminating inventory throughout the value chain.

Compaq (before its acquisition of DEC), Dell, and Gateway 2000 are all tightly focused on the PC business and realize that their corporate survival depends on continued innovation in the PC industry. The other big U.S. players are IBM and Hewlett-Packard, both of which are diversified computer makers, but each has set up PC divisions that operate primarily as independent units. Each of these companies has succeeded through a combination of innovative business models and skillful execution in a highly unpredictable industry.

Similar stories can be told in the printer and hard disk drive markets, where U.S. companies have focused on design, marketing, and technological innovations while moving production to Asia to minimize manufacturing costs. The main competition in hybrid markets is between U.S. and Japanese firms. Other Asian producers have become valuable partners, cooperating rather than competing with U.S. companies. They have taken over much of the decreasing-returns side of hardware production by serving as suppliers and manufacturers for U.S. firms, while U.S. companies have concentrated on the knowledge-based aspects of the business such as design, marketing, and integration of the entire production process. By contrast, Japanese companies have not been innovative in marketing or other distribution to compete more effectively outside Japan, and while they are now starting to tap the Asian production network, they have done so reluctantly. Rather than fully exploit the capabilities of Asia, they have often tried to relocate their Japanese supplier networks to other locations in Asia and have given limited responsibilities to local managers. This gap in innovation and integration, along with a tighter product focus, has so far enabled U.S. companies to protect their markets against Japanese competitors.

In summary, U.S. companies have been able to maintain a strong position in hybrid markets by focusing on the increasing-returns activities such as design, marketing, brand promotion, and customer service, and developing innovations such as build-to-order production and online sales. Their competitive edge is based mainly on knowledge processing, while they depend on Asian partners with strong manufacturing skills to carry out most of the decreasing-returns activities within the value chain. The most successful U.S. companies have also developed innovative logistics, distribution, and information systems to create virtually integrated production networks that span the Pacific. This integrated production network has evolved over the past 20 years as a result of industry dynamics and the efforts of Asian governments to promote computer production.

Emergence of the Asian Production Network

Although IBM operated globally during the mainframe era, most computer companies produced in their home countries, where their markets were concentrated. However, the PC industry, with its much higher production volumes and reliance on standardized components, created opportunities for specialization and network economies in production. In its efforts to bring the PC to market quickly, IBM turned to Asian firms to supply a number of components. By doing so, it created a supply base that was available to other PC makers as they entered the market.

The decentralized production structure of the PC industry opened the door for new companies and countries to enter the industry. U.S. PC makers needed low-cost, reliable sources of components and peripherals and turned to Japan and East Asia, with their well-developed electronics and components industries. U.S. companies also wanted to move labor-intensive production to lower-wage locations and needed cheap sources of simple components that were becoming too expensive to source from Japan. Their search led them to Asia's newly industrializing economies (NIEs) of South Korea, Taiwan, Singapore, and Hong Kong, which had experience making consumer electronics and electronic components. For instance, IBM contracted with Taiwan's Tatung to produce monitors for the original IBM-PC.

At the same time, those countries were looking to move into higher technology industries and saw the emerging PC industry as providing just such an opportunity. The governments of Korea, Taiwan, and Singapore all enacted national strategies to promote the creation of PC industries in the early 1980s and supported them with various grants, loans, and incentives to promote investment, infrastructure development, R&D, technology transfer, and education and training. This confluence of interests between U.S. companies and Asian countries led to a rapid growth in computer production in Asia, as U.S. companies developed a vast supply and manufacturing network throughout the region.

Characteristics of the Asian Production Network

What has evolved over the last 15 years is a vast production system stretching throughout the Asia-Pacific region. Each key country in Asia has established a unique place for itself based on its national capabilities (e.g., technology leadership, manufacturing skills, supply infrastructure, or managerial abilities), its inherent economic advantages (e.g., large domestic market, low-cost labor and land, closeness to a large market), and government policies that support industry and enhance national capabilities.

Each country specializes in particular segments of the computer industry that fit its own capabilities and industry structure (Table 6). For instance, Japan utilizes its superior technology and manufacturing skills to dominate high-end hardware markets such as flat-panel displays and various materials, components, and production equipment. On the other hand, Japan remains weak in software and new product development, as its bureaucratic corporate structures are obstacles to entrepreneurship and innovation. Japanese companies are also being challenged by Korean and Taiwanese competitors in a number of key hardware markets.

Korea's industry structure is similar to that of Japan, with the computer and electronics industries dominated by large conglomerates such as Samsung, Hyundai, and LG Electronics, whose size and manufacturing abilities enable them to compete directly with Japan in high-volume commodity hardware. Korea is already a leader in DRAMs and monitors and is now moving aggressively into flat-panel displays, another Japanese stronghold. However, Korean companies have had little success in PC systems outside their home market and have failed to penetrate markets for peripherals and components beyond DRAMs and monitors. These failures are largely a result of the sluggish response by Korea's huge companies to the rapid product cycles that mark much of the PC industry.

The most broadly successful Asian country in the PC industry has been Taiwan. Taiwan leads the world in production of notebook PCs, monitors, motherboards, scanners, keyboards, and a variety of other hardware products. The global PC industry has come to rely heavily on Taiwan's many small- and medium-sized companies to provide the speed and flexibility that are necessary to keep up in the PC market. The Taiwanese government has provided invaluable assistance to its

Table 6 Country Roles in the Global Production System

Country	Capabilities	Role in Global Production Systems
United States	Design, marketing technology leadership, control of key PC standards.	• Leading supplier of PCs, microprocessors software, printers, networking equipment. • Lead market
Japan	Technology leadership in key components, high quality manufacturing	• Supplier of leading-edge components and peripherals. • Leader in notebook PCs.
Korea	Low-cost, high-volume manufacturing	• Major supplier of DRAMs. • Producer of trailing-edge monitors and flat-panel displays.
Taiwan	Design, flexible manufacturing, entrepreneurial capabilities, close ties to U.S. industry, large supplier base	• Major producer of a wide variety of components and peripherals. • OEM supplier to global industry
Hong Kong	Management, excellent infrastructure, unique legal relationship to China.	• Gateway to China, conduit for trade, technology and capital flows. • Business management for production operations in China.
Singapore	Precision manufacturing, excellent business environment and infrastructure, supplier base.	• Key production and engineering site for disk drive industry, PC and printer production, sound card leader. • Regional business hub for MNCs.

Source: Kraemer and Dedrick, 1998.

entrepreneurial companies, conducting R&D in government research institutions, providing market intelligence, and developing the Hsinchu Science-Based Industrial Park as a center for high-tech research and production.

The other great success story in Asia's computer industry has been Singapore. The tiny city-state has become the hard disk drive capital of the world, accounting for over 40% of global production, and is also a major producer of PCs, printers, and—increasingly—semiconductors. Unlike Taiwan, however, Singapore's success is not built on the basis of strong local companies but relies on production by foreign multinational corporations (MNCs).[2] Singapore serves as a hub for the regional production networks of such leading companies as Seagate, Western Digital, Hewlett-Packard, and Compaq in Southeast Asia. It also has been the most enthusiastic user of information technology in Asia and has ambitious plans to become an "Intelligent Island" whose competitiveness will be based on the presence of a world class information infrastructure. Singapore's government has also played a key role in attracting MNCs and encouraging them to upgrade their activities in Singapore, developing infrastructure, training computer professionals, and promoting IT use throughout the economy.

Hong Kong plays a unique role in the Asian production network. Although there is little computer production in Hong Kong itself, the territory serves both as a gateway for trade and investment to China and as manager for an extensive production network in southern China. Numerous companies maintain managerial functions such as finance, marketing, and logistics in Hong Kong while operating factories in China. These include companies owned by Hong Kong and foreign MNCs, as well as Taiwanese companies who cannot invest directly in China.

Specialization within the Asian production network can be seen in Table 7, showing the share of global production in various market segments. Korea specializes in monitors and DRAM; Japan in notebook PCs and DRAM; Taiwan specializes in PCs, monitors, and motherboards; and Singapore in hard disk drives.

Specialization within the Asian production network, and between the United States and Asia, cannot be explained simply by static factors such as industry structure or policy environment, however. The nature of

[2]The exception to Singapore's MNC dependence is the sound card industry, where local companies Creative Technology and Aztech are the world leaders.

Table 7 Computer Hardware Market Shares for NIEs, 1995

	% Share of Global Production of:					
	Desktop PCs	Notebook PCs	Monitors	Motherboards*	Hard Disk Drives**	DRAMs
Korea	5	1	25	n.a.	2	30
Taiwan	10	27	57	65	0	5
Singapore	3	12	5	n.a.	50	n.a.
Japan	5	27	10	n.a.	24	50

* Includes merchant sales only. Does not include captive production by PC vendors.

** Final assembly.

Sources:—Market Intelligence Centre/Institute for Information Industries (MIC/III), *Asia IT Report*, February 1996 and November 1996 and data provided to authors.

—Electronics Industry Association of Korea, '*95 Statistics of Electronic Industries*

—Peter Gourevitch, Roger E, Bohn and David McKendrick, 1997, "Who Is Us? The Nationality of Production in the Hard Disk Drive Industry," La Jolla, CA: Graduate School of International Relations and Pacific Studies, University of California, San Diego.

this network has evolved over time in a path-dependent process, whereby decisions made at one time shape the environment in which future investments are made. Analyzing the specialization patterns of Singapore's and Taiwan's computer industries, Wong Poh-Kam (1995) focuses on the dynamic interaction of three factors: entrepreneurial innovation, state intervention, and agglomeration of comparative advantage. For instance, the entrepreneurial decisions in the 1970s by foreign companies, including camera maker Rollei and floppy disk drive maker Tandon, to locate in Singapore helped Singapore develop capabilities in mechanical engineering and a supply base of metal parts and electrical components. When Singapore's Economic Development Board (EDB) began promoting the computer industry, it was able to convince Seagate to locate its assembly operations in Singapore. Seagate was followed to Singapore by some of its suppliers, further improving Singapore's supply base, and Singapore's workers gained experience and skills in disk drive production.

This agglomeration of capabilities encouraged EDB to pursue other disk drive makers, and over time a virtuous cycle kicked in, with more suppliers coming to Singapore, followed by more drive makers, with Singapore's workers gaining higher levels of specialized technical skills. This process was path-dependent, in that decisions made over time were dependent on earlier choices by companies and the government. The result of the process was the creation of an industry cluster, which propelled Singapore to world leadership in disk drive production. The capabilities of this cluster have locked in Singapore's position as a critical cog in the industry, even after rising wages made Singapore an unlikely location for such a labor-intensive industry. This type of path-dependent development not only shapes future opportunities for countries such as Singapore and Taiwan, but it also creates barriers to entry for newcomers who are not currently involved in the industry.

Impacts of the Asian Production Network on the United States

We have seen that U.S. companies dominate the increasing-returns businesses of the PC industry and that they have sustained their leadership in a number of hybrid markets by focusing on increasing-returns activities and forging partnerships with Asian manufacturers. But what have been the implications of this division of labor, and what are the prospects for the future?

Company Competitiveness, Production and Employment

The shift of computer production to Asia caused great concern for a time that American companies were putting U.S. leadership at risk by hollowing out the U.S. manufacturing base. Japanese manufacturers had already used their control over key components and manufacturing technologies to drive most of their American competitors out of the consumer electronics industry. By the end of the 1980s, many analysts were predicting that Japan would use its control over production of memory chips and other components to eclipse the United States in computer hardware as well.

Ironically, the U.S. computer industry avoided the fate of the consumer electronics industry partly by tapping the capabilities of other Asian countries to

counter the manufacturing prowess of the Japanese (Borrus 1997). By diversifying their supplier base and moving production to low-cost locations in Asia, U.S. companies avoided dependence on Japanese suppliers and remained competitive against Japanese computer hardware makers.

In the PC industry's new global division of labor, U.S. companies focused on their strengths in software, product planning and design, distribution, and marketing and leveraged the manufacturing capabilities of Asia to maintain their leadership in the industry. As a result, computer production soared in the East Asian NIEs (Korea, Taiwan, Singapore, and Hong Kong), from US$3.4 billion in 1985 to US$46 billion in 1995 (Figure 3). While the United States and Japan remained the largest producers of computer hardware, most of the growth in production was taking place in the Asian NIEs.

Looked at another way, U.S.-based companies still account for 65% of the world's computer hardware sales, but the percentage of computer hardware produced in North America has declined steadily, from 50% in 1985 to 28% in 1995. Meanwhile, the share produced in Asia grew from 23% to 47%, virtually replacing U.S. production (Figure 4).

As U.S. companies have shifted production to Asia, there has been concern about the loss of jobs in the United States. The question is whether U.S. companies are succeeding, but without corresponding economic benefits to the United States. The evidence, as shown in Table 5, is that employment in hardware production has in fact declined since the mid-1980s, but it is largely due to the downsizing of companies such as IBM and DEC. Yet even this minor downturn in hardware employment has been accompanied by a dramatic rise in the number of jobs in software and services (Table 8). Thus, the evidence shows that the U.S. emphasis on increasing-returns industries and activities has paid off for U.S. workers. Also, U.S. hardware production began to grow rapidly in 1994 after stagnating for almost a decade (Figure 3), partly as a result of PC makers

Figure 3 Computer Production in the United States, Japan, and East Asia

Source: Reed Electronics Research, *Yearbook of World Electronics Data,* various years (Oxford: Reed Electronics Research). Note: 1997 is an estimate.

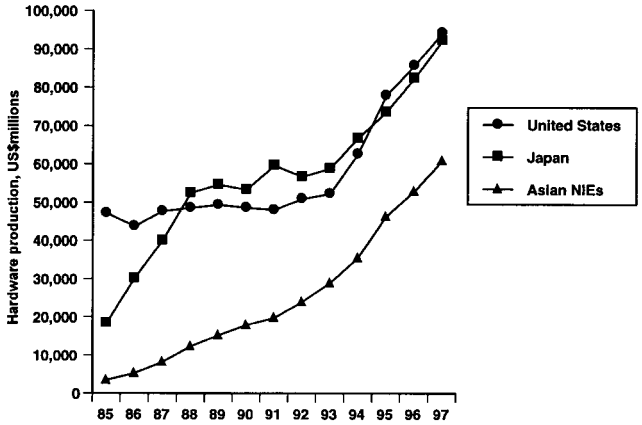


Figure 4 Company vs. Country Position in the Computer Industry

Note: Vendor is headquarters of company selling the product. Production is where the product is made.

Sources: McKinsey & Company, Inc., *The 1996 Report on the Computer Industry* (New York: McKinsey & Company, Inc., 1996). Reed Electronics Research, *Yearbook of World Electronics Data*, various years (Oxford: Reed Electronics Research)

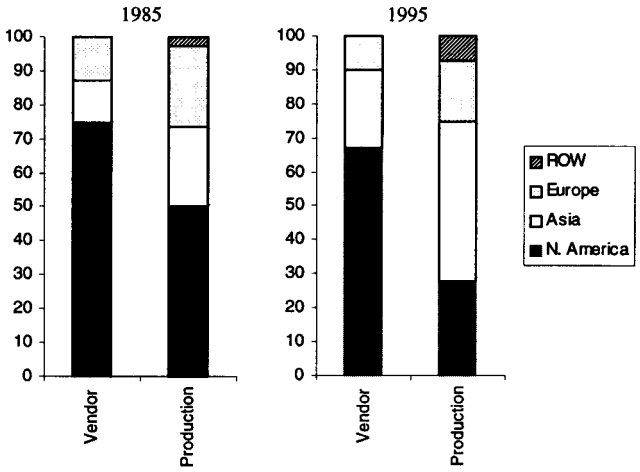


Table 8 Computer Industry Employment, 1985–1994 (Thousands)

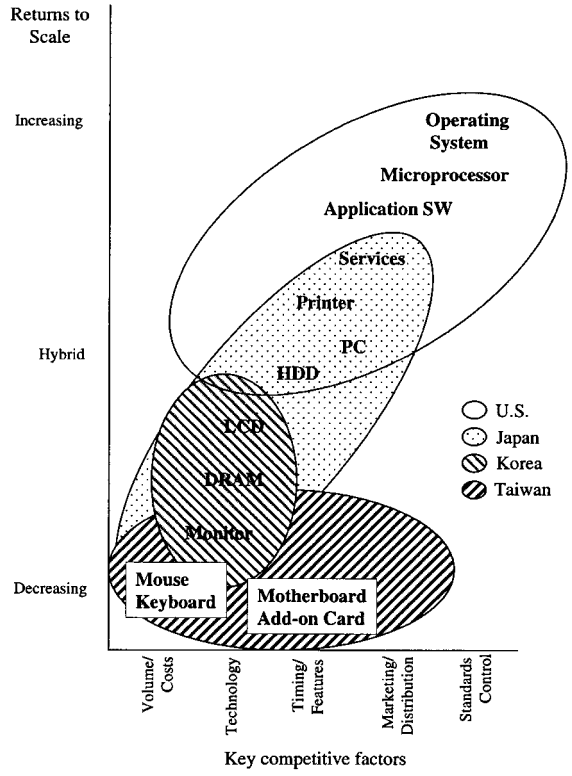
Industry segment	1985	1990	1994
Hardware	350	294	249
Software and services	600	800	1,100

Source: Dedrick and Kraemer, 1998.

Table 9 Company and Country Position in the Global Computer Industry

	Increasing Returns	Decreasing Returns	Hybrids
Position of companies by market segment	U.S. companies dominate in operating systems, packaged software and microprocessors.	Japanese and Koreans lead in DRAMs and LCDs, CD-ROM drives, floppy drives. Taiwanese strong in motherboards, add-on cards, monitors, and other components. Japanese dominate key upstream technologies. Singapore companies lead in sound cards.	U.S. companies lead in PCs, printers and hard drives with competition from Japanese companies. U.S. companies are leaders in information services, with local firms strong in other national markets.
Country location of activities in the value chain	Software development, microprocessor design, engineering and wafer fabrication in U.S. chip assembly and testing in Malaysia, Thailand, HK/China, and other developing countries.	R&D, design, high-value components mainly in Japan. High volume production in Japan, Korea, Taiwan, Singapore. Low-end assembly in SE Asia, China, and other developing countries.	R&D, design, and high-end production in U.S. and Japan. Engineering and production in U.S., Japan, Taiwan, and Singapore. Production moving to developing countries. Information services provided in local markets.

Figure 5 Company Competitiveness: Location of Headquarters



moving production closer to the end user to support build-to-order manufacturing. It is likely that hardware employment has recovered some of its earlier losses in recent years.

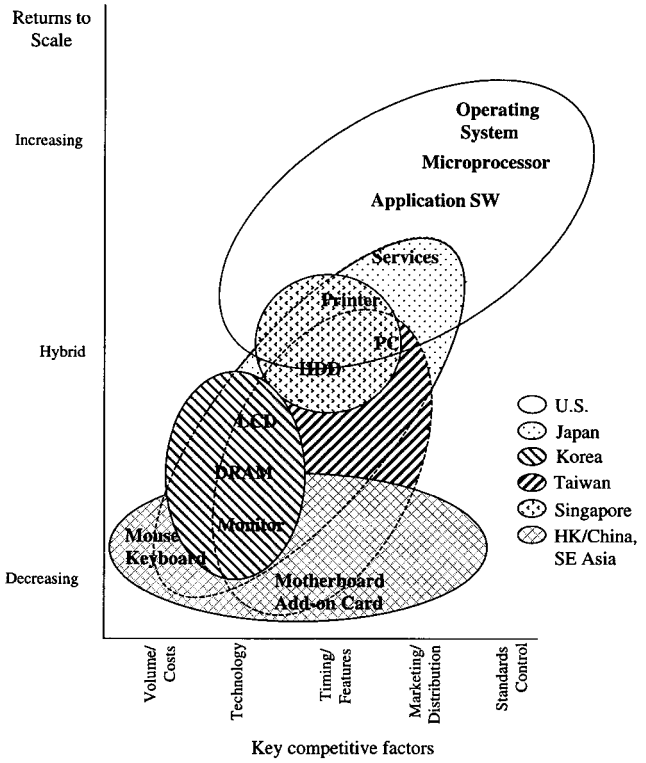
Competitive Position in Increasing- and Decreasing-Returns Markets

Using the framework of increasing and decreasing returns, we have delineated the division of labor and competitive environment within the global computer industry. Table 9 and Figures 5 and 6 summarize these, showing the competitive position of companies and the location of production activities by country.

Both Table 9 (first row) and Figure 5 show that U.S. companies dominate in the increasing-returns segments of the market, with little competition from Asia. Japanese, Taiwanese, and Korean companies dominate in highly competitive decreasing-returns segments such as keyboards, monitors, and DRAMs. U.S. and Japanese companies compete in the key hybrid segments, with U.S. companies currently holding the edge. So far, there is little competition from the rest of Asia in the hybrid markets. Singapore's absence from Figure 5 reflects the near absence of Singaporean companies, in spite of the island's importance as a production platform.

Table 9 (second row) and Figure 6 show how the division of labor within the production network has

Figure 6 **Country Competitiveness: Location of Production Activities**



been organized to take advantage of local capabilities, wherever they exist. Increasing-returns activities such as R&D, product design and engineering, and software development are concentrated in the United States and Japan in order to take advantage of those countries' technological capabilities, human resources, and large domestic markets. Capital-intensive activities such as DRAM and LCD production are mostly located in Japan and Korea, where companies can raise large sums of capital and have access to necessary engineering skills. Actual production of PCs, printers, motherboards, add-on cards, and hard drives are done mostly in Taiwan and Singapore, which have the flexibility, technical skills, and strong supplier bases to get products from design to volume production very quickly. Labor-intensive activities such as assembly of simpler products and components generally take place in Southeast Asia and China, where large pools of low-cost, well-educated workers are available. The multiple overlapping ovals in the lower section of Figure 6 show how competitive the decreasing-returns industries are becoming as more countries vie for a position at the lower levels of the industry.

This picture is merely a mid-1990s snapshot, however, and continues to change. The East Asian NIEs are climbing the technology ladder to carry out more R&D, design, and engineering, while the emerging NIEs such as Malaysia, Thailand, Indonesia, and China attempt to go beyond labor-intensive activities and develop their own technological capabilities. This process has put enormous pressure on everyone involved, particularly in the hardware industry. Japan finds itself losing market share in DRAMs, monitors, LCDs, and other hardware markets to Korean companies. Taiwanese companies are also moving into some of those market segments, often in partnerships with U.S., European, and Japanese companies. Battles over market share are fierce and profit margins are driven to almost nil, just as the theory of decreasing returns would predict.

Future Competition in Increasing-Returns Markets

The U.S. advantage in increasing-returns markets is largely a result of the historical development of the industry. The computer industry was created in the United States with early support from the U.S. government in the form of R&D subsidies and large military procurements. The United States has remained the leading user market, both in size and sophistication, and has provided fertile ground for development of innovative products and services, which can then be sold to global markets. IBM, along with Microsoft, Intel, and the U.S. PC industry, was successful in establishing the IBM/Wintel architecture as a global PC standard; and no one in the United States or elsewhere has produced a viable challenger to that standard.

Non-U.S. companies have had little success in increasing-returns markets. A few, such as Germany's SAP, Canada's Corel, and Japan's Just Systems, have developed successful software applications. But in spite of various European and Japanese government initiatives to promote software production, U.S. companies still control about 75% of the software industry overall and have virtually 100% of the operating system market. The story is similar in microprocessors, where Intel's competition, limited as it is, comes from

U.S. companies such as AMD, Cyrix, Motorola, and IBM.

For the time being, almost everyone seems to agree that a challenge to U.S. control of computer standards and increasing-returns markets is unlikely in the near future. The United States is by far the largest IT market and is the most dynamic. The emerging network era of computing is being defined in the United States by established companies such as Microsoft, IBM, and Sun, and by newer entrants such as Cisco, Netscape, Yahoo!, and Amazon.com. As much as ever, new markets are being defined and new standards established in the United States which points to continued leadership for U.S. companies in increasing-returns markets.

Conclusions

In the final analysis we find that Asian companies and countries represent both opportunities and challenges for the U.S. computer industry. U.S. computer makers can continue to rely on East Asia as a production base and as a reliable, cost-efficient supplier of parts, components, peripherals, and OEM systems. But the same companies who are now partners are developing capabilities that could make them strong competitors in the future.

In addition, the Asia-Pacific market has great long-term potential, in spite of the recent economic troubles in the region. This growth presents enormous opportunities for U.S. companies to expand into new markets, but the growth of Asia as a major market is also a possible threat to U.S. companies. If other Asian countries follow Japan's mercantilist trade and investment policies, U.S. companies could find the region a very difficult place to do business. The innovative marketing strategies of U.S. PC makers often are not easily implemented in Asian markets, and they are forced to play by the rules set by domestic competitors. After a brief surge in market share in Japan, U.S. companies have seen their gains eroded by aggressive price competition and control of distribution channels by Japanese PC makers. The Korean market is almost entirely controlled by Korean companies, who dominate the local distribution channels. China is already the world's third largest PC market, and it has proven to be a treacherous environment for U.S. companies. The combination of government interference and the lack of strong legal structures (such as contract enforcement) and intellectual property protection put outsiders at a disadvantage.

On balance, we would argue that the opportunities outweigh the threats. U.S. companies in increasing-returns markets win whenever the market grows, so they benefit from the availability of low-cost hardware made in Asia and from the growth of the Asian market. The competition in decreasing-returns businesses is mostly a war among Asian companies, with at least some U.S. companies enjoying the spoils. As one Asian executive put it, "We're all killing ourselves to make money for Microsoft and Intel."

For those companies in hybrid markets, the rapid growth offered by Asia compensates at least in part for the increased competition from the region. And while U.S. companies struggle to compete with domestic companies in some Asian markets, their Asian competitors face the same difficulties outside their home markets. Japanese and Korean PC makers have had limited success in other Asian markets, while Compaq, IBM, and Hewlett-Packard have a strong presence throughout the region. As for other Asian companies, only Acer is a major competitor outside its home market.

In spite of the generally positive assessment of the U.S. position in the global computer industry, it would be a mistake for U.S. companies to take their eyes off Asia as a source of future competition. It is easy to dismiss Asia as a region of imitators and ignore the very real progress its countries and companies have already made in improving their technological capabilities. Thousands of Asian engineers have been trained in U.S. universities, and while many of them remain in the U.S.—providing a vital supply of human resources—they retain strong contacts to their home countries. Likewise, many of Asia's computer companies are headed by people who cut their teeth working for U.S. companies, and they know very well what it takes to compete in the U.S. market.

The history of the consumer electronics, semiconductor, and automobile industries serve as a warning to U.S. companies that ignore Asia as a competitive threat. This threat might not show up in the next few

years, but it will increase in the long run as more segments of the computer industry evolve into mature, technologically stable businesses, playing to the strengths of Asian competitors.

Finally, it would be a mistake to assume that Asians are somehow unsuited to competing in the increasing-returns, soft side of the business. The next Bill Gates might be a teenager in China, ready to ride the wave of growth in Asian markets and shift the balance of industry power across the Pacific. If U.S. companies become complacent, or fail to see possible challenges from beyond the water's edge, they risk an unpleasant surprise from across the Pacific.[3]

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