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GLOBALIZATION IN THE COMPUTER INDUSTRY: IMPLICATIONS OF THE ASIAN PRODUCTION NETWORK FOR THE U.S

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INTRODUCTION

The computer industry has been dominated throughout its history by U.S. companies that have developed most of the important innovations, set key technical standards, and still produce over two-thirds of the world's hardware, software and services. Periodic technology shifts such as the introduction of the minicomputer and personal computer have changed the structure of the industry, but in each case it was American companies who were the industry leaders.

Despite the continuing leadership of U.S. companies, the actual production of computer equipment has shifted steadily away from the U.S., mostly to countries in the Asia-Pacific region. While U.S.-based companies still account for 65% of the world's computer hardware sales, the percent of the world's computer hardware produced in North America declined steadily, from 50% in 1985 to 28% in 1995. Meanwhile, the share produced in Asia grew from 23% to 47%, virtually replacing the U.S. production (Figure 1). This development is mainly the result of U.S. companies having organized complex global production networks, and Asian countries finding opportunities to participate in those networks.

Figure 1. Company vs. country position in the computer industry
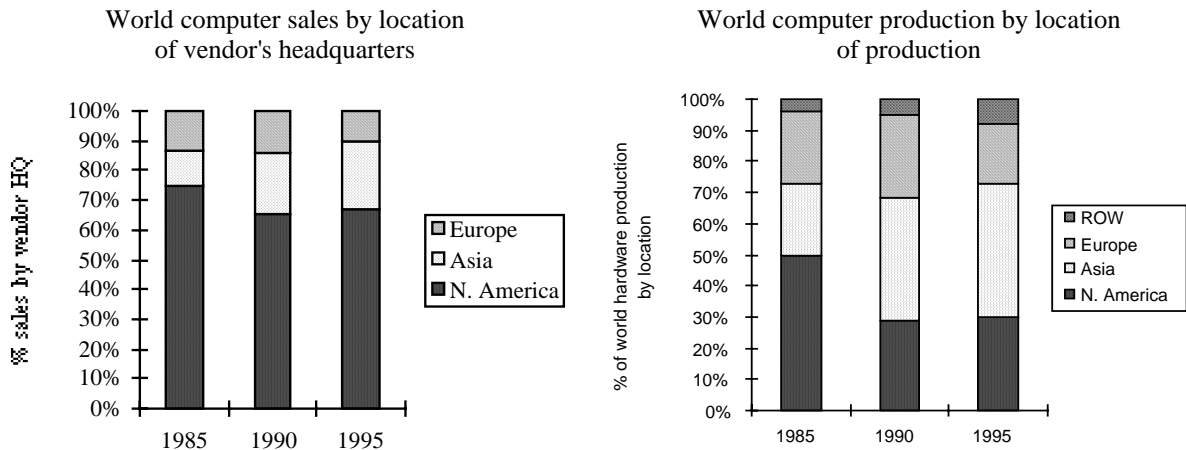
Sources: McKinsey & Company, Inc., *The 1996 Report on the Computer Industry* (New York, NY: McKinsey & Company, Inc., 1996).

Source: Elsevier, *Yearbook of World Electronics Data* (Elsevier Advanced Technology, various years).

The rapid globalization of the computer industry has raised concerns that the U.S. was at risk of losing its industry leadership. Former U.S. Trade 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 as Japan's computer industry was slow to respond to the personal computer era, but the concerns have not gone away. While some in the U.S. celebrate the triumph of Silicon Valley, others worry that the victory could be short-lived as Japanese companies launch a new drive into the U.S. market. Equally troubling is the possibility that U.S. companies might retain their leadership, but that globalization is leading to a "hollowing out" of the U.S. computer industry as jobs and technologies migrate across the Pacific. An example of this trend can be seen in the disk drive industry, where market leader Seagate employs over 100,000 workers, but only about 10,000 of those are in the U.S. In the disk drive industry as a whole, U.S. companies control over 80% of the market, but only 20% of the industry's employment is in the United States (Gourevitch, Bohn and McKendrick, 1997)

These developments have taken place so rapidly that there has been little chance to step back and look at the consequences of globalization for both companies and countries. The purpose of this paper is to develop a clearer picture of the computer industry's global production network, the concentration of that network in Asia, and the implications for U.S. companies and U.S. economic competitiveness.

We will look at a number of questions that have important consequences for the long-term health of the U.S. computer industry. Does it matter who designs a new system, who builds the hardware, whose brand name is on the outside, whose components are inside, or where it is built? Why has so much of the industry concentrated in the Asian countries? Does it matter if the U.S. loses hardware manufacturing if it maintains its lead in the highly profitable software and microprocessor industries? Is another revolution taking place in networked computing that will upend the industry as much as the PC revolution of the 1980s. And what does it mean for the U.S.?

THEORETICAL FRAMEWORK

We use the closely linked concepts of *increasing returns* and *path dependency* to analyze the evolution of the industry, competitive outcomes at the company level, and the geographical distribution of production activities in the industry. The notion of increasing returns is that under certain conditions, higher levels of production can result in lower unit costs, and hence, 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, economies of scale and positive externalities could lead to increasing returns to scale in manufacturing industries.   However, the study of increasing returns lay dormant in the economics literature for most of the post-war period, as neoclassical economists built models based on the assumption that there must be constant or diminishing returns to scale and that competition would drive profits down to the cost of capital.

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, Paul David 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. If the instructions are privately controlled, increasing returns can be appropriated by the company that owns them. Over time, technology diffusion spreads the economic benefits beyond the original developers or owners.

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: 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 and path dependency can also apply at the country or regional level in explaining industrial location patterns. 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. Path dependency might be weak at first, but 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. In time, an industry cluster develops that remains vital even after the initial attraction (such as low wages) has disappeared.   Michael Porter (1990) reviews a number of such industry clusters, arguing that the presence of such clusters are key sources of national economic competitiveness.   The most famous industry cluster is, of course, Silicon Valley. There, initial location decisions by start-ups such as Hewlett-Packard, Varian, and Shockley helped attract other electronics suppliers and support industries, along with many skilled engineers and entrepreneurs, creating a large dynamic industry cluster for computers, semiconductors and software.

Arthur (1994 and 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 million dollars to produce, subsequent disks cost a few dollars (or zero if the program is preloaded on a PC or downloaded from the Internet). 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 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). In each of these cases, some would argue that an inferior standard actually prevailed due to the accumulation of complementary assets and customer lock-in. Similarly, David (1985) argued that the continued dominance of the QWERTY keyboard is one case in which an inferior solution has triumphed in the marketplace because millions of users were trained in its use (David, 1985).

The computer industry is the quintessential increasing returns industry, involving high up front costs, customer groove-in, network externalities and winner-take-all standards competition. 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. 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 and printers are hybrids that involve bulk processing, but include knowledge processing in the form of branding, marketing and logistics. Finally, the information services business is primarily involved in bulk processing (in the form of data processing), but can be transformed into packaged products with increasing returns characteristics (e.g. American Airlines' Sabre reservation system or Ticketmaster's ticket ordering system).

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 hardware commodities, 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 depends partly on their ability to develop and enhance their capabilities in either or both of 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 limited by what has gone before.

In this paper, we use the framework of path dependency and increasing returns for two purposes: (1) As an organizing framework to understand the historical development and current structure of the computer industry; and (2) As a model for framing our analysis of future competition in the network era of computing that is now emerging.

METHODOLOGY

The methodology for conducting the research in this paper included gathering secondary data from a variety of sources, reviewing academic and popular books and journal articles, collecting news reports, and conducting several hundred field interviews in the U.S., Japan, Korea, Taiwan, Singapore, Hong Kong and China. This research has been published in country case studies (Gurbaxani, 1991; Kraemer, Dedrick and Jarman, 1994; Dedrick, Kraemer and Choi, 1995; Dedrick and Kraemer, 1995; Kraemer and Dedrick, 1995; Kraemer et al., 1996), cross-country comparisons of computer production and use (Dedrick and Kraemer, 1994; Kraemer and Dedrick, 1994), and a book manuscript (Kraemer and Dedrick, 1998).

The structure of the paper is as follows: First, we review the changing structure and globalization of the computer industry from the mainframe era to the PC era, and analyze the growth of an Asian production network within the PC industry. 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 then turn to the issue of industrial location, analyzing the role of path dependency in determining the location of activities within the global computer industry, particularly in the case of the East Asian countries. Then we consider the reasons that so much of the computer industry is concentrated in Asia, based on a general model of East Asian economic development. We summarize the performance of both companies and countries in the computer industry and locate them along the dimensions of increasing and decreasing returns and key competitive factors. Finally, we turn to the future. We look first at the emerging network era and its impact on competitiveness in the computer industry. We then analyze competitive threats to the U.S. computer industry in the network era, particularly those that might arise from the Asian region.

STRUCTURAL CHANGE IN THE COMPUTER INDUSTRY

From the time of its invention 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, sometimes referred to as the systems-centric era (Moschella, 1997), 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. The main customers were the MIS departments of large companies and government agencies, and computer companies concentrated on locking those users in to the companies' proprietary architectures.

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 U.S. 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. The relationship of company and country success was fairly simple when what was good for IBM was good for the United States.

This comfortable equilibrium turned out not to be stable, however, but 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, giving the PC credibility as a business tool.

 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 which allowed standardization of components were set when IBM introduced its PC in 1981 with an open architecture, and essentially "made the market" for PCs.

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

inadvertently 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.

A new, decentralized industry structure based on network economies was created in the PC industry, as companies specialized in market niches throughout the production chain. The computer industry in the mainframe era had been dominated by ten giants who controlled 65% of the market in 1975, with another 40 companies controlling 32%. The category "all others" accounted for just three percent of the market. By the 1990s, the industry was populated by thousands of firms, and many of the former market leaders had either gone bankrupt, been acquired, or were a shadow of their former selves.   IBM, which accounted for 37% of the world computer market in 1975, had only 15% by 1994. The "all others" category now accounted for 25% of the market, its growth exactly mirroring IBM's declining market share (Table 1). These "all others" included a large number of companies who were able to enter the computer industry because of the PC revolution, including newcomers such as Apple, Compaq, Dell, Gateway 2000, Novell and Adobe. Successful non-U.S. companies in the PC era include Japan's NEC and Toshiba, Taiwan's Acer, Mitac and FIC, and Singapore's Creative Technology.

Table 1. Worldwide market share (%)
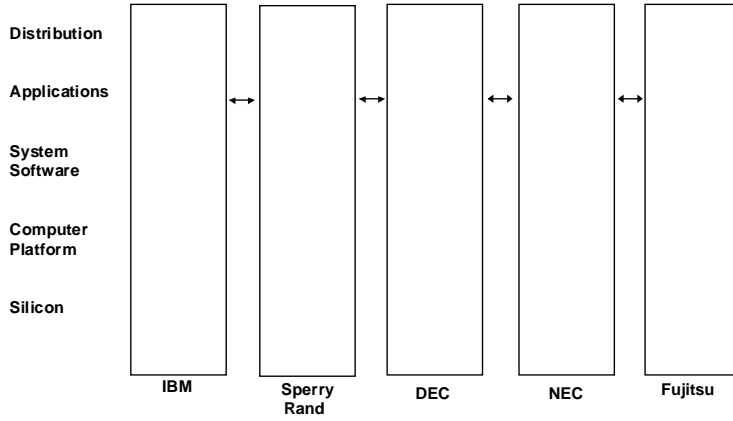
	1975	1985	1990	1995
IBM	37	30	21	14
Companies 2-10	28	29	28	32
Companies 11-50	32	29	28	31
All others	3	18	23	23

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

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. Some segments of the industry, such as disk drives and monitors, eventually consolidated to the point that a few firms controlled most of the market. And of course the microprocessor and operating systems markets became near-monopolies for Intel and Microsoft. But other market segments remain wide open even today. For instance, the top ten PC makers still control only about 40% of the global market, and the largest, Compaq, has just 10%.

Figure 2. Computer Industry Structure: Mainframe and PC Eras

<u>Mainframe, Systems-Centric Industry Structure</u>

	IBM	Sperry Rand	DEC	NEC	Fujitsu
Distribution					
Applications	↔	↔	↔	↔	
System Software					
Computer Platform					
Silicon					

<u>PC Industry Structure</u>

Distribution	Computer Dealers		VARs	Internet	Mail Order	Superstores	General Retailers
Applications	Word Processors	Project Managers	Spreadsheets	Databases	Graphics	Groupware
Integrated Suites	MS Office				Corel Perfect Office	Lotus Smart Suite
System Software	DOS	MS-DOS/Windows 3.1			MAC	OS/2 — Windows NT
Network Software	Novell			IBM	Banyans	Windows NT
Computer Platform	IBM/Wintel					Apple MAC
Printer Software	Adobe		Apple		Microsoft	
Peripherals	Printers	Disk Drives	Monitors	Flat Panels	CD-ROM	Scanners	Keyboards Mice
Components	Motherboards	Add-on Cards	Chip Sets	Power Supplies	Cables & Connectors	Memory
Silicon Microprocessors	Intel X86/Pentium				Other X86	Motorola — Power PC

Source: Kenneth L. Kraemer and Jason Dedrick, 1998, *Asia's Computer Challenge: Threat or Opportunity for the U.S.* New York: Oxford University Press. Adapted from Andrew S. Grove, 1996, *Only the Paranoid Survive*, New York: Doubleday, p. 44.

Creation of an Asian Production Network

Not only did the PC create opportunities for new companies, but it opened the door for new countries to participate in the industry. U.S. PC makers needed low-cost, reliable sources of components and peripherals, and initially turned to Japan, with its well-developed electronics and components industries. The 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 were already making consumer electronics and electronic components. At the same time, those countries were looking to move into higher technology industries to sustain economic growth, 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 personal computer industries in the early 1980s and supported them with government spending and incentives for infrastructure development, R&D, technology transfer, education and training, and industry promotion. 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.   These networks involve a complex web of relationships between manufacturers, suppliers and customers linking companies and countries in the U.S. and Asia.

These shifts in production, especially to Japan, caused growing concern in the U.S. that American companies were weakening the U.S. computer industry by moving production to Asia. Japanese manufacturers had already used their control over key components and manufacturing technologies to drive their American competitors out of the market for most consumer electronics products. 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 U.S. 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 the Asian production network to counter the manufacturing prowess of the Japanese (Borrus, 1997). Countries such as Taiwan, Korea and Singapore moved rapidly upstream from simple assembly and production of cheap components to challenge Japan's leadership in large segments of the PC market. Korea's Samsung moved into first place in memory chips, while Taiwanese companies took the lead in motherboards, monitors and other peripherals, and Singaporean companies controlled the world sound card market. Japanese companies were struggling with high production costs and the inflexibility of their vertically integrated production structure, and were slow to take full advantage of the capabilities of its neighbors. Meanwhile, U.S. companies focused on their strengths in software, design and marketing, and leveraged the manufacturing capabilities of Asia to maintain their leadership in the PC industry, as well as to regain competitiveness in other electronics industries.

What has emerged over the last fifteen years is a vast production system stretching initially between the U.S. and East Asia, but now throughout the Asia-Pacific region. Each focal country in Asia has established a unique place for itself based upon its industry's capabilities (e.g., technology leadership, commodity manufacturing, supply infrastructure, business hub) overall comparative advantage (large domestic market, low cost labor and facilities, closeness to large market), and technology policy supporting industry or leveraging comparative advantage (Table 2).

Table 2. Country Roles in the Global Production System

	Capabilities	Role in global production systems
United States	Design, marketing, techno-logy leadership, control of key PC standards.	• Leading supplier of PCs, microprocessors, software. • 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.	• 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.	• Production platform for disk drive industry, large PC assembly operations, growing semiconductor industry. • Regional business hub for MNCs.

Source: Kraemer and Dedrick, 1998.

The success of U.S. companies in staying competitive by shifting production to Asia raises other issues, however. One is that the success of U.S. companies might benefit Asia more than it benefits the U.S. How much does it benefit the U.S. to have its companies controlling the industry if most of the manufacturing jobs are being created overseas? Another is the possibility that a repeat of the consumer electronics story will still take place, only that the new competitors will come from the entire Asian region rather than just Japan. Already, Taiwan's Acer has jumped into the top ten PC makers in the world, and Korean companies have acquired U.S. companies AST and Maxtor. And Japan certainly cannot be counted out, with Toshiba leading the world in notebook PC production, NEC taking control of Packard Bell, and Sony, Fujitsu and Hitachi all aggressively targeting the U.S. PC market. A third concern is that Asian companies are better positioned to take advantage of the huge market potential in the Asian region, which is the fastest growing computer market in the world. Will U.S. advantages in software, marketing and distribution be negated once the key market battleground moves to places like China, Indonesia and India?

RETURNS TO SCALE IN THE COMPUTER INDUSTRY

These concerns can be better addressed when we look at the computer industry in terms of increasing and decreasing returns segments. The shift from vertical integration to horizontal segmentation in the computer industry had a profound effect on the nature of competition in the industry. In the mainframe industry, IBM had achieved network externalities in the form of applications software and plug-compatible peripherals that were available to anyone who bought an IBM or IBM-compatible computer. Other mainframe makers either produced IBM-compatibles or tried to survive with a small captive user base. For IBM, mainframes were an increasing returns business, since its marginal costs for each system sold declined over the life cycle of each product family, and sales of applications, services, peripherals and upgrades expanded as the user base expanded. IBM also benefited from strong customer lock-in with

users who had heavy investments in equipment, software and training on IBM systems. And since IBM controlled all of the key technologies that made up its systems architecture, other companies were relegated to the margins of the industry.

IBM's decision to outsource most of the components for the PC, and its loss of control over the microprocessor and operating system, created a new competitive environment altogether, as illustrated in Figure 2 and Table 3. The microprocessor and operating systems markets became new increasing returns businesses, with near monopoly industry structures, while most of the hardware segments of the industry evolved into highly competitive decreasing returns businesses. A few segments, such as application software, printers, PC systems and services fall somewhere in between purely increasing- and decreasing-returns markets. Within these segments, there were important distinctions among the types of companies that succeeded, as well as among which countries played important roles.

Table 3. Competition in the computer industry, 1995

Microprocessors[a] % market share*		Operating systems[b] % market share**		PC systems[c] % market share**		Printers[d] % market share**	
Intel	73.0	Microsoft	80.1	Compaq	10.0	Hewlett Packard	39.0
AMD	8.0	Apple	8.2	IBM	8.0	Epson	14.0
Motorola	8.5	IBM	6.7	Apple	7.8	Canon	12.0
Texas Instruments	1.9			Packard Bell	5.3	Okidata	8.0
NEC	1.1			NEC	4.8	Panasonic	6.0
Top 5	92.5	Top 5	95.0	Top 5	35.8	Top 5	79.0
Near-Monopoly				Open competit		Oligopoly	

Hard disk drives[e] % market share*		Floppy disk drives[g] % market share**		CD-ROM drives[g] % market share**	
IBM	25.6	Mitsumi	24.6	MKE	27.5
Seagate	19.3	Teac	17.3	Sony	14.1
Quantum[f]	14.5	Sony	15.0	Mitsumi	10.3
Western Digital	8.6	Seiko Epson	8.3	NEC/HE	7.8
Conner	8.4	Alps	5.7	JVC	5.5
Top 5	76.4	Top 5	60.9	Top 5	65.1
Oligopoly					

*Share of worldwide <u>revenues</u>, 1995 (for microprocessors, 1994).

**Share of worldwide <u>shipments</u>, 1995.

[a]Martin Fransman, *Japan's Computer and Communications Industry: The Evolution of Industrial Giants and Global Competitiveness* (Oxford, UK: Oxford University Press, 1995): 171.

[b]International Data Corporation (IDC), "Worldwide Market Share of New PCs Shipped 1995," *The Gray Sheet 30*(1995): 19-20.

[c]IDC, 1996. "Worldwide PC market grew 24 percent in 1995." IDC press release.

[d]Computer Intelligence InfoCorp, September 25, 1995.

[e]Includes both high-end and low-end, and captive and noncaptive shipments. *1996 Disk Trend Report*., Mountain View, CA: Disk/Trend, Inc. p.24.

[f]Most of Quantum's disk drives are manufactured by Matsushita Kotobuki Electronics (MKE).

[g]MIC, *Asia IT Report*, June 1996.

Decreasing returns markets

Although there is a great deal of variety among the industry structures of different segments of the hardware industry, 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 and flat-panel displays are very capital- and technology-intensive, high-volume industries that operate in commodity-like markets, with little differentiation among products and boom and bust price cycles. 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. The only large U.S. DRAM producers are IBM and Texas Instruments, both of which are large, diversified companies in their own right. Only IBM is a significant player in flat-panels, and that is through a joint venture with Toshiba.

Among countries, Japan and Korea have dominated in high-volume commodity markets not only because of the strengths of their individual companies, but also because both the Japanese and Korean governments promoted the growth of large, globally competitive conglomerates as a matter of industrial development strategy. The companies were protected in their home markets and received various subsidies to help them catch up in strategic industries such as semiconductors and computers. The tendency toward agglomeration of resources favored the growth of high-volume commodity industries.

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 the global production system via the overseas Chinese network.

There are also market segments based on more stable technologies, in which price is the determining factor, such as monitors, floppy disk drives, CD-ROMs, 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.

Finally, the hard disk drive industry is perhaps the most unusual of the hardware segments. HDD production requires constant improvement in basic technologies in order to pack more data onto a given area of storage media, and market success depends almost entirely on speed-to-market in order to hit the "sweet spot" in the product cycle. A company that is even a couple of months late to market with a new generation of hard drive can miss all of the profits from that generation. The industry used to have low entry barriers, and more than 200 companies have come and gone from the market, but the past few years have seen a consolidation as costs of R&D and production facilities have risen. Now, four companies, Seagate (including the former Conner Peripherals), IBM, Quantum and Western Digital, control

over 75% of the market. All of these are U.S. companies, but most of their production has been located in Singapore and elsewhere in Southeast Asia in order to tap low-cost labor and a well-developed supplier base (although product design as well as production of many key components remains in the U.S.). Japan's computer leaders NEC, Fujitsu and Toshiba also make hard drives, but mainly produce for their own captive use, as they have failed to keep up with the brutally short product cycles of the global industry. U.S. computer makers Hewlett-Packard and DEC were unable to keep up, and decided to drop out of the disk drive industry altogether.

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. Even 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.

Increasing returns markets

The classic case of an increasing returns business is the operating systems market. Microsoft gained a critical first mover advantage when IBM chose MS-DOS as the operating system for the original IBM PC. As IBM did much of the heavy lifting involved in making the IBM PC the dominant standard for PCs, Microsoft gained the corresponding dominant market share in operating systems. 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). So as more people adopted Windows, the incentives grew for others to follow, exemplifying the increasing-returns pattern that "things that get ahead tend to get farther ahead."

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 much easier to switch from WordPerfect to Word than it is to switch from Windows to Macintosh. 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, where Intel has enjoyed a market share of over 70% since IBM selected its processors for the original IBM PC. Microprocessors seem a less obvious increasing returns product. They are after all hardware products that require billion dollar facilities to manufacture. But through its ability to control the 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, thanks in part to the huge profits garnered in this increasing returns market. Intel can thus afford to make heavy investments in R&D and production capacity in order to stay ahead of competitors technologically and achieve

lower marginal production costs. It has also spent heavily on its "Intel Inside" campaign to create a franchise based on branding as well as architectural standards.

The world of increasing returns in the computer industry has been dominated by U.S. firms as far back as the original IBM mainframes. A few non-U.S. companies have found success in software applications, such as Germany's SAP, Canada's Corel, and Japan's Just Systems. But U.S. companies still control about 75% of the software industry overall, and have virtually 100% of the operating system market. The vast majority of that software is still developed in the U.S., although U.S. companies have turned to foreign countries in some cases for low cost programmers or product localization. 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. And while the microprocessor industry is more globalized that the software industry in its production, most of the highest value design, engineering and wafer fabrication activities still take place in the U.S. While some of those activities have expanded to Europe and Asia, most offshore production involves low-end assembly and testing.

Hybrid markets

Some segments of the computer industry are not clearly in the increasing or decreasing returns world, but show characteristics of both. These industries might start out as increasing returns businesses and mature into decreasing returns businesses, as was the case with the original IBM PC once other companies unlocked the secrets of cloning the IBM architecture. Others can start out in the decreasing returns business, 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. Arthur (1996) illustrates the notion outside the computer industry with the example of McDonald's restaurants, which have gone beyond simply providing food service to create network externalities in the form of customer loyalty and strong brand name recognition.

Some examples of this effect also can be seen in information services, where the simple data processing or outsourcing businesses can be packaged into a product or franchise that gains its own increasing returns characteristics. 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 Corp. at a disadvantage outside of the U.S market.   No matter how good they are in the U.S., 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 taking advantage of local capabilities developed over the years to support its hardware business. Still, there are limited network externalities available in the services industry, as the business is based mainly on providing custom solutions for each client's needs.

The situation changes, however, if the business can be changed from a decreasing returns basis (such as outsourcing, maintenance, or custom programming) to one of increasing returns by packaging services into a product that can be resold at a lower marginal cost. For example, a banking automation system or transaction processing system developed for an individual bank can be sold as a package to banks around the world with minimal customization. In the case of ATMs, there is an incentive for all banks to standardize on a common platform to offer customers a wider range of locations to access their accounts. The marginal cost to each new customer goes down while the marginal benefit increases—a classic increasing returns market.

The hardware industry also has its hybrids. Among these are the PC systems and printer industries. 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. Yet, the flip side to the commodity nature of PC hardware is the fact that success in the industry is now determined largely by factors from the knowledge-based world, namely branding, customer service, innovative distribution and logistics. Companies such as Dell and Gateway 2000 have grown rapidly with a made-to-order sales mode that offers additional value to customers. While volume matters in terms of getting the best prices on components, small local companies build their own PC clones to order and provide specialized service to business users, and continue to hold their own against the industry's giants. By focusing on the knowledge side of the equation, these companies gain a competitive edge in what is primarily a decreasing returns business.

Printers are perhaps even a better example, since the leading companies not only take advantage of strong brand names, but also control key technologies such as printer software, ink jets and electronics (Hewlett-Packard) and laser engines (Canon). The printer industry has been rapidly transformed from being driven by technology to being market-driven. HP in particular has leveraged its technology strengths and reorganized internally around market segments in order to provide a wide variety of printer configurations for different markets. While HP utilizes the global production network to reduce production costs and produce close to its users, it competes mainly on the basis of technology and marketing, both of which belong to the knowledge-based, increasing-returns world.

In such hybrid markets, U.S. companies have done well, and have maintained some production in the U.S. even while utilizing global production networks. This has occurred in the face of the general shift of hardware production to Asia and the expectation of many that the U.S. could not compete in hardware against low-cost Asian producers. In fact, the low-cost Asian producers, particularly the Taiwanese, have taken over much of the decreasing returns side of the PC business by serving as original equipment manufacturers (OEMs) to U.S. and (increasingly) Japanese companies. In printers, the major producers have kept most of the final production in-house, but have moved a good deal of it to places like Singapore, and have sourced many components from Asia as well. But the knowledge-based part of the business has remained mostly in the U.S. and Japan. The other Asian countries have not yet developed the key technologies or marketing capabilities to compete directly in the printer market.

Path Dependency and Industrial Location

Success or failure at the country level in the computer industry is not measured simply by the success of domestically-owned companies, but also includes the decisions of multinational companies to locate production activities within one's borders. Singapore in particular has thrived almost entirely on the basis of serving as a host for multinationals. Contrary to the notions of comparative advantage, however, the ability to become such a production platform does not depend only on some predetermined set of initial conditions such as the availability of land, labor or capital. Rather it is very much dependent on a dynamic, path-dependent process of interaction between business decisions, government policy, and external events such as technology shifts or changes in the market. The global production system has evolved through a complex pattern of such interactions over time, and each country's role in the industry has been determined by its own evolution within that system.

As we have argued earlier, the development of industry clusters is a path-dependent process. While Silicon Valley is the best known, it is not the only industry cluster in the computer industry. In Asia, major clusters can be found in Korea for DRAMs, in Taipei for PCs, components and peripherals, in Singapore for disk drives, and in Japan for a variety of high-end components and peripherals. The presence of such clusters has given these countries strong competitive positions in different segments of the global computer industry (Table 4).

Table 4. 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 (1994)	5	27	10	n.a	24	50

* Includes merchant sales only. Does not include captive production by PC vendors.
** Final assembly
Sources: MIC/III, *Asia IT Report*, February 1996 and November 1996
                   Electronics Industry Association of Korea, *'95 Statistics of Electronic Industries*

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 electronics companies, including camera maker Rollei and floppy disk drive maker Tandon, to locate in Singapore helped Singapore develop capabilities in mechanical engineering and develop a supply base of metal parts and electrical components. When Singapore's Economic Development Board (EDB) began promoting the computer industry, it targeted disk drives and 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 production process, even after rising wages made Singapore an unlikely location for such a labor-intensive industry.

The success of Taiwan's PC industry is likewise best seen as a dynamic process that involved entrepreneurship, industrial policy and path dependent agglomeration. Companies such as Acer and Mitac were highly entrepreneurial companies that sought and found opportunities within the newly emerging PC industry in the early 1980s. They were supported by a strong supplier network that had evolved from earlier foreign investments, local entrepreneurial efforts and government initiatives. The efforts of the private sector were complemented by government industrial and technology policies such as investment in R&D, training of engineers, and assisting Taiwanese companies to identify and exploit export opportunities. Over time, Taiwan developed capabilities in flexible manufacturing, systems engineering, market responsiveness

and logistics that were unmatched anywhere in the world. It also developed an exceptionally broad and deep supply base, with thousands of small and medium-sized firms in the Taipei region producing every imaginable electronic component. This agglomeration of capabilities has led every major PC maker to rely on Taiwanese suppliers for components, peripherals, OEM production and even logistics and distribution (Kraemer et al., 1996).

Sometimes a country is not able to lock in its position in an industry segment, as was the case of Korea in PCs. While Korea's output and exports of PCs grew on a pace to match Taiwan in the 1980s, Korea did not attract as many foreign companies and did not develop an supplier base with the depth and breadth of Taiwan's. Why did Korea fail to continue to build on its early success in PCs? For one thing, Korea's industry is dominated by a few giant electronics firms and lacks the strong base of small suppliers that gives Taiwan's industry its depth and agility. For another, the evolution of Korea's PC industry was short-circuited by the government's decision to raise barriers to imports and foreign investment in the 1980s. As a result, Korean companies failed to develop close ties to multinational computer makers at the design and engineering level, and were not ready for major shifts in the PC market in the late 1980s and early 1990s. Since then, Korea has struggled to catch up with Taiwan and Singapore in the PC industry, and has been limited mainly to supplying DRAMs and monitors (Dedrick, Kraemer & Choi, 1995).

Explaining East Asia's Success

Given the concentration of much of the computer industry's global production network in the countries of East Asia, it is natural to ask what explains their success. In other words, is the rise of East Asia to a leading position in the global computer industry due to some common characteristics of industry structure and policy, or is it simply an accident of geographical proximity?   Are the similarities merely superficial, or do they point to a common underlying model of industry development?

 We would argue that our findings on the computer industry fit well with the notion that there is an East Asian model of economic development. Furthermore, using the elements of the East Asian model, we can explain much of the success and failure of the individual East Asian countries in the computer industry, as well as their general success relative to other regions of the world.

Four features are emphasized in various attempts to develop a general East Asian economic development model: (1) Building and enhancing national capabilities; (2) An outward orientation aimed at promoting exports technology transfer; (3) Strong policy coordination within government and between government and the private sector; and (4) Emphasis on production over consumption.[1]

The emphasis on building and enhancing national capabilities, including human resources, infrastructure, technology and managerial skills, has been critical to East Asia's success in computers. Other countries such as Mexico, India and Brazil have attracted foreign

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[1]   There is an extensive literature on East Asia's economic miracle, ranging from neoclassical models that emphasize free market forces, exemplified by the World Bank's (1993) report, to analyses that emphasize the role of government policy in guiding the development process (e.g., Johnson, 1982; Amsden, 1989; Anchordoguy, 1989; Wade, 1990). The four features of the model presented here are generally agreed upon as being present in each of the East Asian countries, with the exception of laissez faire Hong Kong. There is much less agreement on the relative importance of each element of the model, especially the role of government coordination. Our analysis of the computer industry has led us to conclude that each of these factors is not only present, but important in determining the Asian countries' position in the industry.

MNCs, or developed local industries to supply their own protected markets, but failed to develop capabilities needed to support global competitiveness in computers. By contrast, each of the East Asian countries has continuously tried to upgrade its capabilities in order to advance to producing more sophisticated products with more local inputs and value added. This common focus has helped the East Asians remain competitive even as rising wages drove labor-intensive production offshore. On the other hand, where the East Asians have been less successful, it has been often due to gaps in specific capabilities. For instance, Korea has developed strong skills in semiconductor engineering, but can't compete with Taiwan in PC engineering skills. More generally, none of the East Asian countries has developed software skills anywhere near the quality of their hardware skills, a fact reflected by the near absence of a competitive software industry in any of those countries.

The second aspect of the East Asian model has taken on different characteristics across the countries, with resulting different outcomes. The outward-oriented model employed by Japan and Korea has been based on using a domestic profit sanctuary, protected by formal or informal trade and investment barriers, to subsidize exports. However, this approach has only served to leave Japan and Korea relegated to the role of providing high-volume components, but lacking tight linkages to the global production system. On the other hand, Taiwan, Singapore and Hong Kong have had much more open policies toward trade and investment, and have becoming deeply integrated into the global industry.

The third element of the East Asian model is the importance of policy coordination, both within government and between government and industry. Successful policies have been most common when government consults closely with both local and international business people, and when government policy is coordinated and policy jurisdictions are well-defined. The model of such policy coordination was Japan's Ministry of International Trade and Industry (MITI), whose guidance of the Japanese economy was imitated by economic pilot agencies in Korea, Taiwan and Singapore. However, by the advent of the PC era, both Japan and Korea faced vigorous bureaucratic infighting, and policymakers seemed to become less attuned to the needs of the private sector. The result has been a number of disjointed policy initiatives such as R&D consortia that have often seemed to completely ignore the dramatic changes happening in the international computer industry.   By contrast, Singapore and Taiwan have been better able to coordinate their policies internally. Even more importantly, policymakers in those countries have consulted with business leaders and other experts at home and abroad to monitor the global market environment, and their policies have been generally more attuned to the demands of the market.

A final aspect of the East Asian model has been the promotion of production over consumption, a strategy often contrasted with the high priority given to the consumer in the United States. While the wisdom of such a strategy can be debated in other industries, there is no question that it has been detrimental in computers. Other than Singapore, which has explicitly promoted computerization, the Asian countries have also been slow to exploit the economic benefits of computer use throughout the economy. Japan, Korea, Hong Kong and Taiwan are now investing heavily in computers and information infrastructure to try to catch up, but they remain behind the U.S. and other countries which have much more experience in applying information technology in business, government and education. The secondary effect of promoting production over use is the lost opportunities for developing software and services industries. The price of such lost opportunities becomes ever clearer as hardware markets become increasingly competitive and East Asian companies continue to work harder for less profit. Meanwhile the fastest growing and most profitable segments of the computer industry

remain firmly in the hands of U.S. companies, who benefit from their proximity to the largest, most sophisticated computer market in the world.

To summarize, we would conclude that there has been an East Asian model for computer industry development, despite the many variations among countries. That model is now being employed by other emerging NIEs in the region, such as Malaysia, Thailand, Indonesia, China and the Philippines, who hope to follow the East Asian NIEs in developing globally competitive computer industries. That hope is fueled by global competition and cost pressures, which are once again causing firms to move more production abroad, this time from the NIEs to the emerging NIEs. The strength of the East Asian model is its outward orientation and its focus on developing national capabilities. Its weakness is its emphasis on hardware production at the cost of ignoring software and IT use. The result of this emphasis has been to leave the Asian countries battling among themselves in the decreasing returns segments of the market, while leaving most of the increasing returns business to the U.S.

Country and Company Performance

Using the framework of increasing and decreasing returns, Table 3 and Figures 3 and 4 summarize the present competitive situation in the computer industry. They show both company position by market segment and the location of production activities by country within the global value chain. The predominance of decreasing returns business in East Asia can be seen clearly in these figures.

Table 3. 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. U.S. leads in hard drives. Singapore in sound cards.	U.S. and Japanese dominate in PCs and printers. U.S. companies are leaders in information services, with local co's strong in local 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/South China and other developing countries.	R&D, design, high-value components mainly in Japan and U.S. High volume production in Japan, Korea, Taiwan, Singapore. Low-end assembly in HK/South Chin and other developing countries.	R&D, design, and most production in U.S. and Japan for printers and PCs. Engineering and production in U.S., Japan, Taiwan, and Singapore. Production moving to developing countries. Information services provided in local markets.

Insert Figures 3 and 4 here

The message of the foregoing table and figures is quite simple. U.S. companies dominate in the increasing returns segments of the market, Japanese, U.S. and Korean companies dominate in decreasing returns segments, and U.S. and Japanese companies dominate the hybrid segments. Activities tend to be located in order to take advantage of local capabilities. Increasing returns activities such as R&D, product design and engineering, and software development are concentrated in the U.S. 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. Activities that rely on speed and flexibility such as PC, motherboard, and hard drive production are mostly done in Taiwan and Singapore, which have the skills and strong supplier bases to get products from design to volume production very quickly. Labor-intensive activities generally take place in Southeast Asia and China, where large pools of low-cost, well-educated workers are available, and in the case of Hong Kong/South China, strong managerial capabilities.

This picture is merely a mid-1990s snapshot, however, and is changing rapidly. The East Asian NIEs are steadily moving up the value-added scale 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 well-financed Korean companies. Taiwanese companies, with the support of the Taiwanese government, 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.

So far, however, U.S. companies have been able to sustain their position in the increasing returns businesses, and are moving aggressively to leverage their leadership in those markets to gain control of new market segments in the emerging network businesses. Those companies are also finding opportunities to turn hybrid markets into increasing returns businesses, particularly in information services.

The Network Era: An Emerging Competitive Paradigm

It is now commonly accepted that the computer industry is entering a new era of competition based on networked computing, as exemplified by the explosion of Internet use in recent years. The network era presents new opportunities and challenges for existing companies and for many newcomers who are developing Internet-based businesses. Companies such as Sun, Netscape, Cisco, Yahoo!, and products such as hubs, routers, web browsers, search engines and electronic commerce networks are defining the new era. The decision of Microsoft to revamp its entire business to focus on the Internet verified and legitimized the arrival of the network era, just as the introduction of the IBM PC did for the PC era.

The network era promises to expand the reach of the IT industry by an order of magnitude by connecting millions of households and businesses to the global Internet and other networks. The business opportunities are enormous, but as in earlier eras, there will be a distinction between increasing returns and decreasing returns segments of the market. Companies that establish and control key standards will enjoy rapid growth, high profits and increasing returns to scale in their businesses. The rest of the industry will battle in the large, but low-margin decreasing returns markets. More than ever, companies are acutely aware of the potential rewards of increasing returns markets and are aggressively promoting their own

standards for network computers, web browsers, switching systems, electronic commerce and other technologies. Strategic positioning, alliances and competitive pricing (to the extent of giving away software) are being employed in the pursuit of standards dominance.

Asian companies and countries are certainly aware of the importance of network computing and are trying to position themselves to participate. Japanese companies have set up U.S. subsidiaries and are participating in various national information infrastructure (NII) test-bed projects in the U.S. They have also established alliances with leading U.S. firms. Meanwhile, Asian governments have launched their own NII initiatives to improve their infrastructures and catch up in applying network technologies. Japan is especially concerned that it not become a backwater in the network era as it did in the PC era, but even developing countries such as Malaysia have launched ambitious NII and multimedia projects. Hong Kong and Singapore already boast exceptional telecommunications networks and Singapore's IT2000 plan is a model for other countries' NII strategies (including Vice-President Gore's information superhighway initiative).

However, as in the mainframe and PC eras, the key competitive arena is the U.S. market, and it is U.S. companies that are the leading competitors in the network era. While the Internet is a global network, it is assumed that standards set in the U.S. will ultimately dominate around the world. So far, the Asians are concerned mainly with staying close to the evolution of the market so that they can take advantage of opportunities as users and develop products based on standards set in the U.S.

Competitive Threats: Where are the Challenges to the U.S. in the Network Era?

The fact that U.S. companies are the leaders in the network era does not mean that there are no serious potential challenges from abroad. After all, the U.S. long dominated the consumer electronics industry, only to be overwhelmed by Japanese competitors that made better, cheaper products based on technologies developed in the U.S. Once the standards for the network era are set, many U.S. companies will be left competing in the decreasing returns side of the business, and Asia has already proven its capabilities in such markets.

The most plausible Asian challenges to the U.S. computer industry fall into two categories. The first is a new challenge from a reinvigorated Japanese computer industry, and the second is a challenge from the rapidly growing Greater China region.

Japan

The prospect of a resurgent Japan taking over the global computer industry just as it did consumer electronics does imply serious threat to the existing order. This prospect has been a recurring concern to the U.S. industry, and has been raised again in the past year or two as major Japanese companies have targeted the U.S. market. All the major Japanese computer makers have finally adopted the global Wintel PC platform, reorganized their operations, formed alliances to boost their global presence and are now positioned to compete in the U.S. market. It is argued that a pitched battle is therefore on the horizon, with the prospect that the long feared Japanese takeover of the global computer market will actually occur by 2005 (Normile, 1996; Boyd, 1996).

The rationale for the rejuvenation of the Japanese juggernaut is multifaceted but it comes down to strategic positioning. The Japanese computer and electronics manufacturers have finally realized that the PC is a strategic product in several regards. First, the PC is at the heart of the client/server architecture that is gradually replacing mainframes in the business market,

and is also the key platform for the Internet and multimedia. Second, the PC is key to growth beyond the Japanese market. Third, success in PCs will help the vertically-integrated Japanese manufacturers retain their leadership in many key PC components in the face of competition from Korea and elsewhere.

The Japanese have come to realize that they must be major players in the U.S. market, where market and technology trends are still set. NEC, which feels it "must aim for more than 10% of the world market" in PCs, sees success in the U.S. as the key to success in Asia on the grounds that "what will sell in the U.S. will be successful in Asia." Toshiba, the most successful laptop computer company in the world, sees expansion into desktops for business and the home in the U.S. as a key to gaining market share globally.

The competitive blood bath has already started, but mostly in Japan so far. Although U.S.-based Compaq Computer introduced price competition in Japan in 1992, Fujitsu went one better in 1995 by launching an all out price war in order to gain market share. It succeeded, going from around 9% to 20% of the Japanese market at the end of 1996 (West and Dedrick, 1996). So far, the Japanese computer makers are taking away market share from each other in Japan, and repelling the invasion of U.S. companies there, but what about their prospects in the rest of the world?

The real opportunity for Japanese companies could come from the convergence of consumer electronics and computers. They have unequaled hardware technologies, product development, and manufacturing know-how; they are the world leaders in miniaturization; they have deep pockets to buy their way into markets through acquisitions and protracted price wars; and they have confidence from their past take-over of global markets in consumer electronics. A company such as Sony might find it hard to compete in PCs with U.S. leaders who are well established in that market, but it brings formidable strengths to the consumer market.

But so far, the Japanese are still only targeting the decreasing-returns hardware side of the network business. Japan still trails the U.S. in Internet use, and Japanese companies are largely absent in the battle to set new standards for the network era. It is indicative that no major company in Japan is restructuring an entire company around the Internet. The only exception might be Softbank, which has been aggressive in targeting Internet business opportunities, particularly through acquisitions of U.S. companies. However, Softbank is an anomaly in Japan--a relative newcomer run by an ethnic Korean educated in the U.S. The large Japanese computer makers have done little in the way of Internet business beyond developing online services for the Japanese market.

In short, the vertically integrated, top-down, bureaucratic Japanese companies excel at making products for well-defined and steadily growing markets. While they have restructured for more efficient commodity manufacturing, they have yet to truly reorient themselves to compete in knowledge-based, innovation-driven markets. Japan's weakness in software, its relatively low adoption levels of information technology, and it linguistic isolation (lack of English skills) put it at a disadvantage in the increasing returns businesses.

Moreover, the global strategies of Japan's computer makers are not in tune with the network era. The large Japanese firms seek growth by extending their grip on an ever growing range of technologies from silicon to systems, continuing to pursue vertical integration rather than horizontal specialization. This view reflects a fundamental failure of Japanese computer makers to understand network economies and increasing returns businesses. They are locked into organizations, strategies and businesses with diminishing returns. With the exception of Toshiba which has been successful in the U.S. market for more than a decade, the Japanese computer makers also do not understand the U.S. market well, and are uncomfortable with the free-wheeling corporate style of Silicon Valley. Thus, they can be expected to compete strongly

in making commodity hardware for the network era, but they are not likely to take the lead from U.S. computer firms in software, networking or content.

Greater China

The network era presents a strategic opportunity for the Greater China (including China, Taiwan and Hong Kong) and the broader China Circle (which includes the Chinese populations of Southeast Asia). Whereas the developed countries' computerization efforts began in the central computing era, and the Asian NIEs in the PC era, China's efforts and those of other developing countries coincide with the network era. The China circle is not only a rapidly growing market, it is also a possible leading market for a new range of network computer technologies. For instance, China is an ideal market for low cost information appliances, as are its Asian neighbors and many low income countries throughout the world.

China is also developing capabilities to participate in the global computer industry. It already has a vast pool of talented programmers (around 1 million), engineers and an even larger pool of low cost labor to support hardware production. It is building the modern telecommunications networks needed to support widespread computer networks. China's central government has the desire to compete in the computer industry and the ability to marshal the resources needed to do so. China's vast market gives it the leverage needed to attract technology, foreign investment, skilled designers and experienced entrepreneurs needed to compete in the global industry. But China can't do it alone.

Hong Kong and Taiwan can provide other key resources that China needs. Hong Kong's entrepreneurs know how to do business with China and the West and provide import-export linkages between China and the rest of the world. Hong Kong also manages production for foreign multinationals, Taiwanese subsidiaries and mainland companies in nearby Guandong Province. These roles could be expanded post-1997 to all of South China. Taiwan has design and production capabilities, strong linkages to foreign multinationals, market intelligence in leading and emerging markets, and the managerial capabilities to coordinate production across the China Circle. Taiwan is already probably the single largest investor in China via Hong Kong, and future rapprochement between the two governments could unleash further investment.

If China's industry and government can provide leadership to exploit the Internet and the network computer, to create a strong industry cluster, and to cooperate with Hong Kong, Taiwan, and with the many multinationals operating in the region, the China Circle could become a leader in the emerging network era and a competitor to the U.S. and Japan. Cultural and linguistic ties, as well as family and business networks have created linkages among the countries in the China circle. The business organizations, which tend to be decentralized, free-wheeling and highly adaptive, are well-suited to the demands of the global industry.

The major obstacles to the China Circle scenario are political. While there are strong incentives for China to manage a smooth transition in Hong Kong, there are questions as to whether Beijing will allow Hong Kong to retain its free-wheeling Western flavor and maintain the integrity of the legal system and civil service. And while China and Taiwan have every reason to seek a peaceful settlement, their political and economic systems are so different that it is difficult to imagine how they will do so. Another obstacle to success in the network era could be the desire of the Chinese government to control the network from the top. The combination of regulation, censorship and barriers to information flows could leave China isolated from the Internet and the global information economy.

The China Circle scenario implies that production of computer hardware would shift even more to Asia than in the past, and that software and services industries will be developed to serve

the large Chinese-language population, creating a second center of gravity for the global industry. The key question is whether such a China Circle would cooperate or compete with Japan and the U.S. Although Japanese foreign policy promotes "Asia for Asians," and continues to pour foreign aid into the region, Japan's history in the region and its closed in-house business model limit its scope of integration in the Asian production network (Ernst, 1994). There is greater potential for cooperation between the U.S. and the China circle because there are many overseas Chinese in the U.S. with ties to the China circle. The tendencies of U.S. businesses to outsource much of the production function and to give local managers more responsibility have meshed well with the capabilities of the China Circle.

However, the Chinese government in the long run would like to develop independent technological capabilities. It already requires technology transfer in return for access to the Chinese market in many cases, and if U.S. companies are too willing to accept such a tradeoff, they may find that they are creating their own competitors. This situation puts U.S. companies in a difficult position—they cannot afford to be left out of Greater China, but they must protect the intellectual property that is their primary competitive advantage in the industry.

CONCLUSIONS: IMPLICATIONS FOR THE U.S. COMPUTER INDUSTRY

In the final analysis we find that Asian companies and countries represent both threats and opportunities for the U.S. computer industry.

Japan dominates the technology for many components, and some Japanese companies achieved near-monopoly positions in a number of key upstream materials, components and process technologies. These strengths could help Japan to take over larger shares of industries such as hard drives, printers and notebook PCs. Other Asian companies and countries will likely take over more and more of the high volume production of parts, components and assembled systems for the global computer industry. This will result in the losses for some U.S. firms and could cost U.S. jobs in the hardware business. But despite their remarkable success in a short period of time, East Asia's competitive threat remains limited to the decreasing-returns and hybrid segments of the industry.

On the other hand, we conclude that U.S. companies will continue to be leaders in software and microprocessors and in the design, marketing and distribution of systems. Microsoft and Intel have virtual monopolies in their businesses, supported by the powerful effects of increasing returns markets. Firms like Compaq and Dell bring innovations in design, marketing and distribution. Established firms like Hewlett-Packard and IBM provide the full-service solutions that large businesses desire. Information service providers like EDS, CSC, and IBM already have global reach necessary to provide services to large multinational corporations.

Asia also provides some attractive opportunities. For one, the U.S. computer industry 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. Secondly, the Asia-Pacific region is a tremendous market whose potential is only starting to be realized. The Asian market has grown faster than the North American or European markets for a decade and is expected for continued double digit growth into the 21st century.

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. And for those companies in decreasing returns markets, the rapid growth offered by Asia at least compensates in part for the increased competition from that region.

Responding to the Asian Challenge

Exploitation of Asia's market potential will not be easy however. It requires new strategies by U.S. companies and the U.S. government.

- U.S. companies need to consider each country's market potential separately because the realizable potential often is at odds with popular perceptions. Success will require developing effective channels, setting up sales and service, being patient for return on investments, and partnering with domestic companies for access to markets. In large markets such as China it will also require setting up production facilities, exporting a substantial portion of production, transferring technology and upgrading local skills.
- While Asia presents a great market opportunity, U.S. companies must take care to protect their intellectual property so as to avoid creating new competitors in their core markets. The risks come not only from local partners, but even from employees. Anyone who conducts research on Asian high-tech companies will be struck by how many executives and technology professionals have previously worked for U.S. companies, both in the U.S. and in their home countries. Taiwan's computer industry and its government research labs look like an IBM alumni association. The same could be said of Silicon Valley, but from a U.S. point of view, there is a tremendous leakage of knowledge and talent from the U.S. to Asia. On the positive side, this flow of knowledge has helped create the Asian production network that U.S. companies have tapped so effectively. But by the same token, U.S. firms should not be blind to the possible costs of having their technologies walk out the door to potential competitors.
- The U.S. government can assist U.S. computer companies by promoting adoption and implementation of intellectual property laws in Asia, reinforcing the agreement to remove tariffs by the year 2000, and taking actions to eliminate informal trade barriers as well. It could do much more, however, especially on behalf of smaller companies who lack the resources to exploit the opportunities presented by the Asian market. The quality of publicly available market information on Asian markets is seriously deficient, and private market research is very expensive and often inconsistent and contradictory. Government organizations such as the Japan External Trade Organization (JETRO) and Taiwan's Market Intelligence Center are good examples of how the U.S. government could support U.S. companies trying to do business internationally.
- Government and industry need to make a commitment to improving education in the U.S. The government is mainly responsible for the overall quality of the educational system, but industry can play an important role in supporting scientific and technical training. The number of computer science graduate from U.S. universities has been declining since 198x (NSF, 1996), and graduate engineering programs are filled largely with foreign students, many of whom will return to their home countries after graduation. For an industry that depends on skilled human resources as its most critical input, this should be a major concern.

One final implication of these findings is that while the news is generally good for the U.S. computer industry, the industry might take its eyes off Asia as a source of serious competition. Complacency led to the downfall of IBM as the industry leader, just as it left Japan vulnerable to competition from Korea's semiconductor industry, and it could turn out to be the greatest danger for the U.S. in general.

The Greatest Danger

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. As one executive of an Asian computer maker told the authors, "If I need information on what an American company is doing, I can make a few phone calls and know by the next day." 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. These companies are often valuable suppliers and partners to U.S. companies, often their former employers, but U.S. companies should not ignore the potential competitive threat from their Asian partners.

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 will increase in the long run. Many segments of the computer industry will evolve into large, mature, consumer-oriented 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. The present structure of the computer industry is as much a result of history as of the inherent capabilities of American companies or citizens. 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.

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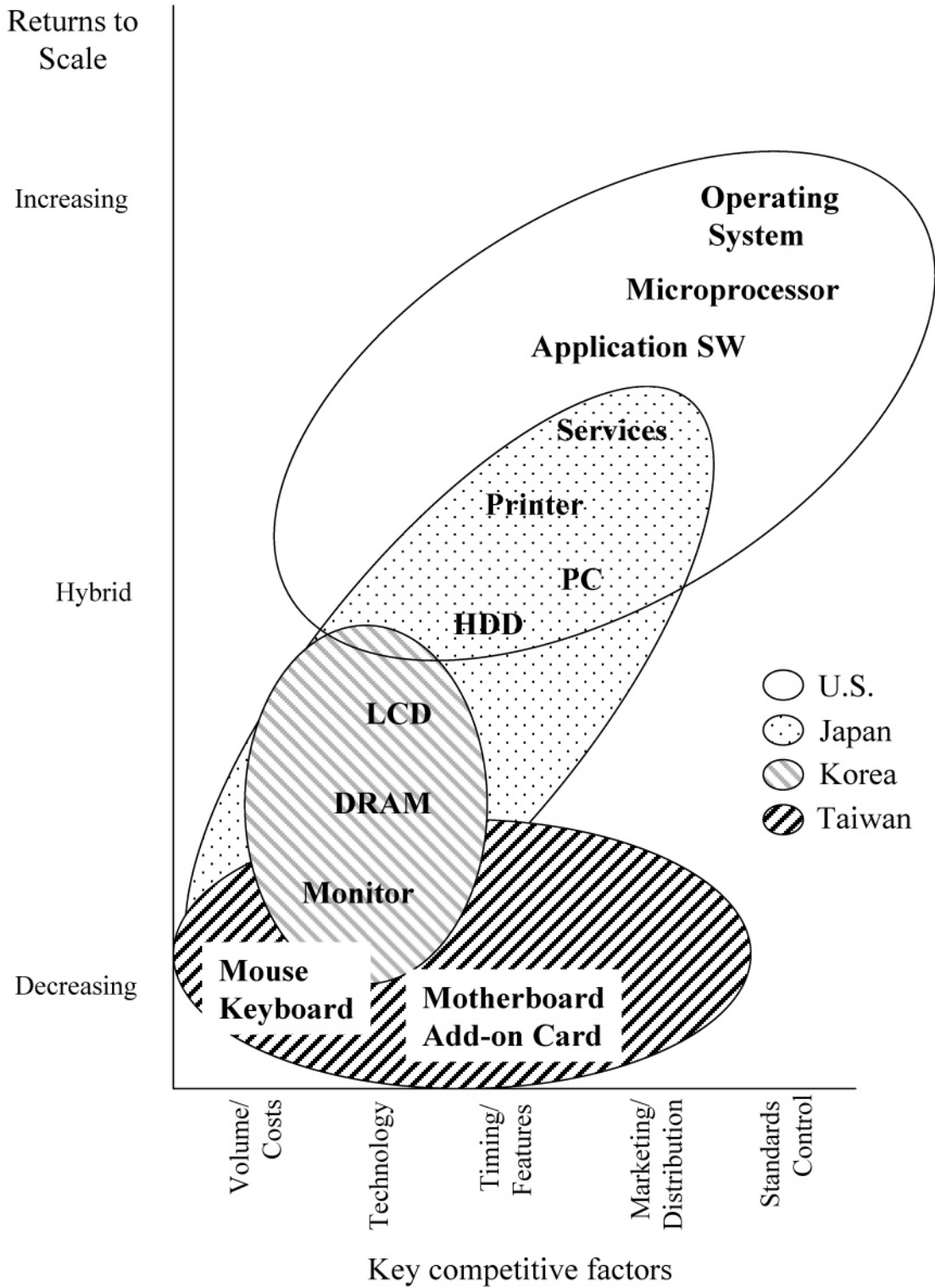**Figure 3. Company Competitiveness: Location of Headquarters**

Figure 4. Country Competitiveness: Location of Production Activities