Globalization of the Personal Computer Industry: Trends and Implications

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INTRODUCTION

Globalization is a highly controversial issue in the U.S. and around the world. Debates over policy initiatives such as the World Trade Organization and NAFTA have pitted free trade advocates in government and industry against organized labor, environmentalists, human rights organizations, and companies seeking protection from global competition. In the academic realm, neoliberal economists are lined up in favor of open markets and globalization,[1] but some skeptics still raise questions about impacts on local companies, workers, language, culture and social institutions.[2]

These debates have been fought largely on the basis of ideology, theory, logic or anecdote, supported by only limited empirical data. There is clearly a pressing need for new research that provides both empirical evidence as to the scale and characteristics of globalization, and clearer analysis of its impacts. The purpose of this paper is to present a fact-based picture of globalization and its impacts within a specific industry--the personal computer industry.

The personal computer industry offers a valuable case study of the process of globalization. The industry is one of the most global of industries, with leading companies coordinating production networks that span the major regions of the world. It also has been the most dynamic segment of the electronics industry since the early 1980s, both in terms of growth and the creation of new models of firm and industry organization. Decisions made in the PC industry have rippled through the rest of the computer industry and out to other industry sectors, ranging from contract manufacturing and electronic components production to distribution, logistics, service and support.

Globalization and Industry Restructuring

Scholars have noted that there are two fundamental processes at work today that have implications for the competitiveness of companies and prosperity of countries. The first is the process of global relocation of economic activities, or globalization. The second is the process of industrial reorganization, especially of production and distribution systems, to create cross-border value networks. These two processes are complementary in that new forms of industrial organization are enabling the global relocation of economic activities (Berger, et al., 1999).

Globalization refers to "tendencies towards the integration across borders of markets for labor, capital, goods and services and the emergence in all of these markets of a common set of actors" (Berger, et al., 1999). These actors are primarily multinational corporations (MNCs) who can perform a wide range of functions on a global basis, allowing them to locate activities anywhere that is strategic. The historical strategy of these global MNCs has been either to establish centrally-controlled production and distribution networks with local subsidiaries carrying out sales and service functions in national markets, or to establish highly autonomous national or regional business units with full responsibility for product development, manufacturing, distribution and service functions for each market. In the first case, production was centralized

[1] For instance, see Burtless, et al. (1998),
[2] For instance, see Polanyi (1944), Reich (1991) and Rodrik (1997).

in one or a few locations, with parts and components produced internally or by closely aligned suppliers. In the second case, MNCs relied mostly on local suppliers in each market.

More recently, a new form of industrial organization has emerged: the global production network. Such networks are based on horizontal specialization rather than vertical integration. They rely on market transactions between independent firms rather than internal transfers between business units of MNCs or members of an identifiable business group or family (e.g., the Japanese keiretsu or Korean chaebol). Firms compete within a horizontal industry segment and grow by capturing market share and achieving economies of scale, rather than by extending vertically into upstream or downstream activities. The global organization of these networks is a function of the location decisions of these firms, rather than any master plan on the part of any particular firm (although the decisions of one leading firm may influence those of its competitors, suppliers or customers).

The personal computer industry was a pioneer in developing the global production network model of industrial organization, and has extended its production network throughout much of the world. It has continued to develop new management practices and organizational structures, with new approaches to manufacturing, logistics, distribution and marketing in a dynamic technological and market environment. Most recently, PC makers such as Dell Computer have been leaders in linking together the key members of the production network via information technology to create a so-called virtual corporation, aiming to combine the cost advantages of horizontal specialization with the close coordination of vertical integration.

Many of the PC industry's innovations have been adopted by other segments of the electronics industry and by other industries as well. As such it provides a valuable case study of both globalization and industrial restructuring, both from a historical point of view, and as a study of emerging trends in globalization. It also offers useful insights into the impacts of globalization on company competitiveness, trade and investment flows, and employment trends.

This paper describes the value network of the PC industry and the globalization of that network over time. It then analyses the key factors shaping the location of production in different segments of the industry. It identifies key historical and current industry trends. Next, it looks at global patterns in PC production that have shaped the location factors and key industry trends. It presents new data on the computer industry as a whole, as well as on individual PC companies and their key suppliers. These data provide insights into historical and recent trends in production, trade, investment and employment. Finally, it draws conclusions from the PC industry about the evolution and impacts of globalization on companies and countries.

THE PERSONAL COMPUTER INDUSTRY VALUE NETWORK

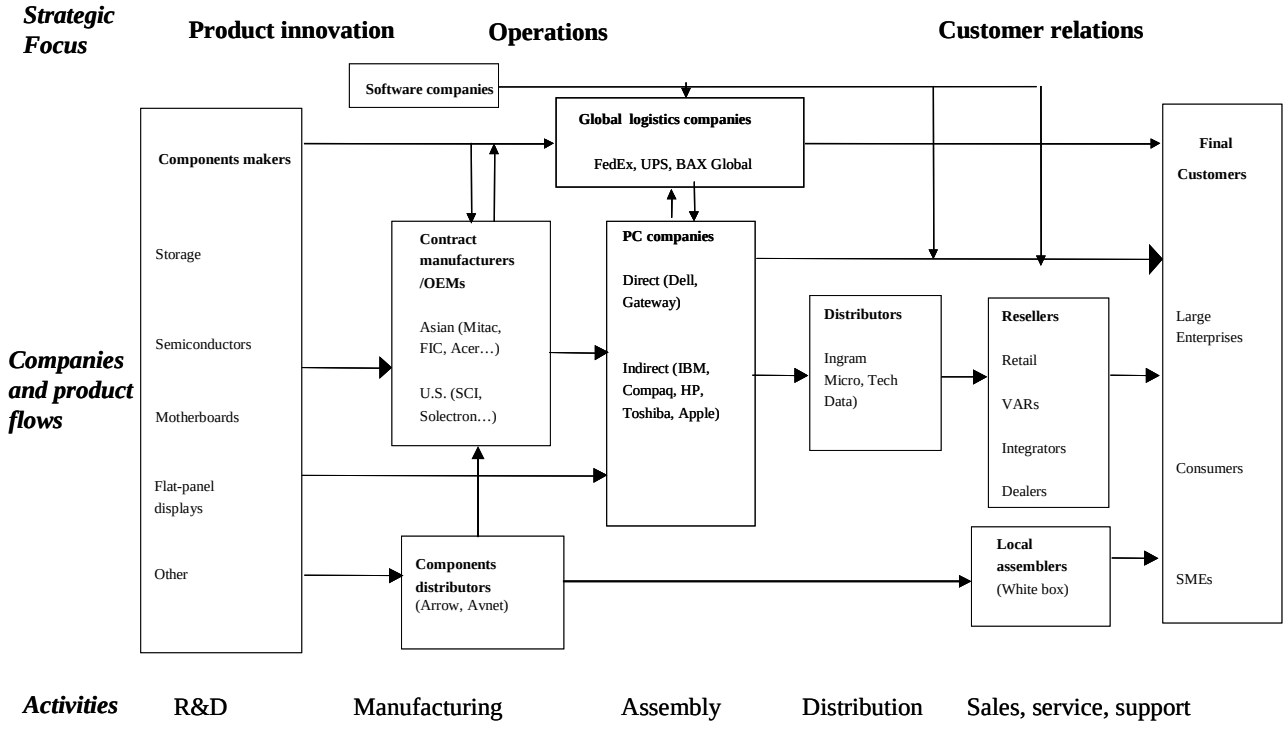
The PC industry is a complex network of companies involved in different industry segments, from microprocessors and other components to complete systems to operating systems and applications. Depending upon the industry segment, these firms specialize in different activities, from R&D to design, manufacturing, assembly, logistics, distribution, sales, marketing, service and support.

These firm activities can be classified using a taxonomy that draws on Treacy and Wiersema (1995) and Hagel and Singer (1999). This model groups a company's activities into three areas: product innovation, operations, and customer relations. These categories include the following activities:

- Product innovation includes R&D, design, market research, and new product introduction.
- Operations include process engineering, manufacturing, logistics, IT, finance and human resources. In this analysis we focus on manufacturing and logistics, as we are concerned with the location of production activities.
- Customer relations include marketing, sales, advertising, distribution, customer service, and technical support.

Figure 1 broadly groups the activities in the PC industry value chain under these three categories. The boxes in the figure show groups of companies in different industry segments and how they focus on specific activities in the value chain, while the arrows show the flows of components, subassemblies, systems, software and services from suppliers to the end customer. As the figure illustrates, the PC companies are only a small part of the overall value system. However, they are the focal point of the value system, making the production decisions that drive the whole system and coordinating the activities of other players in the system.

Figure 1. PC industry value network



Source: Adapted from Curry and Kenney, 1999.

Historically, vertically integrated computer companies operated in all industry segments and carried out the major functions of product innovation, operations and customer relations internally. However, in the PC industry, most companies specialize in one industry segment (e.g., PCs, motherboards, hard drives) and concentrate most of their resources on one or two major activities.

This strategic focus has occurred because the PC is a modular product assembled from standard parts which can be produced almost anywhere by anyone. Only limited value is added by PC assembly, and there is little innovation on the part of PC assemblers. Architectural standards are mostly determined by Intel and Microsoft. PC components and peripherals makers can design products that meet those interface standards, with little need to interact directly with the PC assembler. For the most part, PC makers add value through customer relationships, either directly via direct sales and service relationships, or indirectly through branding, marketing, and quality assurance. They also add value by coordinating the logistics of the global production networks that turn components into finished products and deliver them to customers, even if they add little value through actual physical transformation of the product (Curry and Kenney, 1999).

GLOBALIZATION OF THE PERSONAL COMPUTER INDUSTRY

The computer industry has long been one of the most global of industries. In the mainframe computer era, this was due to the market leadership of International Business Machines, a company whose very name attests to its global orientation. IBM created a single standard for mainframe computers that dominated most of the world's markets. It also operated on the basis of global optimization, assigning product development and manufacturing responsibilities to individual laboratories and plants worldwide, each of which specialized in certain products and technologies. IBM even took care to roughly balance its internal trade among the three major regions (Americas, Asia-Pacific, Europe) so as not to create a major trade deficit in its host countries.[3]

The PC industry offered a much more extensive opportunity for globalization thanks to the nature of the dominant IBM PC architecture. Following the example of the highly successful Apple II, and in a hurry to catch up in the emerging PC market, IBM created an open, modular architecture that allowed suppliers to develop components and peripherals that utilized standard interfaces with the core CPU and operating system (Langlois, 1992). IBM chose to outsource most of the components for the original IBM PC, and other PC makers took advantage of the supply network created by IBM to produce their own IBM-compatible PCs.

The PC production network took on a global nature almost from the beginning. IBM sourced some parts for its original PC from Asian suppliers, and U.S. suppliers of components such as disk drives and printed circuit boards set up production facilities abroad in order to reduce costs. In order to tap these emerging supply networks and gain access to foreign markets, IBM and other PC makers began locating assembly plants around the world and sourcing many parts and complete systems from foreign suppliers. The resulting production networks were global, but

[3] 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.

were concentrated most heavily in the Asia-Pacific region, where earlier investments by U.S. and Japanese electronics firms had created an existing supplier base.

The Asia-Pacific production network was concentrated in Southeast Asia, particularly Singapore and Taiwan. In Singapore, many U.S. and other MNCs set up production of computer hardware, especially disk drives. In Taiwan, entrepreneurial local companies found opportunities supplying the major PC makers, beginning with simple parts and moving up to more sophisticated components, subassemblies, and final assembly of PCs and peripherals. Over time, labor-intensive activities were relocated to low-wage locations such as Thailand, Malaysia and China, with Singapore and Taiwan coordinating production in these sites and handling more sophisticated manufacturing processes at home. Japan and Korea were less successful as global PC producers, but were the major suppliers of high volume components such as memory chips and flat-panel displays.[4]

FACTORS SHAPING THE LOCATION OF PRODUCTION

PC makers locate production activities in order to optimize a combination of factors, all aimed at the goal of delivering their product to the final customer in a timely way at the lowest overall cost. These factors differ by product and market, so that production of laptop PCs for the European market will have different requirement from production of desktop PCs for North America, and both will depend on whether products are built to order or to forecast, and on what distribution channels are used. The two broad categories are cost-related factors and market-related factors.

Cost Factors

The set of cost factors taken into account can be complex, but these can be grouped into three broad categories for better understanding. These are: production costs, depreciation, and logistics costs. These cost dynamics often conflict; for instance, depreciation costs can be reduced by air shipment, but this increases logistics costs. The decision about where to locate requires optimization across these cost factors.

Production cost

Production costs are the direct costs involved in manufacturing, including land, labor, materials and utilities. Assembly operations, whether PCs, printed circuit boards, hard disk drives, or semiconductors, tend to be labor intensive, although there are degrees of automation in each of those activities. Labor costs are becoming a bigger share of PC production costs as PC prices decline in concert with falling components prices. To illustrate, for a $2000 PC (the typical price in the early 1990s), assembly costs were $50, or 2.5% of total costs. On a $1000 PC (the typical price today), if assembly costs are still around $50, that figure now represents 5% of the total (Curry and Kenney, 1999). Therefore, reducing assembly costs now has a bigger relative impact on overall costs, so there is more pressure to take advantage of lower-cost labor or to improve labor productivity.

[4] Dedrick and Kraemer, 1998.

Depreciation cost

Some parts of the PC have extremely high rates of innovation. Moore's Law is well known, and reflects the rapid improvement in semiconductor performance, driving microprocessors, DRAM and various other chips. Similar performance gains are seen in hard disk drives. PCs incorporate ongoing innovation in components, and thus also have a high rate of depreciation (estimated by some at 1% per week). Depreciation costs are reduced by increasing inventory turnover within the plant and distribution channel, and also by reducing the time that products spend in transit from one location to another.

Logistics costs

It is possible to minimize depreciation costs, and to take advantage of low cost production locations by using air shipment, which can reach anywhere in the world in a few days. However, air shipment is much more expensive than shipment by truck or by sea. Whether it is viable to ship by air depends on the value of the item relative to the cost of shipping it. The actual cost of air shipment is determined by weight or volume of the shipment, and distance shipped. Another factor is the availability and cost of shipping services. Semiconductors, disk drives, and even notebook PCs can be shipped by air, as their value is very high relative to their size and weight (and hence shipping cost). Desktop PCs, motherboards, and some other components and peripherals might be shipped by air as well, but the shipping cost relative to value is higher. Power supplies, plastic and metal parts, and picture tubes for monitors are generally too heavy or low value for economical air shipment. Logistics costs can be reduced either by using low-cost shipping options or by producing close to the final assembly point, so that shipping distance is minimized.

Market Access

Selling PCs in a national or regional market generally requires a local presence. Vendors need to understand local market preferences and tailor products to local demand, as well as to provide local sales and marketing, distribution, and customer support services. In many markets, these functions are carried out by a local sales office, or through distribution and service agreements with local partners. In other markets, it is necessary to have more a more extensive presence to compete with local vendors or to surmount various trade barriers.

The cost of selling in a national market depends on the level of tariffs, taxes and various non-tariff barriers. If tariffs are high, it may not be competitive to export to a country if there are other vendors producing locally. Some non-tariff barriers also require a local presence to circumvent. For instance, government agencies may not be willing to buy imported products if locally-made alternatives are available. PC makers are likely to simply bypass small markets with high costs of market access. But for large (or potentially large) markets such as China or Brazil, they may choose to set up local production, as companies such as Dell, IBM, and Compaq have done. As countries such as China join the WTO and reduce formal trade barriers, the cost of market access should be reduced, but non-tariff barriers are likely to remain, requiring local production.

Government policies can also have the opposite effect of reducing costs. Various investment subsidies, favorable tax laws, and other incentives can lower the cost of producing in a given location. These may be offered by national governments or by state, provincial or local governments to attract investment, and PC makers often take advantage of such incentives to reduce their costs.

Relative Importance of Location Decision Factors

A survey of U.S. electronics companies conducted by McMillan et al. (1999) asked managers what factors were most important in deciding where to do business. The most important factors cited were infrastructure (18% of respondents), political stability (17%), skilled labor cost and availability (17%), proximity to customers and suppliers (16%), and tax incentives (10%). Unskilled labor costs were only cited by 3%. Referring to the categories outlined above, logistics and depreciation costs are most affected by infrastructure and proximity to customers and suppliers, as they determine the time and cost involved in delivering a product to the customer. The main determinant of production cost is labor cost and availability. Market access is affected by proximity to customers. Political stability does not affect costs or access directly, but is an important determinant of the risk involved in investing in any location. It appears from these results that electronics companies are balancing all of these factors.

These findings are borne out in general by our interviews with PC companies and contract manufacturers. However, our interviews indicate that the cost and availability of both skilled and unskilled labor is more important than these findings suggest. Firms sometimes locate some distance away from existing manufacturing clusters for availability of skilled and lower cost workers (e.g., Dell located its China plant in Xiamen, far from the electronics industry clusters of Guangdong province and the Shanghai area, and its Brazil plant in Eldorado do Sul, away from the Sao Paulo electronics industry cluster).

Another issue is how one defines skilled and unskilled labor. Even assembly workers need to be literate and have some computer skills to work in a modern PC plant where production orders arrive on computer printouts and must be closely followed throughout the assembly and testing process. In this context, completely unskilled labor is not a key factor. But considering that assembly workers in many countries work for less than $2 per hour doing repetitive tasks, it is somewhat misleading to think of them as skilled labor. Indeed, leading PC assembly plants have engineered intelligence into their shop floor computer networks to enable relatively unskilled labor to be effective. For example, a bar-coded bill of materials for each PC being built is scanned into the network that then turns on lights above the proper components bins to tell workers which components to select for each PC. This reduces the chance for human error and decreases the skills required in some areas of PC assembly. A better definition of these workers is probably semi-skilled, a category not included in the McMillan et al. survey.

To describe the actual location decision, our research shows that a multi-level process is involved. PC makers start with global strategic goals, such as expanding into new geographies, cutting production costs, or restructuring logistics to improve product delivery times. This points to a set of potential regional locations, such as Eastern Europe or Southeast Asia. They then select from a set of countries that meet minimum standards of political stability and

infrastructure. Beyond that, there are tradeoffs, for instance between more advanced infrastructure, labor costs and location relative to suppliers. Once the list is shortened to the most viable options, firms often negotiate with governments for the best package of tax incentives and then make a final decision. There also seems to be path dependency in that once a company is operating in a particular location, it is more likely to expand its operations there than move to a new location, other things being equal.

A final variable is the nationality of the company involved. While firms locate many activities on a global basis according to the factors discussed above, they tend to have a larger share of employment in their home country than can be explained by factors of cost and market size. Path dependency is again a factor as the main headquarters and manufacturing activities were originally located in the home country. While much manufacturing might later be located outside the home country, certain corporate activities (R&D, finance, IT) usually remain concentrated in the headquarters country.

Industry Clusters

The role of industry clusters has been given great importance in recent literature on firm competitiveness and national economic development (e.g., Porter, 1990;Castells and Hall, 1994; McKendrick et al., 2000). These researchers argue that industry clusters are characterized by a concentration of specialized skills that provide tangible value to firms, and are dynamic centers that can drive economic growth and innovation in a country or locality. The notion of the value of industry clusters has driven many policy makers to try to create or nurture their own clusters through various types of government incentives.

PC makers, however, show little need to be in any cluster location. In fact, there is almost no clustering of PC companies in the U.S., as production is scattered in places such as Texas, South Dakota, North Carolina, Tennessee, Virginia, and California, none of which has more than one PC company present. PC companies even try to avoid such clusters and their associated high land and labor costs, and high worker turnover rates. If several PC companies have located in one place, such as Ireland or Scotland, it is more likely a result of each being attracted by the same local factors such as infrastructure or government incentives, more than the presence of specialized skills.

The fact that most PC companies do very little product innovation means that being part of an industry cluster with specialized capabilities is of little value. By contrast, much of the innovation in the PC value chain is done mostly by suppliers of components such as semiconductors and flat-panel displays, who do tend to locate in clusters in the U.S., Japan, Korea and Europe. Clustering also tends to take place when product engineering, development, and ramp-up require close interaction between engineers from assemblers and suppliers, as is the case with Taiwanese original design manufacturers who are densely clustered in the Taipei-Hsinchu corridor. The disk drive industry has separate clusters for design—mostly Silicon Valley and other U.S. locations—and production—Singapore and nearby locations in Malaysia and Thailand (McKendrick et al., 2000).

These patterns suggest that industry clustering can be an important factor in determining location decisions, but that it is necessary to distinguish activities that benefit from proximity to specialized skills and those that do not. They also should suggest caution to policy makers who hope to create or nurture industry clusters as an economic development strategy.

PC INDUSTRY TRENDS

The PC industry has gone through frequent shifts in competitive dynamics since its inception in the mid-1970s. Familiar brands such as Packard Bell, AST, DEC, and Micron Electronics have followed early leaders such as Osborne and Tandy into oblivion. One-time industry leader IBM has scaled back its PC business after losing billions of dollars and long-time innovator Apple holds on to a shrinking niche market. Meanwhile, Dell Computer, which held less than 4% of the worldwide PC market as recently as 1995, is now the number one PC vendor worldwide with 13 percent of the global market, and holds nearly a quarter of the U.S. market.[5]

By the mid-1990s, a relatively mature global industry structure was in place, with the U.S. specializing in design, advanced components such as microprocessors, software and services, Asia providing much of the hardware manufacturing, and Europe mostly producing hardware, software and services for its own markets. The industry was changing, however, as new competitive forces emerged, including:

- *Increasing clockspeed:* Shorter PC product cycles have enhanced the importance of depreciation and time-to-market considerations in determining location decisions. In the words of a Taiwanese PC executive, "Even if you manufacture a machine at very low cost in Asia and save 5% on the manufacturing cost, by the time it gets shipped to the U.S., the price erosion is 10%."[6]

- *Mass customization:* The build-to-order strategies of PC makers such as Dell and Gateway have segmented the PC market into individual customers, creating a demand for more customized PC configurations. This puts greater pressure on the entire supply chain to respond quickly to shifts in demand for particular components, peripherals and software, rather than just general product lines.

- *Outsourcing*: Some PC companies have long outsourced much of the production process, relying on contract manufacturers (CMs) to produce subassemblies and complete products. Other companies such as Compaq, IBM, Apple and Toshiba relied more on in-house production, including motherboard assembly (motherboard production is often considered the dividing line between manufacturing and simple assembly in PCs). In recent years, however, these PC makers have sold off board assembly plants to CMs, turned notebook PC production over to Taiwanese suppliers and even turned to outside suppliers for design, engineering and logistics services. PC makers still do much of their own final assembly for desktop and laptop PCs, especially for more complex build-to-order models, but even final assembly is being outsourced in some cases.

[5] IDC, 2001
[6] Craig Addison, 1999. "The Future Belongs to the Fleet." *Electronic Business Asia*, 10(9): September. pp. 52-54.

- *Electronic commerce:* Selling directly on the Internet has accelerated the industry's clockspeed by shortening the distance between the PC vendor and end customer. It also has further increased the demand for customization as customers can easily configure products and compare prices online. On the other hand, e-commerce and the Internet have made it easier for PC makers to respond to the pressures of clockspeed and customization. Online configurators replace telephone sales representatives, online support replaces call centers, and e-commerce technologies are used to link PC makers with suppliers and service partners in real time. Supply chain integration through electronic commerce is being used to respond to the industry's product cycle and customization trends.

These trends have had important impacts on the organization and location of activities in the PC industry. Increased clockspeed and build-to-order production both tend to push final assembly closer to the end customer in order to reduce inventory depreciation and minimize order fulfillment time. The result is that most PC companies have located one or more assembly plants in each major geographical region. This has pushed some suppliers and contract manufacturers to locate their facilities closer to the PC vendors' build-to-order assembly sites. For instance, a number of contract manufacturers have set up production in Mexico to serve U.S. PC makers.[7] Both CMs and Asian suppliers have set up more production in Europe as well.

Current Trends and Issues

Today, the PC industry is going through its most wrenching period ever, with revenues declining and profits disappearing. The industry faces the possibility of a shakeout more serious than anything it has seen. The proposed acquisition of number two PC maker, Compaq, by the number four vendor, Hewlett-Packard, is the most dramatic evidence of major change taking place in the industry's competitive dynamics. Based on interviews conducted in late 2001 with industry executives and analysts, along with recent news articles and industry analyst reports, the following key industry trends have been identified.

Demand dynamics. PC demand has grown at double digit rates since the late 1970s, driven by rapid gains in performance in hardware, and ever-larger software applications that required more powerful hardware to run. These dynamics accelerated in the late 1990s, as falling component costs allowed PC makers to drive prices down, while Internet and multimedia applications drove demand upward. With little warning, this cycle abruptly ended in mid-2000. Consumer demand was satiated and few new applications required more powerful hardware. Corporations began to slow down replacement cycles to save money in a slowing economy. In 2001, PC demand declined for just the second time in the industry's history.

Changing profit dynamics. In 1990, PC makers captured 49% of profits in the PC industry, while suppliers, including Microsoft and Intel captured 51%. By 1995, the share of profits captured by PC makers had dropped to 27.5% and in 2000 to just 13%.[8] Profits also were falling or had disappeared in more cyclical components industries, such as DRAM, hard disk drives and flat-panel displays.

[7] Jason Dedrick, Kenneth L. Kraemer, and Juan J. Palacios, 2001. "Impacts of liberalization and economic integration on Mexico's computer sector," *The Information Society*, 17(2): 119-132.

[8] Data provided by industry sources for 1990 and 1995. Data for 2000 calculated from company annual reports of Intel, Microsoft, Compaq, Dell, Gateway, HP and IBM.

Meanwhile, the profits of Microsoft and Intel continued to grow, and now account for over 80% of the industry's profits. There is speculation that Dell may gain a large enough market share to be able to recapture some of these profits, and the HP/Compaq pairing may hope to do the same, but some industry insiders say that once margins decline, they never rebound.

In the past, some PC makers could justify losing money on desktop PCs because they helped cover the fixed costs of infrastructure (e.g., assembly plants, call centers, sales and marketing activities) that also supported profitable products such as notebook PCs and servers. Also, PC sales contributed to top-line revenue growth. However, in 2001, a brutal price war has eliminated profit margins for most of the industry. PC executives say that during the current downturn, most companies' desktop PC sales fail to cover direct costs or make a contribution toward covering fixed costs. Greater competition is driving down margins for notebooks and low-end servers as well.

Market and distribution trends. Competitive advantage in the PC industry today is driven more by sales, distribution and customer relationships than by manufacturing or product innovation.[9] Dell's direct sales model has proven to have inherent advantages over the indirect channel, including cash management, rapid inventory turnover, and stronger customer loyalty.[10] Other PC makers have tried to implement their own direct sales models, but have faced serious problems with channel conflict, as well as with making the internal changes necessary for such a shift. While the direct channel has significant advantages, it is not well established outside of the U.S., U.K, and a few other markets. There are questions as to whether the direct model can succeed in major markets such as Japan, Germany, France and Italy, and in high-growth emerging markets such as China, Korea, India and Brazil. If not, the world PC market could be divided, with Dell dominating those markets that are receptive to the direct model, but limited in its growth opportunities in other markets. If major U.S. PC makers such as Compaq and HP continue to lose money in the U.S., will they be able to retain their strength in many foreign markets, or will local and regional firms begin to capture more of these markets? This question is probably most relevant in the Asia-Pacific region, where strong local competitors already dominate the Japan, Korea and China markets. The result could be greater regionalization in the PC industry, with different market leaders in different countries or regions.

New product and technology directions. In the past five years, mobile IT products (notebooks, PDAs and other devices) have gained an average of 1.75% annually as a share of total end computing devices sold.[11] With the advent of 3G mobile communications services and wireless networking standards such as Bluetooth, the shift toward mobility in data communications and computing is likely to continue. Such a shift means new opportunities for growth and for innovation on the part of PC makers. It also may shift the competitive landscape, as firms in the PDA and wireless industries begin to compete with PC makers. Already, there is strong competition between Palm OS vendors (Palm and Handspring), and Windows CE/Pocket PC vendors (Compaq and HP) in the PDA market. These markets are more fluid, with no dominant players, and with no set standards in a variety of technology arenas. Also, with Europe and some parts of Asia leading in wireless adoption, new technology standards, dominant product designs and market leadership will not necessarily be determined in the U.S. There is a strong possibility of regional standards

[9] Product innovation is concentrated in a few key suppliers such as Intel, Microsoft and Seagate who set industry standards and whose products are used by all PC makers, resulting in mostly undifferentiated products.
[10] See Kraemer et al., 2000.
[11] Data provided by industry executive.

emerging. This creates a different environment for PC makers used to developing products to one global standard set in the U.S.

New business strategies. Faced with mounting losses, vendors such as Compaq and Gateway are attempting to move away from a pure box-building business by offering a combination of hardware and services, or "solutions," a strategy already implicit in IBM's business. Such an approach requires a strong local presence in each market to provide services, leading to higher overhead costs and a loss of economies of scale. Gateway may be acknowledging this with its decision to withdraw from overseas markets and concentrate on the U.S., where it has sufficient scale to justify investing in service capabilities. The HP/Compaq combination will try to match IBM's global services scope. However, the services business is much different from the PC business, and there is reason to question how many of the PC makers can make such a transition.

GLOBAL PATTERNS IN COMPUTER PRODUCTION

As early as 1988, the Asia-Pacific region had surpassed the Americas as the largest producer of computer hardware, even though the largest market was in the Americas and most leading PC vendors were U.S. companies (Figure 1).[12] Asia-Pacific gained production at the expense of both the Americas and Europe/Middle East/Africa (EMEA) until 1990; since then it has grown relative to EMEA while the Americas' share of production has remained stable. In absolute terms, production has continued to grow in all regions (Table 1).

There are other interesting trends at the country level (Table 2). In the Americas, the U.S. has remained the dominant producer, regaining the number one position worldwide after falling behind Japan in the early 1990s. The other major producers are Brazil and Mexico, with Mexico seeing rapid growth in the late 1990s as major contract manufacturers set up production there to supply U.S. PC companies.

In Europe, production was concentrated in Germany, the UK, France and Italy during the 1980s. Each of these countries had a "national champion" computer vendor that had been nurtured through government procurement and other policy measures. However, none of the national champions made a successful transition from mainframes to personal computers. As a result, production stagnated in the mid-1990s in all of the countries except the UK, which attracted IBM and Compaq to locate PC production in emerging industry clusters in Scotland and Wales. Meanwhile, newcomer Ireland managed to surpass France and Italy and nearly match Germany by 2000, thanks to investments from leading PC makers Dell, Gateway and Apple, and a number of their suppliers.

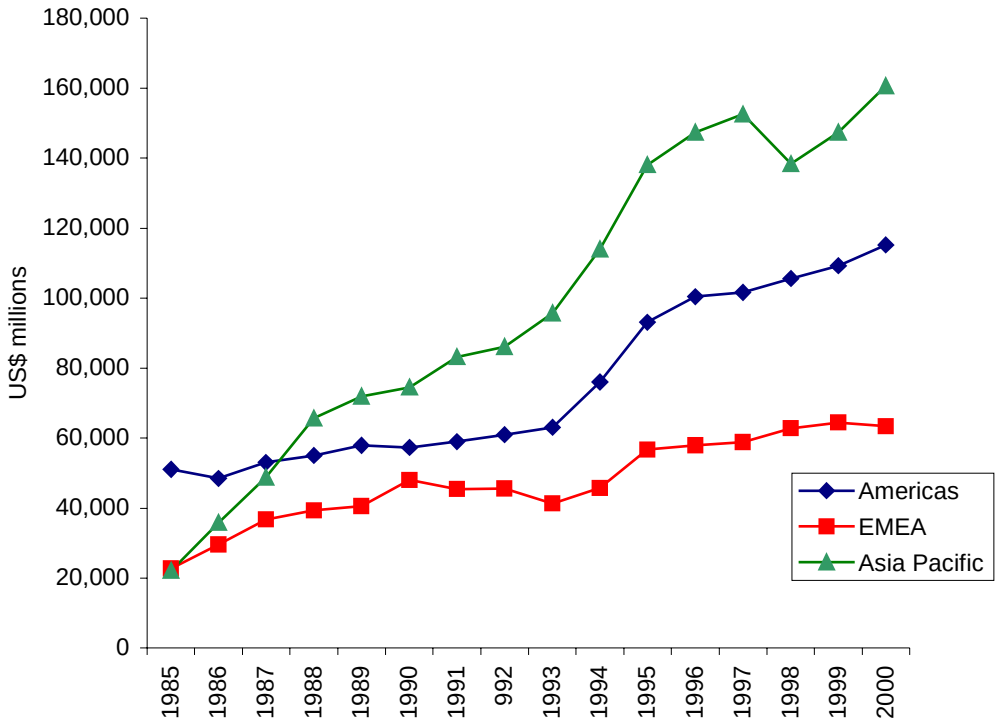
[12] Comprehensive data on PC production is not available by geography, so we use total computer hardware, for which country data is available. PCs and related peripherals now account for about 65% of total hardware sales (IDC). Secondary literature review shows that production of larger systems is distributed among the three regions, but with less dispersion beyond traditional locations—mainly the U.S., Japan, France, Germany and the U.K.

Table 1. Share of global production by region

	1985	1990	1995	2000
Americas	53%	32%	32%	34%
EMEA	24%	27%	20%	19%
Asia-Pacific	23%	41%	48%	47%

Source: Reed Electronics Research, *Yearbook of World Electronics Data*

Figure 1. Computer hardware production by region



Source: Reed Electronics Research, *Yearbook of World Electronics Data*

In the Asia-Pacific region, production was dominated in the 1980s by Japan, which nearly tripled production between 1985 and 1990 to surpass the U.S. as the world leader (Table 2). During this time, Singapore and Taiwan also saw rapid growth, followed by Korea. In the early 1990s, Japan continued to see solid growth in production, while Singapore and Taiwan each tripled their production to become the third and fourth largest producers in the world. In the late 1990s, however, Japan's production declined precipitously, and Singapore and Taiwan saw much lower growth rates. The fastest growth was now occurring in the less developed ASEAN countries of Malaysia and Thailand, and most dramatically in China, which has leaped to number four in world production. This shift to developing countries was driven by investments by U.S., Japanese and Taiwanese firms looking for lower cost production sites and, in the case of China, looking for market access as well.

Table 2. Leading computer producing countries, 1985, 1990, 1995, 2000 (hardware production in US$ millions and share of total global production)

	1985		1990		1995		2000		
	Value	Share	Value	Share	Value	Share	Value	Share	Global Rank
Americas									
US	47,122	49.2%	48,559	27.0%	76,284	26.5%	88,489	26.1%	1
Brazil	2,725	2.8%	4,634	2.6%	6,500	2.3%	9,084	2.7%	11
Mexico	n.a.	n.a.	1,161	0.6%	3,110	1.1%	10,281	3.0%	9
Asia-Pacific									
Japan	18,096	18.9%	52,428	29.2%	72,678	25.2%	55,340	16.3%	2
Singapore	1,194	1.2%	6,974	3.9%	21,127	7.3%	25,797	7.6%	3
Taiwan	989	1.0%	5,886	3.3%	16,007	5.6%	22,157	6.5%	5
China	n.a.	n.a.	645	0.4%	5,600	1.9%	23,075	6.8%	4
Malaysia	42	0.1%	381	0.2%	5,280	1.8%	10,638	3.1%	8
Thailand	56	0.1%	1,586	0.9%	5,440	1.9%	8,731	2.6%	12
S. Korea	579	0.6%	3,073	1.7%	6,795	2.4%	7,681	2.3%	13
EMEA									
UK	4,416	4.6%	9,121	5.1%	13,460	4.7%	16,167	4.8%	6
Germany	5,445	5.7%	10,161	5.6%	8,054	2.8%	12,001	3.5%	7
Ireland	1,447	1.5%	3,817	2.1%	6,452	2.2%	10,013	3.0%	10
France	3,692	3.9%	7,550	4.2%	7,836	2.7%	7,135	2.1%	14
Italy	3,137	3.3%	6,863	3.8%	6,748	2.3%	5,754	1.7%	15

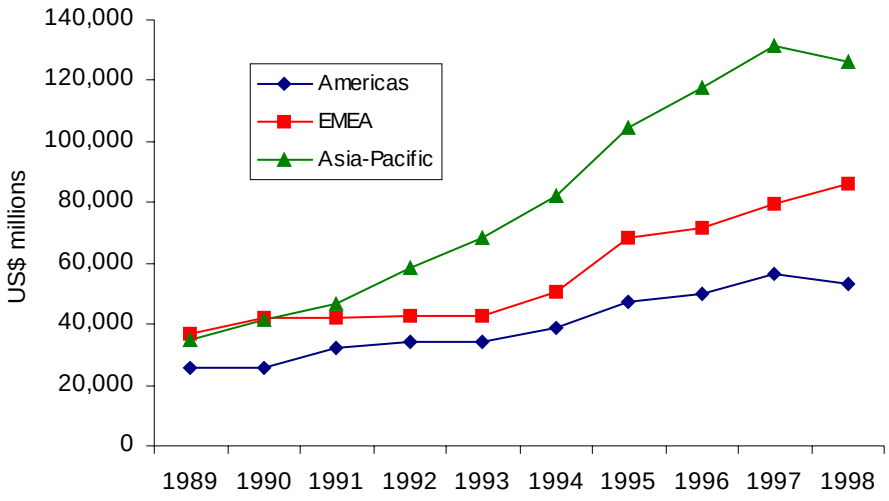
Source: Reed Electronics Research, *Yearbook of World Electronics Data*

Impacts on Trade

Among the three major regions, Asia-Pacific emerged in the early 1990s as the largest exporter, matching its position as the largest producer. Asia-Pacific is followed by EMEA and then by the Americas, both of whose production is more oriented to regional markets (Figure 2). EMEA has been and remains the largest importer, followed by the Americas and Asia-Pacific (Figure 3).

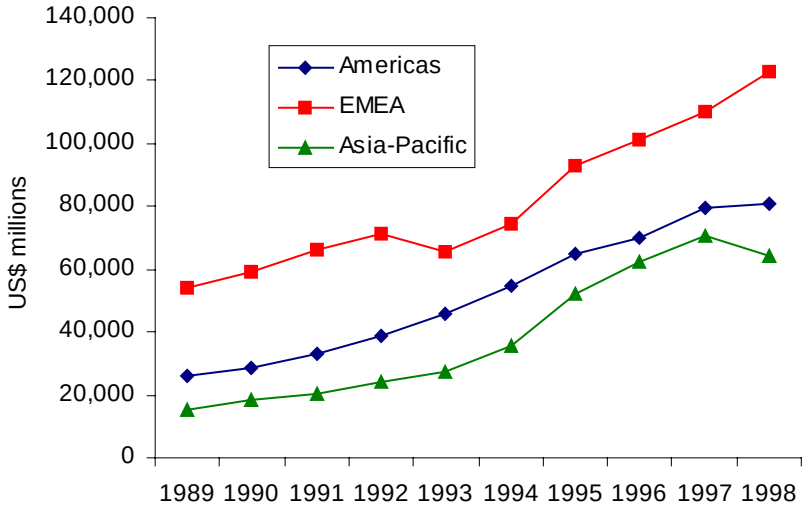
In terms of trade balances, the Americas entered the 1990s with a small deficit, while Asia-Pacific ran a surplus of about $19 billion and EMEA ran a $17 billion deficit (Figure 4). During the 1990s, Asia-Pacific's surplus tripled to over $60 billion, EMEA's deficit grew to $37 billion, and the Americas fell to a deficit of over $27 billion. These trends reflect the shift of production and sourcing by American firms to Asia-Pacific countries, the low levels of computer spending in Asia-Pacific, and the growing reliance of Europe on hardware produced outside the region.

Figure 2. Computer hardware exports by region



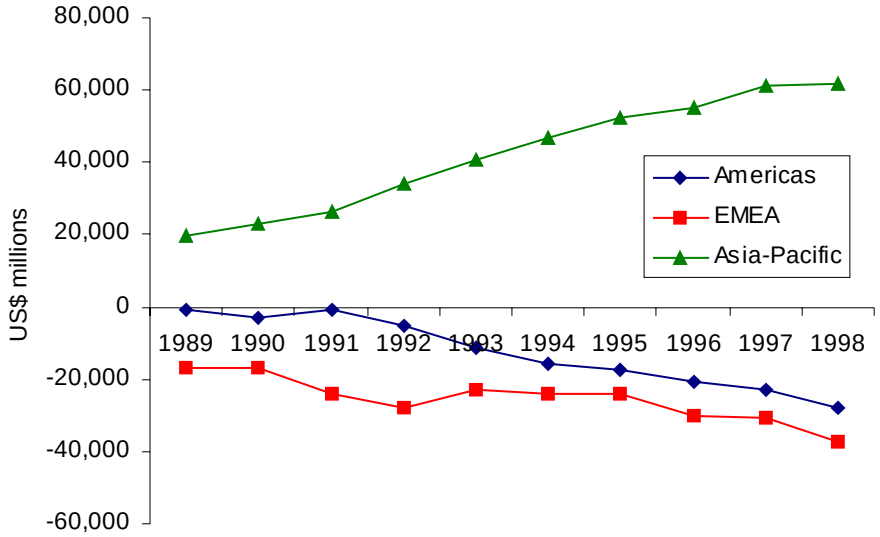
Source: Reed Electronics Research, *Yearbook of World Electronics Data* (data only available to 1998)

Figure 3. Computer hardware imports by region



Source: Reed Electronics, *Yearbook of World Electronics Data*

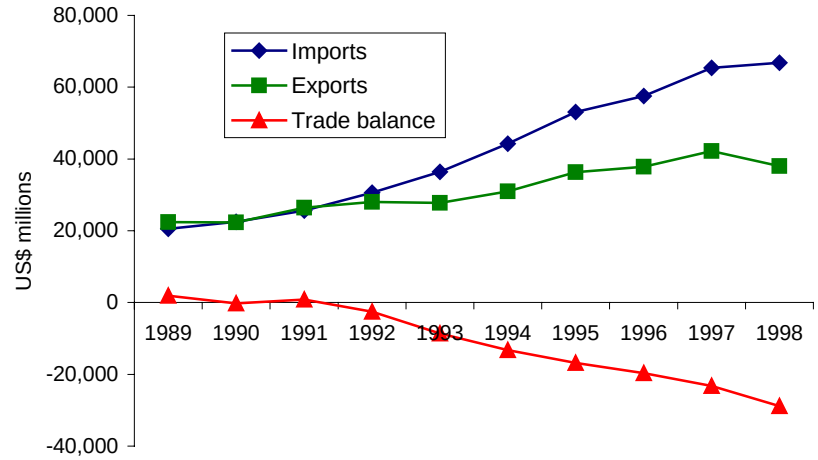
Figure 4. Computer hardware trade balances by region



Source: Reed Electronics Research, *Yearbook of World Electronics Data*

Looking specifically at the U.S. (Figure 5), we see that the balance of trade fell from a small surplus in 1991 to a deficit of nearly $29 billion by 1998. This was not due to a decline in U.S. production. In fact, production grew very rapidly during the 1990s, from $45 billion to $85 billion by 1999. Instead the deficit was due to the fact that computer demand grew even faster than production, and the gap was filled by imports, mostly from Asia-Pacific countries. U.S. exports grew slowly but steadily throughout the 1990s until 1998, when the Asian financial crisis cut deeply into demand in most Asia-Pacific markets.

Figure 5. U.S. trade balance in computer hardware

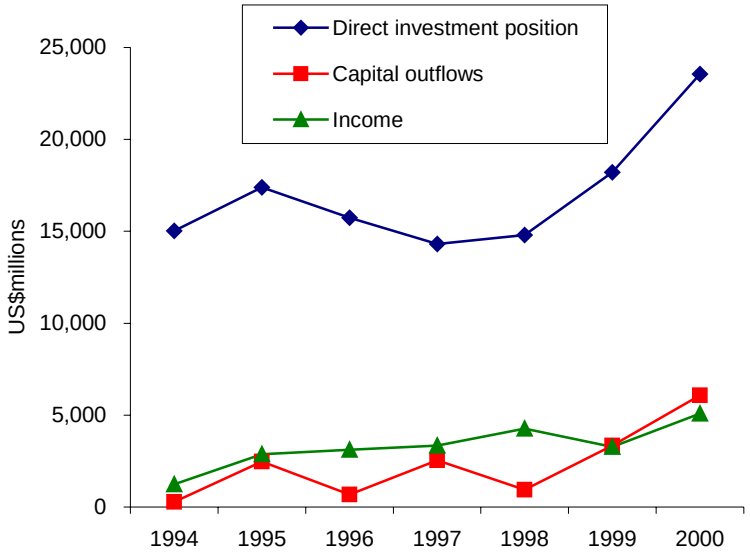


Source: Reed Electronics Research, *Yearbook of World Electronics Data*

Foreign Direct Investment

Outward foreign direct investment by U.S. computer companies was relatively low in the mid-1990s, and the net direct investment position hovered around $15 billion (Figure 6). However, in 1999 and 2000, there was an upswing as FDI jumped to over $6 billion from $938 million in 1998 and the net investment position rose to $23.5 billion.

Figure 6. Foreign direct investment by U.S. computer and office equipment companies



Source: Bureau of Economic Analysis, 2001

The data suggest that U.S. computer companies had not been increasing their global presence mainly through FDI. Based on case studies and firm data, it appears that global expansion is more in the form of outsourcing to foreign suppliers or to U.S. contract manufacturers in foreign locations. The data do not distinguish between foreign investment by computer vendors and that by CMs who are producing computers, so the jump in FDI from 1999-2000 may represent CMs investing abroad. Among U.S. PC makers, only Dell added new capacity abroad, opening plants in China and Brazil.

To put computer industry foreign investment in perspective, note that the computer and office equipment sector ranks seventh among four-digit SIC codes for total direct investment position by U.S. companies (Table 3).

Table 3. Foreign direct investment position of U.S.-based companies by sector, 2000

Industry	Direct investment position $ millions
Crude petroleum extraction and natural gas	65,841
Motor vehicles and equipment	38,274
Drugs	32,355
Industrial chemicals and synthetics	32,216
Computer related services	26,262
Professional and commercial equipment and supplies	24,793
Computer and office equipment	23,548

Source: Bureau of Economic Analysis, 2001.

Role of Multinational Corporations (MNCs)

In 1998, U.S.-based MNCs employed 396,200 workers in computer and office equipment manufacturing outside the U.S., with a total compensation of $26.9 billion,[13] a figure much larger than the total employment of the computer hardware industry inside the U.S. Of the 251,000 computer industry workers in the U.S., 35,700 work for affiliates of foreign firms, earning $1.9 billion.[14] So the net effect of MNC activity was that U.S. firms had created over ten times as many computer industry jobs abroad as foreign MNCs had created in the United States.

This investment abroad results in significant benefits for U.S. multinationals, whose overseas sales of computers and office equipment in 1998 were $157 billion, with profits of $8.7 billion. These MNCs spent nearly $12 billion in R&D outside the U.S., tapping technical skills overseas and developing products for those markets.[15]

Contract Manufacturing

Contract electronics manufacturing reached US$103 billion worldwide in 2000, up from US$72 billion in 1999. Of this amount, 24% was accounted for by computers, with an additional 10% by servers and storage, and 5% by peripherals, for a total of 39% accounted for by production of computer hardware. The largest share of production was in the Americas (58%), followed by Asia (22%) and Europe (19%) (Table 4). However, IDC's data does not include many of the Taiwanese OEM/ODM companies and smaller Asian CMs, whose inclusion would increase the share of production in Asia.

[13] Mataloni, 2000, Table 10.2
[14] Zeile, 2000, Table 10.2.
[15] Mataloni, 2000, Table 10.2

Table 4. Contract manufacturing production by region, 2000

Region	Production (US$ billions)	Share of world (%)
Americas	60	58
Asia	23	22
Europe	20	19
Rest of world	1	1
Total	103	100

Source: IDC, 2001

The expansion of contract manufacturing is illustrated by production trends among contract manufacturers in Europe (Table 5). Contract manufacturer production increased from $4.9 billion in 1993 to over $20 billion in 2000, with the majority accounted for by U.S.-based contract manufacturers.

Table 5. Contract manufacturer production in Europe (in $millions)

	1993	**2000**
Eastern Europe	519	3,940
United Kingdom and Ireland	1,468	5,341
Germany, Austria, Switzerland	907	2,615
France & Benelux	993	3,213
Nordic	302	3,933
Italy	518	1,897
Spain	228	894
Totals	4,935	21,833

Source: Adapted from Michael Hannon and Associates, Scotland, 2000.

Employment by Region and Country

Estimates of employment by country reflect the same patterns as production and trade, with Asia accounting for well over half the jobs in the industry (Table 6). In fact, Asia's share of jobs in the industry is even greater than its share of production, since production in low-wage Asian countries tends to be more labor intensive than in the U.S. or Europe.[16]

[16] Data in Table 6 is mixed, as recent data is not available for some countries, and no data is available for others. However, given these limitations, the table does reflect a broad view of employment levels by country and region.

Table 6. Hardware industry employment by country and region, most recent year

Americas	
Canada (1998)	14,161
Mexico	*24,000*
U.S. (2000)	251,000
Venezuela	*600*
Brazil	*23,000*
Puerto Rico	*16,000*

EMEA	
Belgium (1997)	2,978
Croatia (2000)	1200
Czech Rep. (1997)	1,411
Denmark (1995)*	2,009
Finland	*2,000*
France (1994)*	37,877
Germany (1999)	29,340
Greece (1996)	1,020
Hungary (1995)	1934
Ireland (1995)	14,420
Italy (1998)	7,945
Netherlands (1997)	7,293
Norway (1997)	767
Poland**	25,900
Portugal (1993)***	2,728
Romania (2000)**	2000
Russian Federation	*7,500*
Slovak Rep.(1997)	5953
South Africa (1998)	954
Spain	*16,000*
Sweden (1996)	1409
UK (1996)	67,787

Asia-Pacific	
Australia	*7,400*
Hong Kong (1999)	2,051
India	*30,000*
Indonesia	*2800*
Japan (1998)****	181,503
Korea	*27,000*
Malaysia (1996)	17,439
New Zealand	*600*
Philippines	*30,000*
Singapore (1997)	55,066
Thailand	*35,000*
Taiwan	*55,000*
China	*300,000-500,000*

* Includes software
** Includes services
*** Includes communications
****Called "electronic application equipment"
U.S. data from Department of Commerce, 2000. Other data from Reed Yearbook(s) of World Electronics Data.
Numbers in *italics* are estimates for 2000 based on proportionate share of total electronics employment or based on computer production data.

European jobs have tended to be in assembly as components have been shipped from Asia. However, wages have been increasing in key production hubs such as Ireland and Scotland, and therefore more and more production is being outsourced. The outsourcers in turn are moving to lower cost production sites in Eastern Europe (Table 4), especially in Hungary and the Czech Republic. In 2001, Compaq announced it would outsource most of its European PC production to Taiwanese companies FIC and Hon Hai, who would produce Compaq PCs in the Czech Republic. Compaq will continue to produce servers and configure-to-order PCs at its Scotland plant.[17]

In the Americas, employment declined in the U.S. from 350,000 in 1985 to 201,000 in 1994, and then rebounded to 251,000 by 1998 (Table 7). Employment has increased in Mexico; especially in the past few years. Mexico has captured labor-intensive processes such as PCB assembly due to its much lower wages than the other two NAFTA members. As of 2001, only IBM, HP and

[17] Emir Halilovic, "Compaq outsources PC assembly to Bohemia," Prague Business Journal**,** 04/09/2001

Acer were doing final PC assembly in Mexico (along with a few small domestic companies), but news reports suggested Dell was considering opening a plant in Monterrey.

The U.S. has retained many high wage jobs in the hardware industry. As a result, wages paid in the U.S. account for a larger share of global wages than the U.S. share of total employment. As Gourevitch et al (1997) showed, in the hard disk drive industry, the U.S. has 20% of total world employment, but accounts for 42% of wages paid. These jobs, in R&D, design, marketing, customer service, finance and various headquarters functions, are better matched to the wage and skill levels of most of the U.S. work force than low-skilled assembly jobs. In PCs, the assembly jobs that remain in the U.S. tend to be in more skill-intensive operations such as configure-to-order assembly, which requires relatively high levels of literacy and some computer skills, and in low-volume production of prototypes and specialized products.

The heavy reliance of U.S. computer makers on offshore production and outsourcing clearly entails a loss of manufacturing jobs in the U.S., but is likely a factor behind the surge of employment in software and services in the past decade (Table 8). The availability of low cost hardware produced offshore means that firms and consumers can afford more hardware, creating demand for additional software and services.

Table 7 U.S. and offshore employment in computer hardware

	1985	1989	1990	1994	1995	1997	1998
Hardware employment in the U.S.	350,000	265,000		201,000	210,000	246,000	251,000
-production workers		96,000		75,800	78,900	101,000	
-employed by foreign firms			30,831				35,700
Offshore employment by U.S. MNCs (computer and office equipment)				429,000		424,000	396,200

Sources: Dedrick and Kraemer, 1998 (for 1985); Department of Commerce, 2000 and 1998; Mataloni, 2000; Mataloni and Fahim-Nader, 1996

Table 8 U.S. employment in IT services and software

	1985	1992	1995	1996	1997
Information services	600,000 (including software)	704,700	909,100	1026,700	1,181,000
Packaged software		131,020			266,380

Source: Dedrick and Kraemer, 1998 (for 1985); Department of Commerce, 2000 and 1998; U.S. Census Bureau, http://www.census.gov/epcd/ec97sic/E97SUSI.HTM#I73

Firm-level Employment

It is still early to see major impacts of more recent trends such as clockspeed and customization on total employment, and up-to-date employment data is much harder to come by than production and trade data. The most recent data available is at the company level, where we find that companies such as Dell and Gateway rapidly expanded their employment in the U.S. and overseas in the late 1990s to keep up with rising demand, then cut back in 2001, while Compaq has been cutting jobs since its acquisition of DEC in1998. It appears that employment levels by region roughly match the share of total revenues for Dell, Gateway and Apple (Tables 9 and 10). For Compaq, U.S. employment is a much higher share of total employment than the U.S. share

of total revenue. The Compaq numbers, however, reflect the fact that DEC had many more employees than Compaq prior to acquisition, and many of those were involved in IT services business in the U.S. (See also tables 11-14, after references, showing global employment for Dell, Gateway, Apple and Compaq.)

Table 9. PC company employees by region, end of 2000

	Dell	Gateway	Apple	Compaq
Americas	24,300	1,700	5,700	39,352
EMEA	9,100	1,700	1,000	17,000
Asia-Pacific	2,500	17,600	1,020	3,500
Not accounted for	0	0	2,904	25,248
Total	35,900	21,000	10,624	85,100

Source: Company reports and various news articles

Table 10. PC company sales by region, 2000 (in US$ billions)

	Dell	Gateway	Apple	Compaq
Americas	25.3	7.4	3.53	17.35
EMEA	5.6	0.5	1.31	3.0
Asia-Pacific	1.8	0.7	1.16	n.a.
Other	0	0	0	18.18
Total	25.3	8.6	6.13	38.52

Source: Company financial reports

Possibly the most important trend to watch is the location of production by contract manufacturers such as Solectron, SCI, Flextronics and Celestica. The outsourcing trend in the computer industry means that more and more production is being done by these companies rather than the computer vendors themselves. It will be also important to compare the location patterns of these North American CMs in comparison to Taiwanese contractors such as Acer, Mitac, FIC, Hon Hai, and Quanta, who also carry out high volumes of manufacturing for the PC industry.

So far, data show that the Taiwanese tend to keep most production in Taiwan or China, while the U.S. CMs have a more global profile (see tables 15-16 for data on employment at Solectron and Flextronics). As an example, the leading Taiwanese contract manufacturer and parts supplier, Hon Hai, has an estimated 40,000 employees in China, which is its main manufacturing base worldwide. Its subsidiaries, Foxconn and Foxteq, have much smaller manufacturing operations in the U.S. and Europe for lower volume production and prototyping/new product introduction functions. By contrast, large U.S. CMs such as Solectron and Flextronics (jointly U.S. and Singapore based), have high-volume production capabilities in the three major regions, and multiple plants in each region to support different customers or provide different capabilities.

Impacts of PC Industry Slump, 2000-2001

The dramatic downturn in PC demand that began in the second half of 2000 has been felt throughout the PC industry value chain. PC makers have laid off thousands of workers, as have contract manufacturers, components suppliers, distributors and resellers.

The industry's turmoil is having impacts on the geographical structure of the global production network, although it is difficult to determine overall trends in a process that is still ongoing. Some examples of changes are as follows:

- Gateway announced it would close all of its non-U.S. operations; closing plants, call centers and other facilities in Ireland, Japan, Singapore, Malaysia and elsewhere. It also has closed an assembly plant in Salt Lake City, Utah and call centers in Lake Forest, California, Hampton, Virginia; and Vermillion, South Dakota. It closed all of its Country Stores overseas and 27 stores in the U.S. All told, Gateway laid off over 7,000 workers, about half in the U.S.[18]

- Dell laid off over 5,000 workers, mostly in its headquarters locations in the Austin, Texas area. It dropped plans to open a call center in Fort Worth, Texas, after negotiating a lucrative package of incentives to locate there.[19] Outside the U.S., Dell continued to increase employment at Xiamen, China, and announced it would shift desktop PC production for the Japan market from Malaysia to China.[20]

- Compaq laid off 8,500 workers, including 2,800 in its headquarters city of Houston, Texas. It also laid off 1,750 workers in Europe, and shifted most of its European production out of its own facilities in Scotland to those of contract manufacturers FIC and Hon Hai in the Czech Republic.[21] If the merger goes through, the combined HP-Compaq will lay off an additional 15,000 workers, although there is no word as to how many will be in the PC business. Given the overlap of the two companies' product lines and excess production capacity, it is likely the amount would be substantial.

- IBM announced it would outsource all of its desktop PC manufacturing in the U.S. and Europe to contract manufacturer Sanmina-SCI.[22]

- Surprisingly, Apple has not cut its head count. It has laid off a few hundred workers, but has added workers as it opens new company-owned stores. However, Apple had dramatically cut it workforce earlier in the 1990s.

The general trends that are likely to emerge from the industry-wide downsizing are as follows:

- Consolidation. Industry consolidation has started to occur, most notably in the proposed merger of HP and Compaq. The contract manufacturing sector had already been going through a consolidation, with Flextronics acquiring Dovatron, and Solectron acquiring NatSteel. More recently, Sanmina acquired SCI, the number one contract manufacturer of

[18] Mike Allen, "Gateway's 'Retrenching' Continues," *San Diego Business Journal*, 9/3/2001, p. 1.
[19] John Pletz, "Dell Computer's Future Growth Will Occur Outside of Texas, Chairman Says," *Austin American-Statesman*, 5/25/2001.
[20] "Dell Transfers Desktop Production to China," *AsiaPort Daily News* 9/25/2001, p. 40.
[21] Tom Fowler, "Compaq doubles up on local layoff plans," Houston Chronicle, 8/10/2001, p. 1
[22] William M. Bulkeley, "As Computer Industry Slumps, IBM Hands Off Manufacturing of Desktops." *The Wall Street Journal*, January 9, 2002. http://interactive.wsj.com/articles/SB1010509813382486240.htm

PCs. HP's announcement that it would cut its CMs from twenty to four suggests that further consolidation is likely in order for CMs to compete for large OEM customer contracts. In components, Maxtor took over Quantum's hard disk drive manufacturing operations, HP is dropping out of CD-RW production, and IBM has dissolved its flat-panel display partnership with Toshiba. Other companies have either disappeared or are barely hanging on, including Micron and eMachines in PCs, Hynix in DRAM, and three of the top five wholesale distributors.

- A continued shift to outsourcing. PC vendors do not want to be saddled with the fixed costs of manufacturing facilities, and outsourcing turns manufacturing into a variable cost that can be adjusted to fluctuations in demand. Also, reducing assets can improve a firm's return on assets, an indicator used by many investors to judge management performance.

- A shift of production to low-wage countries. Already, production is growing in China, Mexico, Hungary, Poland and the Czech Republic, while slowing or declining in Taiwan, Singapore, Ireland and Scotland. Standardized products can be produced easily in lower-cost sites, and Dell's success in China shows that even more sophisticated BTO production can be carried out in a developing country. There is still a need for regional production, but it will increasingly be done in places with lower wages in each region.

- A shift from regional production to production in Asia for global markets. Asian contract manufacturers already produce many components and subassemblies in Asia and ship them around the world. CMs are moving production to China, and PC vendors are increasingly outsourcing to those CMs. With China entering the World Trade Organization and reducing barriers to trade and investment, it is very possible that more final assembly will be done in China for global markets. The exception will probably be more complex configuration and orders with short turnaround requirements, which still need to be done close to the customer.

SUMMARY

The purpose of this research was to develop a fact-based picture of globalization and its impacts within the personal computer industry. The following is a summary of findings.

- *Globalization of production*: The computer industry is highly global, with measurable production in over 40 countries. The U.S. leads in computer production, followed by Japan, Singapore, China and Taiwan. The Asia-Pacific region is the leading producer, followed by the Americas and Europe. More skill-based activities such as R&D, product design and engineering, and software development are concentrated in the U.S. and to a lesser extent in Japan and Taiwan, to take advantage of these countries' technological capabilities and human resources. Labor-intensive assembly activities generally take place in Southeast Asia, China, Eastern Europe and Mexico, where large pools of low-cost, well-educated workers are available.

- *Trade balances*: Despite its position as number one computer producer, the U.S. balance of trade has fallen from a small surplus in 1991 to a deficit of nearly $29 billion in 1998. The

reason for this deficit is that computer demand grew even faster than production, and the gap was filled by imports, mostly from Asia-Pacific countries.

- *Foreign direct investment*: U.S. companies did not increase their global presence through foreign direct investment for much of the 1990s. Rather, global expansion is occurring through outsourcing to foreign suppliers or to U.S. contract manufacturers producing in foreign locations. However, outward FDI began to take off in 1999-2000, as computer makers and CMs invested more heavily abroad.

- *Location decisions*: The key factors determining location decisions are production costs, depreciation costs, logistics costs, and market access. The search for lower wage rates continues to drive PC companies to move production or outsource production to lower wage countries.

- *Industry clusters*: PC companies have little incentive to locate in industry clusters, and sometimes intentionally avoid them. This is because PC makers do little product innovation and do not need access to specialized skills available in such clusters. Other segments of the PC value chain, such as semiconductors, disk drives, flat-panel displays, are more R&D- and design-intensive and tend to locate in industry clusters.

- *Role of government incentives*: Location decisions are influenced by incentives offered by host governments, especially when two or more locations are closely matched in terms of other factors such as infrastructure, labor and location. In cases such as Singapore and Ireland, government incentives have attracted multinational PC makers, who have followed on with further investments to upgrade their activities, and have attracted suppliers and other related firms. But PC companies are proving to be footloose as they have shut down or moved production out of those locations to lower-cost sites. One critique of incentives is that while individual locations might benefit, there is a net transfer of money from taxpayers to MNCs who play one location against another to get the best incentive package.

- *Employment*: The net effect of MNC activity on employment is that U.S. firms have created over ten times as many computer industry jobs abroad as foreign MNCs have created in the U.S. While the heavy reliance of U.S. computer makers on offshore production and outsourcing may entail a loss of manufacturing jobs in the U.S., it is likely a factor behind the surge of employment in software and services which has doubled in the past decade to over 1.4 million. The availability of cheaper hardware creates demand for additional software and services.

- *Impacts on computer users*: The globalization of the PC industry has been a boon for computer users, who enjoy ever-lower prices for more powerful computer hardware. While much of the credit for falling prices has been attributed to rapid technological advances in semiconductors, storage and other components, it is clear that moving production to low-cost locations in Asia, Latin America, and Eastern Europe has been an important factor as well.

- *Impacts on local firms:* Globalization has led to the demise of local PC makers in many markets, e.g., Brazil and Mexico, as foreign vendors have come to dominate after liberalization

(Dedrick et al., 2001). In a few cases, such as Taiwan, local firms have become suppliers to MNCs and benefited from access to the global production network. But in most cases, local firms play marginal roles (such as providing packing materials) while key components are imported or produced locally by foreign suppliers. These foreign suppliers create jobs and can serve as channels for technology transfer, but usually do not support R&D or other activities associated with locally-owned firms.

CONCLUSIONS

Globalization in the PC industry is driven by two factors. First is the need to continually cut costs in a highly price-competitive industry. Second is the desire to reach new markets around the world. This drives PC makers to seek locations that balance direct production costs (mainly labor) with logistics and depreciation costs. It also leads them to locate production either regionally or in some cases, in specific countries, to serve important markets. The result has been the creation of a global production network with a significant amount of local specialization. The ability to operate such complex networks requires sophisticated management practices and extensive use of information technology systems to share necessary information and manage processes across great distances. These systems enable coordination both within and between companies in the network.

While advocates and critics of globalization often see issues in black-and-white terms, the case of the PC industry suggests the impacts are mixed and full of nuances. For instance, from the U.S. point of view, critics could point out that the U.S. computer hardware industry employs fewer workers than it did ten years ago, and that the U.S. has gone from a small trade surplus to a large deficit. On the opposite side of the coin, U.S. computer companies have benefited greatly from access to new markets and low-cost production capabilities abroad. Also, while hardware employment has declined, software and services employment has doubled, thanks in part to the availability of low-cost hardware. The availability of cheap hardware also has spurred investment in information technology, which has had a positive impact on overall productivity. On balance, we would conclude that globalization of the PC industry has been positive for U.S. workers and companies, and the economy as a whole.

Outside the U.S., other countries have felt mixed impacts. Those that have become most integrated into the global production network of the PC industry, such as Singapore, Taiwan, Ireland, China and Mexico, have benefited most in terms of jobs, economic output, inward investment, and exports. Other countries, such as France, Italy, Germany and Brazil have seen local firms driven out of the PC industry by foreign competition but have gained little in terms of production, jobs or exports.

More broadly, the globalization of the industry has been good for computer users almost everywhere, as prices have fallen and technology diffusion has moved rapidly. Given the potential productivity gains associated with computer use, the opportunities to develop associated software and services industries, and the spread of hardware production to new countries, we would argue that the benefits of globalization outweigh the costs, while acknowledging that the costs can be real, and the benefits and costs are not evenly distributed.

In terms of industrial organization, the experience of the PC industry clearly illustrates the advantages of a global production network consisting of independent specialized firms. This industry structure enables firms to focus on core capabilities and achieve economies of scale while maintaining a highly competitive and innovative industry environment. Vertically-integrated computer makers such as DEC, IBM, NEC, Fujitsu and Siemens have struggled in the PC industry and have been eclipsed by specialists such as Microsoft, Intel, Dell, Compaq (before its attempt to vertically integrate by acquiring DEC), Seagate, Solectron and Flextronics. The virtual company structure best exemplified by Dell has gone further to improve coordination and performance across the value chain (Dedrick and Kraemer, 2002).

The PC industry's structure has influenced other industry sectors, such as wireless communications, whose leaders are rapidly outsourcing production and relying more on standard components while concentrating their own efforts on product design and marketing. Even firms in more traditional industries such as aerospace, automobiles and retail have looked closely at the Dell model and begun to implement some parts of it.

There are limitations to the general applicability of the PC industry organizational structure however. The ability to rely on a network of specialists depends in part on the nature of the product itself. The PC is a modular product, whose components work together via published interface standards determined originally by IBM and now by Microsoft and Intel. A single disk drive, mouse or sound card design can be used by PC makers around the world, allowing PC makers to source from multiple suppliers, and allowing suppliers to achieve economies of scale by selling to multiple customers. Both corporate customers and consumers increasingly demand standard products because they value price and compatibility over unique design features. This is not the case for many other types of computer hardware, such as printers, routers, or high-end servers, which include many custom components in each model. It is even less true for automobiles, aircraft or clothing, where vendors distinguish their products through unique design. Those industries have their own global production networks, but they are significantly different from the PC industry's organizational structure.

The current turmoil in the PC market is leading to significant changes in the nature of the global industry. Production is being outsourced to take fixed assets off the books of PC makers, providing greater cost flexibility in market downturns and improving PC makers' return on assets. Greater use of the Internet and e-commerce is allowing PC makers more flexibility in supply chain configuration. Consolidation is happening in both the PC and contract manufacturing industries, and weaker competitors are likely to disappear or be acquired. Strong regional and national brands are gaining ground in some key markets. China will soon be the second-largest PC market and the third largest producer of computer hardware, posing both opportunities and threats to other countries and to companies. Dell's growing dominance of the U.S. PC market is leading competitors to adopt many of its practices, from direct sales to demand-driven manufacturing, or to consider abandoning the PC market altogether.

Finally, the PC industry appears to be reaching maturity, with replacement cycles slowing and most markets saturated, so that the entire industry can no longer count on double-digit growth rates. The implications of all these changes are only beginning to be perceived, but it is clear that the industry is going through a consolidation at several levels of the value chain, with a declining

number of PC makers, distributors, contract manufacturers and suppliers of some components. A more mature market with slower depreciation rates could lead to a greater emphasis on reducing production and logistics costs relative to depreciation costs, i.e. by producing in low-wage locations and shipping by lower-cost surface methods. The result could be a two-tier production network, with complex build-to-order products being produced near the end customer and standardized products being produced in one or two locations to supply worldwide demand.

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Table 11. Dell Computer employment and sales by region, country, location, 2000

World	Region	Country	City	Employees	Sales	HQ	Mfg.
Worldwide				**35,900**	**$25.3 B**		
	Americas			**24,300**	**$17.9B**		
		United States					
			Round Rock, TX	20,800		yes	yes
			Nashville, TN	1000			yes
		Brazil					
			Eldorado do Sul	200			yes
		Canada					
		Chile					
		Mexico					
		Colombia					
	Asia/Pacific			**2,500**	**$1.8B**		
		Hong Kong (PRC)		25			
		Australia					
		China		330			
			Xiamen	200			
		India					
		Malaysia					
			Penang	1000			yes
		New Zealand					
		Singapore		130			
		Japan		600			
			Kawasaki				
		South Korea					
	Europe, Middle East, Africa			**9,100**	**$5.6B**		
		England					
			Bracknell				
		Ireland		4,000			
			Limerick				yes

Sources: Dun and Bradstreet, literature searches, company web site, analyst reports

Table 12. Gateway Computer employment and sales by region, country, city, 2000 (note: all international operations closed in 2001)

World	Region	Country	City	Employees	Sales	HQ	Mfg.
Worldwide				**21000**	**$8.6B**		
	Americas			**17600**	**$7.4B**		
		United States		17600			
			San Diego, CA	250		yes	
			North Sioux City, SD	4650			yes
			Sioux Falls, SD	1700			yes
			Vermillion, SD	630			no
			Salt Lake City, UT	600			yes
			Albuquerque, NM	400			no
			Lakewood, CO	300			no
			Colorado Springs, CO	300			no
			Lake Forest, CA				
			Kansas City, MO	1200			no
			Hampton, VA	2100			yes
	Asia/Pacific			**1700**	**$0.7B**		
		Japan		750			no
		Malaysia					
			Malaka (Malacca)	500			yes
		Hong Kong					
	Europe, Middle East, Africa			**1700**	**$0.5B**		
		France					
		Germany					
		Ireland					
			Dublin	1600			yes

Sources: Dun and Bradstreet, literature searches, company web site, analyst reports

Table 13. Apple Computer employment and sales by region, country and city, 2000

W old	Region	Country	City	Employees	Sales	HQ	Manufacturing
Worldwide				**10,624**	**6.13B**		
	Americas				**$3.53B**		
		United States					
			Elk Grove, CA	700			yes
			Cupertino, CA	3100		yes	
			Austin, TX	900			
	EMEA				**$1.31B**		
		Ireland					
			Cork	1,000			yes
	Asia/Pacific				**$1.16B**		
		Japan		270	$0.85B		
		Singapore		750			yes

Sources: Dun and Bradstreet, literature searches, company web site, analyst reports

Table 14. Compaq Computer employment and sales by region, country, city, 2000

World	Region	Country	City	Employees	Sales	HQ	Manufacturing
Worldwide				**85,100**	**$38,525**		
	Americas						
		United States			$17,351		
			Houston, TX	14,065		yes	yes
			Massachusetts	7,000			yes
			Nashua, NH	2,000			
			Colorado Springs, CO	1,700			
			Cupertino, CA	10,827			
			Fremont, CA	600			
		Canada		1,760			
		Brazil		1,400			yes
	EMEA						
		Europe		17,000			
			Scotland	3,000			yes
			UK and Ireland	5,000	$3B		
			Ireland	2,200			
			Munich			yes	
	Asia Pacific			**3,500**			
			Singapore	1,000		yes	

Sources: Dun and Bradstreet, literature searches, company web site, analyst reports

Table 15. Solectron employment and sales by region, country and city, 2000

World	Region	Country	City	Employees	Sales	HQ	Mfg	PC mfg
Worldwide				**46000**	**$8.4B**			
	Americas				**$6.3B**			
		United States						
			Milpitas, CA	6500		yes	yes	
			San Jose, CA	170			no	
			San Jose, CA	300			yes	no
			Fremont, CA				yes	
			Suwanee, GA	1550			yes	yes
			Westborough, MA	600			yes	
			Merrimack, NH	400			no	no
			Charlotte, NC	2400			yes	
			Columbia, SC	470			yes	
			Memphis, TN	300			no	no
			Austin, TX	3600			yes	
			Dallas, TX	3			yes	no
			Everett, WA	1000			yes	
		Brazil	Sao Paulo	1720			yes	yes
		Mexico	Guadalajara	6500			yes	yes
		Puerto Rico						
			Aquadilla	380			yes	
			Aquada	580			yes	
		Canada	Vaughan	300			no	
	Asia/Pacific				**$1.1B**			
		China	Suzhou				yes	
		Japan	Kanagawa	54				no
		Malaysia		7000				
		Taiwan	Taipei				no	
	Europe, Middle East, Africa			**4300**	**$1.2B**			
		France						
			Bordeaux	1000			yes	
		Germany						
			Herrenberg	550			yes	
			Neubiberg	311				no
		Ireland	Dublin				yes	
		Romania	Timisoara	1000			yes	
		Scotland						
			Dunfermline	1400			yes	yes
			Greenock	65			no	
			Port Glasgow	370				
		Sweden	Ostersund	1150			yes	
		UK	Reading	40				

Sources: Dun and Bradstreet, literature searches, company web site, analyst reports

Table 16. Flextronics employment and sales by region, country, city

World	Region	Country	City	Employees	Sales	HQ
Worldwide				**37,000**	**US$4.3B**	
	Americas					
		United States	San Francisco Bay Area	3,000		yes
			San Jose, CA			
			Sunnyvale, CA			
			Palo Alto, CA			
			Fremont, CA			
			Irvine, CA			
			San Diego, CA			
			Youngsville, NC	300		
			Raleigh, NC			
			Rochester, NH	1,000		
			Greeley, CO	165		
			Longmont, CO			
			Niwot, CO			
			Binghamton, NY			
			Dallas, TX			
			Austin, TX			
			Palm Harbor, FL			
			Westford, MA			
		Mexico	Guadalajara	4,000		
			n/a	300		
			Puebla			
		Brazil	Manaus			
			Sao Paulo			
			Sorocaba			
	Asia/Pacific			**1,700**		
		Malaysia	Johore			
			Melaka			
		PRC	Xixiang			
			Doumen			
		Taiwan				
		Singapore				yes
	Europe, Middle East, Africa					
		Czech Republic	Brno			
		Denmark	Pandrup	1,300		
		Hungary		9,000		
			Tab, Sarvar and Zalaegerszeg	8,500		
			Zalalovo			
			Nyiregyhaza			
		Ireland		720		
			Cork			
			Limerick			
		Poland	Gdansk	200		

Sweden		4,000
	Katrineholm	100
	Visby	1,000
	Vasteras	575
	Malmo	160
	Karlskrona	800
	Stockholm	
Norway	Billingstad, Oslo	120
Germany	Paderborn	650
Israel	Migdal Haemek	500
Switzerland	Solothurn	500
Finland	Kyroskoski	900
Austria	Althofen	
	Kindberg	
Italy	Milan	
France	Luneville	
England	London	
Scotland	Hamilton	

Sources: Dun and Bradstreet, literature searches, company web site, analyst reports