



Personal Computer Industry Trends

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The personal computer (PC) industry has grown significantly since its inception in the late 1970s, as the computer has become an essential tool both at work and at home, and has taken on an increasingly important role in communication and home entertainment. Sales of PCs grew at double-digit rates from the late 1970s through the 1990s. In the 1990s, Internet access and new multimedia applications accelerated the pace of this technological change, while stiff competition among PC makers drove prices steadily downward. Over the course of the decade, computing power rose exponentially, while PC prices fell from an average of \$2,500 to under \$500.¹

This growth cycle ended suddenly in 2000, as markets in the US and Western Europe became saturated, and both businesses and households began to hold onto their PCs for longer periods before replacing them. By 2000, a majority of American households already owned at least one PC. Between 2000 and 2001, PC sales actually declined for the second time in 15 years.

Since 2001, the industry has rebounded. In 2004, PC sales in the US increased by 8.3 percent, and worldwide by 11.8 percent, back to the double-digit growth experienced earlier, but this time sales were driven mainly by demand for notebook computers and by demand in developing countries.²

This report outlines the key trends and the global dynamics that are shaping the PC industry, and their implications for employment in the US.

Key Trends

Global division of labor. The personal computer industry has had a global production network almost from its inception. In a rush to catch up with Apple in the early 1980s, IBM decided to standardize the basic components of the PC so they could be assembled in a modular fashion. IBM then outsourced most of those components to other suppliers. The common standards, modular design, and simple assembly of the PC made it possible to disaggregate the production process among the various components, outsource production and even assembly, and locate that

¹ Jason Dedrick and Kenneth L. Kraemer, "The Impacts of IT on Firm and Industry Structure: The Personal Computer Industry," *California Management Review*, Spring 2005.

² Thomas M. Lenard and Michael J. Pickford, *The Digital Economy Fact Book*, The Progress & Freedom Foundation, Washington, DC, 2005.

work anywhere in the world. Some of the components for the original IBM PC came from Asian suppliers. Other components also began to be produced overseas, as IBM and other PC makers began locating their assembly operations overseas to gain access to foreign markets, and as their suppliers moved their operations abroad to reduce production costs.³

Most PC component production and assembly is now outsourced, with component production located mainly in Asia, and with PC assembly located closer to the customer in North America, Europe, and Asia. Given the simplicity of assembly – anyone with minimal training can assemble a PC in 15 minutes with a screwdriver and a socket set – and the lack of differentiation among components, the only way for PC makers to differentiate themselves is by how quickly they get the latest technologies to market, how efficiently they manage their supply chains, and how effectively they manage their branding, marketing, sales, and technical support.

Most PC makers do little product innovation on their own. They have come to rely mainly on their suppliers for product development, and on Microsoft and Intel for new technologies. Apple and IBM have been the exceptions to this rule.

For suppliers of hard disk drives and semiconductors, the main components of a PC, product innovation is critical to their survival. For example, the competitive advantage in hard drives has historically gone to whoever can increase storage capacity the fastest and cut costs at the same time. US hard drive manufacturers have accomplished this through a division of labor that has ended up locating R&D mainly in the US, and production mainly in Asia.

This global division of labor represents a shift from the early days of the hard drive industry. In the early 1980s, virtually all of the world's hard drive production was in the US and Japan. At that time, US firms produced 93 percent of their hard drives in the US, and Japanese firms produced almost all of their hard drives in Japan. However, relentless pressure to cut costs prompted some US firms to move production to Singapore, where they could reduce the cost of labor by 80 percent. Their success prompted others to follow, and by 1990 Singapore was the world's largest producer of hard drives, accounting for 55 percent of global production. By 1995, 70 percent of the world's hard drives were produced in Singapore, Malaysia, and Thailand, while only 5 percent were still produced in the US.⁴ However, these overseas operations remained largely in the control of US-based firms.

By being the first to move production overseas, US firms were able to drive down prices and increase their share of the market at the expense of the Japanese, who were slower to take advantage of the lower-cost labor in nearby countries. And US firms were able to focus more attention at home on R&D, which allowed them to stay ahead of the technological curve. The global leader in hard drives, US-based Seagate Technology, has become the largest private sector employer in Singapore and the largest employer in Malaysia and Thailand, while continuing to increase employment in the US by staying on the cutting edge of technological developments.

³ Jason Dedrick and Kenneth L. Kraemer, "Globalization of the Personal Computer Industry: Trends and Implications," Center for Research on Information Technology and Organizations, University of California, Irvine

⁴ David McKendrick, "Leveraging Locations: Hard Disk Drive Producers in International Competition," in Martin Kenney and Richard Florida, *Locating Global Advantage* (Stanford, CA: Stanford University Press, 2004).

Semiconductors, the other key component in PCs, have followed a pattern similar to hard disk drives. In 1980, around 80 percent of the world's semiconductor fabrication capacity was located in the US and Japan, with 42 percent in the US and 38 percent in Japan. During the 1980s, the Japanese share grew to 45 percent, and the US share fell to 30 percent, while the share of countries like Taiwan and South Korea grew to 12 percent.⁵ This was largely the result of a strategy adopted by new entrants to the US market to design and market semiconductors themselves, and to contract out the manufacturing to facilities in the Asia-Pacific region, particularly in Taiwan. This model became so successful that the established US semiconductor firms followed suit, outsourcing much of their production to Asian facilities.

As a result, the Asia-Pacific countries more than tripled their share of worldwide fabrication during the 1990s, from 12 percent to 38 percent, almost all at the expense of the Japanese, who were slow to respond to this trend. Today, over 90 percent of the world's foundry capacity is located in the Asia-Pacific region, with most of that capacity located in Taiwan.

Since the greatest value added in semiconductors is in their design, US firms have mainly kept design and development work in house and in the US. In addition, some firms like Intel, which is often on the cutting edge with new technologies, also prefer to keep their production in house to avoid revealing technologies they consider to be a strategic advantage.

Build to Order. Another important industry trend has been the advent of a new business model in which PCs are built only after customers' orders are received, rather than building them to forecasts of customer demand, and in which PCs are shipped directly to the customer, rather than going through a retailer. This model, most closely associated with Dell Computer, takes advantage of the commoditization of the PC by relying on consumers' willingness to purchase a computer sight unseen, basing their purchase primarily on a set of specifications, price, and the reputation of the PC maker.

The build to order model has a number of advantages. Building only what the customer orders makes it possible to eliminate a lot of inventory in components and assembled PCs that are normally needed to buffer against differences between forecasted and actual demand. The costs associated with holding this inventory, and with its obsolescence due to rapid changes in technology, are greatly reduced by building only what the customer orders.

There are also advantages on the back end. By shipping directly to the customer, there's no need for distributors or retailers to handle the PC, and take their own cut of the sale. And there are fewer returns by disappointed customers, since customers order exactly what they want.

Dell embraced this new business model wholeheartedly and now sells 90 percent of its PCs directly to the final customer.⁶ Orders from customers are routed directly to the factory and are compiled into daily production schedules. Dell requires its component suppliers to maintain warehouses within 20 minutes of the factory for easy replenishment of parts, and they don't pay

⁵ Robert C. Leachman and Chien H. Leachman, "Globalization of Semiconductors," in Martin Kenney and Richard Florida, *Locating Global Advantage* (Stanford, CA: Stanford University Press, 2004).

⁶ Kenneth L. Kraemer and Jason Dedrick, "Dell Computer: Organization of a Global Production Network," Center for Research on Information Technology and Organizations, University of California, Irvine

suppliers for the parts until they arrive at the factory, eliminating inventory holding costs for Dell. By tracking trends in customer orders in real time, Dell is able to give accurate information to its suppliers on demand for the components they need to have on hand, eliminating the need for suppliers to maintain a large inventory of surplus parts. Dell considers its ability to manage the smooth flow of information and materials needed to make this system work efficiently to be a distinct competitive advantage.

Dell does most of its final assembly for high-end PCs and configuration for its notebook computers in-house, locating operations as close as possible to the final customer. The company has manufacturing facilities in Texas, Tennessee, and North Carolina for the US market, Brazil for the South American market, Ireland for the European market, and Malaysia and China for the Asian market. However, Dell sources most of its low-end PCs, as well as base units for its notebook computers, from Taiwanese firms with contract operations in China.

The build to order model has paid big dividends for Dell, which went from a global market share of 4 percent in 1995 to its current share of 19 percent, making it the global market leader.⁷ Dell is also the industry leader in the US with 30 percent of the market.⁸ During the downturn from 2000 to 2003, when most other PC makers were reporting big losses, Dell continued to make money and to increase its market share. The saturation of the US and European markets touched off a price war, which Dell was well positioned to win with its vastly more efficient production and distribution system. Dell also benefited from the rapid rise in Internet access and the trend toward shopping on-line.

Dell's success has prompted other PC makers to implement their own build to order and direct sales models, but they have had mixed results. Trying to implement build to order has proven difficult in organizations that have traditionally built to forecast. Also, shipping directly to the customer competes with the distribution and retail channels that those organizations already have in place.

Global Dynamics

Ironically, the business model that Dell exploited to become the industry leader over the past decade may be losing some of its potency. With the markets becoming saturated in the US and Western Europe, an estimated 80 percent of new PC sales are expected to come from developing markets like India and China in the next 5 years.⁹ Worldwide, more than 80 percent of PCs are currently sold by retailers, where customers can get assistance from salespeople.¹⁰ That figure is even higher in developing countries like India and China, where most people live in rural areas, have little knowledge of computers, no credit cards, and are not accustomed to making purchases over the phone or on-line.

⁷ *International Herald Tribune*, "Apple Passes Lenovo in Computer Sales," July 20, 2005.

⁸ *The Digital Economy Fact Book*.

⁹ Olga Kharif, "Dell: Time for a New Model?" *Business Week*, April 6, 2005.

¹⁰ Steve Hamm, "Lenovo and IBM: East Meets West, Big-Time," *Business Week*, May 9, 2005.

In 2005, Dell's market share in Asia, excluding Japan, dropped by a full percentage point to 7.8 percent.¹¹ While Dell has been focusing on large businesses and government agencies in the large cities in China, the market has been shifting to consumers in smaller cities, where rivals like Lenovo, Hewlett-Packard, and Founder have established retail outlets.

Rise of Lenovo. Lenovo has been increasing its lead in China, currently around 34 percent of the market, in spite of tough competition from local rivals Tongfang and Founder, and US PC makers Dell and Hewlett-Packard. Dell is currently number 4 in China with 7 percent of the market. However, that may slide even further, since Dell's senior VP for the Asia-Pacific market, William Amelio, was recently recruited to be the CEO of Lenovo.¹² That switch may further strengthen Lenovo's sales in the rapidly expanding Chinese market, at the expense of Dell.

Now that Lenovo has acquired IBM's PC division, it is also expected to increase its share of the global PC market, currently at 8 percent, by expanding its sales to businesses. The deal with IBM will give Lenovo access to IBM's 9,000 global business partners and to IBM's global sales force of over 30,000.¹³ Lenovo's chairman has announced plans to also target consumers in the emerging markets in India, Brazil, and Mexico, before focusing on more mature markets like the US.¹⁴ However, Lenovo already distributes its PCs through retail outlets like WalMart, Office Depot, and Best Buy in the US, and currently controls 4 percent of the US market.¹⁵

Lenovo is able to take advantage of the low labor costs in China, where it carries out all of its production operations in its own plants. Its operating costs are around half of the industry average and about the same as Dell's.¹⁶ But rather than treat the PC as a commodity and mainly compete on price, as Dell does, Lenovo also plans to compete on innovation. Even prior to the deal with IBM, Lenovo was first to the market with instant-on capability, and has gotten great reviews for its easy-to-use internet phone service and simple controls on the front of the PC to support high-performance gaming.¹⁷ The deal with IBM gives Lenovo access to IBM's R&D centers, which have consistently beaten Dell to the market with new features for laptop computers.

Role of ODMs. In contrast, Dell is not known for its product innovation. The company spends less than 1 percent of revenue on R&D, and most of that is focused on fine-tuning its manufacturing and distribution processes.¹⁸ Like most major PC makers, Dell relies heavily on its suppliers for product innovation. That tendency has fueled the growth of original design manufacturers (ODMs), mostly based in Taiwan, which are responsible for design as well as manufacturing for leading PC makers, especially for notebook computers.¹⁹

¹¹ *Business Week*, "Dell May Have to Reboot in China," October 27, 2005.

¹² Bruce Einhorn, "Lenovo's New Boss – from Dell," *Business Week*, December 21, 2005.

¹³ Steve Hamm, "Lenovo and IBM: East Meets West, Big-Time."

¹⁴ *Business Week*, "A Tough Sell for Lenovo," December 12, 2005.

¹⁵ Bloomberg News, "Apple Passes Lenovo in Computer Sales," *International Herald Tribune*, July 20, 2005.

¹⁶ Steve Hamm, "Lenovo and IBM: East Meets West, Big-Time."

¹⁷ T.C. Doyle and Michael Vizard, "Lenovo's Leadership Eyes More Market Share," *VARBusiness*, March 17, 2005.

¹⁸ Peter Burrows, "Innovation, Lego-Style," *Business Week*, June 23, 2003.

¹⁹ John Hagel, "Offshoring Goes on the Offensive," *The McKinsey Quarterly*, March 17, 2004.

Ten years ago, Taiwanese ODMs were responsible for 27 percent of the world's notebook PC production.²⁰ By 2004, they were responsible for 70 percent of the world's notebook production, with operations mainly in China.²¹ There is evidence that product design and development work may be following production work to Taiwan.²² Currently, for notebook PCs, an estimated 80 percent of design and development work is either done in Taiwan jointly between PC makers and ODMs or by ODMs alone, while only 20 percent is done in house by PC makers themselves.²³

Among the largest PC makers, Dell, Hewlett-Packard, and Gateway rely heavily on ODMs for design and manufacturing of their notebooks. Toshiba designs and manufactures its more advanced notebooks in house, but outsources its low-end models to the ODMs. Apple relies on the ODMs to manufacture its products, but does all of its design work in house, including writing much of its own software.²⁴ Lenovo designs and manufactures all of its notebooks in house.²⁵

This heavy reliance on ODMs is significant, because the market for PCs is shifting toward notebook computers. In 2004, notebook computers started outselling desktop models, and that trend is likely to accelerate as more consumers and businesses seek the flexibility and mobility offered by wireless connections.²⁶ Currently, the brand-name PC makers don't view the ODMs as competitors, because the ODMs lack their own capacity in sales, marketing, and distribution. However, another deal like IBM and Lenovo, this time between a brand-name PC maker and an ODM, could change the competitive landscape very quickly.

Implications for Employment

How will these trends affect PC industry employment in the US? First, it's important to note that, even though PC sales have rebounded since 2000, employment in the industry has continued to fall. Over the past decade, the number of jobs in the PC industry has fallen from 298,700 to 212,100, or roughly 29 percent. The Bureau of Labor Statistics predicts that industry employment will continue to fall over the next decade, despite projected growth in output of 23 percent, which is higher than any other industry.²⁷ The combination of rising output and falling employment is mainly due to continuing technological advances, the outsourcing of production work overseas, and stiffening competition from imports.

Some of the stiffest competition from imports is at the low end of the market, where imports from China are starting to make inroads in the US and around the world. That trend is likely to

²⁰ Jason Dedrick, Kenneth L. Kraemer and Fei Ren, "China IT Report: 2004," Personal Computing Industry Center, Graduate School of Management, University of California, Irvine, September 2004.

²¹ Jason Dedrick and Kenneth L. Kraemer, "The Impacts of IT on Firm and Industry Structure: The Personal Computer Industry."

²² Jason Dedrick and Kenneth L. Kraemer, "Is Production Pulling Knowledge Work to China? A Study of the Global Computer Industry."

²³ Jason Dedrick and Kenneth L. Kraemer, "Is Production Pulling Knowledge Work to China? A Study of the Global Computer Industry," Personal Computing Industry Center, University of California, Irvine, 2006.

²⁴ Peter Burrows, "Apple's Blueprint for Genius," *Business Week* Online Extra, March 21, 2005.

²⁵ T.C. Doyle and Michael Vizard, "Lenovo's Leadership Eyes More Market Share."

²⁶ Cliff Edwards, and Olga Kharif, "Intel to AMD: Bring it On," *Business Week*, August 24, 2005.

²⁷ Jay M. Berman, "Industry Output and Employment Projections to 2014," *Monthly Labor Review*, November 2005.

continue, as growth shifts to developing countries, where the demand is mainly for low-end PCs. In general, China is well positioned to benefit from the shift to low-end PCs, because of its low labor costs and high-volume manufacturing. China is also well positioned to benefit from the shift to notebook PCs, because 85 percent of notebook PCs are already being made in China today.²⁸

With one-third of the Chinese market, which on its way to becoming the largest market for PCs in the world, and an expanded global reach following its deal with IBM, Lenovo is in a strong position to become the world leader in low-end PCs. Dell is no longer able to lay claim to being the lowest-cost PC provider, and with margins thinning at the low-end of the market, they will need to focus more attention on the high end of the market.

Demand for high-end PCs will continue to increase, particularly in developed countries, and especially if the PC becomes central to the digital home and office. The key to how growth at the high end of the market will affect employment in the US over the next decade will be innovation. Currently, the picture is mixed for US-based PC makers and their suppliers.

With the exception of Apple and IBM, US PC makers have not made a big investment in R&D. As mentioned earlier, they have mainly relied on their suppliers for product development, and on Microsoft and Intel for new technologies. For example, in 2004 Microsoft spent \$6.2 billion on R&D (16 percent of revenue), and Intel spent \$4.8 billion (14 percent of revenue), while Dell spent just \$463 million (less than 1 percent of revenue). In contrast, IBM spent \$5.7 billion on R&D in 2004 (6 percent of revenue), while Apple spent \$489 million on R&D in 2004 (6 percent of revenue).²⁹

Lenovo is now in a position to benefit from IBM's investments in R&D. In addition, Lenovo is opening joint innovation centers in Beijing and Raleigh, NC to leverage the R&D capacity of Microsoft, Intel, Symantec, and LANDesk, as well.

Convergence. Another factor affecting employment in the PC industry is the emergence of new devices that perform many of the same functions as a PC. For example, in the home, many TV sets now have set-top devices that perform many of the same functions as a PC. And video game consoles, like Microsoft's XBox, are becoming increasingly sophisticated and include many of the same components as a PC. Businesses are turning to wireless personal digital assistants (PDAs), such as the Blackberry, to keep their employees connected. Wireless PDAs accounted for more than half of all PDAs shipped in 2005, and sales of Blackberry devices grew by 76 percent, making it the global leader in PDAs.³⁰ Wireless phones are also starting to perform many of the same functions as a PC, particularly as wireless broadband access becomes more available and more phones come equipped with 3G technology.

It's unclear at this point whether PC makers will be helped or hurt by this trend. They have been trying to establish a foothold in these new product markets, but they face well-entrenched players, and stiff competition, particularly in the consumer electronics industry where there's

²⁸ T.C. Doyle and Michael Vizard, "Lenovo's Leadership Eyes More Market Share."

²⁹ 2005 SEC Filings (10K Reports) for Microsoft, Intel, IBM, Apple, and Dell.

³⁰ *The Digital Economy Fact Book.*

fierce price competition. They are also relying heavily on the ODMs for design and technology expertise that they lack in these new arenas, which limits their ability to differentiate themselves based on design, since they all use the same ODMs.

Gateway was one of the first PC makers to branch out beyond PCs, establishing itself as an early leader in plasma televisions, betting that consumers would link their PCs with their TVs in a wirelessly networked home. Hewlett-Packard has expanded into digital cameras, capturing 6 percent of the market from industry leaders such as Nikon and Canon.³¹ Dell has targeted printers, MP3 players, TVs and smart phones, hoping to leverage its direct sales model to get a foothold in new markets. Lenovo offers its own cell phones, digital cameras, and printers domestically, with plans to begin exporting them globally.³²

Dell has managed to eke out a 2.4 percent market share in LCD TVs, and a 3.3 percent market share in plasma-screen TVs.³³ But, Dell's direct sales model may be getting in the way. Most consumers prefer to see what kind of picture they will get before buying a TV. Gateway sells its TVs through major retailers like Circuit City, Best Buy, Comp USA, and Costco to take advantage of this preference.

Apple has opened its own retail outlets, as well as selling through major retailers. And the company has hit it big with its iPod, which has more than 70 percent of the market for all types of MP3 players, and 90 percent of the market for those with built-in hard drives.³⁴ Apple claims that the success of the iPod is boosting computer sales, with two out of five computers it sells through its Apple Stores going to first-time Mac buyers. Apple's strategy is to become the digital hub that connects all of consumers' digital devices together through the computer, using software developed by Apple that works with all digital devices, no matter who they are made by.³⁵

It remains to be seen which strategy will work best for PC makers. However, PC component suppliers like Seagate and Intel are clearly benefiting from convergence already. Their substantial investments in R&D have allowed them to stay on the cutting edge of new technologies. For example, Seagate's strategy has been to focus its R&D on the most technically advanced, lowest cost products in the widest range of markets. They are now positioned to supply disk drives to hand-held media players, digital video recorders for TV, home networks, gaming consoles, PDAs, and media servers. Their revenue from these devices grew from 5 percent of total revenue in 2004 to 13 percent of total revenue in 2005.³⁶

Between them, US-based Intel and Advanced Micro Devices (AMD) control almost the entire global semiconductor market for PCs. Intel continues to increase its spending for R&D, which reached \$4.8 billion in 2004. Approximately 25,000 Intel employees were involved in R&D in

³¹ John Hagel, "Offshoring Goes on the Offensive."

³² T.C. Doyle and Michael Vizard, "Lenovo's Leadership Eyes More Market Share."

³³ Andy Serwer, "Dell's Midlife Crisis," *Fortune*, November 16, 2005.

³⁴ Ina Fried, "Apple Earnings Continue to Hum Along," CNET www.news.com, April 14, 2005.

³⁵ Joe Wilcox, "Jobs: Flat-Panel iMacs on the Way," CNET www.news.com, January 7, 2002.

³⁶ "2005 Shareholder Letter," Seagate.com, accessed January 3, 2006.

2004, out of a total workforce of 85,000, with the majority of them located in the US. However, product development work has been shifting to Israel, India, Malaysia, China, and Russia.³⁷

In general, there's evidence that an increasing number of design jobs in the semiconductor industry are going overseas, driven by the need to reduce costs to keep expanding demand³⁸. As they recover from the downturn in 2000, semiconductor firms now appear to be expanding their design operations abroad faster than at home. Further, there's evidence that in their efforts to gain a foothold in China, semiconductor firms are breaking with their recent pattern of locating innovation in Silicon Valley and manufacturing in China, and relying more on Chinese engineers for design.³⁹

In sum, global PC production has been shifting to Taiwan and China, and will likely continue to do so. The global market has been shifting toward notebook PCs, developing countries, low-end products, and distribution through retail outlets. Those trends favor PC makers like Lenovo, which is well positioned to expand globally, at the expense of Dell, the current global leader.

Dell and most other PC makers are shifting their focus to high-end products and to emerging products that perform many of the same functions as a PC or can be packaged with the PC as part of a digital home or office. However, they are limited by their over-reliance on others for innovation and by the stiff competition they face from other companies already entrenched in these product markets. Apple is the exception, with their heavy emphasis on innovation and their strategy of tying other companies' products together with Apple's software.

The key to keeping high-wage jobs in the US will be innovation, but with the exception of Apple, US-based PC makers make limited investments in R&D and rely heavily on Taiwanese ODMs for product design and development. On the other hand, Lenovo is in a strong position to pursue innovation through its deal with IBM and through its partnership with Microsoft, Intel, Symantec, and LANDesk to jointly conduct R&D.

R&D for hard drives and semiconductors, the main components of the PC, remains rooted in the US, at least for the time being. And these high-paying jobs are likely to expand, given the dominance of US-based companies like Seagate, Intel, and AMD in world markets, and the success they are having in bridging into new technologies.

³⁷ Intel Corporation, "2004 Annual Report," www.intel.com.

³⁸ Clair Brown and Greg Linden, "Offshoring in the Semiconductor Industry: A Historical Perspective," Center for Work, Technology, and Society, University of California, Berkeley, 2005.

³⁹ Suzanne Berger, *How We Compete* (New York: Random House, 2006).