Chapter 5
Offshoring Trends

Offshoring and Outsourcing in the PC Industry: A Historical Perspective

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1 Introduction

Offshoring and outsourcing of manufacturing and knowledge work is a highly visible and controversial issue in the public debate over the impacts of globalization. In their efforts to expand markets and optimize production for competitive advantage, firms distribute their activities around the world through their own offshore subsidiaries, by outsourcing to other firms, or both. This pattern is blamed by many critics for job losses in the U.S., while credited by others with benefiting U.S. firms, shareholders and consumers. In reality the impacts of offshoring and outsourcing are hard to measure as they can be subtle and indirect. For instance, there is no measure for jobs that were never created in the U.S. because new products were sourced from overseas from almost their inception.

However, by observing one industry over time, it is possible to identify patterns in the location of production work and knowledge work, and to qualitatively assess the impacts of offshoring on firms and workers. Production work is operations-oriented and includes activities such as subassembly, final assembly and logistics. Knowledge work is innovation-oriented and includes activities such as R&D, design and development of new products and process engineering. We focus on the PC industry, which offers an important case for understanding the forces that influence U.S. firms to outsource their activities, and for identifying the impacts of those decisions.

Production work was the first to be offshored, but now knowledge work is also being pulled offshore to the locus of production. Although the PC industry was concentrated in the U.S. at the beginning,[1] the industry quickly went global for production. The industry first went offshore to source low cost components from Asia and then moved manufacturing offshore to reduce distribution/logistics costs in overseas markets. As competition in the industry grew more intense, companies outsourced much of their subassembly to contract manufacturers and later also

[1] The top ten companies were U.S. firms who did most production themselves, with 50% in the U.S., and who had a 73% share of the global market in 1985 (Dedrick & Kraemer 1998).

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outsourced much final assembly. Between 1985 and 2005, over 125,000 computer hardware jobs were lost in the U.S., the same time that global computer production more than tripled. So not only have jobs been lost, but new jobs have been created elsewhere as the industry has grown. These jobs in manufacturing, engineering, management and customer service were created in places like Taiwan, Singapore, Malaysia, the Philippines, Mexico, Scotland, France and Ireland, but now those places also are losing jobs as production shifts en masse to China.

Today, this pattern is being repeated in product design and development, especially for notebook computers which are much more design/development intensive than desktops. Notebook development shifted from the U.S. to Taiwan in the 1990s as U.S. firms outsourced development to Taiwanese original design manufacturers (ODMs). Again, more than losing jobs, the U.S. never saw those jobs created, as leading PC makers built their notebook businesses from the ground up using Taiwanese ODMs. As the notebook/laptop segment grew from a very small share of the market to reach over a quarter of all PCs sold in 2005, engineering jobs were created in Taiwan (and to some extent in Japan, where IBM designed most of its notebooks), rather than in the U.S. The knowledge jobs that do exist in the U.S. are mostly in market research, conceptual design, project management and marketing (Dedrick J. & Kraemer K.L. 2008).

Even some of those jobs are now being "pulled" offshore to be closer to the actual engineering development of new products (Dedrick J. & Kraemer K.L. 2006). Branded PC firms such as Apple, Dell and Hewlett–Packard have set up design centers in Taiwan in order to better monitor ongoing contracts and upgrade the capabilities of their suppliers so more design activities can be shifted there (Digitimes 2007). Dell, which had previously done final assembly of notebooks with base units shipped to Malaysia from China, is reported to be considering having the ODMs do full assembly and shipping direct.

At the same time, the Taiwanese manufacturers are moving more engineering activities to China to be close to their manufacturing plants. They also are expanding their design and project management capabilities at home in order to take over more of the design process from the lead PC makers (Yang 2005).

The impact of globalization in the U.S. PC industry is one of continuing job losses, with ever fewer, although higher paying, knowledge jobs retained in the U.S. for new product development, sales and support for large customers, and headquarters operations. On the other hand, U.S. PC companies remain world leaders in market share and U.S. consumers benefit from ever-cheaper hardware. Many U.S. jobs also have been created in complementary industries such as software, IT services and on the Internet, thanks in part to the availability of low cost PCs made offshore. It is beyond the scope of this paper to try to measure all of the economic costs and benefits of offshoring and outsourcing. However, it is possible to distill some lessons from the PC industry by looking at the following issues:

- How have offshoring and outsourcing evolved for operations and innovation activities in the industry?
- What factors have influenced firm decisions?
- What has been the impact of offshoring and outsourcing on the competitiveness of U.S. companies and on U.S. jobs in the industry?

2 Conceptual Framework

2.1 Firm Strategy and Competitive Advantage

Our conceptual approach, which is based in historical analysis similar to Brown and Linden (2005), relies on relating theories of firm strategy to the factors shaping sourcing decisions, and ultimately to the impact of those decisions on jobs and competitiveness (Teece 1986; Porter 1990; Hagel & Singer 1999). Competitive advantage can be built through strategic focus on: (1) differentiation through innovation, and/or (2) operational excellence through efficiency in production (Porter 1990).

These strategic foci are related to the principal reasons that PC firms keep certain activities in-house and outsource other activities. Innovation in the PC industry is focused mainly on new product development at the system level as component innovation is done upstream by suppliers of chips, software, storage, flat panels, batteries and power supply. It emphasizes developing slightly different products for narrowly defined market niches on short product cycles (Dedrick J. & Kraemer K.L. 2008). Innovation requires access to the lead market and capabilities in market analysis, concept design and product development.

In contrast, operational excellence focuses on production and is related to time and money – rapid product cycles, leveraged procurement, high quality manufacturing, lean supply chains (McMillan et al. 1999; Treacy & Wiersema 1995). As will be seen, the principal reasons for offshoring and outsourcing in the PC industry have been cost and access to specialized capabilities. While operations have been offshored for cost, innovation has been kept in-house for specialized capabilities which are now available offshore too.

2.2 Industry Dynamics

There is a dynamic to industry competition, which may ultimately change industry structure and jobs. When a branded PC company offshores an activity to reduce cost, it potentially improves its competitive position against rivals. In an expanding market, the firm will grow and hire more workers, some of whom will be in the home country and some offshore. If the branded firm is successful, rivals will imitate its actions (Brown & Linden 2005).

Some of the workers in the home country may lose their jobs as the activity is shifted offshore; however the remaining home country workers may benefit if the company grows and is more profitable, and new jobs may be created in other areas (e.g., marketing instead of engineering). Likewise, consumers may benefit from lower prices on products outsourced offshore. The lower prices may expand the home market for the product as well as complementary products, thereby creating jobs in related industry segments (such as software, services, retail). It is difficult to estimate this job creation. In a growing industry, it is also difficult to estimate the number of jobs that would have been created in the U.S. if an activity had not been moved offshore (Brown & Linden 2005).

Competitors and suppliers often follow successful firms in outsourcing offshore, and over time, firm investments in a foreign location may transform that location in a way that changes the industry's structure. A foreign location that initially was little more than a source of low cost labor for production might develop into a specialized industry cluster that becomes a favored location for certain activities for the whole industry (Brown & Linden 2005). In the PC industry, production clusters have emerged in the Taipei/Hsinchu region of Taiwan, in Singapore, in Penang, Malaysia, and in the Shenzhen/Guangdong Province and Shanghai/Suzhou regions of China. These clusters developed extensive supply bases to support manufacturing of PCs, components and peripherals. Some have further developed their capabilities to attract activities farther up the value chain, such as product development and software development, resulting in more outsourcing by branded firms. The knowledge and experience gained in managing these outsourced activities offshore may encourage expanding to other activities such as R&D and design. Within the PC industry, the notebook segment illustrates this dynamic as design, development and manufacturing have become spread across geographic borders, development and manufacturing has been outsourced and the industry increasingly concentrated in the Shanghai/Suzhou area of China.

2.3 Methodology and Data

Within this framework, we describe the historical evolution of operations and innovation activities in the PC industry – analyzing the factors that have shaped the sourcing of these activities over time, assessing the impacts on jobs and competitiveness and drawing industry lessons from the experience. Within operations we focus on manufacturing and within innovation we focus on product design and development (Fig. 1). We also distinguish between desktops and notebooks as their patterns differ.

The data for this analysis is from secondary sources (indicated in tables), news media, our own prior research and over 100 field interviews with PC makers, ODMs

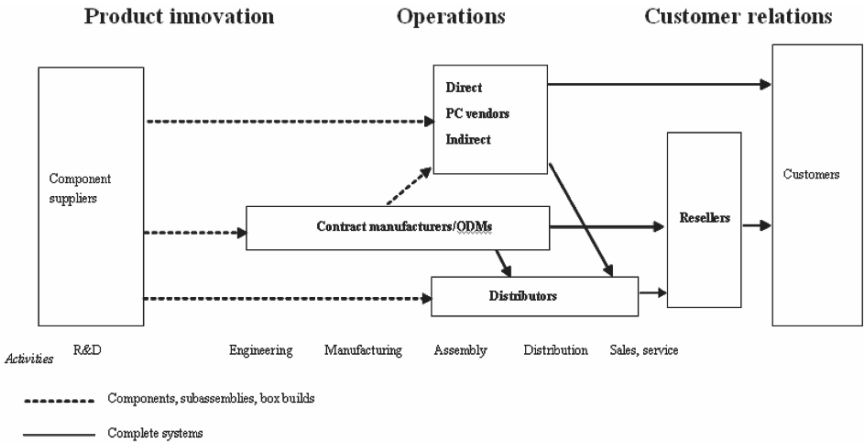

Fig. 1 The PC industry value chain. Adapted from Curry and Kenney, 1999

and component suppliers in the U.S., Japan, Singapore, Malaysia, Ireland, Taiwan and China over the period 1995–2005 (see Dedrick J. & Kraemer K.L. 2005 for list of firms interviewed).

3 The Evolution of Offshoring in the PC Industry

Historically, offshoring in the PC industry occurred in three major phases that map the changes in the industry's key operations and innovation activities. Table 1 provides a detailed timeline and Appendix A summaries key aspects of the industry's evolution for operations and innovation activities.

Table 1 Offshoring evolution in the PC industry

Year	Operations (Manufacturing)	Innovation (Design and development)
Phase 1		
1980	– U.S. assembly of desktops in-house, onshore – Some components sourced offshore from Asia (motherboards, disk drives, cases, power supply)	– U.S. design, development in-house, onshore
1985–1989	– In-house production offshored to major regions – Notebook production begins in U.S., Europe, Asia	– U.S., Japan, Europe (very limited) design, development in-house, onshore
Phase 2		
1990	– Desktop base builds (subassemblies) outsourced to Asia – Desktop final assembly outsourced to contract manufacturers (CMs) in regions	– U.S., Europe, Asia design, development in-house, onshore
	– Notebook production outsourced to Japan and Taiwan	– Notebook design – U.S., Japan in-house, onshore
1995	– Complete desktop systems (low end) outsourced to Taiwan	– Development outsourced to Taiwan
	– Notebook production concentrated in Taiwan	– Taiwan begins notebook development (low end), upgrades capabilities
Phase 3		
2000	– Desktop base builds concentrated in Shenzhen, China	
	– Desktop systems shipped direct from China (low end)	– Design, development outsourced to Taiwan (low end)
	– Notebook production moved from Taiwan to Shanghai, China; systems shipped direct from China	– Notebook development outsourced to Taiwan
2003		– Vendors establish design centers in Taiwan – ODMs establish R&D centers in Taiwan
2005		– Vendors and ODMs do collaborative design

The first phase is the offshoring of operations from the U.S. and Japan to multiple locations around the world beginning in the early eighties, but accelerating in the late eighties. It coincided with the disaggregation of the computer industry from large vertically integrated companies to a horizontally-segmented structure distributed around the world (Grove 1996; Dedrick J. & Kraemer K.L. 1998). Offshoring started with the sourcing of components from abroad, followed by offshore assembly by U.S. subsidiaries and outsourcing of complete systems to offshore CMs (Contract Manufacturers) and ODMs (Original Design Manufacturers). The second phase is the offshoring of innovation in the form of product design and development in the early 1990s. PC makers first outsourced design of motherboards and other subassemblies, and eventually turned to ODMs to develop complete systems. Most of this activity was concentrated in Taiwan. The third phase in the offshoring of the PC industry is the reconcentration of operations and innovation in China beginning in 2000. This began with operations, and has progressed to the point where nearly all notebook PCs and a large share of desktop PCs are now manufactured in China. The next step is the relocation of innovation activities to China, starting with process engineering for manufacturing and, more recently, some product development activities as well. The next three sections describe this industry evolution in detail.

3.1 Phase 1: Offshoring of Operational Activities

While the PC industry emerged first in the U.S., with most production concentrated there, the industry began to deconcentrate globally early in its history.

3.1.1 Offshoring of Component Production

The first step in the global deconcentration of the industry was the offshore production of many components. Apple and others sourced components from Asian suppliers before 1980, but offshoring of component production expanded dramatically in the early 1980s when IBM sourced components for the original IBM PC from Taiwanese companies (Dedrick J. & Kraemer K.L. 1998). The developers of the IBM PC used outsourcing to bring the PC to market quickly, which required using outside capabilities rather than developing them internally.

There were many small and medium enterprises (SMEs) in Taiwan that had the needed capabilities and therefore the work could be divided among them to provide IBM with flexibility in responding to demand. Taiwan also had low labor costs and skilled workers experienced in electronics assembly (CRTs, cables, connectors) and metalworking (cases). Other components were sourced from Japan and Korea, especially high volume memory chips and displays.

At the same time, the hard disk drive (HDD) industry began moving production to Singapore, led by U.S. companies such as Seagate. Government tax incentives and a skilled, disciplined work force were major factors for the offshore movement

of the HDD industry to Singapore. By locating in Singapore, the HDD firms could source labor-intensive parts such as coils and head assemblies from countries with lower labor costs such as Malaysia and Thailand, and do only final assembly in Singapore where labor costs were higher. Like the HDD industry, the semiconductor industry also moved final assembly offshore in the 1980s, also to locations in Southeast Asia such as Penang, Malaysia.

This offshore sourcing of labor intensive components supported final assembly jobs in the U.S. There were few job losses in the U.S. from offshore sourcing of components because most of these manufacturing jobs were created offshore; for instance, Seagate moved HDD production to Singapore only a year after the company was founded (Dedrick J. & Kraemer K.L. 1998). The effect was more a matter of jobs not created in the U.S. rather than a loss of existing jobs. In addition, the rapid growth of the industry enabled by offshore sourcing created many new U.S. jobs in the broader PC industry, including final assembly, distribution (logistics, wholesale, retail) and support (education, training, maintenance). However, this offshore sourcing had a huge impact on future job creation by developing the capabilities of Asian firms that would be eager to move down the supply chain to capture more value added and profits. The most dramatic example is Foxconn (the trade name of Hon Hai Precision Industry), which began as a manufacturer of cables and connectors, and is now the world's largest contract electronics manufacturer with over 200,000 employees and a major producer of PC components and subassemblies as well as PCs, iPods, video games and other final products.

The competitive impact of this initial offshoring was to create a low cost supply base that anyone could use, and more than 200 branded PC makers entered the industry (Langlois 1992). By 1985, IBM was the number one PC maker with 25% of the market, followed by Commodore and Apple with 14% each (Table 2). However, as IBM lost control of the key technology standards to Microsoft and

Table 2 Rank and percent share of world shipments by top 10 PC makers

	1985		1995		2005	
1985 Rank	Firm	% share	Firm	% share	Firm	% share
1	IBM	25	Compaq	10	Dell	18
2	Commodore	14	IBM	8	HP/Compaq	16
3	Apple	14	Apple	8	IBM	6
4	Tandy	8	Packard Bell	7	Acer	4
5	Compaq	3	NEC	4	Fujitsu/Siemens	4
6	Atari	3	HP	4	Toshiba	3
7	HP	2	Dell	3	NEC	3
8	ZDS	2	Acer	3	Lenovo	2
9	DEC	1	Fujitsu/ICL	3	Gateway	2
10	NCR	1	Toshiba	3	Apple	2
Top 10 share		73		53		60
U.S. share of Top 10		100		75		78

Source: International Data Corporation: table provided to authors and press releases

Intel, its competitors were able to use the supply base that it created to attack IBM's market share with low cost systems. At the national level, building a supply base in Asia helped U.S. companies to compete with Japanese PC makers who many feared would dominate the PC industry as they had in consumer electronics (Borrus 1997; Dedrick J. & Kraemer K.L. 1998).

3.1.2 Offshoring and Outsourcing of Subassembly and Final Assembly

Beginning in the late 1980s, leading PC makers such as IBM, Compaq, Apple and Dell set up subassembly and final assembly operations for desktops and notebooks offshore. PC makers did assembly in each major world region using their own subsidiaries (including Ireland, Scotland, and France for Europe; Malaysia and Singapore for Asia Pacific; Mexico for the Americas).

Subassemblies such as motherboards and base units were sourced from Asian suppliers or U.S. contract manufacturers who located some production near the major vendors. The motivations for offshore desktop assembly were to reduce logistics cost by producing close to the market, to better understand country requirements, and to utilize local capabilities (suppliers, human resources, language). In addition, PC makers were attracted to Ireland, Malaysia and Singapore by generous tax incentives and a low cost, educated workforce.

3.1.3 Desktops versus Laptops

The form factor of desktops versus laptops has implications for their sourcing. For desktops, their bulk, weight and lower average selling price (ASP) results in concentrated assembly of "base units" in the lowest cost location with shipment by sea to final assembly plants located regionally. Base units include the metal case, motherboard, fan, power supply, and cables and connectors. High value parts such as microprocessor, memory, hard drive, and optical drives are added at final assembly to minimize depreciation. The smaller, lighter form factor, tightly integrated physical design, and higher ASP of laptops leads to full assembly in one location and air shipment to distribution centers and customers.

By 2000, desktop assembly moved in two additional directions. Most PC makers (except Dell) outsourced standard build-to-forecast production completely to CMs or ODMs, who produce in low-cost locations (e.g., Eastern Europe, Mexico, China) for each major region (Europe, Africa and the Middle East; Americas; and Asia–Pacific, respectively). Most build-to-order production was still done by the PC makers themselves in countries with more sophisticated logistics and skilled workers (e.g., Ireland, Scotland, U.S., Malaysia), with base units and components shipped in from Asia. Since 2003, even this pattern has changed, as IBM, HP and Apple all outsourced build-to-order production by selling existing plants to CMs such as Sanmina-SCI who specialize in desktop production.

U.S. PC makers began moving notebook production offshore in the early 1990s. Some turned to Japanese or Korean partners who had developed engineering and fabrication capabilities for small form factors through their consumer electronics businesses. Taiwan developed a homegrown industry focused on notebook PC production, led by a set of ODMs such as Quanta and Compal, who developed specialized technical knowledge in issues critical to notebook performance such as battery life, heat dispersion, rugged mechanicals and electromagnetic interference. The Taiwanese ODMs soon surpassed Korean competitors who specialized in high volume production but lacked flexiblity and system integration skills developed by the Taiwanese. And while one original Apple Powerbook model was manufactured by Sony, Japanese firms generally concentrated on making their own brand name notebooks rather than being contract manufacturers or ODMs.

As vendor pricing pressure increased on the ODMs, the Taiwan government removed restrictions on manufacturing notebooks in China, and the Taiwanese notebook industry moved en masse to the Shanghai/Suzhou area of eastern China.[2] In turn, the PC vendors began sourcing more full systems directly from the ODMs. By 2005, 73% of the world's notebook computers were produced by Taiwanese firms (Table 3), and U.S. PC companies sourced from 40 to 100% of all notebooks from Taiwanese companies (Table 4). In 2007, virtually all notebook production by Taiwanese ODMs is in China. Japanese firms, such as NEC, Toshiba, Sony and Fujitsu, who long touted their manufacturing skills as critical to competitive advantage are increasingly outsourcing notebook production to the Taiwanese firms (Table 4).

Table 3 Taiwanese notebook industry share of global shipments, 1998–2005 (shipments by Taiwan-based firms, including offshore production)

	1998	1999	2000	2001	2002	2003	2004	2005 (f)
Shipments volume[a]	6,088	9,703	12,708	14,161	18,380	25,238	33,340	39,035
Shipments value[b] ($)	8,423	11,073	13,549	12,239	13,847	16,809	21,830	25,177
Average sales prices ($)	1,384	1,141	1,066	864	753	666	655	645
Global market by volume[a]	15,610	19,816	24,437	25,747	30,033	37,857	46,110	53,473
Taiwan's share of global market volume (%)	40	49	52	55	61	66	72	73

Source: MIC (2005);
[a]Units in thousands;
[b]U.S. dollars (millions)

[2] It is significant that knowledgeable experts say that the decision to relocate notebook/laptop production to China was jointly undertaken by Taiwan ODM firms and their brand name partners from the U.S., Japan and Europe. Cited by Merritt T. Cooke (2004) and discussed in an article by Ho and Leng (2004).

Table 4 PC makers outsourcing production to Taiwan firms

Flagship companies	Subsidi-aries in China	Outsourcing, 2003[a] (%)	Outsourcing, 2005[b] (%)	Taiwan ship-ments, 2005[c] (%)	Taiwanese ODM suppliers[a]
Apple		100	100	5.1	Quanta, Asus, Elite
Dell[d]	Xiamen	90	90	21.6	Quanta, Compal, Wistron
HP	Shanghai	90	100	19.1	Quanta, Compal, Wistron, Inventec, Arima
IBM[e]	Shenzhen	40	40	4.2	Wistron, Quanta
Acer		100	100		Quanta, Compal, Wistron
NEC	Shanghai	80	100	5.3	Arima, FIC, Wistron, Mitac
Sharp		50	n.a.	n.a.	Quanta, Mitac, Twinhead
Sony	Wuxi	20	60	4.0	Quanta, Asus, Foxconn
Toshiba	Hangzhou	15	70	9.6	Quanta, Compal, Inventec
Fujitsu-Siemens		15	50	4.0	Wistron, Mitac, Uniwill, Quanta, Compal

[a]Ministry of Economic Affairs (2004);
[b]Digitimes (2005a);
[c]Digitimes (2005b);
[d]Dell's outsourcing figure refers to production of base units. Most of Dell's final configuration is done in its own plants in Penang, Malaysia and Xiamen, China;
[e]IBM's PC business is now part of Lenovo, but this information is for IBM prior to its acquisition. Although IBM had its own notebook factory in Shenzhen, it sourced from Taiwanese firms for lower end products. The number estimated for IBM in the MOEA report for 2003 was 100%; we instead use an estimate of 40% from DigiTimes (2005a), which is consistent with information provided by IBM

3.2 Phase 2: Offshoring and Outsourcing of Innovation – Design and Development

As operations moved offshore, they eventually pulled other activities offshore as well, including new product design and development. Product design involves understanding customer wants and needs, tracking technology trends and translating technological capabilities into products that meet customer needs at the right price. This requires a combination of market intelligence, product planning, financial analysis, high-level technical analysis, and the ability to communicate with both customers and suppliers. Product development is where the actual mechanical, electrical and some software

development are done, with prototypes developed and tested. This requires electrical and mechanical engineering skills and experience with small form factor products (for notebook PCs). It also requires expensive physical test facilities.

The branded U.S. PC makers did notebook design/development in-house and onshore in the early years, but fell behind Japanese competitors who had superior skills in miniaturizing components and developing small, light, thin products. For instance, IBM did notebook design/development in the U.S. in the 1980s, but its PC Convertible was a failure and was withdrawn from the market in 1989 (Business Week 1991). IBM reacted by moving notebook design to its IBM Japan subsidiary, which came up with the award-winning Thinkpad design. Compaq worked with Japan's Citizen Watch Co. to engineer its notebooks and produce key subassemblies. Apple contracted with Sony for one of the original Powerbook models.

In time, however, most PC makers turned to Taiwanese ODMs for manufacturing, partly to lower costs and also to avoid dependence on Japanese partners who were competitors. The Taiwanese ODMs developed specialized engineering skills and began to take over product development for companies such as Compaq and Packard Bell. Other companies such as Dell and Gateway were able to enter the notebook market by working with the ODMs on design and development, taking advantage of the capabilities nurtured by their competitors. Currently, the major PC makers keep concept design and product management in-house, while outsourcing product development and process engineering to the ODMs.

A major factor influencing the move to outsourcing development was a "pull" from the ODMs. Taiwanese ODMs often did not charge explicitly for development, but did it in order to win production contracts (interviews in Taiwan and China). In addition, once the ODM had a contract, the relationship created incentives for both sides to continue outsourcing for future upgrades and enhancements to the product. There was a great deal of tacit knowledge created in the development process that was known only by the ODM. In addition, the close linkage of development activities to manufacturing and the feedback to design from manufacturing and sustaining support, created linkages favoring continuing the ODM relationship in order to reduce costs and improve quality (Dedrick J. & Kraemer K.L. 2006).

Some PC makers (Dell and HP) have set up their own design centers in Taiwan in recent years, thus offshoring design while keeping it in-house. The motivations were multiple: lower cost engineers and programmers, faster development by having test facilities nearby, availability of experienced engineers, host government tax incentives and closeness to emerging markets in Asia. However, the primary motivation was proximity. By being close to the ODMs, the design center can send personnel to the ODM for problem solving and use the ODM's testing facilities. If the design team were in the U.S., they would have to duplicate the problem in their own testing facility and try to solve it, which takes time and unnecessarily duplicates testing facilities (PC company design center interview). In addition, by being close to the ODMs, the offshore design center can work on multiple products and with multiple ODMs. Coordination with headquarters marketing people and aligning with other product lines is handled by having a few design center staff located there and establishing common standards and software platforms.

It is significant that the design centers have been located in Taiwan. A design center in Taiwan supports design activities for all the ODMs who might be suppliers to a PC maker. Taiwan has a skilled, experienced pool of moderate cost engineers and software professionals and the Taiwan government provided financial incentives to attract the vendors. It also provided incentives to the Taiwanese ODMs to establish R&D centers in Taiwan to reinforce the linkage.

It is difficult to estimate the impact of this outsourcing on jobs in the U.S., but it is clear that there have been job losses. Dell and HP each employ 300–500 engineers in their Taiwan design centers. More importantly, there has not been new job creation in the U.S. for a growing product line, as there has been a permanent shift of knowledge and skills in notebook development from the U.S. to Taiwan. Dell is now planning to reduce design engineers in the U.S. and Taiwan, relying more on the ODMs for notebook design (Digitimes 2007). In addition, the same ODMs that develop most notebooks have moved into other products such as cell phones, where they are applying their engineering talent to develop new products sold under their own brand names and on an ODM basis to cell phone providers such as Motorola, Siemens, Nokia, Sony Ericsson and Panasonic (Pick 2005).

3.3 Phase 3: Concentration of Operations and Innovation in China

The final stage in the evolution of offshoring appears to be bringing the industry full circle. The U.S. PC industry began with most activities concentrated in the U.S., with some component production in Asia. It then disintegrated, offshored and outsourced activities to various countries. It is now reconcentrating – not in the U.S., but in China. Production and logistics are already operating there, and development is starting to be moved (You-Ren & Hsia 2004). Just as manufacturing has pulled development to China for better time-to-market, flexibility and efficiency, so might development eventually pull design activities, especially as the China market becomes a key market for PCs.

For desktops, the reconcentration is occurring in the Shenzhen area of South China, where nearly all desktop "base builds" are manufactured as well as complete systems for the Asia–Pacific and U.S. markets (at least in build-to-forecast production). For notebooks, the reconcentration is occurring in notebooks as Taiwanese ODMs move development to the Shanghai/Suzhou area. The Taiwanese motivation is described as cost-effective human capital augmentation (Lu & Liu 2004). Accessing capable yet cost effective engineers with the additional benefit of geographical and linguistic proximity is the major motive. Also, Taiwan's supply of engineers does not meet demand, whereas China has a large pool of well-educated local engineers who are about half the cost of their Taiwanese counterparts. China and Taiwan share a common culture and language which facilitates communication. Shanghai/Suzhou and Taiwan are not far apart, which makes managers willing to relocate for several years and also makes it possible for executives in Taipei to supervise operations first hand.

The ODMs' Taiwan design units are responsible for the development of advanced technologies and new products that provide competitive advantage for the parent company. As these products are moved into production in China, development of product variations, incremental improvement and life cycle support has followed. The two major PC makers who continue to manufacture significant amounts of notebooks in-house, Lenovo (including the former IBM PC division) and Toshiba, have concentrated production in China, and also have moved some product development there. By locating development close to production, the manufacturing sites get immediate technical support for the rapid product cycles of notebooks while the designers get immediate feedback from manufacturing and support that enables them to make improvements.

4 Factors Influencing Outsourcing and Offshoring

4.1 Costs

As the foregoing discussion has indicated, offshoring has been shaped primarily by cost and capabilities. Cost has been the major factor pushing production activities offshore in the first instance, while the upgrading of capabilities by offshore firms has been a major factor pulling knowledge activities offshore. Cost pressure is particularly acute in the PC industry because Intel and Microsoft reportedly capture 90% of the industry's profits.[3] Cost has been reduced by locating in lower cost areas, leveraging location for financial incentives from host countries, and outsourcing to CMs and ODMs.

Because the early PCs (desktops and portables) were heavy and bulky, and had to meet different country requirements, production had to be decentralized to major regions rather than concentrated. Most vendors did only final assembly themselves relying on regionally-based CMs and ODMs for base units and suppliers for components. As the industry grew, new entrants located near the first movers in order to achieve agglomeration economies by using their supply base. As competition in the industry increased, vendors sought still lower costs by outsourcing more production to the CMs who could achieve cost savings by large-scale purchasing and assembly for multiple vendors.

[3] In the debate over HP's acquisition of Compaq, data presented by Walter Hewlett showed Microsoft and Intel capturing 90% of the industry's profits in 2002. Dell's efficient model enabled it to lower prices, which other vendors have had to match by greater use of outsourcing and continuous pressure on ODMs and suppliers to cut costs. Vendors force the ODMs to compete with one another for business and expect continuous quarterly cost reductions of 5–7% (field interviews with ODMs and suppliers). Suppliers have gone along with these practices in the hopes that lower prices would grow the market and enable them to achieve economies of scale. Low profits on the order of 1–2% have led some ODMs to vertically integrate and to develop their own brand products, while others have moved upstream to produce subassemblies and components. The result for the PC industry has been a continual increase in the volume of units sold, but only a modest increase in the dollar volume of sales, and a continual decline in profits for both PC makers and suppliers.

The PC vendors leveraged their location decisions with government incentives. Tax holidays, land, facilities and work force training attracted vendors to locate in places like Ireland and Scotland in Europe, Tennessee and North Carolina in the U.S., and Singapore and Malaysia in Asia. Usually, the vendors encouraged/required their suppliers and contract manufacturers to locate production or at least supply hubs nearby, which further increased their leverage. As the costs of these places rose over time, the supply bases were moved to lower cost places in Eastern Europe and China. If the government incentives continued, some or all final assembly might be kept in the original location (e.g., Dell in Ireland, Malaysia), or other activities such as regional headquarters, IT services or call centers moved to the old plant location (e.g., Apple in Ireland). Later, even some of these activities were turned over to outsourcers in order to further reduce costs.

4.2 Capabilities

The global production capabilities of large CMs such as Solectron, SCI and Flextronics were also a factor in the move to outsourcing by PC vendors, especially for desktops. The CMs had a global footprint, which enabled them to serve customers anywhere in the world. They built large industrial parks capable of incorporating suppliers, supply hubs and logistics firms for agglomeration economies. Their factories also could run one or many production lines, offering flexibility in responding to the volatile PC demand. As cost pressures increased, the branded vendors decided to also outsource additional activities such as final assembly,[4] logistics and warranty repair to 3–4 global CMs and logistics partners.

For notebook PCs, firm capabilities were also important but the pattern was different as both development and production were outsourced and these capabilities were concentrated in a few ODMs in Taiwan. They had developed skills in small form factor products through work in consumer electronics that they could apply to notebooks. Their lower costs and government assistance enabled the ODMs to invest in new skills (industrial design, engineering design, system integration) and technological upgrading (R&D, prototyping and testing facilities), which they then used to "pull" development activities from the PC vendors. In some cases, the branded PC makers pushed the ODMs to develop greater design skills and even assisted them (Firm interviews). In contrast to desktop computers, where design and development was decentralized due to the high modularity and large form factor, design in notebooks was concentrated because the high level of integration in such a small form factor required design and production engineering to be close to one another and the form factor enabled cost-effective shipment by air to end customers from a centralized production site (Dedrick J. & Kraemer K.L. 2008).

[4] Dell outsourced base unit production, but not final assembly because its business strategy and marketing emphasized build-to-order and configure to order production as a differentiator, especially for commercial customers.

5 Impacts of Offshore Sourcing

5.1 Geographical Shift of Activities

The most consequential change from offshore sourcing is the geographical shift of production and development activities from the Americas and Europe to the Asia–Pacific. In 1985, the Americas led in production with a 53% share, with the remainder nearly equally divided between Europe and the Asia–Pacific. By 1990, the Asia–Pacific region 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 (Table 5). The Asia–Pacific region has continuously gained production at the expense of both the Americas and Europe/Middle East/Africa (EMEA) to the present. The share of production in the Americas was stable from 1990 to 2001 at 31–32%, but has since fallen to 24% (Table 5).

At the country level, the U.S. was the leading computer hardware producer until 2004 when China took over the leading spot with 24.3% of world shipments compared to 17.9% for the U.S. It is likely that the U.S. share will continue to decline as more production is shifted to China. Within the Asia–Pacific region, Japan was the leading producer as late as 2000, with significant production also moving to Taiwan, Malaysia, Thailand and Singapore. Since 2000, China's production has tripled, while Taiwan's production has declined by two–thirds and Japan's has fallen by nearly half (Table 6). This is not a coincidence as most Taiwanese computer manufacturing moved to China, while major Japanese companies have established factories in China as well.

Table 5 Percent share of global computer hardware production by region, 1985–2005

	1985	1990	1995	2000	2005
Americas	53	32	32	31	22
EMEA	24	27	20	17	15
Asia–Pacific	23	41	48	52	63

Source: Reed Electronics Research, *Yearbook of World Electronics Data*, 2006

Table 6 Leading computer producing countries, 1990–2005 (% share global production)

Country	1990	1995	2000	2005	2005 Rank
China	0.4	1.9	7.3	32.4	1
U.S.	27.0	26.5	24.0	17.3	2
Japan	29.2	25.2	17.3	8.7	3
Korea	1.7	2.4	4.0	5.6	4
Singapore	3.9	7.3	5.9	5.4	5
Malaysia	0.2	1.8	4.6	3.0	6
Thailand	0.9	1.9	2.2	2.3	11
Taiwan	3.3	5.	7.2	1.5	13

Source: Reed Electronics Research, *Yearbook of World Electronics Data*, 2005

5.2 Competitiveness of U.S. Firms

U.S. PC companies, particularly Dell and HP with 34% of the market, lead the PC industry in terms of worldwide shipments, and Apple has rebounded since 2005, but other U.S. PC makers are losing money and over the years many have disappeared from the market altogether (Commodore, Tandy, Compaq, Atari, ZDS, AST, DEC, Packard Bell, IBM PC Company) by 2005 (Table 2). Whereas U.S. companies constituted all of the Top 10 in 1985, did most production in-house onshore, and had a 73% share of the market, there were only four U.S. companies in the Top 10 in 2005, most production was outsourced offshore, and they had a 44% share. The competitive fate of many firms in the U.S. PC industry is symbolized by the IBM PC Company, which owned 25% of the market in 1985 and was bought by China's Lenovo in 2005. Still, U.S. firms accounted for a larger share of sales among the top ten countries in 2005 than in earlier years.

In terms of competition in the notebook industry, Taiwanese ODMs largely level the playing field in development and manufacturing, greatly reducing the advantages held by firms such as Lenovo/IBM and Toshiba who have strong internal development and manufacturing capabilities. The ODMs upgrading of capabilities have helped to shift the competitive focus of PC makers away from development to concept design, marketing, branding, distribution and customer service. This plays to the strengths of U.S. companies, and HP and Dell have become the two leading notebook vendors worldwide. The leadership of U.S. companies is even more pronounced in the desktop market, where products are more commoditized and the importance of marketing and service is greater.

5.3 Jobs and Employment[5]

The heavy reliance of U.S. computer makers on offshore production and outsourcing clearly entails a loss of manufacturing jobs in the U.S. For example, the U.S. lost nearly 100,000 jobs in computer hardware between 1998 and 2003, of which 40,000 were production jobs (Table 7).

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. There also is production for corporate customers who require rapid order fulfillment and those that require the PCs to be made in the U.S. for security reasons (such as military, government and their contractors).

[5] 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. 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 7 U.S. and offshore employment in computer hardware

	1998	2000	2001	2002	2003	2004	2005	2006
Hardware employment in U.S.	322,100	301,900	286,200	250,000	224,000	210,000	205,100	198,800
Production workers	126,100	116,000	103,800	97,700	86,000	87,300	116,900	131,000
Employed by foreign firms	35,600	26,600	24,600	29,800	24,800			
Offshore employment by U.S. MNC's		216,900	205,100	221,700	211,300			

Sources: Dedrick and Kraemer 1998 (for 1985 hardware employment); Bureau of Labor Statistics 2003, Current Employment Statistics Public Data Query (for Hardware employment and Production workers in the U.S. 1990–2003); Mataloni 2000–2005 (for Offshore employment by U.S. MNCs); Mataloni and Fahim-Nader 1996; Zeile 2000–2005 (Hardware employment by foreign firms)
Note: Numbers in italics are after the classification system switch from SIC's Computers and Office Machinery to NAICS/s Computers and Peripheral Equipment

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

	1985	1990	1995	2000	2004	2005	2006
Information services	600,000	650,900	892,100	1,616,200	1,466,400	1,508,400	1,591,200
Packaged software	Included above	141,500	210,500	324,000	282,200	282,400	284,500

Sources: Dedrick and Kraemer 1998 (for 1985 data); Bureau of Labor Statistics 2003 (for all other years) Website: http://data.bls.gov/PDQ/outside.jsp?survey = ce.

The U.S. has more nonproduction jobs in computer hardware, such as design, marketing, customer service, finance and various headquarters functions. These are better matched to the wage and skill levels of most of the U.S. work force than low-skilled assembly jobs. However, nearly 60,000 of those jobs disappeared from 1998 to 2003 (calculated from Table 7).

It is not possible to measure how many jobs were moved offshore and how many disappeared through automation or for other reasons, but it is clear that the rapid growth of the worldwide PC market, led by U.S. PC makers, was accompanied by a substantial loss of computer hardware jobs in the U.S. The decline of U.S. production from 26.5% of world production in 1995 to 17.3% in 2005 (Table 6) suggests that some of the job loss shown in Table 7 was due to offshoring.

More broadly, offshoring (and increased productivity) in hardware production appears to have been beneficial for the U.S. in the short run—though clearly some sectors, firms and workers lost out. It was likely a factor behind the surge of employment in software and services from 1985 to 2000 (Table 8).

The availability of low cost hardware meant that firms and consumers could afford more computers, creating demand for additional packaged software and

information services in the U.S. and around the world. Given that U.S. companies dominated these sectors, their growth led to job creation in the U.S., but now design, software and services jobs are also now going offshore (and in some cases becoming more automated). Since 2000, the U.S. has lost about 220,000 jobs in IT services and another 40,000 in packaged software (Table 8). With the shift of software and services to India and other locations, it is unlikely that these jobs will be recaptured.

6 Conclusion

6.1 Lessons from the PC Industry

Several important lessons can be gleaned from the experience of offshoring in the PC industry. These are generally consistent with findings from the semiconductor industry (Brown & Linden 2005), which suggests that they may be applicable to high-tech industries more generally. *The first lesson is that offshoring was instrumental in the birth and growth of the PC industry, providing affordable products through sourcing components offshore in Asia*. The extension of offshore production through subsidiaries outsourcing to foreign suppliers fueled market growth by reducing production and logistics costs. During the 1980s, there was great concern that Japan would dominate the computer industry as it had earlier with consumer electronics, but it did not happen. Japanese PCs sold well in Japan but were a failure outside because proprietary features made them expensive and incompatible. European champions (ICL, Siemens, Olivetti) also could not compete outside their home markets. U.S. firms' overseas operations helped them to better target global markets, grow the industry, achieve economies of scale and produce profits for reinvestment. For the U.S., offshoring appears to have been an important competitive tool.

The second lesson is that offshoring leads to the redistribution of activities across both organizational and geographical boundaries, thereby changing industry structure. This is most apparent in notebooks where Taiwanese ODMs have taken over product development, manufacturing, and some customer service functions (such as warranty repair), with development in Taiwan and China, assembly in China and services provided in regional markets. Branded PC makers control design, marketing and customer services (sales, technical support). Design is located in the U.S. and in design centers set up in Taiwan close to the ODMs, marketing is mostly in the U.S. and other key markets.

A third lesson is that offshoring can lead to a "sequential hollowing out" of activities from one location to another. Notebook PCs were originally assembled in the U.S., but full assembly migrated to Taiwan and now is in China. The practice of "Taiwan Direct Ship" and now "China Direct Ship" means that logistics is migrating as well, as notebook factories in China ship direct to customers by air. The bulk and weight of desktops means that build-to-order production is done close

to the final market, but base units are being sent by sea from China to regional assembly sites with more and more components preinstalled so that only very expensive or custom components are added during final assembly in the local market. Also, build-to-forecast PCs are being built in China and shipped to distributors in the final market.

A fourth lesson is that the loss of manufacturing does not necessarily mean hollowing out of all activity in a particular location. Apple Computer has been in Cork, Ireland for over 20 years, with employment fluctuating between 1,000 and 1,500, but the composition of that work force has changed dramatically since 2000. Apple has outsourced nearly all European production, but its European operations (headquarters, design center, call centers, IT, software localization and some custom assembly) have been consolidated in Cork. Thus, jobs have been lost in several European locations while there has been consolidation of other activities in Cork (Gantly 2003). Likewise, while Quanta has moved all of its notebook production to China, it has built a new R&D center at its Taiwan headquarters, where it expects to employ up to 7,000 scientists and engineers (Quanta interviews). Other ODMs are doing the same.

A fifth lesson is that offshoring can lead to the development of capabilities that "pull" higher level activities to the offshore location. The sourcing of PC components from Asia led to the upgrading of capabilities by local companies; this in turn led to the sourcing of subassemblies and full systems by the PC makers. Local firms in Taiwan became proficient in product development and used those services as a competitive factor for winning production business. Product development in Taiwan is now pulling multinational corporation (MNC) design centers to Taipei, just as manufacturing in China is pulling some development activities from Taiwan to China. Proximity, which enables faster problem resolution and better communication, is a key "pull" factor, reinforced by the availability of lower cost and specialized engineering talent.

A final lesson is that it is unclear whether offshore outsourcing is directly creating new global competitors in the PC industry. For 15 years, most CMs and ODMs have not sought to develop their own brands for global markets. This has been due to lack of marketing and distribution capabilities and fear of losing business from the flagship customers if they are seen as trying to compete with them. Acer, which was both a branded PC company and an ODM, created an independent subsidiary (Wistron) for its ODM business. As the notebook makers have moved to China, they also have not established branded businesses for the China market. Instead, they are suppliers to the Chinese PC makers just as they are to the foreign MNCs. So far there has not been any sign of spin-offs by Chinese entrepreneurs who have worked for U.S. or Taiwanese firms in China.

However, there are signs that some Taiwanese ODMs might become direct competitors in the future. Acer, which separated its ODM business from its own brand business, is now ranked the fourth largest PC maker in the world, and is the leader in Europe. Asustek and Arima are following Acer's example by developing separate companies and promoting their own brands. The huge potential of the China market

(and possibly Indian market) and the low profit margins for ODM firms (around 1–2%) are dual motivators for this trend.

6.2 Implications for the PC Industry

In an industry such as PCs, manufacturing and even product development skills are no longer a source of competitive advantage (with the exception of Apple, which charges a premium price for its proprietary PCs, which have distinctive hardware designs), but instead can be purchased in a relatively open global market. Offshoring enables firms to access lower cost knowledge and production workers through their own subsidiaries and through outsourcing to specialists such as CMs and ODMs. The economic advantage of outsourcing is even greater when specialist firms are clustered geographically and serve multiple branded companies, thereby providing economies of scale and specialization that branded firms cannot achieve internally (Hagel & Singer 1999). However, once activities are outsourced offshore, firms need to be aware that they will be giving away current capabilities and need to develop other skills to compete and survive.

The skills that will create competitive advantage for branded technology companies still involve innovation and operations but these are defined differently when activities such as product development and manufacturing can be outsourced to specialists who take advantage of low cost global resources. Today, operational advantage is gained by careful planning and execution in concert with outside manufacturing and logistics partners, so that supply meets demand, quality is maintained and warranty costs minimized—all cost factors. The key activities are demand forecasting, product lifecycle management, and supply chain management.

Innovation-based advantage requires adopting an integrator role (Prencipe 2003), in which the firm creates new products by integrating different mixes of internal and external technologies and capabilities. The skills required include market intelligence, industrial design, product architecture definition, and technology integration. For newer product categories such as the Apple iPod and Microsoft xBox360, successful innovation involves integration of hardware, software and services into a smoothly functioning and attractive entertainment system.

In this environment, firms must develop different skill mixes at home and abroad, and recognize the fact that this can mean eliminating or relocating activities and jobs from the U.S. While more experienced knowledge workers with the "right skills" may get higher paying jobs in the U.S., the less fortunate are replaced by more cost-effective offshore workers. However, those firms who fail to make necessary changes ultimately eliminate the most jobs, as well as destroy shareholder value. The biggest job losses in the PC industry have not come in successful companies, but in the many companies that have disappeared altogether. The best way for executives in the PC industry to sustain employment (including their own) is to learn to succeed in the new global environment, taking advantage of the capabilities that exist beyond their borders while developing new capabilities inside.

Appendix A – Form Factor and Offshore Sourcing

While both desktop and notebook PCs are based on the Wintel standard, there are important differences between these two form factors (Table 9) that affect sourcing.

Desktops are heavy and bulky and too expensive to ship by air so manufacturing is concentrated for scale economies while final assembly is regionalized for closeness to the market. The larger form factor makes two-step assembly easy, and enables using a few chassis upon which multiple models or SKUs can be designed for different markets and with different configurations. On the design side, modularity means that developing a desktop product is primarily a problem of industrial design and system integration, i.e., deciding on the physical design of the product and incorporating new technologies into products and ensuring that they work together.

Most desktop models are based on industry standard form factors, such as the full-tower and mid-tower chassis, and there are standard motherboard layouts available from Intel and various third-party manufacturers that are designed for these chassis. While the design of a new chassis takes around 9 months, a new model based on an existing chassis can be built and tested in as little as 2 weeks. With a configure-to-order model, Dell and others might have thousands of potential hardware and software permutations on a single platform. This complexity creates many opportunities for conflicts and incompatibilities, so testing all of these combinations becomes a major part of the new product development process, which is why design activity is being pulled to development locations.

Notebook PCs have characteristics that create challenges in product development as they must be able to run on batteries, incorporate the display as part of the unit, they must be lightweight yet very sturdy, plus they are more visible so users care about style as well as function. Components must be packaged very tightly into a product that is small, thin, light, portable, durable and energy efficient, and which doesn't become too hot to handle from the heat generated in its operation. Manufacturability is a major issue, as the product must be built in high volumes and at low cost, so final assembly must be a relatively simple process that allows packing components and subassemblies into a very tight space quickly and with a high level of reliability. As a result of these characteristics, notebooks have a longer and more expensive product development process. Even an upgrade of a model based on an

Table 9 Desktop versus notebook form factor

Desktop	Notebook
■ Highly modular design. ■ Development = system integration of new parts and software ■ Mostly standardized parts, e.g., motherboards, drives, chips. ■ Design for easy assembly, repair ■ Shorter product cycles, more models ■ Mature product	■ Highly integrated design. ■ Development = complex mechanical and electrical engineering challenges due to size, heat, ruggedness requirements ■ Mix of standard and customized parts. ■ Design for manufacturability critical ■ Longer product cycles, fewer models ■ Newer, still evolving product

existing platform can take 3–6 months to develop, and a new chassis takes 12–15 months. As with desktops, scale economies require concentration of production, but the small form factor of notebooks enables air shipment. On the other hand, the complexity of notebook development requires close proximity of design teams.

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