The Impacts of IT on Firm and Industry Structure: The Personal Computer Industry

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The use of information technology (IT) is thought to have wide-ranging consequences for the organization of economic activities within firms and across firm boundaries. The adoption of IT within firms has been closely associated with organizational changes such as process restructuring and the elimination of layers of management.[1] As companies have applied IT to improve their internal processes, they also have developed interorganizational systems (IOS) linking suppliers, customers, and business partners to improve efficiency throughout the value chain.[2]

The Internet has increased the potential impacts of IT by lowering the cost and expanding the reach of electronic networks far beyond those of earlier proprietary systems. Because of the explosive growth in Internet-based electronic commerce since the mid-1990s, along with continued growth in IT investment, it is important to look closely at the impacts of such technologies on the value chains of individual firms and the production networks of entire industries.

Major changes in firm and industry structure have occurred in the PC industry since the mid-1990s, driven by technological change, competitive pressures, and strategic responses to those forces. PC vendors have adopted demand-driven, build-to-order production techniques and have outsourced functions in the value chain to outside partners in order to reduce costs and to respond more quickly to changes in a volatile market. PC makers increasingly focus internal efforts on core activities such as marketing, sales, and product management. They coordinate other activities such as product development, manufacturing, distribution, and customer service with external partners who include contract

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manufacturers (CMs), original design manufacturers (ODMs), logistics providers, distributors, and various service specialists.

At the industry level, a broad value network has developed that encompasses specialized industry clusters in the U.S., Taiwan, China, and elsewhere, yet this network is global in scope and not bound by the need for physical proximity. The capabilities of this network allow PC makers flexibility in configuring value chains for different products and markets.

Information technology has played a critical role in supporting the growth of this flexible value network. First, the internal information systems of PC makers have enabled them to manage complex demand-driven processes. Second, the internal information systems of outside specialists (such as CMs, ODMs, distributors, and logistics specialists) enable them to take over broad processes such as order fulfillment (including assembly) and new product development. Third, interorganizational systems link members of the value network electronically, enabling them to standardize routine processes and transfer data in real time to operate in a high-volume, high-clockspeed environment.

Industry Structure: Theory and Overview of Findings

Transaction cost theory identifies two ways of organizing economic activity: hierarchies and markets.[3] Hierarchies organize activities within the boundaries of the organization, using managerial authority to make and execute decisions. Markets organize activities by means of arm's-length transactions, with decisions based on price. According to transaction cost theory, firms chose organizational forms to economize on production and transaction costs. Production costs include the direct costs involved in producing and delivering a product or service, such as labor and land. Transaction costs include selecting suppliers, negotiating prices, writing contracts and monitoring performance, as well as the risk of opportunism on the part of transaction partners (particularly when asset-specific investments must be made in resources that are specific to a particular relationship).

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Others have argued that there is a third organizational form, the community or relational network, which relies on trust and proximity to coordinate activities and reduce the risk of opportunism.[4] Adler states that these three are not discrete and mutually exclusive forms, but that "empirically observed arrangements typically embody a mix of the three ideal-typical organization forms and rely on a corresponding mix of price, hierarchy and trust mechanisms."[5]

In the PC industry, the network structure incorporates all three organizational arrangements, but it is primarily market-based. A distinguishing feature of the industry is the presence of *de facto* product architecture standards set mostly by Intel and Microsoft that allow suppliers to develop many common components and subassemblies that can be used by any PC maker. This product modularity allows PC makers to select from multiple suppliers of most components and to choose different suppliers for different products. For these standard or "commodity" parts and components, which account for the bulk of the product, the relationship is mostly market-based. When more complex and specialized activities such as build-to-order assembly or new product development are outsourced, the interaction is closer to the community/relational form and may require higher levels of trust. However, even for these activities, PC makers usually keep more than one supplier and put new products out for competitive bidding. Hence the market mechanism continues to be used by PC makers to keep costs down and reduce the potential for opportunistic behavior by suppliers. Finally, PC makers generally keep activities within their firm hierarchy when they are considered strategic or when they have internal capabilities that give them lower costs than potential partners (e.g., Dell's build-to-order capabilities). In summary, the PC industry is organized primarily as a market-based or modular network,[6] with some instances of market-disciplined community/relational ties and strategically focused internalization of activities in the hierarchies of PC companies.

The Impacts of Information Technology on Organizational Form

A number of researchers have analyzed the potential impacts of information technology on organizational forms using the transaction cost framework. Some have argued that the use of information technologies would have a greater impact on transaction costs, thus favoring markets.[7] The argument is that the use of IT reduces both the complexity and asset specificity of many products and services, allowing them to be supplied through market transactions with a minimal risk of opportunistic behavior. However, others argue that IT does not necessarily drive firms towards markets or hierarchies, but that organizational outcomes depend on whether IT has a greater impact on internal or external transaction costs.[8]

In the PC industry, IT has supported the use of market-based network forms for organizing routine processes, as these can be automated and codified through the use of interorganizational IT standards such as EDI and XML. The Internet in particular, with its open, non-proprietary standards, has reduced asset specificity of IT investments and reduced the costs associated with market transactions. By contrast, some processes such as build-to-order assembly or new product development are either too complex or too unpredictable to allow simple automation or codification via existing standards. Instead, they require the use of internal IT systems or the development of customized IOS. Given the high marginal cost of developing a customized IOS with each supplier, the impact of IT in such cases is to encourage closer long-term relationships with a

few partners or internalization of activities. The industry has tried to develop common Internet-based standards such as RosettaNet to automate more processes, but progress has been slow in this direction and the resources and capabilities of many suppliers to adopt the automated processes have been limited.

The Evolution of the Personal Computer Industry

We have conducted extensive empirical research on the PC industry using multiple research methods, including case studies of individual firms, field interviews with business executives and IT managers, and literature review and industry monitoring over the 1995-2004 period. During the course of this research, we interviewed over 100 people in 20 firms in North America, Europe, and the Asia-Pacific region (see Appendix).

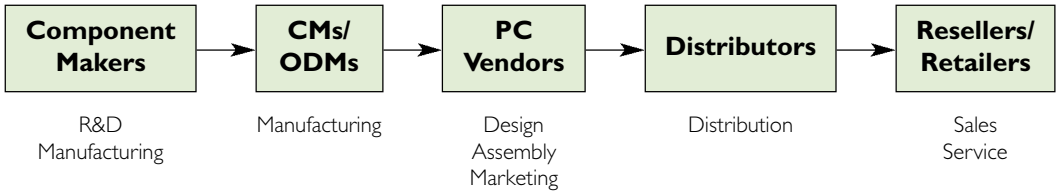
Industry Characteristics

The personal computer is a modular product whose components, peripherals, and software can be designed independently and integrated into the final system using standard technical interfaces.[9] The modular nature of the PC enabled the creation of an industry structure marked by a high degree of specialization and separation of functions since its inception in the mid-1970s. This pattern was reinforced by IBM's decision to rely on outside suppliers for many of the components in the original IBM PC in 1981. Thousands of firms became involved in a global production network that was loosely organized by the major PC vendors, but with fluid and shifting buyer-seller relationships. Firms generally competed in one or two market segments involving either manufacturing components, subassemblies, or complete systems; developing software; or providing sales, distribution, technical support, or other services.[10]

A key feature of the industry is the global dominance of the "Wintel" product architecture based on de facto standards set originally by IBM and later controlled by Microsoft and Intel. This has allowed PC makers and their suppliers to achieve economies of scale by developing products for a worldwide market. Today, all of the components needed to assemble a PC are available from independent suppliers, and PC makers can even turn over product development and final assembly to outside specialists.

By the mid-1990s, the PC industry had matured into a fairly well established industry structure, as shown in simplified form in Figure 1. PCs were assembled by the major vendors using standard assembly line production methods, with production volumes set to meet demand forecasts. Components and sub-assemblies were shipped by component manufacturers and CMs to meet production schedules. Finished systems were sent to distributors, who held inventory for sale to retailers and resellers, who also held inventory for sale to the final customer. All of this entailed high levels of inventory throughout the system, and many transfers and touches of the product on the way to the customer.

FIGURE 1. PC Industry Value Chain, ca. 1995



Source: Kenneth L. Kraemer and Jason Dedrick, "Dell Computer: Using e-Commerce to Support the Virtual Company," CRITO, University of California, Irvine, CA, <www.crito.uci.edu/GIT/publications/pdf/dell_ecom_case_6-13-01.pdf>, 2001.

This apparently stable industry structure was disrupted in the late 1990s, however, by three developments. One was a rapid decline in PC prices, which had previously remained stable in the $2500 range. Packard-Bell and Acer introduced PCs for about $1000, and they were followed by Compaq and others. By the end of the decade, PCs were being sold for under $500. Along with prices, gross profit margins for PC makers fell from an average of 25.6% in 1998 to 20.1% in 2003, creating pressure to reduce costs.[11]

The second factor was acceleration in the product cycle, due to an increased rate of innovation in key components (particularly microprocessors and hard disk drives). This led to faster depreciation of components and finished goods inventories, putting a premium on minimizing inventory throughout the value chain.[12]

The final factor was the success of the direct-sales/build-to-order strategy exemplified by Dell and Gateway. Under this model, PC makers assemble systems as orders come in, usually allowing customers to choose from a set of configurations on basic models, and ship the product directly to the customer. Selling direct disintermediates distributors and retailers, taking out their profit margin and eliminating two layers of inventory. Meanwhile, the shift from supply-driven (build-to-forecast) to demand-driven (build-to-order) production translates into lower parts inventories and faster cash conversion, as PC makers do not buy parts and components until an order is in hand. While Gateway struggled with execution and its decision to open hundreds of company-owned stores, Dell maintained its focus on refining and extending its direct model and achieved superior performance (see Table 1). By contrast, indirect vendors often did not know who their final customers were, nor how much inventory was in the hands of distributors and

TABLE 1. Performance Indicators: Dell versus the Industry, 2003

	Dell	Industry Average
Gross Profit Margin	22.6%	20.7%
Net Profit Margin	6.4%	4.5%
Return on Equity	44.2%	21.1%
Inventory Turnover (per year)	106.3	88.4

Source: *Hoovers Online*, 2004.

TABLE 2. Worldwide PC Market Shares, 1995, 2001, 2004

1995	%
Compaq	10
IBM	8
Apple	8
Packard Bell	7
NEC	4
HP	4
Dell	3
Acer	3
Fujitsu/ICL	3
Toshiba	3

2001	%
Dell	12.7
Compaq	11.1
HP	6.9
IBM	6.1
Fujitsu/Siemens	4.4
NEC	3.5
Toshiba	2.8
Acer	2.6
Apple	2.4
Sony	2.2

2004	%
Dell	17.9
HP/Compaq	15.8
IBM	5.9
Fujitsu/Siemens	4.0
Acer	3.6

Source: International Data Corporation, data provided to authors and press releases.

retailers. They faced resistance from resellers when they tried to sell direct, and were hesitant to absorb the potential loss in revenues if they shifted aggressively to the direct model.

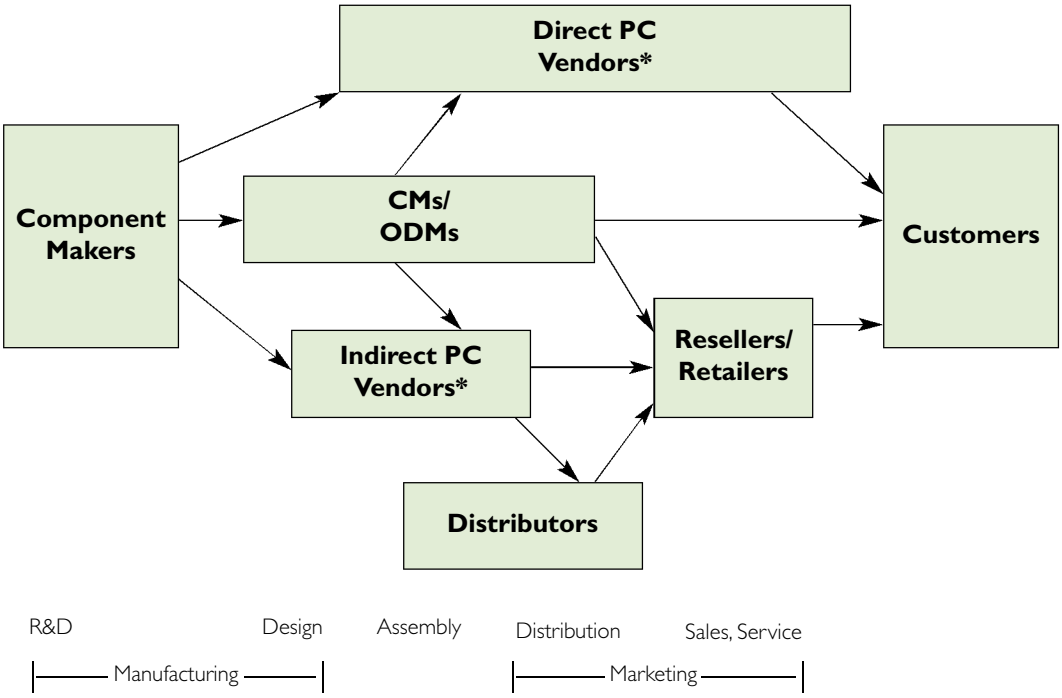
The impacts of these forces were amplified in 2000-2003, when continuing price wars and an unexpected drop in demand hit the industry. In an industry marked by accelerating product cycles and falling margins, Dell's operational advantages enabled it to increase market share while remaining profitable. Dell became the number one PC seller in the world in 2001, and has extended its lead since then (see Table 2).

Most major PC makers reported losses during this period, and by 2002 consolidation had begun, beginning with the merger of HP and Compaq, followed by Gateway's acquisition of e-Machines and Lenovo's purchase of IBM's PC business. Meanwhile, Intel and Microsoft were able to sustain pricing power and capture a large share of the industry's total profits. For Intel, this was due to its dominant position in the microprocessor market, whereas for Microsoft it was due to its near-monopoly position in the PC operating system market.

Interestingly, the financial struggles of most of the industry came in spite of notable improvements in operational performance. Indirect sellers such as Compaq, IBM, and HP had spent years experimenting with hybrid build-to-order systems in conjunction with distributors and retailers as well as adopting many of Dell's supply chain innovations. In time, these efforts paid off; for instance, the industry average for inventory turnover rose from 23.6 turns per year in 1998 to 88.4 turns in 2003.[13]

The PC makers were able to achieve such improvement in large part by revamping their upstream supply chains through just-in-time and vendor-managed inventory systems. Suppliers kept inventory in supply hubs near final assembly plants, and retained ownership of that inventory until it was delivered to the plant for assembly. More sophisticated forecasting and planning tools

FIGURE 2. PC Industry Structure, 2004



* Some PC vendors sell through both direct and indirect channels.

Source: Adapted from Martin Kenney and James Curry, "The Internet and the Personal Computer Value Chain," in BRIE-IGCC E-conomy Project, *Tracking a Transformation: e-Commerce and the Terms of Competition in Industries* (Washington, D.C.: Brookings Institution Press, 2001).

helped ensure an adequate parts supply without excessive inventory costs. Just as importantly, the indirect vendors were eventually able to establish better relationships with distributors and retailers and convince them to share information on demand and inventory levels. They also cooperated with these channel partners to coordinate sales and marketing efforts to better match supply and demand. In general, the entire industry has substituted information for inventory and for physical processes, and it has more closely matched supply and demand through closer coordination across the value network.[14]

Changing Structure of the PC Industry

While some companies have disappeared or merged, the major names in the industry remain, and they still carry the same nominal roles of PC vendors, component suppliers, CMs, distributors, and resellers. However, the nature of those functions has changed and the scope of activities of firms in the industry has often either expanded or become more focused. Figure 2 shows that most PC makers have narrowed their scope of activities, primarily by outsourcing manufacturing, final assembly, and much of the product design and

development process (especially in notebook PCs). This has been accompanied by a broadening scope of activities on the part of other players in the value network, especially CMs, ODMs, and distributors. One result is an overlap of firms and their functions. As one example, final assembly is now done by PC makers, CMs, and ODMs, and distributors.

Component Production

Under the build-to-order model, component makers are often required to locate inventory near the final assembly site to support demand-driven production. PC makers share market forecasts and production information to allow better planning by the suppliers, and PC makers are also requiring immediate information on component availability in order to manage their own production schedules. This involves the use of web-based applications, EDI, and, in some cases, supply chain management applications. Still, the fundamental roles of the component makers (R&D and manufacturing) have not changed much, and their interaction with PC makers is based mostly on market transactions.

Manufacturing

A common distinction between manufacturing and assembly of PCs is whether a firm assembles the motherboard, the main circuit board that holds the microprocessor, related chips, and other electronic parts. Motherboard manufacturing was initially done in-house by the major PC vendors such as IBM, Compaq, and Apple. Other PC makers, such as Dell and Gateway, outsourced motherboard manufacturing from the start. Virtually all motherboards are outsourced today.

The companies who specialize in board assembly included CMs such as SCI, Solectron, and Flextronics, as well as Taiwanese firms such as Asustek, ECS, Gigabyte, and Hon Hai. Taiwanese ODMs such as Quanta, Compal, Arima, and Inventec specialize in notebook manufacturing, including motherboard assembly and final system assembly.

Over the years, both groups have extended their capabilities and expanded their activities well beyond simple board assembly. The major CMs have expanded globally, invested in advanced manufacturing equipment, and also added capabilities such as new product introduction, parts procurement, production planning, logistics, and after-sales services.[15] They have made investments in advanced IT systems that enable them to manage complex production processes, optimize capacity utilization across multiple plants, and manage inventory. Taiwanese motherboard specialists also have developed strong design skills, and now work closely with Intel to incorporate new chipsets into motherboard designs that PC makers can use in their systems.

Notebook PCs require much more sophisticated design and manufacturing processes than desktops because of the need to assemble components in a very small package with tight tolerances to ensure durability, heat dispersion, and energy efficiency. Taiwanese manufacturers developed strong design skills for notebook PCs and became known as ODMs. Taiwanese ODMs work closely

with PC vendors to develop new notebook models and, in some cases, design their own models that are selected off-the-shelf by vendors. Some ODMs also offer final configuration and after-sales services in major markets.[16] Among the major PC vendors, IBM and Toshiba design and manufacture their more advanced notebooks in-house and outsource lower-end machines to Taiwanese ODMs. Dell, HP, and Gateway rely on ODMs for design and manufacturing. In 2004, Taiwanese ODMs manufactured 70% of the world's notebook PCs, mostly in China.[17]

Historically, Taiwanese suppliers were slow to develop their own IT capabilities, but in recent years the ODMs have invested in enterprise information systems and have adopted EDI, and they are now investing in e-commerce technologies as part of a Taiwanese government program.[18]

Final Assembly

The final assembly of a PC is a fairly simple labor-intensive process with minimal value added. PC makers have outsourced much of their final assembly to CMs and ODMs who operate increasingly in locations with low-cost labor. However, the move from build-to-forecast (BTF) to build-to-order production means that rather than having long runs of the same product, firms must assemble PCs to fill individual orders, making final assembly a more complex, information-intensive process. Most PC makers have chosen to do build-to-order production internally, partly because they have developed sophisticated order fulfillment applications to integrate order entry, manufacturing, financial, and logistics functions. Some CMs and ODMs also have these capabilities, and there has been a shift to more outsourcing of build-to-order assembly. For instance, beginning in 2002, IBM sold its desktop assembly plants in the U.S., Scotland, and Mexico to Sanmina-SCI (a major contract manufacturer),[19] and HP sold its PC assembly plants in Scotland and France to Sanmina-SCI as well.[20] In 2004, Apple closed its plant in Elk Grove, California, and outsourced final build-to-order assembly to an unnamed supplier in southern California.[21]

Dell outsources many functions, but Dell insiders argue that execution of the build-to-order model is strategic to the company; therefore, final configuration is not outsourced. "Dell doesn't want to pass on the secrets of the direct model to subcontractors. Dell doesn't have to move away from making boxes. It simply needs to keep focused on quality, price, and delivery."[22] They further argue that Dell assembly plants are showcases that help sell large corporate customers on Dell as their supplier. For notebook PCs, Dell contracts with ODMs for product development and to build base units (minus configurable components), and then does final configuration in its own plants, thus taking advantage of the capabilities of ODMs without completely outsourcing the process.

Distribution

Distribution has changed significantly in recent years. While distributors are supposedly disintermediated by the direct-sales model, they actually can play an important role in supporting direct sales. For instance, distributor Ingram

Micro fills orders for hundreds of third-party products on Dell's web site. Ingram performs the same function for many Internet-based retailers, such as Buy.com, who thus avoid the need to carry their own inventory.[23]

Ingram Micro also has created a business called IM Logistics, which handles physical logistics and manages much of the information flow between manufacturers and retailers. This allows manufacturers to ship directly to retailers and to reduce inventory costs without having to create their own logistics capabilities. In addition, Ingram and other distributors also operate their own PC assembly facilities to fill orders on behalf of branded PC makers and private brand resellers.

The new roles played by distributors rely heavily on their IT capabilities. Ingram's Impulse order management system holds product, price, and availability data for over 200,000 products in Ingram's warehouses. In the IM Logistics business, Ingram's systems coordinate EDI messages and other communications that manage the process from order entry to delivery.

Retailing

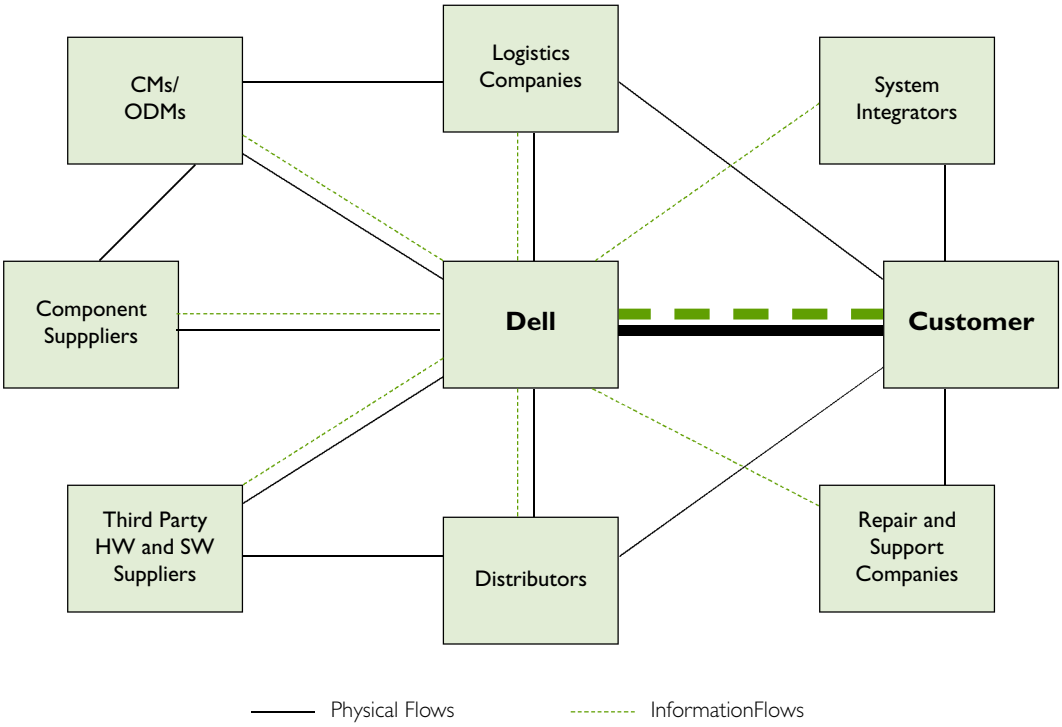
The retail sector has been put under great pressure by competition from the direct vendors, and it has been pressured to change its focus by indirect vendors who want a direct customer relationship. Corporate and small business resellers are encouraged to pass orders on to PC vendors for direct delivery in return for a commission and to focus their attention on providing services such as installation, integration, technical support, and maintenance. In the late 1990s, a new group of retailers emerged selling PCs directly over the Internet, attempting to create a new electronic channel. Some of these have struggled or disappeared, but others such as CDW have been more successful. Consumer PC sales in the U.S. have increasingly shifted to large chains such as Best Buy, CompUSA, Wal-Mart, and Office Depot.

Organizational Mechanisms in the Value Network

The PC industry value network is organized primarily by market mechanisms, with a few activities organized via market-disciplined relational/community mechanisms. The market end of the spectrum (represented by interactions with most component and subassembly suppliers and third-party product suppliers) accounts for the greatest share of links in the network and of transaction volumes. It includes, among others, links among PC companies and suppliers of processors, memory chips, network cards, power supplies, cables and connectors, hard drives, CD/DVD drives, cases, screws, keyboards, mouse devices, LCDs, and a variety of software that is preloaded with PCs. These transactions are generally routine and standardized, although there is some closer coordination at the product development stage when new components are being designed into systems.

Closer to the relational/community end of the spectrum are ties between PC makers and ODMs (who develop and manufacture notebook PCs), CMs and ODMs (who assemble and ship systems directly to customers on a build-to-order

FIGURE 3. Dell Computer Value Network



Source: Kenneth L. Kraemer and Jason Dedrick, "Dell Computer: Using e-Commerce to Support the Virtual Company," CRITO, University of California, Irvine, CA, <www.crito.uci.edu/GIT/publications/pdf/dell_ecom_case_6-13-01.pdf>, 2001.

basis), and providers of specialized services (such as system integration and warranty repairs). In these cases, PC makers work with a few partners, and each side must make more asset-specific investments to coordinate complex and nonstandard processes, which create switching costs and encourage long-term relationships. However, PC makers are careful to avoid excessive dependence on one supplier—in the words of a PC executive, "as soon as the ODM figures out it's the only game in town, your prices go up." Avoiding dependence involves maintaining more than one supplier and putting nearly all new products out for bid to several suppliers, as well as closely monitoring costs in the industry. As another PC maker stated, "It always helps to have two strong players and a third one in the wings that is trying to get your business." The result is a market-disciplined relational/community organizational mechanism.

The Value Network of a PC Company

The structure of an individual firm's value network, its organizational forms, and the role of IT can be seen in the case of Dell Computer (see Figure 3). About 90% of Dell's sales are direct to the final customer, to whom Dell

connects through a range of technical and personal means, including online sales and services, call centers for sales and technical support, and a direct-sales force and technical personnel to serve larger customers in person. The close relationship that develops with the customer, supported by customized IT links, is cited by both Dell and several of its largest customers as a factor in Dell's ability to get repeat orders and in some cases to become a company's sole PC supplier.[24]

The key role of Dell within the value network is in coordinating the information flows and physical processes needed to fill thousands of orders that arrive in unpredictable numbers and configurations on a daily basis.[25] It also must monitor and forecast market and technology trends in order to plan and develop new products and bring them to market. In the words of a Dell executive, "Dell has the most efficient build-to-order processes in the industry. Information systems driven by direct sales make it possible. We get rich market signals from customers and pass them to suppliers to coordinate our whole network."[26] As the figure illustrates, the network involves flows of both physical products and services as well as information, with Dell as the information hub even when it is not directly involved in the physical process (for instance, provision of third-party products such as sales of software and peripherals on Dell's web site that are fulfilled by distributors).

Configuring Value Chains for Products and Markets

The PC industry value network provides a "menu" from which individual firms can design their own value chains. Table 3 shows value chains for major PC makers by product line in the U.S. market. As the table illustrates, the capabilities of the CMs, distributors, and other specialists give PC makers the flexibility to design different value chains for individual products and markets.

Looking at a specific case, IBM has outsourced production of desktops to Sanmina-SCI. IBM is involved in information flows such as order management, billing, and customer service, but it does not handle the product physically at all (Figure 4). By contrast, IBM has consolidated most of its notebook production internally (Figure 5). These products are designed and developed by IBM in North Carolina and Japan, and the are manufactured and shipped worldwide by its IIPC subsidiary in Shenzhen, China.[27] The decision to keep notebooks inside the company reflects IBM's strength in notebook design and development, which enables it to differentiate its products from competitors, and the fact that notebook development integrates both product and process engineering and thus involves working closely with the facility where the product will be manufactured.

Use and Impacts of IT in the PC Industry

The PC industry has invested in a variety of IT systems and applications over the past decade. This has included investment in internal IT applications by PC makers and other members of the value chain as well as in the external networks and applications that link them together. Specifically, there has been

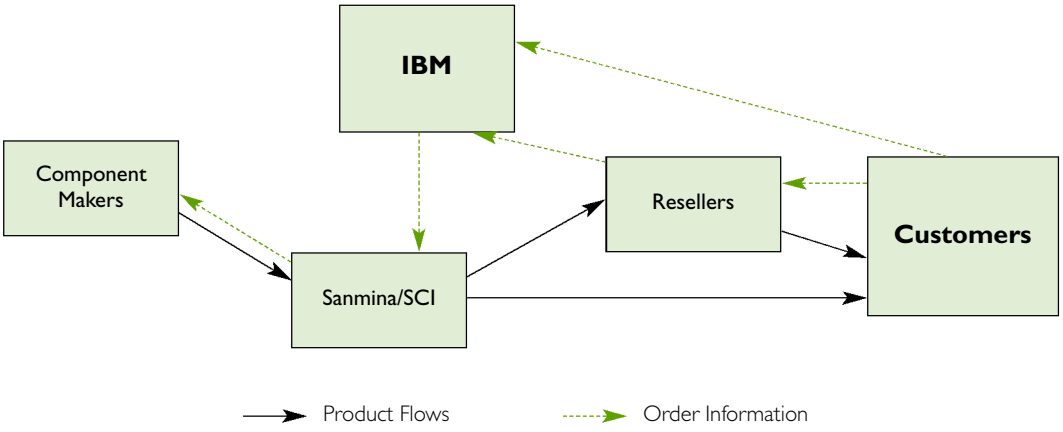
TABLE 3. Flexible Models of PC Production for U.S. Market

Company	Product	Components/ Subassemblies	Assembly	Distribution	Sales/ Service
Compaq (before HP merger)	Custom desktops (CTO)	Outside suppliers/CMs	Compaq (online)	Compaq (online)	Compaq (online)
	Standard desktops (BTF)	Outside suppliers/CMs	Compaq, Mitac, Hon Hai	Distributors	Resellers
	Notebooks	Outside suppliers/ODMs	Inventec, Arima	Compaq (online), distributors and resellers	Compaq (online), distributors and resellers
IBM, 2004	Desktops	Outside suppliers/CMs	Sanmina-SCI	Distributors	IBM (online) and resellers
	Notebooks	Outside suppliers/ODMs	IBM (IIPC), Wistron	Distributors	IBM (online) and resellers
Apple, 2004	Custom desktops (G4/G5)	Outside suppliers/CMs	Apple (outsourced in late 2004)	Distributors	Apple (stores, online) retailers
	Standard desktops (iMac)	Outside suppliers/CMs	LG, Hon Hai	Logistics specialist	Apple (stores, online) retailers
	Notebooks	Outside suppliers/ODMs	Quanta, ATC	Distributors	Apple (stores, online) retailers
Dell, 2004	Desktops and servers	Outside suppliers/CMs	Dell	Dell	Dell
	Notebooks	Outside suppliers/ODMs	Dell (configuration) Quanta, Compal, Wistron (base units)	Dell	Dell

Source: Press reports; company interviews with PC makers, CMs, ODMs, distributors; see Notes.

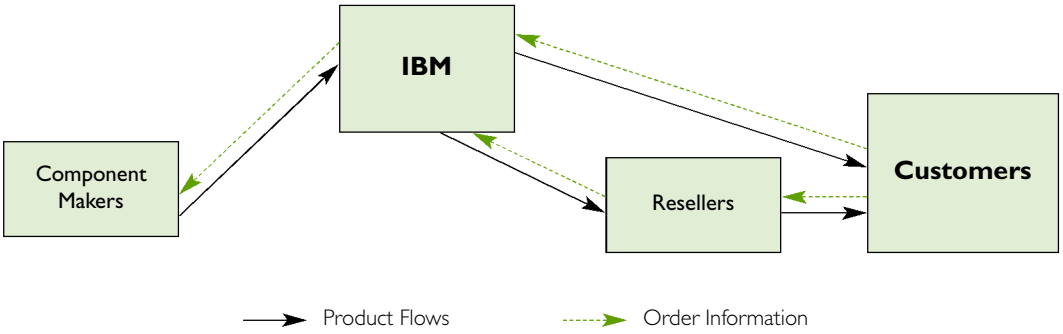
a large-scale adoption of the Internet and an expansion of e-commerce as the means of integrating the value chain. These investments have not been made in a vacuum, however. Instead they have been associated with major changes in business processes, such as outsourcing of manufacturing, adoption of more complex demand-driven production, and greater use of direct sales to control the customer relationship and offer a wider range of products and services.

FIGURE 4. IBM Value Chain for Desktop PCs, 2002



Source: News reports and company interviews.

FIGURE 5. IBM Value Chain for Notebook PCs



Source: News reports and company interviews.

Internal IT Systems

As PC makers have shifted from high-volume assembly line production to flexible build-to-order production, they have reorganized the factory floor into production cells and have adopted just-in-time inventory systems. They also provide information on product availability to salespeople, who can push the products that are available and keep complete product information for each serial number shipped so that tech support can offer better service. These changes in business processes have been accompanied by the introduction of IT in the form of manufacturing planning systems, factory floor applications, order

management systems, enterprise resource planning applications, supply chain management and customer relationship software, and a variety of specialized applications and often middleware to link them all together.[28] These systems have enabled firms to improve operational efficiency, reduce inventory, and better coordinate sales, manufacturing, procurement, and customer service. They have given managers better information to make decisions and have provided the necessary infrastructure to support online sales.

Similar investments have been made by major value chain partners such as CMs and distributors, increasing the capabilities that these partners can offer to PC makers. They are mostly generic and not asset-specific, so that they can be utilized to serve multiple customers and reap economies of scale for the firms making the investment. For instance, Sanmina-SCI's MRP system can coordinate manufacturing and material flows for over 40 plants worldwide, allowing it to shift production as necessary to meet the needs of multiple customers.

The complexity and interdependence of processes such as build-to-order production is one reason they are often still managed within a single firm's hierarchy, either the PC company or a single outside supplier (e.g., Sanmina-SCI in the case of IBM). Internal IT systems have capabilities to coordinate a variety of functions in the order management process, such as checking technical specifications, financing options and availability of components, managing complex production schedules, downloading software, tagging products, and transferring relevant information to sales, customer service, and technical support personnel. Until more robust and widely adopted standards and applications are available to integrate such processes across company boundaries, it is likely that these processes will remain integrated within the hierarchy of one company.

Interorganizational IT Systems

The PC industry was an early adopter of the Internet, using the Web to sell its products, to provide customer service, and to communicate with suppliers and business partners. The most aggressive was Dell, which began selling online in 1996 and by 2000 had claimed that half of its sales volume was web-enabled through its customized web pages and web-supported call centers.[29] It also offered a variety of online services, many of which were tailored for large corporate and institutional customers. Gateway also was quick to offer online sales and services, while the indirect vendors were more cautious due to concerns over channel conflict.[30]

The direct, build-to-order system is well suited to the Internet, given the thousands of possible product configurations and the need to match production and procurement to constantly shifting demand. The ability to operate such a complex, time-dependent order fulfillment process at high volumes puts heavy demands on speed and accuracy. This requires an integrated order management system able to provide information to various internal departments, as well as external partners, to manage production planning, procurement, payment, order tracking, and technical support. In the past, these interorganizational information exchanges were usually handled by faxes and phone calls and occasionally

Electronic Data Interchange (EDI). In recent years, more firms have adopted EDI as well as supply chain management applications and various web-based tools to communicate with partners.

The PC industry uses the Internet for a variety of functions, including product configuration, sales transactions, information exchange, and customer service. Pure Internet sales by PC vendors account for only about 10% of final sales in the U.S., while Internet-enabled sales account for a larger share.[31] A larger volume of upstream B2B transactions is carried out electronically. For instance, Intel has shifted the majority of its sales to the web, while Dell, HP, IBM, and others conduct much of their procurement online or via EDI.

In spite of the large investments made throughout the industry since 1995 and the industry's reputation as a leading user of the Internet, the industry's value chain is still linked by a mix of information systems, ranging from e-commerce applications and EDI to e-mail, faxes, phone calls, and in-person meetings. There are few common standards across the industry, and smaller participants often have minimal IT capabilities. Creating closer links between incompatible IT systems can require costly integration via middleware and custom programming. Outside the U.S., the situation is worse, especially in Asia where the largest share of manufacturing takes place. This lack of standardization is the main driver of RosettaNet, an industry effort to set XML-based standards for exchanging data. Both the Chinese and Taiwanese governments have programs to connect second- and third-tier suppliers with their customers using RosettaNet. So far, adoption of RosettaNet standards has been limited to routine processes such as purchase orders, invoicing, shipping documents, and payment. However, routine processes account for a large share of transactions in the industry, so more widespread adoption of IT standards will likely encourage greater use of automated market-based transactions for significant segments of the value network.

Impacts of IT on Industry Structure

The use of internal and interorganizational IT has had a significant impact on the PC industry structure. The availability of the Internet and other forms of e-commerce, combined with existing and emerging internal IT applications, has enabled many of the changes in firm value chains and industry organization.

- The capabilities of tightly integrated internal IT systems have supported the shift from supply-driven to demand-driven production by linking the entire order fulfillment process, from order taking to delivery. The internal IT systems of PC makers are able to handle large amounts of complex data and transmit necessary information to internal units and external partners to fulfill their functions.
- The internal IT systems of CMs, ODMs, and distributors are important resources that enable these firms to expand their capabilities and geographic scope. As a result, these firms can cover a wider range of value chain activities and PC makers can outsource a broader range of related processes.

- The Internet provides a common infrastructure and set of standards to all firms without the need for investment in expensive private networks. As a result, routine information (e.g., about products, inventory, and prices) can be exchanged quite easily. This information may be relatively simple but is all that is needed for many of the transactions that take place in the industry.
- Interorganizational systems support streamlining of processes by substituting information for physical inventory and activities. If manufacturing is outsourced, it is faster and more efficient to have direct shipment from the contract manufacturer to the customer, but this requires a number of information flows to trigger and record physical actions and financial transactions among the vendor, manufacturer, and customer. One example, provided by a major logistics provider, showed how the fulfillment of a single order from the manufacturer to customer involved two physical shipments (first to a distribution hub, then directly to the customer) but entailed 12 information exchanges.[32]
- There remains a lack of process and IT standardization in much of the industry, so there is still a good deal of customization involved in integrating IT and processes across firm boundaries. Both PC makers and CMs state that adding a new partner requires significant IT investments and creates switching costs when processes are outsourced. Ingram Micro has made a virtue of its flexible internal IT systems that can handle a variety of interfaces, including EDI, web, and machine-to-machine interconnections. Ingram can thus tap its extensive product database and sophisticated order management system to handle order fulfillment for multiple PC vendors and online retailers.
- The Internet is well suited to direct sales, and this has helped Dell in its rise to become the leading PC maker. It would have been costly for Dell to achieve its rapid expansion without using the Internet as a tool for functions such as order taking and customer service. The cost advantages of the direct model would have caused disruption with or without the Internet, but the Internet accelerated the shift in market share and the urgency of other players to react.
- Both internal and interorganizational IT investments can lead to higher returns on investment as transaction volumes increase. The investment in an order management system is mostly an upfront cost, with the marginal costs of handling additional transactions being very low. By contrast, each time a physical good is handled, there is a direct cost. If information can be used as a substitute for physically handling a product, or for keeping inventory on hand, the cost savings can be significant. As volumes increase, the cost savings potentially continue to mount without corresponding increases in IT investment.

Conclusions

The PC industry has undergone a significant shift in structure since the mid-1990s, driven by industry-wide competitive pressures and by the ascendance of Dell Computer to the top of the industry. Facing shrinking margins and reacting to the inherent efficiencies of Dell's direct-sales/build-to-order strategy, PC companies have revamped their supply and distribution chains to reduce costs and respond more quickly to demand signals.

While these changes were driven by competitive and market conditions, information technology has enabled particular forms of organizational restructuring, such as the shift from supply-driven to demand-driven production and the formation of different value chains to most effectively support demand-driven production processes.

Implications for Theory

The PC industry is the prototype of the market-based, or modular network form that has been identified with the U.S. electronics industry.[33] In many segments of the industry, branded vendors have outsourced more of their production in order to concentrate on defending their competitive position, while CMs have grown and achieved economies of scale and scope that have reduced production costs for the whole industry. This industry structure also lowers transaction costs as suppliers invest largely in non-specific assets (such as standard tools, manufacturing processes, logistics systems, and information systems) whose costs can be spread across multiple customers. The risk of opportunism is reduced by the fact that both buyers and sellers avoid dependence on a single partner. For less-routine or standardized activities, more trust-based organizational forms are visible, but even these relationships are disciplined by market-based competition for new contracts.

With respect to the impacts of IT on industry structure, our findings support the arguments of Gurbaxani and Whang[34] and Bakos and Treacy[35] that IT can affect production costs as well as internal and external coordination costs. As they point out, the overall impact depends on which factors are affected most by the use of IT. Unlike Malone et al. and others, we do not find an inherent bias towards market transactions as a result of IT or the Internet.[36] Instead, our findings show that the impact of IT depends on more specific issues that are raised in the literature. For instance, complexity of products and processes turns out to be an important issue, as predicted by Malone et al. and Wigand et al.[37] Internal IT systems can be integrated more easily and extensively than interorganizational systems and are more capable of supporting complex business processes such as configure-to-order production. As a result, most firms keep complex processes in-house or outsource them to one or two partners whose own internal IT systems are capable of handling them.

Implications for Managers

Our findings show that IT-enabled process change is a potential source of competitive advantage for firms that are best able to apply IT to coordinate their own value chains and take advantage of the capabilities of the industry's value network. The sources of competitive advantage in the new IT-enabled organization structure are the substitution of information for inventory and the ability to tap into external economies in the global production network. While the external economies can be accessed by any firm, the demand-driven organization is best positioned to take advantage of these economies because it can use real-time information moving up and down the value chain to drive the production network in response to demand and when necessary to manage demand in response to production capacity. The interorganizational information systems carry the signals that coordinate the whole system and therefore contribute to the firm's competitive advantage.

Notes

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APPENDIX. Firms Interviewed

Name	PC-Related Business	Number of Interviewees	Locations
IBM PC Division[a]	PC Maker	24	U.S., Japan, China, Scotland
Dell	PC Maker	12	U.S., Singapore, Taiwan, Ireland, Japan
Compaq[b]	PC Maker	11	U.S., Japan, Singapore, Malaysia Ireland, Scotland
HP	PC Maker	3	U.S., Japan
Gateway	PC Maker	11	U.S., Ireland, Malaysia, Japan
eMachines[c]	PC Maker	2	U.S.
Apple	PC Maker	9	U.S., Japan, Singapore, Ireland
Acer	PC Maker	5	U.S., Taiwan, Netherlands, Mexico
Lenovo	PC Maker	3	China
Toshiba	PC Maker	3	U.S., Japan
Sanmina-SCI[d]	Contract Manufacturer	2	U.S., Ireland,
Flextronics	Contract Manufacturer	2	Mexico, Ireland,
Foxconn (Hon Hai)	Contract Manufacturer	4	U.S., China, Ireland, Scotland
Solectron	Contract Manufacturer	3	U.S., Mexico, Ireland,
Quanta	Original Design Manufacturer	8	Taiwan, China
Compal	Original Design Manufacturer	3	Taiwan, China
Arima	Original Design Manufacturer	2	China
Wistron	Original Design Manufacturer	3	Taiwan, China
Asus	Original Design Manufacturer	1	China
Ingram Micro	Distributor	2	U.S.

a. All interviews were prior to the announced purchase of IBM's PC division by Lenovo in December 2004.

b. All interviews prior to initial announcement of merger with HP.

c. Interviews were conducted during and after acquisition by Gateway, but only referred to eMachines. Gateway interviews were all prior to the acquisition.

d. Includes interviews with SCI before its merger with Sanmina.

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22. Interview with Dell executive.
23. Ingram Micro interviews.
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28. Kraemer et al. (1999), op. cit.
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