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The Impacts of Information Technology, the Internet, and Electronic Commerce on Firm and Industry Structure: The Personal Computer Industry

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July 2002

This research has been supported by grants from the Sloan Foundation and the U.S. National Science Foundation (CISE/IIS/DST) under Grant No. 9907881. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Jason Dedrick and Kenneth L. Kraemer

Abstract

The adoption of information technology is expected to have major impacts on firm and industry organization. We study the personal computer industry, and find a shift from supply-driven to demand-driven production, accompanied by the creation of a modular production and distribution network. The use of IT has been a key enabler of both trends, allowing firms to coordinate more complex business processes associated with demand-driven production, to standardize data transfers among firms, and to reduce the asset specificity of investments made by PC makers and their suppliers.

I. Introduction

The use of information technology (IT), including the Internet and electronic commerce, is expected to have wide ranging consequences for the organization of economic activities within and among firms. The use of IT within firms has been closely associated with business process restructuring and related organizational changes such as eliminating layers of management, and coordination of activities within the firm (Malone, et al., 1987; Gurbaxani and Whang, 1991; Pinsonneault and Kraemer, 1997, 2002). As companies apply IT to improve their own processes, they have also developed interorganizational electronic linkages with suppliers, customers and business partners to improve efficiency throughout the value chain (Bakos, 1998; Kambil, 1997). Such changes could transform the organization of individual firm value chains and the structure of entire industries.

The spread of the Internet has increased the potential impacts on organizational structure by lowering the cost and expanding the reach of electronic networks far beyond those of earlier proprietary systems. The explosive growth in Internet use since the mid-1990s, along with the expansion of e-commerce and continued growth in IT investment in general make it important to look closely at the impacts of such technologies on the value chains of individual firms and the production and distribution networks of entire industries. We have selected the personal computer industry for intensive study in order to analyze the impacts of IT, the Internet and e-commerce on firm and industry structure.

We find that PC vendors have increasingly 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. This trend has driven other members of the value chain, including contract manufacturers and distributors, to expand their capabilities and take over larger segments of the value chain. There also is a shift throughout the industry to direct sales and demand-driven production in response to the success of market leader Dell Computer. At the industry level, a new form of industry structure has been created: the modular production and distribution network. For individual PC makers, there is more flexibility in tailoring value chains for different products and markets.

The impact of IT has been threefold. First, the internal information systems of PC makers have enabled them to manage the increased complexity of demand-driven production. Second, the internal information systems of outside specialists such as contract manufacturers and distributors enable them to take over larger pieces of the value chain and manage complex processes on behalf of the PC makers. Third, interorganizational information networks such as EDI, e-commerce networks, and the Internet link members of the value chain electronically and enable them to standardize and automate the transfer of complex data. This helps reduce external coordination costs and increases flexibility in organizing appropriate value chains for different products and markets.

For the most part, major changes in firm and industry structure have been *driven* by competitive pressures in the industry and strategic responses to those pressures. However, IT, the Internet and e-commerce have played a critical role in *supporting* the restructuring of business processes, for instance by allowing firms to adopt highly complex demand-driven production processes in a high-volume, high-speed environment. As such, they have *enabled* changes in the organization of firm value chains, as well as in the structure of the industry's global production and distribution network.

II. Theory

Forms of economic organization

Williamson (1975) identified two ways of organizing economic activity: markets and hierarchies. Markets organize value chain activities by means of arms-length transactions between independent firms or individuals, with decisions based primarily on price. Hierarchies organize activities within the boundaries of the organization, using managerial authority to make and execute decisions.

Ensuing research, including that of Williamson himself (1985), as well as Powell (1990) Clemons et al., (1993), Wigand (1997), Bakos and Brynjolffson (1997), Dyer and Singh (1998), and Helper et al. (2000) have argued that a third type of organizational form is increasingly prevalent in many industries—the network organization.[1] Powell (1990) states that networks "involve neither the explicit criteria of the market, nor the familiar paternalism of the hierarchy." Instead, "one party is dependent on resources controlled by another and there are gains to be had by the pooling of resources." According to Wigand (1997), these networks are based on trust, and enable the network members to gain or sustain competitive advantage vis a vis competitors outside the network by reducing both production and coordination costs. Examples of such networks include subcontracting relationships in the construction industries, supplier networks in Japanese industry groups (keiretsu), Italian industrial districts, and technology districts such as Silicon Valley.[2]

[1] Different authors use different terms, such as strategic network, value-added partnership, community or virtual organization to refer to this type of organizational structure. They also define these structures somewhat differently, and in most cases acknowledge that they are describing a stylized form of organization (e.g., see Powell, 1990, p. 300) .

[2] Other explanations have been offered for the organizational forms adopted by firms and industries outside the U.S. For instance, the Japanese keiretsu and Korean chaebol forms of industrial groups have been explained as partly the result of government industrial policy incentives (Dore, 1986; Amsden, 1989; Wade, 1990), while Chinese business

Sturgeon (2002) argues that a new form of network organization, the modular production network, has arisen in the American electronics industry. The modular production network was created as leading firms (branded vendors) gradually outsourced more and more of their production in order to concentrate on establishing and defending their competitive position in fast-changing markets. Taking advantage of the opportunities created, contract manufacturers steadily expanded the scope of their capabilities and geographic reach in order to offer a full range of manufacturing services, including procurement, production, logistics and even customer support, on a worldwide basis.

Unlike other network forms, the modular production network is not strategic in the sense of creating competitive advantage vis a vis firms outside the network. Instead, it is an open, shared network in which contract manufacturers sell to multiple customers, and those vendors buy from multiple suppliers. It is not based on local or regional proximity, but instead is a global network in which buyers and sellers do business together in multiple locations around the world. It does not involve heavy investments in relation-specific assets, but instead involves investments in generic assets that can be shared with multiple partners. Finally, there is limited reliance on tacit knowledge and personal communications, and heavy reliance on codification of information and use of standardized information and communications technologies at the interface between firms. While the modular production network is prevalent across much of the electronics industry, it is probably seen most clearly in the PC industry.

Factors determining organization structure

The choice of organizational structure is influenced by a number of factors, including production and coordination costs, asset specificity and opportunism risks, and capabilities for dealing with complexity and uncertainty (Table 1).

Production costs include land, labor, materials, tools and other direct costs involved in producing and delivering a product or service. Coordination costs, also referred to as transaction costs, include making design decisions, selecting suppliers, negotiating prices, writing contracts and monitoring performance. In the simple market/hierarchy dichotomy, markets are considered to have the advantage in achieving lower production costs, as production is carried out by firms who develop specialized skills and can achieve economies of scale by producing for a number of customers. Coordination costs are generally considered to be lower within a firm's hierarchy, as decisions can be made and enforced without much of the information gathering, negotiation and monitoring required by market transactions (Williamson, 1985; Wigand et.al., 1997).

Asset specificity is the degree to which investments are made that are specific to a particular product, process or relationship, and cannot easily be used again outside that context (Malone et al.,1987). Since the costs cannot be amortized over a number of customers, investments in specific assets increase production costs and reduce the cost advantage of markets. So when

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groups are associated with extended family structures, alumni ties and other personal networks (Dedrick and Kraemer, 1998). Kodama (1995) describes the advantages of Japanese organizational structures in terms of the ability to create and nurture "tacit" or non-codified knowledge and capture its value within the firm.

asset-specific investments are required, it is considered most likely that the activity will be carried out inside the hierarchy.

Another factor is the risk of opportunism, i.e., that one party in a transaction will withhold or manipulate information in order to take advantage of the other (Williamson,1975). Williamson argues the risk of opportunism favors the use of hierarchies, where the interests of individuals and business units are more closely aligned than those of separate firms in market transactions.

A related factor is uncertainty. When future conditions (such as market demand or technological trajectories) are highly uncertain, there is a strong need to retain flexibility. Investing in such an environment is risky, so it is safer to rely on market transactions than to make possibly irreversible investments within the hierarchy. Also, the bureaucratic structures of large hierarchies can make them quite rigid and slow to respond to changing conditions.

Another factor is complexity, both of the product or service being sold, and of the processes involved in providing them (Malone et al., 1987; Wigand, 1997). More complex products and processes require extensive capabilities for information collection, processing and communication. Complexity raises coordination costs, making it more likely that complex products, or products whose delivery involves complex processes, will be provided within a firm's hierarchy than through market transactions.

In the simple view of markets versus hierarchies, firms must weigh the advantages and disadvantages of each organizational form and come to a decision for each activity in the value chain. There would always be some tradeoff, e.g., accepting higher production costs in order to reduce coordination costs or risks of opportunism. However, the network organizational models promise to change the assumptions behind these calculations and offer more attractive ways to organize the value chain.

Let us start with the network model described by Malone, Powell, Wigand and others, and labeled "relational" networks by Sturgeon (Table 1). These closely integrated networks of independent firms achieve production cost advantages associated with specialization, as well as speed and flexibility in responding to changing conditions and new opportunities. They also reduce the coordination costs associated with arms-length market transactions through the build-up of trust and through social norms that mitigate the tendency toward opportunism (Adler, 2001). This type of network works especially well when linked by geographic proximity, family or ethnic ties, or professional affiliations that transcend firm boundaries.

The modular production network achieves similar benefits through different means (Sturgeon, 2002). Suppliers invest mostly in non-specific assets, such as standardized manufacturing processes, logistics capabilities, and information systems, whose costs can be spread across multiple customers. Suppliers can shift capacity from one customer to another as market conditions change, allowing them to sustain high levels of capacity utilization and allowing their customers to adjust production without investing in new capacity, hiring or laying off workers, or idling capacity. The risk of opportunism is minimized by the fact that both buyers and sellers avoid dependence on a single partner. Because it is based on exchange of codified information, rather than tacit knowledge, the modular production network is less reliant on location or

personal relationships and is thus more geographically flexible than relationship networks. This makes it easier to access new markets and to take advantage of resources and capabilities wherever they may exist globally.

Table 1. Features of basic organizational forms

Features		Market	Hierarchy	Relational Network	Modular production network
Cost	Production costs	Low	High	Medium	Low
	Coordination costs	High	Low	Medium	Medium
Risk	Asset specificity of investments	Low	High	Medium	Low
	Risk of opportunism	High, especially of number of suppliers is low	Low	Medium	Low to medium
Capabilities	Ability to manage complexity	Low	High	High	Medium
	Flexibility	High	Low	Medium	High

Source: Adapted from Malone et al., 1987; Powell, 1990; and Sturgeon, 2002.

The impact of information technology on organization structure

Information technology impacts organization structure through its effects on the factors outlined above. Malone, et al. (1987) predicted that the use of information technologies would lower both production and coordination costs, but would have a greater impact on coordination costs, thus favoring markets, an argument supported by empirical evidence in Brynjolfsson et al. (1994). The argument is that the use of IT reduces both the complexity and asset-specificity of many products and services, allowing them to be more easily supplied through market transactions. Wigand, et al. (1997) argue that IT reduces coordination costs, thus favoring markets over hierarchies. Brusoni and Prencipe (2001) identify computer systems and databases as enablers of the shift toward greater externalization of activities and leaner organizational structures.

Gurbaxani and Whang (1991) argue that IT can reduce production costs as well as internal and external coordination costs. The ultimate impact on firm structure will depend on where the cost reductions are the greatest, but at the time the authors surmised that the trend would be toward less vertical integration and greater horizontal integration (market share growth within a horizontal segment). Bakos and Treacy (1986) argue that IT can affect asset specificity, production costs and transaction costs, thus affecting the economics of markets versus hierarchies in ways that depend on the relative impacts of IT on each of those factors.

Wigand et al. (1997) argue that IT can increase market transparency and reduce information asymmetry, thus reducing the risk of opportunistic behavior. Interorganizational IT networks such as the Internet provide easier access to price information from a variety of sources, so that buyers can reduce the risk of opportunistic behavior by a given supplier. In general, the use of IT, particularly those external forms that link the firm to outside partners and information sources, should lower transaction costs and risks, thus favoring markets.

However, while interorganizational applications such as EDI, e-mail, and extranets can be used to automate many interfirm transactions, they have limitations in dealing with complexity. Coordinating complex business processes across firm boundaries requires often expensive and difficult efforts to integrate disparate information systems, adding to the transaction costs involved in a market relationship. On the other hand, internal enterprise information systems allow smoother coordination of various functions, such as finance, order management, and customer service. Thus, the tendency of complex processes to favor the use of hierarchy may be reinforced by the use of IT, due to the relative capabilities of internal versus interorganizational information systems.

Other researchers credit IT and e-commerce as factors behind the advance of the network organization. Malone et al. (1987), Clemons et al. (1993), and Bakos and Brynjolffson (1997) argue that IT reduces the risk of opportunistic behavior by allowing better monitoring of partners in a strategic network relationship. Sturgeon cites the use of IT as a necessary precondition for the creation of modular production networks. IT, along with standardization of parts and processes, allows firms to interact via formalized transactions and without the build-up of assets specific to an individual relationship.

In theory, then, IT has the potential for supporting a shift towards markets, hierarchies, and different forms of networks. Yet actual evidence of the impacts of IT is quite limited. Bakos and Brynjolffson (1997) admit that "it is possible that this new emphasis [on network structures] is unrelated to IT, and is simply due to a belated realization that these investments [in non-contractibles] ultimately affect profits, or to an increasingly fierce competitive environment that makes quality a competitive necessity and forces firms to find new ways to differentiate their products."

Methodology

What is needed is empirical evidence of the impacts of IT, preferably at the industry level, as this is the level of organization at which value chains and production networks are defined. In order to assemble such evidence, we used multiple research approaches, including case studies of individual firms, field interviews with business executives and IT managers, literature review and industry monitoring over the 1995-2001 period. During the period of the research (1999-2001), we interviewed over 100 people in more than a dozen firms in North America, Europe and Asia-Pacific. We use that material first to identify changes that have taken place in the industry's structure since the mid-1990s. We then analyze the role of IT as either a driver or enabler of those changes.

III. The Changing Structure of the Personal Computer Industry

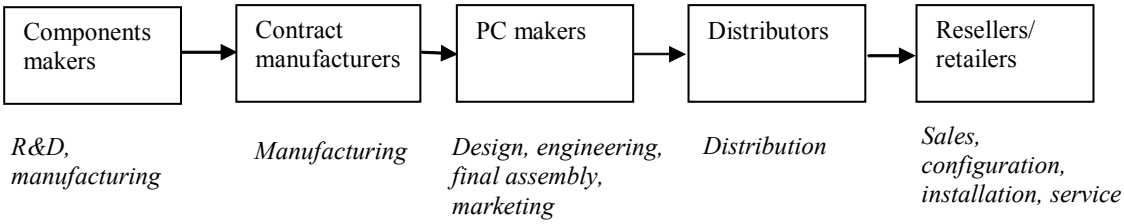
The personal computer is a based on a modular architecture whose components, peripherals, and software can be designed independently and integrated into the final system using standard technical interfaces. This means that these elements can be designed and produced by separate firms who develop deep expertise in their specialties (Ulrich, 1995).

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 utilize outside suppliers for most of the parts in its original PC in 1981. Firms generally compete in one or two horizontal segments, making components, subassemblies or complete systems, developing software, or providing sales, distribution, technical support or other services (Grove, 1996). Today, all of the components needed to assemble a desktop PC are available from independent suppliers and a finished system can be built with little more than a rudimentary technical knowledge.[3]

Given the characteristics of the product, and the strategic decisions of early PC makers, the PC industry was organized mainly on the basis of market transactions rather than internal hierarchies. Thousands of firms became involved in a global production network that was loosely organized by the major PC vendors, but one which was very fluid with shifting buyer-seller relationships. There had been a steady flow of companies into and out of the ranks of leading PC vendors, so that six of the top ten PC makers in 1995 were not in the top ten in 1985 (Dedrick and Kraemer, 1998).

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 contract manufacturers 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



This apparently stable industry structure was disrupted in the late 1990s, however, by three developments. One was the rapid decline in PC prices, which had long remained stable in the $2500 range. Packard-Bell and Acer introduced PCs in the $1000 range, and were followed by Compaq and others. By the end of the decade, PCs were being sold for under $500, and even the major vendors offered well-equipped PCs for under $1000. Gross profit margins for PC makers fell from an average of 25.6% in 1998 to 20.9% in 2001 (Hoovers Online, 1999 and 2002), creating enormous pressure to reduce costs.

[3] This is less true for laptop or notebook PCs, which require more sophisticated design and manufacturing skills to achieve the required size, weight, durability and energy management.

The second factor was acceleration in the rate of product cycles, 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 (Curry and Kenney, 1999).

The final factor was the success of the direct sales, build-to-order (BTO) 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. Direct sales disintermediates distributors and retailers, taking out their profit margin and eliminating two layers of inventory. Meanwhile, business processes were fundamentally altered by the shift from supply-driven (build-to-forecast) to demand-driven (build-to-order) production. The system requires high levels of coordination between PC makers, suppliers, logistics providers and others to achieve the flexibility demanded by the new model (Kraemer et al., 1999; Dedrick and Kraemer, 2001).

The direct model as executed by Dell achieved superior performance in measures such as net profit margin, return on equity and inventory turnover (Table 2), as well as the ability to maintain close direct relationships with the final customer. In an industry marked by accelerating product cycles and rapid product depreciation, these advantages proved critical, and the direct vendors' market share grew steadily at the expense of traditional indirect vendors. Indirect sellers such as Compaq, IBM and HP struggled with resistance from the channel when they tried to sell direct, but each of them worked with channel partners to develop hybrid direct delivery processes, leading to major improvements in efficiency across the industry. For instance, the industry average for inventory turnover rose from 12.9 turns per year in 1998 to 53.5 turns in 2001 (Kraemer et al., 1999; Hoovers Online, 2002).

Table 2. Performance indicators: Dell versus industry averages, 2001

	Dell	Industry
Gross profit margin	17.0%	20.9%
Net profit margin	5.5%	2.7%
Return on equity	26.1%	4.7%
Inventory turnover (per year)	74.7	53.5

Source: Hoovers Online, 2002

The impacts of these forces were amplified in 2000-2001, when continuing price wars and a precipitous drop in demand staggered the whole industry. Dell gained market share and became the number one PC seller in the world in 2001, but saw its profit margins and return on equity decline. Other PC makers reported losses and number two PC vendor Compaq merged with number three HP in 2002. Meanwhile, Intel and Microsoft were able to sustain pricing power and capture an ever greater share of the industry's total profits.[4]

On the surface, the value chain of the PC industry in 2002 looks much the same as it did in 1995. A much larger share of sales in the U.S. go through the direct channel—37% in 2000 (estimated to reach 40% in 2001) versus 18% in 1994 (Dataquest,1995 and 2000)—but the indirect channel

[4] Based on annual reports and data from Hoovers Online, we estimate that the five largest U.S. PC makers (Dell, Compaq, HP, IBM, Gateway) had PC-related profits of only $3 billion on sales of $99 billion in 2000, while Intel and Microsoft had profits of $20 billion on sales of $57 billion.

accounts for a much larger share outside the U.S., where the direct model has been slow to catch on in most markets. Some companies have disappeared or been acquired, but the major names are mostly the same, and they still carry the same nominal functions of component suppliers, contract manufacturers, brand name vendors, distributors and resellers. Attempts to develop new models for marketing PCs, such as the free PC (sold in conjunction with an Internet service contract) have been unprofitable and largely disappeared. New ways of organizing the supply chain, such as electronic marketplaces, have had limited acceptance.

A closer look at the industry reveals that much has changed, however. While the same functions are being performed, the relatively neat match between firm and function seen in Figure 1 has been replaced by a more flexible structure as seen in Figure 2. Firms previously in different categories now have overlapping functions (e.g., contract manufacturers, PC vendors and distributors all do final assembly). PC makers now have more latitude in designing value chains, and often create different value chains for different products and markets using the mix of capabilities available in this new flexible industry structure.

As might be expected, PC makers also see their core capabilities differently than before. "Manufacturing has been the core competence in the past, but managing a portfolio of products and services delivered to the end customer is the core in the future. Compaq wants to own the customer relationship. Whether Compaq makes or buys is not important. We are now managing a portfolio of products and services and it is critical that Compaq control the relationship with the customer, but not that we do everything ourselves" (Interview with Ian McNair, Compaq, November 2000).

The transformation of the industry structure has been driven by the market forces detailed above, and has been enabled to a large extent by the use of internal and interorganizational information technologies by firms across the industry network. To understand how such a mix-and-match environment has developed, and the role of the Internet and e-commerce in the enabling it, we must take a closer look at the activities carried out in the value chains of the PC industry and the changing roles of participants in the value chain.

Value chain functions

As outlined above the main value chain functions in the PC industry are component production, manufacturing, assembly, distribution and retail sales. Each of these functions has been affected by the industry changes of the past few years, but most important has been the change in roles of contract manufacturers, PC makers 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 suppliers to provide immediate information on availability. This involves the use of web-based applications, EDI, and in some cases data provided by supply chain management

applications. Still, the fundamental role of the component makers has not changed much, and their relationship with PC makers is based mostly on market transactions.

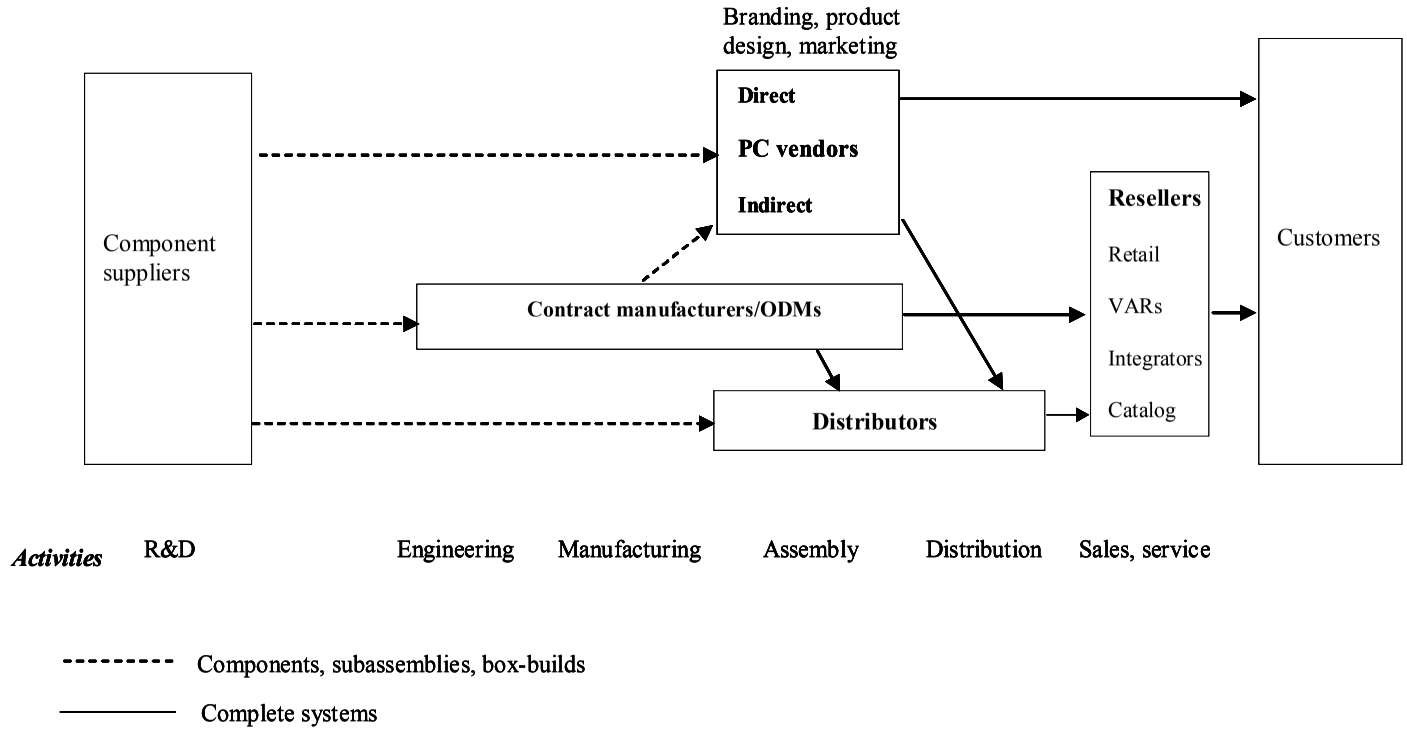
Manufacturing

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. For notebook PCs, manufacturing generally includes building a base unit, which can be configured in the final assembly process. Motherboard and notebook manufacturing were 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 and notebook manufacturing from the start.

The companies who originally specialized in board assembly included contract manufacturers (CMs) such as SCI, Solectron, and Flextronics, as well as Taiwanese firms such as Asustek, GVC, and FIC. Other Taiwanese firms such as Quanta, Arima and Inventec specialized in notebook production. 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 (Sturgeon, 2002). They also have made investments in advanced IT systems that enable them to manage complex production processes, optimize capacity utilization across multiple plants, and manage inventory (Interviews with John Sullivan Flextronics; Ted Murphy, SCI; and Brian Brown, Solectron, November 2000).

Taiwanese manufacturers developed strong design skills focused on the PC, and became what is now called “original design manufacturers” (ODMs). Taiwanese ODMs now often develop their own designs for motherboards and base notebook models, and PC vendors select from those designs to create their own products (Dedrick and Kraemer, 1998). Some ODMs also offer final configuration and after-sales services in major markets (S.H. Chen, 2001). Historically, Taiwanese suppliers have been slow to develop their own IT capabilities, but in recent years the ODMs have invested in enterprise information systems, adopted EDI, and are now investing in e-commerce technologies in conjunction with their large customers as part of a Taiwanese government program (T.J. Chen, 2001).

Figure 2. PC industry structure, 2002



Source: Adapted from Kenney and Curry, 2001

Final assembly

The final assembly of a desktop PC is a fairly simple labor-intensive process with minimal value added. PC makers have outsourced much of their final assembly to contract manufacturers who operate increasingly in locations with low-cost labor.[5] However, the move from build-to-forecast (BTF) to build-to-order (BTO) 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 BTO production internally, partly because they have developed sophisticated order fulfillment applications to integrate order entry, manufacturing, financial and logistics functions. Some CMs also have these capabilities, and there may be a shift to more outsourcing of assembly. For instance, in early 2002, IBM sold its desktop assembly plants in the U.S. and Scotland to Sanmina-SCI (Dyrness, 2002), while HP sold its only PC assembly plant in Europe, located in France, to Sanmina-SCI as well (Ristelhueber, 2002).

Dell makes extensive use of outsourcing, but Dell insiders argue that execution of the build-to-order model is strategic to the company; therefore, final assembly/configuration for different markets and customers will not be 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." They further argue that Dell assembly plants are showcases that help sell large corporate customers on Dell as their supplier.[6]

Notebook PCs require much more sophisticated design and manufacturing processes because of the need to pack all of the components in a very small package with very tight tolerances to ensure durability, heat dispersion and energy efficiency. Among the major notebook producers, IBM and Toshiba design and manufacture their more advanced notebooks in-house and outsource lower end machines to Taiwanese ODMs. Compaq, Dell, HP, and Gateway rely on Taiwanese suppliers for design and manufacturing. Taiwanese suppliers now make 60% of the world's notebook PCs and 90% of Compaq and Dell notebooks (Blincoe, 2002).

Distribution

Distribution has changed significantly in recent years. While distributors are supposedly cut out of the picture by the direct sales model, they often play an important role in supporting direct sales. For instance, Ingram Micro, the largest distributor, fills orders for Dell's Gigabuys web site, which sells thousands of third-party products, such as software, scanners and digital cameras. Ingram performs the same function for many Internet-based retailers, such as Buy.com, which thus avoid the need to carry their own inventory (Interviews with Guy Abramo, Ingram Micro, 2001 and 2002).

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[5] In 1995, Apple employed around 1800 people in manufacturing in Cork, Ireland which served the European, Middle East and Africa market. In 2000, Apple employed about 400 people in manufacturing, having outsourced all but CTO manufacturing to Taiwanese firms located in the Czech Republic and Taiwan. Interview with Tommy O'Connell and Martin Collins, Apple Computer, Cork, Ireland, November 2000.

[6] Quotation is from interview with Sean Corkery, Dell Computer, November, 2000. Also, interviews with Reginald Freake, November 2000, and Louise O'Brien, April 2001, Dell Computer.

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 reduce inventory costs without having to create their own logistics capabilities (Interview with John Martinez, Ingram Micro, 2000). 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 has been threatened with disintermediation by indirect vendors who want a direct customer relationship. Resellers are being encouraged by PC vendors to pass orders on to the 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. A new group of retailers emerged in the late 1990s selling PCs directly over the Internet, attempting to create a new electronic channel. Some of these have since disappeared, but others such as CDW have been more successful. Overall, the growth of direct sales and pure Internet sales has meant a decline in retail PC sales in the U.S. (IDC, 2001). It is likely that those retailers who deal directly with vendors electronically and are able to provide valuable services to the final customer will be the survivors, while others will struggle.

The result: Flexible value chains

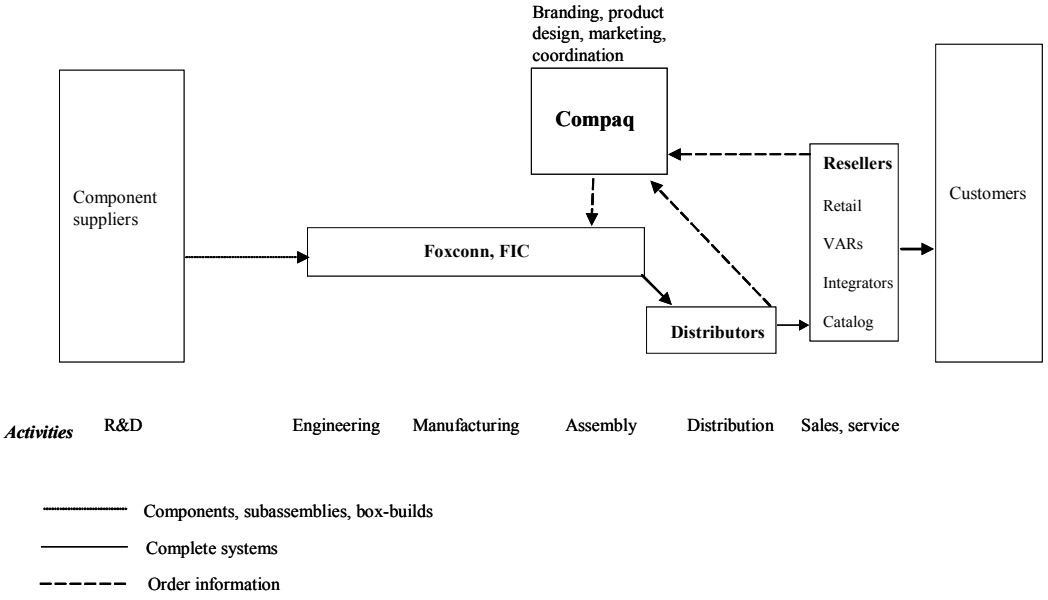
Table 4 shows value chains for major PC makers by product line in European and U.S. markets. As the table illustrates, the capabilities of the CMs, distributors and other specialists such as logistics companies give PC makers the flexibility to design different value chains for individual products and markets. For instance, in the European market, Compaq outsources production of standard desktops to two Taiwanese manufacturers in the Czech Republic. Compaq is only involved in information flows and does not take physical possession of the product (Figure 3). On the other hand, it produces configure-to-order PCs for direct sale at its own assembly plant in Scotland, and ships them directly to customers (Figure 4). Compaq uses a somewhat different organization of its value chain for these products in the United States, with more reliance on channel partners (Table 3). However, in order to offer custom configuration, it bought Inacom's configure-to-order facilities, bringing that process in-house after trying to work with outside distributors before.

Table 3. Flexible models of PC production

Company/ location	*Product/ process*	Components/ Subassembly	Final assembly	Distribution	Final sale
Compaq Europe	*Custom desktops(CTO)*	Outside suppliers/CMs	Compaq		
	Notebooks	Outside suppliers/CMs	Inventec, Arima	Distributors, resellers, Compaq (online)	
	Standard desktops(BTF)	Outside suppliers/CMs	Hon Hai, FIC	Distributors	Resellers
Compaq USA	*Custom desktops (CTO)*	Outside suppliers/CMs	Compaq and Inacom	Compaq (online), and distributors and resellers	
	Standard desktops (BTF)	Outside suppliers/CMs	Compaq, Mitac, Hon Hai	Distributors	Resellers
	Notebooks	Outside suppliers/CMs	Inventec and Arima	Compaq (online) and traditional distributors and resellers	
IBM USA	*Desktops*	IBM, outside suppliers/CMs	Sanmina/SCI	Distributors	IBM (online) and resellers
	Notebooks	IBM and suppliers/CMs	IBM, Acer	Distributors	IBM (online) and retailers
Apple USA	*Custom desktops (G4)*	Outside suppliers/CMs	Apple	Distributors	Apple (online) and retailers
	Standard desktops (iMac)	Outside suppliers/CMs	LG, Hon Hai	Ingram IM Logistics	Apple (online) and retailers
	Notebooks	Outside suppliers/CMs	Quanta, ATC	Distributors	Apple (online) and retailers
Dell USA	*Desktops and servers*	Outside suppliers/CMs	Dell		
	Notebooks	Outside suppliers/CMs	Quanta, Compal, Dell	Dell	
Toshiba USA	*High-end notebooks*	Toshiba/Philippines (some outside suppliers)		Distributors	Resellers
	Low-end notebooks	Outside suppliers/CMs	Compal, Inventec	Distributors	Resellers

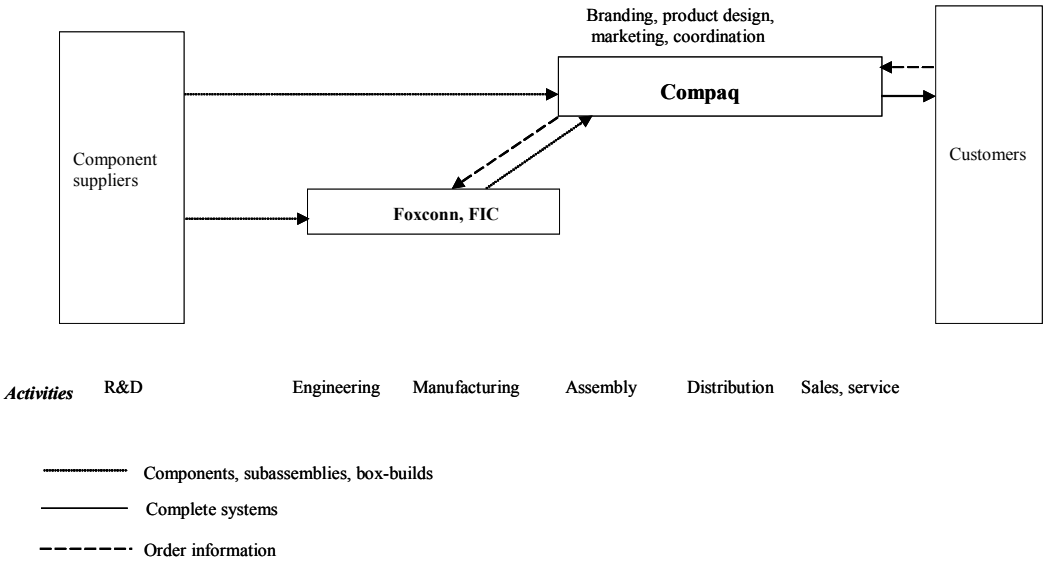
Source: Dedrick and Kraemer, 2002; press reports; company interviews with Dell, Apple, Ingram Micro, Toshiba America Information Systems, Hon Hai (Foxconn); see references.

Figure 3. Compaq Europe, value chain for standard desktop PCs



Source: News reports and company interviews

Figure 4. Compaq Europe value chain for build-to-order desktop PCs



Source: News reports and company interviews.

IV. The Impacts of IT, the Internet and E-commerce on 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 external networks and applications that link members of the value chain. Specifically, there has been a large-scale adoption of the Internet and an expansion of e-commerce as 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 use of the direct sales relationship to control the customer relationship and offer a wider range of products and services to the final customer.

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, adopted just-in-time inventory systems, and linked sales and service functions to production so that salespeople can push the products that are available and tech support has complete information on each unit that is shipped. These changes in business processes have been accompanied by the introduction of manufacturing planning systems, factory floor applications, order management systems, enterprise resource planning applications, customer relationship software, and a variety of specialized applications, as well as middleware to link them all together (c.f., Kraemer et al., 1999; Dedrick and Kraemer, 1998). 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 contract manufacturers 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, SCI's online, real time MRP system coordinates manufacturing and materiel flows for over 40 plants worldwide, allowing it to shift production as necessary to meet the needs of multiple customers (Ted Murphy, SCI interview, 2000).

The robustness of internal IT systems is one reason that the most complex processes such as configure-to-order production are often still managed within a single firm's hierarchy. Internal IT systems have capabilities to coordinate a variety of functions needed, 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 standards and sophisticated applications are available on the Internet to manage such processes across company boundaries, it is likely that these processes will remain integrated within the hierarchy.

Interorganizational IT systems

The PC industry was an early adopter of the Internet, using the web to sell its products, provide customer service, and communicate with suppliers and business partners. The most aggressive was Dell, which found the Internet to be well suited to both direct sales and build-to-order production, as its customers could configure a PC online and either purchase it online or through a call center. Dell began selling online in 1996, and by 2000 it claimed that half of its sales volume was web enabled in some way (Kraemer and Dedrick, 2001). It also offered a variety of online services, many of which were tailored for large corporate and institutional customers. Gateway quickly followed suit with online sales and service to consumers, while the indirect vendors were more cautious due to concerns over channel conflict (Dedrick et al., 2001).

The direct, build-to-order system was not created on the Internet, but it is well-suited to the Internet, given the thousands of possible product configurations[7] and the need to match 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 suppliers and business partners to manage production planning, procurement, payment, order tracking, and technical support. In the past, these interorganizational information exchanges were usually handled by simple faxes and phone calls and in some cases by electronic technologies such as traditional EDI. In recent years, web-based applications and extranets have been used to communicate with value chain 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, while Internet-enabled sales account for a larger share.[8] There is probably a larger volume of sales within the value chain that are carried out on the Internet or via EDI. For instance, Intel has shifted the majority of its sales to the web, while Dell, Compaq, IBM and others conduct much of their procurement online.

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 an uncoordinated mix of information systems, ranging from EDI to web-based applications, e-mail, faxes, phone calls and in-person meetings.[9] There are few common standards across the industry, and smaller participants often have minimal IT capabilities. EDI is expensive and limited in capabilities and therefore used only with major suppliers or customers. Creating closer links between separate firms' internal IT systems often requires costly customization via middleware and message broker layers. Outside the U.S., the situation is worse, especially in

[7] At one time, Gateway offered as many as 23 million possible configurations of all its models, a number it has since reduced to simplify its production systems (Fried, 2001).

[8] IDC defines pure Internet sales as those for which the order was placed and payment made online. Other sales may involve use of the web for information gathering, configuration and order placement, but not include payment online.

[9] For instance, Ingram Micro takes orders via EDI, dumb terminal connections, fax, phone, web interface, and a special inside connection for online stores to link to its databases (John Martinez interview, December 2000).

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 information across the value chain. As might be expected, the CMs, major distributors and some PC makers are leading the drive to these industry-wide standards.

Impacts of IT on industry structure

What impacts have internal and interorganizational IT use had on the PC industry structure? We find that 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 as described previously.

- 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 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 an entire set of processes to them.
- The Internet provides a common infrastructure and set of standards to all firms, without the need for investment in expensive proprietary network infrastructure. As a result, at least some forms of information can be exchanged quite easily, such as product information, constantly updated sales and production forecasts, inventory information, price information, and technical documentation. This information may be relatively simple, but is all that is needed for many of the transactions that take place in the industry, given the standardization of products and processes.
- The Internet and EDI (to a lesser extent) support the modular production and distribution network by making IT investments less asset specific. Ingram's use of its sophisticated order management system to support the web storefronts of both PC vendors and retailers is an example. The Internet not only provides the infrastructure to support these storefronts, but allows Ingram to present information from its internal systems in the same way for multiple customers, and to let those customers link up to Ingram's systems with either a web interface or direct access. If Ingram had to engage in extensive custom programming to link up to each customer individually, it would be forced to make asset-specific investments that could not be leveraged over a number of customers.[10]
- The Internet and EDI, when linked to internal IT systems, allow for greater flexibility in designing the value chain. Direct shipment from a contract manufacturer to the customer is simpler and faster than having the product change hands several times, but requires complex information flows to trigger and record physical actions and financial transactions. One example provided by Ingram Micro's IM Logistics business showed the fulfillment of a

[10] As stated above, Ingram interacts with customers and suppliers in various ways, but the number of methods is limited. It does not need to create customized links for each partner, and it uses the same back-end databases and order management system for all customers.

single order for a product from manufacturer to customer involved two physical shipments but 12 information exchanges (Source: diagram provided by Ingram Micro).

- The Internet is well-suited to direct sales, and has helped Dell in its rise to become the leading PC maker. It would have been more costly for Dell to achieve the rapid expansion that it has without being able to automate functions such as order taking and customer service at least to some degree, and the Internet has been a key enabler of this automation. Dell's success has caused its competitors to move toward more direct sales and delivery channels, causing some of the transformation that has occurred in the distribution and retail segments of the industry. The cost advantages of the direct model would have caused disruption with or without the Internet, but the Internet at least 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 a fixed cost, with the marginal costs of handling additional transactions being very low. By contrast, each time a physical good is handled, there is a marginal cost. If information exchanges 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.

To summarize, the driving forces behind the changes in the value chains of the PC industry have been a combination of competitive pressures including the rise of the direct sales model, falling prices throughout the industry, and faster product cycles increasing the importance of inventory costs. The use of IT, the Internet and e-commerce have enabled many of the changes in the industry and have helped shape the new forms of industry organization that have emerged.

V. Implications for theory

Our research suggests that Williamson's concerns with the risk of market transactions has been addressed in ways that usually do not involve bringing activities into the firm hierarchy. Instead, new organizational forms have been developed that achieve the lower production costs of market transactions while reducing the risk of opportunism and uncertainty. The emergence of such an alternative was posited by Powell (1990), Clemons, et al (1993), Wigand (1997), and even by Williamson himself (1985), in the form of the network organization. The PC industry exhibits a particular form of network structure, defined by Sturgeon (2002) as a modular production network consisting of multiple suppliers and vendors avoiding interdependence through flexible, formalized relationships. We expand on this definition to include the distribution side of the value chain, which has similar characteristics in terms of relationships among firms.

A new contribution to theory is our finding that the modular network industry structure serves as a kind of menu from which individual firms can design their own value chains, and that firms have considerable flexibility in optimizing value chains for different products and markets. There are multiple potential paths to reducing costs and increasing efficiency across a value chain, and the choices made by firms are driven by their own capabilities and strategic imperatives, rather than being determined by formal relationships, path dependency, asset specificity, or the absence of alternative partners. As a result, there is no dominant form for

organizing value chains in the PC industry. Rather there is a wide array of individual value chain structures existing within the industry's broad modular production structure.

With respect to the impacts of IT on industry structure, our findings support the arguments of Gurbaxani and Whang (1991) and Bakos and Treacy (1986) that IT can affect a variety of factors, including production costs, coordination costs, and asset specificity. As they point out, the impact depends on which factors are influenced most by the use of IT. Unlike Malone et al. (1987) and others, we do not find an inherent bias towards market transactions as a result of IT or the Internet.

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 especially processes turns out to be an important issue, as predicted by Malone et al., (1987) and Wigand, et al. (1997). 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 a single partner whose own internal IT systems are capable of handling them.

One of the most important themes in the transaction cost literature is that of asset specificity. Theory (Williamson, 1975; Malone et al., 1987) states that greater asset specificity should lead to greater use of hierarchies, as suppliers cannot spread the cost of such investments over multiple customers. In the PC industry, the modular production network minimizes the asset specificity of investments, as both PC makers and their partners tend to make generic investments that can be applied to multiple partners. IT investment has been a major force in the reduction of asset specificity throughout the production network. Internal IT systems are usually not asset specific; rather they can be used with multiple partners. Interorganizational IT systems allow for the codified linkages that Sturgeon (2002) credits as a key to the operation of the system without "excessive buildup of asset specificity and mutual dependence." Standardized formats for collecting, storing and transmitting data allow information exchange between firms to be codified and automated.

VII. 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. The trend has been towards greater use of outsourcing, but with fewer partners, as firms try to lower production costs while reducing the coordination costs usually associated with market transactions.

The result is a modular global production and distribution network, with firms developing generic, non-specific assets that can be leveraged with multiple partners, and both buyers and sellers avoiding excessive dependency on one partner for any activity. Within this industry structure, firms have a great deal of flexibility in designing individual value chains for different products and markets, taking into account their own capabilities and strategies.

IT has supported the evolution of this industry structure in several ways. Internal IT systems enable firms to take over multiple steps in complex processes such as configure-to-order production, and also are developed as generic assets that can be offered to multiple partners. Interorganizational IT systems allow relationships to be formalized and enable processes to be automated between firms. The Internet in particular, with its open, non-proprietary standards, has reduced asset specificity and reduced the costs associated with market transactions, and increased firms' flexibility in their selection of partners for individual value chains.

As we argued at the beginning of this paper, IT, the Internet and e-commerce have *enabled* 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. They have also enabled changes in the structure of the industry's global production network. For the most part, however, major changes were actually *driven* by competitive pressures in the industry.

These changes in IT and organization structure suggest that IT-enabled structural change is an additional 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 modular production and distribution network. The sources of competitive advantage in the new IT-enabled organization structure are the substitution of information for inventory in the demand-driven organization 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.

Dell Computer has outperformed the industry and its closest competitors in terms of inventory turns, profit margins and market share through its use of IT-enabled business processes. Other firms have sought to imitate the demand-driven model, tailor value chains for different products, take advantage of the industry's modular production network, and invest in new IT systems to better coordinate the whole system. They have shown gains in operational performance over earlier times, but most remain considerably behind the market leader because of channel conflict and the complexity of execution. It remains to be seen if superior use of IT-enabled processes and structures will remain a source of competitive advantage as more PC makers fully adopt demand-driven production processes, and as interorganizational IT becomes more standardized, putting all firms on a more equal footing in exploiting the capabilities of the modular production network.

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