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Impacts of internal and interorganizational information systems on the outsourcing of manufacturing

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ABSTRACT

Drawing on transaction cost economics, this paper looks at the relationship of IT use to the outsourcing of manufacturing using survey data from US manufacturers. We find that greater use of interorganizational systems (IOS) is associated with greater outsourcing, but we do not find any main effects between internal IT and outsourcing. A negative interaction effect is found between measures of internal IT and IOS, suggesting that the two may be substitutes rather than complements. This distinction between internal IT and IOS, and the relationship of the two, offers scholars a more nuanced understanding of the nature and impacts of IT. It provides managers insight into how different types of IT can support different sourcing options.

1. Introduction

Recent years have seen a decrease in vertical integration in manufacturing, exemplified by the rapid growth in outsourcing to outside contractors (Bardhan et al., 2006; Marchant and Kumar, 2005; Sturgeon, 2002). This has been accompanied by the widespread adoption of techniques such as build-to-order production and lean manufacturing in industries such as computers (Dedrick and Kraemer, 2005), clothing (Abernathy et al., 1999), and automobiles (Holweg et al., 2005; Sharif et al., 2007). These changes likewise have been accompanied by the adoption by manufacturers of information technologies such as enterprise information systems and operations management systems (Bardhan et al., 2007), as well as interorganizational systems (IOS) aimed at improving coordination with external partners (Teo et al., 2003; Malhotra et al., 2005; Brews and Tucci, 2004; Son et al., 2008). The fact that these trends have occurred together raises the question of whether the use of IT and the adoption of new manufacturing practices are related to the increased use of outsourced manufacturing.

Manufacturing firms have increased outsourcing to focus on core competencies, increase production flexibility and improve quality, but the main reason is to reduce cost (Bardhan et al., 2006), as outsourcing specialists can focus on operational efficiency and attain economies of scale by producing for multiple customers. Competition among outsourcing suppliers also drives down costs to clients. Hence, reducing vertical integration through outsourcing is expected to improve firm performance. Research in the computer industry has found empirical evidence that greater vertical integration is associated with

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lower performance (Peyrefitte and Golden, 2004) but others have found that an optimal mix of vertical integration and strategic outsourcing can lead to better performance (Rothaermel et al., 2006).

There are costs associated with market transactions that can nullify the gains from outsourcing, including the costs of searching for suppliers, negotiating and contracting with suppliers, and monitoring performance (Williamson, 1975). Information technology can reduce transaction costs associated with external sourcing, especially search and monitoring costs, thus favoring greater use of markets (Malone et al., 1987; Bardhan et al., 2006). On the other hand, IT can reduce the cost of coordinating production internally as well, making production within the firm's hierarchy more competitive (Gurbaxani and Whang, 1991). Recent research has found evidence that the impact of IT on vertical integration is dependent on industry characteristics, particularly industry concentration and demand uncertainty (Ray et al., 2009), and on the relationship specificity of the IT employed (Kim and Mahoney, 2006).

We seek to understand the relationship of IT to the organization of activities in markets versus hierarchies by studying the outsourcing of manufacturing in a dynamic environment in which IT use is growing and changing, and new manufacturing techniques are being adopted. To do so, we develop a set of hypotheses based on the literature and on field research in the personal computer industry. We test our hypotheses through quantitative analysis of data from a survey of 297 manufacturing companies in the US.

We extend theory and contribute to the IS literature by distinguishing between internal IT and IOS and hypothesizing different impacts for each. While Bardhan et al. (2007) found different impacts for two types of internal IT on manufacturing outsourcing (enterprise management and operations management systems), and Kim and Mahoney (2006) find that the impacts of IT on vertical integration depend on its relationship specificity, ours is the first study we are aware of to study the different impacts of internal IT and IOS on outsourcing.

This study also has important practical implications. There is evidence that outsourcing can lower costs and improve quality for manufacturing firms (Bardhan et al., 2006), yet coordinating production outside the firm's boundaries remains a challenge. The potential for IT to enable more effective use of outsourcing (or conversely to make internal production more competitive) thus has important implications for sourcing strategies. This study also is important in understanding the potential for IT to reduce transaction costs within the supply chain. These implications are discussed more fully in Section 8.

2. Theory

The theory most widely employed in studies of IT and the organization of economic activities is transaction cost economics (TCE). TCE theory states that firms organize transactions within markets or hierarchies to economize on the sum of production and transaction or coordination costs (Williamson, 1975, 1981).[1] Transaction costs are associated with asset specificity, uncertainty and complexity of transactions, and with the bounded rationality and opportunism of individuals. As transaction costs go up, firms are more likely to internalize transactions rather than use markets.

It has been argued that IT use can reduce transaction costs and will lead to greater reliance on market transactions rather than internal hierarchies (Malone et al., 1987; Wigand et al., 1997). One reason is that IT can reduce the asset specificity of investments, for instance, by making manufacturing equipment more flexible (Clemons et al., 1993). Another is that IT can reduce complexity by allowing more data to be processed and communicated readily (Malone et al., 1987). In addition, IT enables better monitoring of outside partners, reducing the risk of opportunism associated with market transactions (Clemons et al., 1993).

A less deterministic argument is that IT does not inherently favor markets or hierarchies, but that its impacts depend on whether IT leads to greater reduction in internal or external costs (Bakos and Treacy, 1986; Gurbaxani and Whang, 1991; Hitt, 1999; Afuah, 2003). IT can reduce external transaction costs but also can reduce internal transaction costs associated with monitoring employee performance, coordinating work across different units within the firm, and providing information to decision makers. If external costs are reduced more, the result will be more use of markets; if internal costs are reduced more, the result will be more use of hierarchies.

Only limited empirical research has tested these theorized relationships of IT to sourcing decisions. In these studies, higher levels of IT investment are associated with decreased firm size (Brynjolfsson et al., 1994) and also with lower levels of vertical integration, but also with increases in horizontal diversification, suggesting that IT enables internal coordination of a complex mix of activities (Dewan et al., 1998; Hitt, 1999). This is consistent with the argument that IT can reduce both external and internal coordination costs (Gurbaxani and Whang, 1991). Other research has found that firms' depth of internetworking is positively related to greater specialization, reduced hierarchy, and greater external partnering (Brews and Tucci, 2004).

Research on the impacts of IT on the organization of manufacturing found a strong relationship between levels of IT investment and outsourcing of production activities in US manufacturers (Bardhan et al., 2006). Other empirical research has found that the use of electronic procurement is associated with buying from more suppliers for custom goods but fewer suppliers for commodity goods, supporting the argument that the impact of IT depends on the nature of the goods being transacted (Dedrick et al., 2008). Grover and Saeed (2007) find that the use of electronic data interchange (EDI) by electronics manufacturers with component suppliers is higher when component complexity is greater, market fragmentation is low, and

[1] As in much of the literature, we use "transaction" and "coordination" costs interchangeably.

an open information-sharing environment exists. Mithas et al. (2008) find that firms are more likely to use electronic markets (reverse auctions) for commodity goods than for specialized goods, and less likely when non-contractibility is greater in the exchange relationship. There is less evidence of the impacts of IT use and the nature of the activity on internal versus outsourced manufacturing.

Most studies of IT and organization of economic activities treat IT as a homogeneous technological input into an economic model. However, some researchers distinguish by the type of IT in use (Orlikowski and Iacono, 2001). One distinction is between the impacts of enterprise integration systems and operations management systems on sourcing and performance (Bardhan et al., 2007). Another interesting distinction comes from the stream of research on IOS such as EDI and Internet applications, which are explicitly or implicitly distinguished from internal systems (Kaufman, 1966; Barrett and Konsynski, 1982; Cash and Konsynski, 1985; Melville et al., 2004). One such study finds different impacts of internal and external IT capabilities on productivity (Nevo et al., 2007).

While the literature on IT and sourcing of manufacturing has continued to develop, there remain two important gaps. First, most prior empirical studies of IT and organization do not incorporate variables for activity characteristics such as complexity, uncertainty or asset specificity that are critical in TCE theory (an exception is Bardhan et al., 2006). Including these variables should lead to a more fully specified model, but there are no widely employed measures of these factors. Second, while researchers have distinguished different impacts from different types of IT in some contexts, there is little research that considers the type of IT in use in terms of its specific relationship to market versus hierarchy sourcing decisions. Since there are a number of different ways in which IT can be characterized, as discussed above, there is a need to identify a classification scheme that is likely to relate to the manufacturing sourcing decision considered in this study. In addition to these gaps, there is also a need for continued empirical research that addresses the impacts of IT in the context of current technologies. In their review of the IOS literature, Robey et al. (2008, pp. 508–509) call for research that engages state of the art Internet-based technologies, as most IOS research had previously focused on EDI.

Given these gaps in the literature, particularly at the time we began this study (early 2000s), we developed a two phase study. We first conducted qualitative research on firms in the personal computer industry, and then conducted a broader survey of 297 manufacturing firms. The purpose of the qualitative study was to develop good measures of transaction cost variables, and to better define the IT variable in terms of its relevance to the sourcing decision. A second purpose was to better understand the outsourcing of manufacturing itself in order to develop measures of outsourcing that would go beyond a simple binary outsource/no outsource decision. The goal was a more comprehensive, nuanced model that captured the important elements of the transaction, IT use, and outsourcing, and that could be tested empirically in the follow-on quantitative study (described in Section 4 below).

3. Qualitative analysis and hypothesis development

The reason for doing qualitative analysis was to study developing trends in sourcing decisions, IT use and manufacturing practices at the leading edge, before these trends might show up in the broader population of companies. In particular, we wanted to understand the sourcing decision by manufacturers that are heavier users of outsourcing, as well as leading adopters of IT and advanced manufacturing techniques, in order to understand the factors that are driving outsourcing. The personal computer industry was chosen because it has been a leader in each of these trends. PC companies had outsourced over 70% of laptop production as of 2005 (Digitimes, 2006), they were pioneers in adopting practices such as build-to-order production and just-in-time distribution hubs, and they have been aggressive in adopting new information technologies such as sophisticated order management systems, shop-floor technologies, supply chain management systems, e-commerce, and online customer service (Dedrick and Kraemer, 2005). By studying these trends and their relationships in such an emerging environment, we were able to operationalize variables for IT use, activity characteristics and outsourcing, and to posit relationships among them based on the context of an advanced manufacturing industry.

Our research on the PC industry draws on established procedures for conducting qualitative research (Glaser and Strauss, 1967; Lee, 1989; Miles and Huberman, 1994). We used multiple data collection methods, including field interviews with business executives, literature review and industry monitoring. We interviewed over 100 people in 20 firms, including PC companies, contract manufacturers, original design manufacturers, component manufacturers and distributors in North America, Europe and the Asia-Pacific. Company reports and other sources (e.g., Compustat, Hoovers), were used to collect data on organizational structure and financial performance of the companies or their PC divisions.

The primary data consisted of semi-structured interviews based on a common protocol, which evolved over time in response to insights from previous interviews. Interviews were conducted in person (or, in a few cases by telephone), with extensive notes taken. As recommended by Dubé and Paré (2003), a project database was maintained. This includes a Microsoft Excel workbook with information on the organization, interviewee and interview, as well as data displays and searchable files of all interview notes and secondary material. This research is summarized in Appendices A–C.

The qualitative data was analyzed using cross-case displays with firm names on one axis and theoretically determined factors and outcomes on the other (Miles and Huberman, 1994).

Outcomes included percent of desktop and notebook PC production outsourced, while factors included differences in production methods, and uses of different types of internal and interorganizational IT. For each company, direct quotes or other information from the interviews were included in each category. Secondary data was included as relevant.

It was clear right from the initial interviews that desktop and notebook PCs were very different in terms of product characteristics (cost, weight, manufacturing tolerances, and product requirements such as battery life and ruggedness), and were often managed under separate business units. As a result, we developed separate data displays for desktops and notebooks to understand cross-case differences and similarities for each, then compared the two displays to develop constructs that would capture additional differences between the two product categories. Appendix C presents abridged versions of the displays for desktops and notebooks from branded PC vendors, with additional insights from supply chain partners.

Our qualitative findings enabled us to identify measures of variables found in the literature, such as complexity and asset specificity, for which good measures were either lacking or were not well suited to the manufacturing sourcing context. They also provided insights to extend theory by delineating between two types of IT, internal and interorganizational, and hypothesizing different impacts for each. The interplay of existing literature and qualitative findings in guiding our hypothesis building and testing are explained next.

3.1. Constructs and hypotheses

3.1.1. Dependent variable: outsourcing

In studies of the impact of IT on organizational structure, the organizational outcome has been measured in terms of average firm size (Brynjolfsson et al., 1994), vertical integration and diversification (Hitt, 1999), business scope, hierarchy reduction and external partnering (Brews and Tucci, 2004), asset ownership (Baker and Hubbard, 2003), extent of outsourcing (Bardhan et al., 2006) and number of suppliers (Dedrick et al., 2008).

Our interest is in the extent to which manufacturing is outsourced, which we operationalize at the firm level as the share of production[2] that is outsourced versus that done internally. Other researchers have measured outsourcing at the activity level using a binary measure of whether an activity is outsourced (Bardhan et al., 2006). The additional advantage of our measure is that it yields a continuous variable and can capture the degree to which production is outsourced, not just whether a particular activity is outsourced or not.

3.1.2. Information technology

Prior research has theorized that IT can lead to changes in organizational outcomes, by reducing internal or external coordination costs. We asked firms about what types of information systems they employed, how those systems were used to coordinate their production and other activities, and whether the use of IT influenced their outsourcing decisions.

Most respondents did not see IT driving the outsourcing decision (which was usually based on cost), but saw it as a key factor that either lowered the cost of in-house production or enabled outsourcing by supporting coordination between the firms. As a Dell executive stated, in answer to why Dell keeps final assembly in-house, "Dell has the most efficient processes in the industry. Our information systems make us more efficient than anyone in handling build-to-order production. And BTO is what differentiates us from the rest of the industry".

Further, a number of respondents distinguished between the two types of IT when discussing coordination of production activities within and across firms. As one PC industry executive stated in an interview, "Keeping IT in-house makes it easier to have a system that works. You could put in a system that links together four different companies, but if they all have different IT systems you would have to cobble it all together".

Internal IT systems are considered a tool for lowering production costs. As one contract manufacturer stated, "We run an MRP system that is networked with all our plants worldwide, so it is possible to know plant capacity and stock availability worldwide. This means that we can transfer production from one plant to another—literally overnight. This enables us to optimize labor, parts and capacity worldwide".

IT also has a potentially significant impact on internal coordination. Using internal IT, firms can link business processes such as order management, manufacturing, procurement, sales and customer service for greater efficiency. Our interviews identified use of key applications and integration of IT systems to support coordination of processes as potentially reducing internal costs.

External coordination costs are affected more by the use of IOS, including the IOS capabilities of suppliers and the use of IOS by the focal firm to network with its partners. IOS enable business processes to be integrated and detailed information to be shared in real time, which makes possible the outsourcing of more complex activities.

"We get the same capabilities with some CMs as with our own factories. Those companies can do direct shipment and BTO. But it means they have to have the IT capabilities. The CMs are passed data from our SAP systems using EDI and the Internet". PC executive.

The distinction between internal IT and IOS is consistent with the IS literature, going as far back as Kaufman (1966). Barrett and Konsynski (1982, p. 94) point out that firms in the early 1980s were shifting from focusing only on internal IT systems to also include IOS in their IT planning. Cash and Konsynski (1985, p. 137) specifically identify IOS as an enabler of changes in organization structure, and as having the potential to redefine the relationship between buyers and suppliers.

[2] Production includes final assembly and subassembly. Subassembly is assembling systems such as motherboards or base-builds (an enclosure, motherboard, cables and connectors) for PCs, transmissions, braking systems or dashboards for cars, or wings and hydraulics for airplanes. These partial assemblies are put together in final assembly. Buying a component such as a memory card or a tire from an outside supplier does not count as outsourced subassembly.

Based on the literature and our PC industry interviews, we develop separate variables for internal IT and IOS and hypothesize different impacts for each. Internal IT includes use and integration of applications, databases, and other systems used within the firm. IOS includes the use of information systems to conduct transactions and coordinate with external partners.

Theoretically, propositions about the impacts of internal IT and IOS on outsourcing build on Gurbaxani and Whang's (1991) arguments about the ability of IT to reduce both internal and external production and coordination costs. We expect that higher levels of internal IT use will lower internal coordination costs, and hence be associated with greater internalization (less outsourcing) of production. Conversely, we expect that higher levels of IOS use will lower external coordination costs and be associated with greater outsourcing of production.

3.1.2.1. Internal IT. We present two hypotheses with regard to internal IT use and outsourcing. The first considers the level of use of internal IT. The use of such applications has been associated with organizational impacts in the literature (Sánchez-Rodriguez et al., 2006; Devaraj and Kohli, 2003). It also was identified as a key factor in determining internal production costs by both PC makers and contract manufacturers.

Hypothesis 1. Higher levels of internal IT use will be associated with lower levels of outsourcing.

A second characteristic of internal IT that is expected to influence coordination costs, and hence the level of outsourcing, is the degree of integration of IT systems. For instance, Dell integrated a variety of applications and databases to handle high volume BTO production. The high level of IT integration maximizes through-put and minimizes inventory requirements, and was long credited as a source of cost advantage over other PC makers (Kraemer et al., 2000).

The significance of IT integration as a factor influencing organizational outcomes is also found in the literature. For instance, back end (internal) IT integration is identified as a value-creating resource for the firm, and hence is likely to be associated with internalization of related processes (Zhu and Kraemer, 2005).

Hypothesis 2. Higher levels of internal IT integration will be associated with lower levels of outsourcing.

3.1.2.2. Interorganizational systems. Since IOS by nature involves coordination with outside partners, we hypothesize that higher levels of IOS will lead to lower external coordination costs and thus be associated with greater outsourcing of production. The following hypotheses are based on both theoretical arguments about the impact of IT and on the empirical findings of our qualitative research. The first relates outsourcing to the level of supplier use of the Internet, a measure of the extent to which the firm operates in an internetworked industry environment (Brews and Tucci, 2004; Zhu and Kraemer, 2005). The IOS capabilities of the firm's suppliers were identified as a key factor in determining whether production was outsourced in our interviews.

"IT is a big factor. A supplier's management capabilities are reflected in their IT. It's also necessary to be able to link your IT to theirs. We do go out to bid and do change suppliers, but only after we examine their IT capabilities. State of the art fulfillment requires very robust IT capabilities". PC maker.

Hypothesis 3. Higher levels of supplier use of the Internet will be associated with higher levels of outsourcing.

A second hypothesis relates outsourcing to the extent of Internet purchasing by the focal firm, a measure of use of electronic markets (Malone et al., 1987). Firms that use the Internet extensively for purchasing goods and services are more likely to have developed processes and skills to coordinate digitally with outside partners. As one PC company manager said, "E-commerce allows us to better manage and coordinate processes. Using the Internet for purchasing helped us move to supplier-owned inventory, which leads to a big savings". The skills developed to manage and coordinate with outside suppliers in general facilitate the decision to outsource actual manufacturing, by enabling better coordination with the outside manufacturer(s).

Hypothesis 4. Higher levels of Internet transactions for purchasing will be associated with higher levels of outsourcing.

3.1.3. Interaction of internal IT and interorganizational systems

Internal and interorganizational systems do not exist independently, but are generally integrated with each other to some extent. While we did find companies who took orders by EDI, then hand-typed them into an internal order management system, most companies in the PC industry had developed some linkages between internal and interorganizational systems. It is thus possible that internal IT facilitates the use of IOS to coordinate outsourced production. If so, we would expect a positive interaction effect such that firms with extensive internal IT systems would show a stronger positive relationship between IOS and outsourcing than those with limited internal IT capabilities.

On the other hand, internal IT and IOS may be substitutes for each other in integrating the production process. For instance, order information can be transmitted internally via an order management system, or it can be transmitted via EDI or XML-based links between firms. Production planning information can be relayed to internal or external suppliers via supply chain management applications or via EDI or web-based tools. If this is the case, we would expect a negative interaction effect. Thus we present two alternative hypotheses.

Hypothesis 5a. There is a positive interaction effect between internal IT and IOS on the level of outsourcing.

Hypothesis 5b. There is a negative interaction effect between internal IT and IOS on the level of outsourcing.

3.1.4. Activity characteristics

We also need to consider differences in the nature of the manufacturing process as a factor that will influence the level of outsourcing. TCE theory posits that characteristics such as complexity and asset specificity will affect transaction costs and influence the sourcing decision, yet these are not operationalized in a way that is specific to manufacturing processes. In our qualitative research, we found two factors consistent with complexity and asset specificity that influenced the decision to conduct activities in-house or to outsource. An indicator of complexity was whether production was build-to-order (BTO) or build-to-forecast (BTF).[3] This is consistent with more recent literature which emphasizes the higher levels of complexity involved in BTO compared to traditional BTF production (Fredriksson and Gadde, 2005; Gunasekaran and Ngai, 2005; Moses et al., 2004; Sharif et al., 2007).

Interviewees in the PC industry consistently stated that BTO production is substantially more complex and more difficult to outsource than BTF. As one interviewee stated, "High volume build-to-order is very complex. It requires the ability to anticipate demand to have available adequate plant capacity, workers, and parts and components, as well as the ability to adjust quickly to actual demand that can fluctuate a lot from day to day". Keeping production in-house facilitates this ability to manage complexity. An interviewee from the same firm stated, "(Our company) is bringing in more of the box with more stuff in it from suppliers, *but keeps control of the complex parts of the process*".

To implement BTO production requires more than just effective demand planning. In addition, innovative processes such as flexible production cells and vendor-managed inventory are usually employed. Complex outbound logistics are needed to quickly ship orders to different locations. Sophisticated order management and shop-floor coordination is needed to maximize through-put of the whole system. An analysis of desktop and notebook assembly by PC companies showed that BTO assembly was outsourced in only 40% of cases, while BTF assembly was outsourced in 88% of cases (Appendix A).

Hence, we expect that firms doing more BTO production will tend to keep production in-house rather than outsource. This is broadly consistent with TCE theory (Malone et al., 1987) and empirical research (Novak and Eppinger, 2001) which argue that more complex activities will tend to be done within the firm's hierarchy due to the higher coordination costs involved.

Hypothesis 6. Higher levels of build-to-order (BTO) production will be associated with lower levels of outsourcing.

The second factor identified as influencing the outsourcing decision was the degree to which specialized or custom inputs and equipment are required for production. Interviewees consistently distinguished between standard parts and components that are available from a variety of sources and custom parts that are non-interchangeable and often available from only one source in the short term. Several identified a higher level of risk associated with use of custom inputs, both risk of failure to perform and risk of opportunism on the part of suppliers. As one PC company interviewee stated, "As soon as the [supplier] finds out it's the only game in town, your prices go up".

The risk associated with customized inputs can theoretically be related to asset specificity. This measure of asset specificity has been used in other empirical research (Pilling et al., 1994). Consistent with transaction cost theory, we hypothesize that firms will tend to keep production in-house when they require more customized inputs in the form of parts or machinery and equipment.

Hypothesis 7. Higher levels of customization will be associated with lower levels of outsourcing.

Our next phase of research was to test these hypotheses using quantitative methodology on data from a sample covering a much broader range of manufacturing firms than the PC industry. The model tests the impacts of internal IT, IOS, BTO and customization on the degree to which manufacturing is outsourced.

4. Quantitative data and methodology

A survey was conducted of purchasing/procurement professionals in the manufacturing sector to test the hypotheses presented above. According to our discussion with managers in the PC industry and other industries, these professionals are highly involved in supplier selection, and often are part of the product management team that decides whether to manufacture a product in-house or to outsource. Also, previous surveys studying transaction costs and organizational outcomes have used purchasing personnel as respondents (Heide and John, 1990, 1992; Pilling et al., 1994). Our field research showed us that these professionals are knowledgeable about their firms' use and integration of IT internally and externally with suppliers.

Based on an extensive review of interview transcripts from our qualitative research and a literature review, an initial set of questions was developed to measure each of the variables in the model. An expert panel of five purchasing managers reviewed each of the items on the questionnaire for its content, scope, and purpose (content validity).

The firms surveyed were all manufacturing firms, selected from subsectors in which manufacturing involves assembly processes, such as automobiles, clothing, electronics, and furniture and appliances. Firms in such industries can keep both subassembly and final assembly in-house, or they may outsource them. They may build products to order or to forecast and they may use customized or standard parts and equipment. As such, these groups are likely to capture sufficient variety

[3] Build-to-forecast is often called build-to-stock, the term used in our survey.

of organizational outcomes and activity characteristics to test the model, while reducing variation due to industry differences that might mask effects in the model (Heide and John, 1990).

The final sample consisted of purchasing managers and related professionals in 297 manufacturing firms in the United States. The telephone survey was conducted by SRBI Inc. during the period of June 9–July 20, 2005. The sample was drawn from a population of companies in the manufacturing sector (2- digit SIC = 20 thru 39) using the industry selection at www.hoovers.com. The total sample frame consisted of 2365 companies. The sample was stratified to include only those companies which use the Internet and/or EDI for purchasing direct production materials (parts, components, machinery and equipment). The response rate was 32.2% for eligible respondents, in this case, firms that use the Internet or EDI. The largest subsectors in the final sample were electrical and other electronic (24.6%), industrial machinery and equipment (20.5%) and instruments and related products (21.5%).

4.1. Variable measurement

4.1.1. Activity characteristics

Based on the results of our study of the PC industry, we use build-to-order production as our first activity characteristic. Respondents were asked what percent of their firm's production was build-to-order versus build-to-stock.

Our second activity characteristic is the degree of customization involved in a product. We measure customization as the extent to which production inputs (parts and materials) and capital equipment are customized or specific to the firm, as used by Pilling et al. (1994). Respondents were asked what percent of materials and parts for production, and what percent of equipment and machinery, are customized versus standard goods.

4.1.2. Internal IT and IOS

We utilize two variables for internal IT and two for IOS. For internal IT, the first is the number of applications that the firm uses, from a list of generic applications relevant to manufacturing (ERP, MRP, shop floor, supply chain, production planning). This is a measure of *IT in use*, which has been identified as a key link between IT investment and impacts (Devaraj and Kohli, 2003). While it does not measure the extent to which these applications are used, the presence or absence of such major enterprise and operations applications are evidence of the penetration of IT into the firm's internal business processes. The second is the degree to which data can be shared among the firm's applications and databases. This is a measure of internal *IT integration*, which has been defined as a key factor in IT value (Zhu and Kraemer, 2005; Rai et al., 2006).

For IOS, the first measure is the extent to which a firm's suppliers use the Internet, a measure of the extent to which the firm's overall trading community is networked and uses interorganizational systems (Teo et al., 2003; Dedrick et al., 2008). The second is the extent to which the firm uses the Internet for purchasing, which measures the firm's actual use of IOS (Zhu and Kraemer, 2005; Brews and Tucci, 2004). This consists of the sum of Internet purchases as a percent of total purchases of parts, machinery and equipment (Son et al., 2008).

4.1.3. Sourcing outcomes

Our measure of the extent to which activities are organized within the firm or through market transactions is the degree of outsourcing. Respondents were asked what percent of final assembly and subassembly were outsourced. We use the sum of the two, which is called total outsourcing as our measure. While other research has used other organizational measures such as firm size (Brynjolfsson et al., 1994) or vertical integration (Hitt, 1999), degree of outsourcing is a more direct measure of use of markets versus hierarchies in the organization of manufacturing. Our measure is similar to that of Bardhan et al. (2006), but is continuous rather than an index based on binary variables.

4.1.4. Firm size

In all analyses, we control for firm size, using the natural log of number of employees in the firm as reported by the respondent. For public companies, we compared these figures with Compustat data to ensure reliability of reported figures. All constructs from the conceptual model and the measurement items used are reported in Table 1.

4.1.5. Descriptives

The descriptive results of the surveyed companies are shown in Table 2. The mean firm size was 3864 employees; however, the median was just 300. To compensate for this skewed distribution, we use the natural log of employees as a measure of firm size in all analyses.

The mean percent of production that is BTO is 67%, showing that use of BTO is widespread across the sample. This fact is well known in industries such as electronics and computers which have high rates of inventory obsolescence, but the survey data show that the use of BTO production is much more widespread. Customized inputs represent about half of parts and components and 36% of machinery and equipment. Only 27% of all assembly (final and subassembly) is outsourced.

Table 1
Constructs, variables and measures.

Constructs	Variables	Measurement items	Support
Activity characteristics	Build-to-order production	– % of production that is build-to-order	Novak and Eppinger, (2001) PC industry studies
	Customization	– Sum% customized goods for direct materials and parts + equipment and machinery	Pilling et al. (1994) PC industry studies
Information technology	IOS	– Supplier use of Internet = sum of # of existing suppliers who use the Internet: • for exchanging product information • for order processing • for order tracking and delivery – Focal firm use of Internet = sum of • % standard materials and parts purchased on the Internet • % customized materials and parts purchased on the Internet • % standard equipment and machinery purchased on the Internet • % customized equipment and machinery purchased on the Internet	Brews and Tucci (2004), Teo et al. (2003), Steinfield et al. (1995), Barrett and Konsynski (1982), and Cash and Konsynski (1985) PC industry studies
	Internal IT	– Data can be shared among applications (1–5) – Number of applications used among the following: ERP, MRP, SCM, shop floor, production planning	Melville et al. (2004) and Orlikowski and Iacono (2001) PC industry studies
Organizational outcome	Degree of outsourcing	– Sum of % of final assembly outsourced + % of subassembly outsourced	Marchant and Kumar (2005) PC industry studies
Control variable	Firm size	– Natural log of the number of firm employees	

Table 2
Descriptive statistics for sample.

	Mean	Median	SD
# Of employees	3864	300	18,121
Sales ($ millions)	998	82	4157
% Of production build-to-order	67	80	34
% Of materials/parts customized	53	50	29
% Of equipment/machinery customized	36	30	31
% Total assembly outsourced	27	15	30

5. Results

We used OLS regression to test the study hypotheses. Since the outcome variable – percent of production that is outsourced – is continuous rather than dichotomous (build/buy) as in other studies, OLS is more appropriate than a logistic or probit function. Residuals were tested and found to be normally distributed, meeting a key requirement of OLS estimation. Table 3 presents the Pearson correlations among the variables.

A test of the hypotheses regarding factors influencing the degree of outsourcing shows the following results (Table 4):

Hypothesis 1. Higher levels of internal IT use will be associated with lower levels of outsourcing.

We do not find any significant relationship between internal IT use (number of applications) and total outsourcing. Thus, Hypothesis 1 is not supported.

Hypothesis 2. Higher levels of internal IT integration will be associated with lower levels of outsourcing.

We do not find a significant relationship between internal data sharing and total outsourcing. Thus, Hypothesis 2 is not supported.

Hypothesis 3. Higher levels of supplier use of the Internet will be associated with higher levels of outsourcing.

We find that higher levels of supplier Internet use are associated with higher levels of total outsourcing ($p < .10$). Thus, Hypothesis 3 is supported.

Hypothesis 4. Higher levels of Internet transactions for purchasing will be associated with higher levels of outsourcing.

We find that higher levels of Internet purchasing are associated with higher levels of total outsourcing ($p < .05$). Thus, Hypothesis 4 is supported. The support for Hypotheses 3 and 4 shows a positive relationship between IOS use and outsourcing, as predicted.

Hypothesis 6. Higher levels of build-to-order (BTO) production will be associated with lower levels of outsourcing.

Table 3
Correlation matrix.

	Correlations							
	Log of employees	% Of production build-to-order	Total customization	Supplier use of Internet	Internet buying	Data can be shared among applications and databases in your firm	Internal Applications	Total outsourcing
Log of employees								
Pearson correlation	1	−.117	.111	−.088	.065	−.150*	.333**	−.070
Sig. (2-tailed)		.051	.075	.179	.298	.011	.000	.272
N	295	281	260	237	255	285	277	249
% Of production build-to-order								
Pearson correlation	−.117	1	.025	.112	.044	.053	−.060	−.145*
Sig. (2-tailed)	.051		.695	.090	.491	.385	.328	.024
N	281	283	252	230	246	273	269	242
Total customization								
Pearson correlation	.111	.025	1	−.207**	−.046	−.035	.115	−.201**
Sig. (2-tailed)	.075	.695		.002	.480	.575	.070	.003
N	260	252	262	219	235	254	250	223
Supplier use of Internet								
Pearson correlation	−.088	.112	−.207**	1	.274**	.194**	−.004	.182**
Sig. (2-tailed)	.179	.090	.002		.000	.003	.954	.009
N	237	230	219	239	225	233	225	204
Internet buying								
Pearson Correlation	.065	.044	−.046	.274**	1	.011	−.028	.157*
Sig. (2-tailed)	.298	.491	.480	.000		.861	.660	.021
N	255	246	235	225	256	247	241	217
Data can be shared among applications and databases in your firm								
Pearson Correlation	−.150*	.053	−.035	.194**	.011	1	.063	−.061
Sig. (2-tailed)	.011	.385	.575	.003	.861		.303	.340
N	285	273	254	233	247	286	271	243
Internal applications								
Pearson Correlation	.333**	−.060	.115	−.004	−.028	.063	1	−.089
Sig. (2-tailed)	.000	.328	.070	.954	.660	.303		.173
N	277	269	250	225	241	271	279	238
Total outsourcing								
Pearson Correlation	−.070	−.145*	−.201**	.182**	.157*	−.061	−.089	1
Sig. (2-tailed)	.272	.024	.003	.009	.021	.340	.173	
N	249	242	223	204	217	243	238	251

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 4
Determinants of degree of outsourcing.

	B	*t*
Constant	88.847	3.623
Log employees	−3.048	−1.255
Internal applications (Hypothesis 1)	.133	−.027
Data can be shared internally (Hypothesis 2)	−2.124	−.669
Supplier use of the Internet (Hypothesis 3)	2.566	1.894[†]
Internet purchasing (Hypothesis 4)	.143	1.992[*]
BTO (Hypothesis 6)	−.379	−3.181[**]
Customization (Hypothesis 7)	−.185	−2.019[*]
	$N = 168$	
	$R^2 = .158$	
	Adj. $R^2 = .121$	

[†] $p \leqslant .10$.
[*] $p \leqslant .05$.
[**] $p \leqslant .01$.

We find that higher levels of BTO production are associated with lower levels of total outsourcing. The results are very robust ($p < .01$). This supports Hypothesis 6.

Hypothesis 7. Higher levels of customization will be associated with lower levels of outsourcing.

We also find that higher levels of customization of inputs and capital equipment are associated with lower levels of total outsourcing ($p \leqslant .05$). This supports Hypothesis 7.

The control variable, firm size, was negatively associated with total outsourcing but the relationship was not significant.

The R^2 score of the model is .158. Other empirical studies of the organizational impacts of IT have resulted in similar R^2 scores ranging from under .10–.25 in different models (e.g., Brews and Tucci, 2004; Hitt, 1999).

5.1. Interaction effects

Hypothesis 5a. There is a positive interaction effect between internal IT and IOS on the level of outsourcing.

Hypothesis 5b. There is a negative interaction effect between internal IT and IOS on the level of outsourcing.

In order to test Hypotheses 5a and 5b, interaction effects of all internal IT and IOS combinations were tested (Table 5). These were mean centered so that the signs of any interaction effect could be interpreted as supporting either 5a (if positive) and 5b (if negative).

We found a significant interaction effect between the firm's internal applications and supplier use of the Internet. This effect is negative and therefore is consistent with Hypothesis 5b, that internal IT and IOS are substitutes, not complements. For firms using more internal IT applications, the relationship between supplier use of the Internet and outsourcing is weaker.

Table 5
Determinants of degree of outsourcing with interaction effects.

	B	*t*
Constant	88.847	3.623
Log employees	−3.048	−1.255
Internal applications (Hypothesis 1)	.133	−.027
Data can be shared internally (Hypothesis 2)	−2.124	−.669
Supplier use of the Internet (Hypothesis 3)	2.566	1.894[***]
Internet purchasing (Hypothesis 4)	.143	1.992[**]
BTO (Hypothesis 6)	−.379	−3.181[*]
Customization (Hypothesis 7)	−.185	−2.019[**]
Internet buy * Internal applications (Hypotheses 5a and 5b)	−.108	−1.111
Internet buy * Data shared (Hypotheses 5a and 5b)	−.039	−.731
Supplier use * Internal applicaions (Hypotheses 5a and 5b)	−3.336	−1.969[**]
Supplier use * Data shared (Hypotheses 5a and 5b)	−.122	−.119
	$N = 168$	
	$R^2 = .204$	
	Adj. $R^2 = .149$	

[*] $p \leqslant .01$.
[**] $p \leqslant .05$.
[***] $p \leqslant .10$.

Table 6
Robustness test using internal IT and IOS index values.

	Total outsourcing	
	B	*t*
Constant	122.282	7.114*
Log employees	−4.906	−2.211**
Internal IT index	−5.359	−1.249
IOS index	13.509	3.075*
BTO	−.472	−3.789*
Customization	−.147	−1.670***
	$N = 154$	
	$R^2 = .184$	
	Adj. $R^2 = .157$	

* $p \leqslant .01$.
** $p \leqslant .05$.
*** $p \leqslant .10$.

5.2. Robustness test

In order to test for robustness of the basic model, we also ran a regression using index values for internal IT and IOS (Table 6). The results are consistent with the findings in the tested model, showing the results to be robust. Please see Appendix E for details on methodology. We also tested for the interaction effects between the index values of internal IT and IOS. While the results were in the right direction (negative), they fell short of being significant ($p = .125$).

6. Discussion

The model results show that degree of outsourcing is positively associated with both supplier use of the Internet and level of Internet purchases by the firm. This is consistent with our hypotheses that increased IOS use lowers external coordination costs, hence encouraging outsourcing. We must acknowledge that higher levels of outsourcing might in turn lead to greater IOS use to coordinate activities across firm boundaries. This would be consistent with the studies of Dewan et al. (1998) and Hitt (1999), which found similar relationships between IT and organization (vertical integration, horizontal diversification) with models in which causality was reversed. However, given the way that IOS is operationalized in our study, we would argue that the logical direction of causality is most likely from IOS to outsourcing. The first measure of IOS is the extent of use by all of the firm's suppliers; there is a median of 100 major suppliers per firm. The use of IOS by such a large number of suppliers is not likely to be affected much by the decision of one customer (the focal firm) to outsource assembly, usually to a few contract manufacturers at most. Instead, the fact that the focal firm is part of a supply network which is highly digitized is likely to facilitate outsourcing by making it easier to find contract manufacturers who have the capabilities for internetworking and to make the necessary interorganizational linkages.

The second measure, total Internet purchasing as a percent of all direct inputs and equipment, is also a broad measure of a firm's IOS use which is only affected to a limited extent by outsourcing production. The causality is likely to be stronger from IOS to outsourcing, as firms who are using the Internet very extensively for procurement should have greater skill and experience with the technology to reduce coordination costs associated with outsourcing while taking advantage of lower production costs available from specialized manufacturers.

We do not find that internal IT is significantly associated with degree of outsourcing, for either measure of internal IT. This suggests that in spite of the statements by interviewees in our qualitative study, the impacts on internal coordination costs are not sufficient to change the relative cost of internal versus outsourced production for a larger sample of manufacturers. It also might be a sign that by the time of the survey in 2005, both the functionality of the Internet and IOS, and the experience of firms in using technology to interconnect, have matured to where firms can effectively reduce coordination costs with IOS as well as internal IT.

We do find a moderating effect between supplier use of the Internet and internal IT applications, suggesting that internal IT and IOS are acting as substitutes rather than complements. To our knowledge, this is an effect that has not been identified previously in studies based on quantitative data. Hence, it is an important new contribution to theory and empirical research.

In terms of activity characteristics, we found that the degree to which firms outsource production is negatively related to the extent of BTO production. This is consistent with transaction cost theory. It also shows the validity of using BTO as an indicator of complexity and hypothesizing that firms are more likely to keep BTO production in-house, as we found in our qualitative research.

The findings relating customization to lower levels of outsourcing similarly support the use of customization as a variable indicating asset specificity (Pilling et al., 1994) and is consistent with theory in hypothesizing that firms are more likely to keep more asset specific activities in-house. This also is consistent with our qualitative findings.

7. Limitations

A potential limitation is the reliance on respondents' perceptions of both independent and dependent variables. This may call into question the external validity of results, as we have no external measures of variables used except for firm size.[4] Also, using the views of procurement professionals on IT may be questioned as those professionals may have limited familiarity with the full scope of the firm's information systems. On the other hand, there is an advantage in not using IT managers to measure IT use for the purposes of this study, as purchasing professionals have no incentive to overstate the firm's IT use or capabilities. Also, procurement professionals are likely to be very familiar with IT as it is actually used in the firm in the context of purchasing and outsourcing of manufacturing activities. So the choice of target respondents has both limitations and real advantages in our context.

Another limitation is the cross-sectional nature of the data. The lack of longitudinal data limits our ability to measure directly the impacts of changing activity characteristics and IT on organizational outcomes, or to test for causality in relationships.

8. Conclusions and implications

We conclude that TCE is a useful perspective for empirical research about the impacts of IT on the outsourcing of manufacturing. We further conclude that the impacts of IT on outsourcing of manufacturing need to be studied by distinguishing between internal IT and IOS. We also conclude that it is necessary to analyze interaction effects as well as main effects. Finally, we conclude that it is necessary to take into account the nature of the manufacturing process, as per transaction cost theory, as part of a model that relates IT to the organization of manufacturing in markets or hierarchies.

8.1. Implications for theory

This research contributes to academic knowledge of the impacts of IT on organizational outcomes in several ways. First, by distinguishing between internal IT and IOS, our qualitative findings show that greater internal IT use potentially favors more internalization of activities, while IOS use favors more reliance on markets through outsourcing. This is consistent with the argument (Gurbaxani and Whang, 1991; Hitt, 1999; Afuah, 2003; Brews and Tucci, 2004) that IT can influence both internal and external costs, and goes further by showing that those effects depend on the nature of IT in use, consistent with Nevo et al. (2007) and Kim and Mahoney (2006).

On the other hand, our quantitative findings based on a large survey of firms support the electronic market hypothesis that IT use will lead to greater use of markets. We find that the use of IOS supports outsourcing, while the use of internal IT does not seem to have a significant main effect in either direction. These findings are consistent with recent research showing that greater IT investment is associated with higher levels of manufacturing outsourcing (Bardhan et al., 2006).

A new contribution is the finding of a negative interaction effect between one measure of IOS and internal IT. This suggests that internal IT and IOS may be substitutes rather than complements. For instance, in our qualitative research, we found that contract manufacturers had made significant investments in shop-floor management systems, in order to be able to take over and internalize plant-level processes and eliminate the need for the clients (our focal firms) to have such systems in place. The IS literature has not tested empirically whether internal IT and IOS are substitutes or complements, or even framed the issue in those terms exactly. However, there are arguments in the literature that point in one direction or the other. Applying the resource-based view, Barua et al. (2004) find that elements of internal IT (e.g. IT infrastructure) and IOS (partner readiness), along with organizational resources combine to develop a higher order resource they call online informational capabilities, or OIC. This implies that internal IT and IOS are complementary resources. Zhu (2004) finds a complementary relationship between e-commerce capability and IT infrastructure. However, empirical research by Schlemmer and Webb (2009) found that the Internet is not complementary with IT assets in small and medium-sized firms.

None of these studies looks at internal IT and IOS as complements or substitutes in the context of outsourcing, or considers them in terms of TCE. We return to Gurbaxani and Whang (1991) to frame this finding. Specifically, we would argue that both internal IT and IOS can reduce transaction costs; hence in some circumstances IOS can serve as an enabler for outsourced manufacturing, allowing firms to take advantage of suppliers' IT capabilities as an alternative to building or maintaining their own. Further research into the interaction between internal IT and IOS is warranted, as the two types of IT do not exist independent of each other. Both are involved in supporting the firm's manufacturing processes, and their relationship to each other may vary over time or under different circumstances.

A significant contribution of both our qualitative and quantitative studies is in identifying two key characteristics of manufacturing activities that influence the degree of outsourcing. TCE theory posits that characteristics such as complexity and asset specificity will affect transaction costs and influence the sourcing decision, but most previous empirical studies on the impacts of IT on organizational form have not included variables to measure these characteristics. Our study did. The incor-

[4] Measures such as build-to-order production, type of IT in use, and percent of production that is outsourced are not generally available in company financial reports or from sources such as Compustat.

poration of these constructs, and their operationalization as BTO production and customization, provides a more complete specification of the factors influencing outsourcing, and offers insights into the dynamics affecting outsourcing.

8.2. Implications for practice

These findings have implications for managers' decisions about where to make IT investments and develop capabilities. If IOS can reduce overall costs more significantly than internal IT, as the quantitative findings suggest, then it might be worth focusing on IOS, in spite of the acknowledged difficulties in connecting firms with disparate information systems.

Our results provide evidence that use of IOS such as the Internet can reduce external transaction costs and facilitate outsourcing. Managers who wish to take advantage of the potential benefits of outsourcing can do so by employing IOS within their value chain. But our findings also suggest that the nature of the production process (BTO or BTF) and product (customization) must be taken into account when considering outsourcing. The fact that IOS may be a substitute for internal IT offers the potential for saving on IT requirements when manufacturing is outsourced; for instance, if manufacturing is fully outsourced to suppliers with required IT capabilities, it may be possible to phase out certain internal applications. However, this caveat is very important, as outsource suppliers may lack such IT capabilities, especially if they are smaller or located in developing countries.

From the perspective of supplier firms, it is clear that IT capabilities are becoming a requirement to do business with more sophisticated buyers who rely on IT to coordinate their own supply chains. Supplier selection may still be based on price, quality and service, but without adequate internal IT and IOS capabilities, suppliers will increasingly be eliminated from consideration.

8.3. Generalizability of results

This research looks at the impacts of IT specifically on outsourcing of manufacturing. A natural question is whether our findings would apply in other contexts such as services outsourcing. While services are very different from manufacturing, at least some of the findings might apply to certain service activities. For instance, the use of IOS is critical to coordinating with outsourced providers of services such as software development, customer service, or business processes, so there is likely to be a similar relationship between IOS use and outsourcing based on reduction of external coordination costs. Internal systems, such as computer-assisted development tools, call center applications, and project management software can lower internal coordination and production costs, leading to less outsourcing.

This was not the case in our study, but it is possible that the relative impacts on transaction costs would be different in some service industries. It is likely that there would be a similar substitution effect between internal IT and IOS. For instance, a firm that outsources customer service no longer needs customer service applications, but instead can establish IOS linkages to transmit calls or e-mails directly to its outsource providers. The build-to-order and customization variables would need to be adapted or replaced with other measures of complexity and specificity more appropriate for services.

8.4. Future research directions

There are several opportunities for future research that builds on this study. One would be to extend it to other industries, especially the much larger and broader services sector, where both construct development and hypothesis testing would be required. Another would be to conduct a similar study outside the United States, to determine if the findings are influenced by national environment. In addition, further research is warranted to examine more closely the nature of the interaction between internal IT and IOS. A next step would be to conduct new qualitative research to observe the interaction of the two in practice in order to understand how and when one may substitute or complement the other. This would be valuable both theoretically and practically.

Appendix A

See Table A1.

Appendix B

See Table B1.

Appendix C

See Table C1.

Table A1
List of firms interviewed in PC industry research.

Name	PC related business	Number of interviewees	Locations
IBM PC division[a]	PC maker	24	US, Japan, China, Scotland
Dell	PC maker	12	US, Singapore, Taiwan, Ireland, Japan
Compaq[b]	PC maker	11	US, Japan, Singapore, Malaysia Ireland, Scotland
HP	PC maker	3	US, Japan
Gateway	PC maker	11	US, Ireland, Malaysia, Japan
eMachines[c]	PC maker	2	US
Apple	PC maker	9	US, Japan, Singapore, Ireland
Acer	PC maker	5	US, Taiwan, Netherlands, Mexico
Lenovo	PC maker	3	China
Toshiba	PC maker	3	US, Japan
Sanmina–SCI[d]	Contract manufacturer	2	US, Ireland
Flextronics	Contract manufacturer	2	Mexico, Ireland
Foxconn (Hon Hai)	Contract manufacturer	4	US, China, Ireland, Scotland
Solectron	Contract manufacturer	3	US, 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	US

[a] All interviews were prior to the purchase of IBM's PC division by Lenovo in December 2004.
[b] All interviews were 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 its acquisition by Acer.
[d] Includes interviews with SCI before its merger with Sanmina.

Table B1
Company case studies from PC industry research.

Title (date)	Focus
Acer: an IT company learning to use IT to compete (1999)	Development of internal IT systems to support global manufacturing and distribution network
Apple Computer: the iCEO seizes the Internet (2002)	Use of the Internet for sales, customer service, online services such as iTunes
Compaq Computer: information technology in a company in transition (1999)	Development of internal order processing system to support shift to BTO production
Dell Computer: refining and extending the business model with IT (2000)	Internal IT applications and architecture to support BTO and direct sales models
Dell Computer: using e-commerce to support the virtual company (2001)	Internet-based IOS for online sales, customers support, specialized services
Dell Computer: organization of a global production network (2002)	Structure of an IT-enabled global network linking external suppliers, ODMs, logistics partners, and internal production
Gateway Computer: using e-commerce to move beyond the box and to move more boxes (2001)	Internal IT and IOS to support expanded business lines and distribution networks

Appendix D

See Table D1.

Appendix E

E.1. Robustness test methodology

Internal IT use is measured as an index comprising three factors: (1) the extent to which data can be shared across applications and databases; (2) the extent to which Internet applications and EDI are integrated with internal applications; and (3) the respondent's perception of the firm's IT capabilities compared to other firms in its industry.

IOS use is measured as an index comprising four items: (1) the number of years the firm has been using the Internet; (2) the extent to which suppliers use the Internet; (3) the percent of total purchases conducted on the Internet; and (4) the extent to which the firm's IT systems are integrated with those of suppliers.

For internal IT and IOS, principal component analysis was used to identify components for creating the index. Items were factor analyzed using principal components analysis with varimax rotation and Eigenvalues set at 1.0. An initial analysis of

Table C1
Qualitative data displays.

	Dell	HP-Compaq	IBM	Gateway	Toshiba	Apple
Notebook PCs						
BTO as% of sales	>90%	20–30%	30–40%	0%	<10% (based on interviews)	<10%
% Of NB final assembly outsourced	<10%	90%	10–20%	100%	25–50%	90%
# Of CM/ODMs	3	3–4	2	1	2	2
Assembly process	Two-stage: base unit outsourced, final assembly in-house	One-stage: total process outsourced	One-stage: total process in-house	One-stage: total process outsourced	One-stage: total process in-house for some models, outsourced for low-end models	One-stage: outsourced
Desktop PCs						
BTO as% of sales	>90%	30–40% (HP Direct plus ODM's doing CTO)	30–40%	0%	No DT business in US	<10%
% Of DT final assembly outsourced	<10%	~90%	~80%	100%	n.a.	90%
# Of ODM/CM assemblers	0	2	1	2		2
Assembly process	Two-stage: base unit outsourced, final assembly in-house	Total process outsourced	Total process outsourced	Total process outsourced		Total process outsourced

	Dell	HP-Compaq	IBM	Gateway	Apple
Firm-level variables					
Sourcing	Limited outsourcing of final assembly, receive subassemblies from CMs	Mostly outsourced final and subassembly BTO for direct sales	Mostly in-house final assembly, mixed on subassembly	All outsourced final and subassembly	Complete outsourcing of final and subassembly
Customization	Extensive customization	Limited customization	Moderate customization	Customization for web sales	Customization for web sales
Sales and distribution	Mostly direct sales to corporate buyers and consumers	Mostly retail and reseller sales	Most sales through corporate reseller channels	Mostly large retailer sales after 2000. Several shifts in strategy	Apple Stores, online sales, dealers and large retailers
Internal IT	Custom applications and customized packages Abandoned SAP project in 90s "Keeping IT in-house makes it easier to have a system that works. It is simply harder to integrate when you outsource production because you and your partners have different systems" "The company's quality control processes are automated and integrated into the production process which is all driven by Dell's computer network"	Standard and customized pkgs, e.g., Oracle ERP	SAP-F for order management SAP and other customized pkgs "IT is extremely important for systems suppliers (ODMs), less so for commodity component suppliers With commodity suppliers, there are usually more than one, so you can get coverage With system suppliers, if the CM/ODM can't ship the product, you lose sales	SAP Extensive use of forecasting algorithms to match supply and demand in retail channels "IT is very important We need to transfer product plans, invoices, track raw materials Have to do it electronically to be efficient Suppliers need to be able to handle EDI and have adequate internal IT systems"	Standardized ERP, SCM systems Integration with CMs
Interorganizational IT	Extensive use of direct sales online. Web-based and EDI links with suppliers	Web-based and EDI links with suppliers, CMs and distribution partners	EDI with suppliers and distributors	Web-based direct sales, EDI to business customers, EDI with suppliers	Online sales "The contract manufacturers are passed data using EDI and have integration with our SAP systems"

Table C1 (*continued*)

	Dell	HP-Compaq	IBM	Gateway	Apple
	SCCI	Quanta	Wistron		Ingram Micro
Insights from other interviews					
Internal IT capabilities	"IT is taken into consideration when deciding whether a supplier makes the approved vendor list (AVL)."	"IT is a competitive advantage because it enables us to handle daily orders. It enables us to do BTO"	"Our shop-floor system was developed on our own; we do it on our own because different customers have different requirements and we need to be able to modify the system"		
IOS	"IT gives us the ability to get common processes and to create visibility across the supply chain"				"IT enables outsourcing. If an outsourcing partner has economies of scale, IT allows us to capture that"
Complexity	"We don't have BTO requirements for our suppliers, so our IT needs are less with them than with our customers"	"Customers have different requirements, different systems. Sometimes Quanta needs to modify the shop-floor system in real time based on customer needs. Complexity of process causes need for customizable IT"			"As we get towards BTO, higher turn objectives, the need for back end integration goes up. The problem with the new approach is the information systems required to support it"

Table D1
Industry breakdown.

	Frequency	Percent	Valid percent	Cumulative percent
SIC – 2 digits				
Valid				
Oil and gas extraction	1	.3	.3	.3
Textile mill products	3	1.0	1.0	1.3
Apparel and other textile products	4	1.3	1.3	2.7
Furniture and fixtures	7	2.4	2.4	5.1
Paper and allied products	3	1.0	1.0	6.1
Printing and publishing	1	.3	.3	6.4
Chemicals and allied products	6	2.0	2.0	8.4
Rubber and misc. plastics	12	4.0	4.0	12.5
Leather and leather products	1	.3	.3	12.8
Fabricated metal products	12	4.0	4.0	16.8
Industrial machinery and equipment	61	20.5	20.5	37.4
Electronic and other electric equipment	73	24.6	24.6	62.0
Transportation equipment	26	8.8	8.8	70.7
Instruments and related products	64	21.5	21.5	92.3
Misc. manufacturing industries	8	2.7	2.7	94.9
Water transportation	1	.3	.3	95.3
Wholesale trade-durable	1	.3	.3	95.6
Wholesale trade-nondurable	1	.3	.3	96.0
Retail trade	1	.3	.3	96.3
Business services	8	2.7	2.7	99.0
Engineering and management services	3	1.0	1.0	100.0
Total	297	100.0	100.0	

internal IT use included the three items listed above, as well as the number of total applications in use. The latter item did not load with the other factors. When dropped, the remaining factors made an acceptable single item solution. For IOS use, the four items listed were the only measures considered in the survey, and loaded as a single solution. In both cases, the factor scores were saved as variables using regression method, and these factor scores constitute the index variables. Results of the factor analysis are below (see Table E1).

Table E1
Results of principal component analysis.

	Component 1
Internal IT	
Data can be shared among different applications and databases	.727
Internet applications and EDI are integrated with other applications	.743
Rate your firm's IT capabilities compared to other firms in your industry	.745
IOS	
How many years has your firm purchased over the Internet	.667
Your IT systems are integrated with those of your suppliers	.664
% Of procurement conducted on the Internet	.587
Existing suppliers use the Internet	.746

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