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Research Note

Do Large Firms Become Smaller by Using Information Technology?

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The relationship between information technology (IT) and a key organizational design variable, firm size, is an important area of study, particularly given the ongoing transition to an information-based economy. To better understand the more nuanced aspects of the relationship, we formulated a bidirectional and time-lagged model that incorporates different perspectives from organizational theories and transaction cost economics. Our two models—the bidirectional and one-year lagged model and the bidirectional and two-year lagged model—were tested using nine-year panel data on IT spending, IT stock, coordination costs, firm size, and relevant control variables for 277 manufacturing firms. We found a sequential interaction between IT and firm size in both of the two models: as a firm grows in size, its coordination activities increase; the firm then uses more IT to handle the increased activities of coordination; this increased use of IT, in turn, decreases coordination costs, and eventually, the size of the firm decreases. It was also found that the presence of coordination costs is necessary for the sequential interaction between IT and firm size, indicating coordination between and within firms is a major reason for firms to invest in IT and for IT effect to take place on firm size. This study has taken an initial step by attempting to empirically examine dual causality and longitudinal effects between IT and firm size, and to reconcile different theoretical perspectives on the relationship between them. We hope this work can act as a catalyst for developing a better understanding of the complex relationship between IT and organizations, with the ultimate goal of offering robust prescriptions for successful structural change.

Key words: information systems and organizational change; bidirectional model; time-lagged model; longitudinal research; firm size; coordination costs; production theory; transaction cost economics; information processing perspective; coordination theory; structuration theory
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1. Introduction

Leavitt and Whisler (1958) predicted that information technology (IT) would lead to changes in organizational structure. Since then, the nature of the relationship between IT and organizational change has become an important concern to managers and researchers. More importantly, the diffusion of the Internet and electronic commerce is widely considered to be a critical force that causes substantial changes in organizations and even the economy as a whole (Forman 2005, Henry et al. 1999). Consequently, several theories about the impact of IT on organizational change have been proposed (e.g., Attewell and Rule 1984; George and King 1991; Gurbaxani and Whang 1991; Huber 1984, 1990; Jones and Karsten 2008; Malone et al. 1987; Markus and Robey 1988; Orlikowski and Robey 1991; Pfeffer and Leblebici 1997; etc.). However, empirical evidence on the relationships of IT to specific kinds of organizational changes remains scant.

The principal objective of this study is to provide a more complete understanding of the link between IT and organizational change. To do this, this study proposes and empirically examines a bidirectional and time-lagged model for the relationship between IT use and firm size, one important variable in organizational change. In the IS literature, there has been only one industry-level study that empirically confirmed the impact of IT on firm size (Brynjolfsson et al. 1994). However, the study confirmed only the unidirectional impact of IT on firm size. To elucidate the complex relationship between IT and organizations, many information systems (IS) researchers have suggested that reciprocal causality between IT and organizations should be examined (DeSanctis and Poole 1994, Markus and Robey 1988, Orlikowski and Robey 1991, Robey and Boudreau 1999). Moreover, Dewan et al. (1998) and Hitt (1999) have provided empirical evidence that implies the relationship between IT and organizational change may be closer to predicting a time-series effect than a cross-sectional effect. Therefore we incorporated both bidirectional and time-lagged relationship between IT and firm size into our research model.[1] We operationalized firm size as the number of employees[2] and IT use as IT annual budget and IT capital stock.

To the best of our knowledge, this is the first study in the IS area to incorporate reciprocal causality between IT and firm size into a research model and to empirically test the model through longitudinal analysis. This is particularly important given the current interest in developing a better understanding of how IT transforms organizations and creates value (Melville et al. 2004, Sambamurthy et al. 2003).

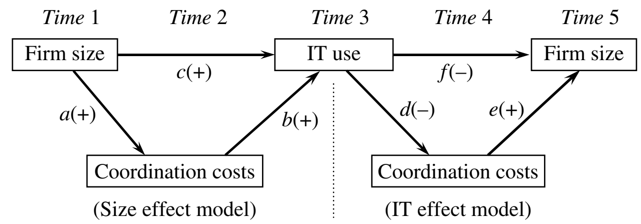
2. Theoretical Framework and Proposition

Brynjolfsson et al. (1994) examined the impact of IT investment on firm size. Using economywide data on IT investment, Brynjolfsson et al. (1994) found that investment in IT is significantly associated with a subsequent decrease in the average size of firms. This finding on the impact of IT on firm size espouses the technological imperative perspective that positions IT as a cause of organizational change (cf. Markus and Robey 1988).

On the other hand, we might argue that the causal relationship between IT and firm size is reversed. Based on organizational theories, it is likely that as firms grow in size, their coordination activities increase. As a result, firms increase their IT use to facilitate increased coordination activities (Baldridge and Burnham 1975, Child 1984, Galbraith 1977, Shin 2006). This expectation is consistent with the organizational imperative perspective that views IT as a tool for solving organizational problems (cf. Davis et al. 1984, Jasperson et al. 2002, Markus and Robey 1988).

We attempt to embrace the two contrary perspectives on the relationship between IT and firm size into a single model. In particular, we seek to formulate a more complete and general model of the relationship between IT use and firm size by (1) including a recursive relationship, (2) incorporating a time-lagged effect, and (3) explicitly considering coordination costs as a mediator.

Figure 1 **Conceptual Research Model: A Bidirectional and Time-Lagged Model**



2.1. Research Model: A Bidirectional and Time-Lagged Model

To better understand the interaction between IT and organizational change, we propose a bidirectional and time-lagged research model (Figure 1). There have been empirical studies on the relationship between IT and firm size.[3] While some researchers use the technological imperative (IT drives firm size), others use the organizational imperative (firm size drives the use of IT). All the previous empirical studies are unidirectional, and most are cross-sectional and do not include time lags. Further, none expands the nomological network through inclusion of a mediator. This study empirically attempts to unravel the often hidden complexity that characterizes the relationship between IT and organization. Two-way causality has been suggested by many IS researchers (DeSanctis and Poole 1994, Markus and Robey 1988, Orlikowski and Robey 1991, Robey and Boudreau 1999). This perspective is consistent with structuration theory and the duality of technology, which views IT as both a consequence and an antecedent of organizational action (Orlikowski 1992, Orlikowski and Robey 1991). While a comprehensive test of structuration theory is beyond the scope of this study, this research reflects the dialectic relationships espoused by the theory. Knowledgeable human actors deploy IT within or in response to an institutional context, which can, in turn, collectively influence the institutional properties themselves.

As shown in Figure 1, moreover, the research model spans five periods to account for the time-lagged effects on the relationships among IT, coordination costs, and firm size. Conceptually, this simply means that a certain amount of time is needed for one variable in the model to exert influence on another

[1] To confirm our study's contributions, we contrast our study with the previous studies of Brynjolfsson et al. (1994), Dewan et al. (1998), and Hitt (1999) in Appendix A.

[2] Firm size can be measured by other surrogates such as sales, assets, and value-added. Our empirical results may be confined to firm size measured by the number of employees.

[3] To make a more convincing argument on our study's contributions, we have searched for previous studies on the relationship between IT and firm size (See Appendix B).

variable. In theorizing the impact of IT on firm size, Malone and Rockart (1991) observed three phases of the impact over time: first, using IT to coordinate existing tasks more effectively (first-order effect), followed by applying IT to conduct more coordination that was not previously possible (second-order effect), and finally, deploying IT to develop new organizational forms that are coordination intensive (third-order effect). This time-lagged effect has been empirically demonstrated by Brynjolfsson et al. (1994), who showed that a decline in firm size is significantly correlated with IT investments for one-year to three-year lags. It might also be impossible for managers to make immediate IT investments to facilitate increased coordination activities, making it reasonable to presume a delay between organizational decisions on IT adoption and the implementation of those decisions.

Figure 1 also shows that the research model consists of two submodels, i.e., size effect model and IT effect model. In the size effect model, we would expect that as firms grow in size, coordination activities within their organizations or with other firms will also increase, and then firms will use more IT to facilitate the increased activities of coordination. In the IT effect model, the increased use of IT will result in decreases in coordination costs, and the size of the firms will eventually decline. Our core research proposition of the sequential interactions among firm size, coordination costs, and IT can thus be stated as follows:

As firms grow in size, coordination costs increase and IT is used more. This increased use of IT, in turn, decreases coordination costs, and eventually, the size of firms declines.

2.2. Size Effect: Positive Impact of Firm Size on IT Use

Based on organizational theories such as information processing perspective and coordination theory (Galbraith 1977, Malone 1988), we argue that because larger firms tend to be internally diverse, have more resources, and have more boundary spanners (Grover et al. 1997), they can afford and should use information systems to facilitate coordination among their subunits, as well as with other firms. Hence we expect a *size effect*, indicating that larger firms use more IT.

In previous studies on the relationship between organizational structure and IT, size is considered a variable that influences the use of IT (e.g., Audia and Greve 2006, Carter 1984, Klatzky 1970, Pfeffer and Leblebici 1997, etc.). In addition, many innovation adoption studies suggest that size is likely to lead directly to an economy of scale, which will enhance the feasibility of innovation adoption (Grover et al. 1997, Kimberly and Evanisko 1981, Lai and Guynes 1997, Lee and Xia 2006, Moch and Morse 1977, Swanson 1994, etc.). These studies imply that there is a fixed component of the cost of implementing an information system; therefore, the larger the organization, the greater the likely benefit from implementation (Gremillion 1984). For example, Swanson (1994) argued that larger organizations with a greater variety of specialized tasks and higher input volume to process can justify more frequent adoption of Type II and Type III IS innovations.[4] In an empirical study that provided support for the Swanson (1994) model, Grover et al. (1997) found that larger organizations are early adopters of IT in their administrative structure and core business.

In literature espousing the information processing perspective, firm size has been viewed as a predictor of the adoption of administrative innovations, including computerization or IS use (Gremillion 1984). Thus the information processing perspective also supports the size effect. Furthermore, it posits that an increase in organizational size is usually associated with an increase in problems with communications and coordination (Galbraith 1977, Kimberly 1976). Therefore, as the organization grows and internal communications and integration become more difficult, it adopts various mechanisms to overcome that difficulty (Baldridge and Burnham 1975, Galbraith 1977). One of the strategies is to invest in IS, which allow the organization to process more information without overloading the communications channels. Thus, to the extent that increasing size means increasing complexity or coordination, size should also be positively related to the increasing use of ITs and systems (Gremillion 1984).

The rationale for the positive impact of firm size on IT use, i.e., size effect, and the mediating effect of coordination can be summarized as follows:

- Larger organizations are more likely to be able to afford the costs of innovation;
- Larger organizations have a greater need for a sophisticated IT infrastructure for communication and coordination; and
- The complexity of larger organizations leads to a greater need for information infrastructure that can improve managerial control and planning systems.

Consistent with previous theoretical developments and empirical findings in organizational studies, we explicitly recognize the mediating role of coordination in explaining the impact of firm size on IT use in the left half of our research model (Figure 1). We expect a direct impact of firm size on IT use and an indirect impact (mediation) of firm size on IT use through coordination costs. This *size effect* is postulated as follows:

Part or all of the positive impact of firm size on IT use is transmitted through an increase in coordination costs.

[4] Swanson (1994) classifies IS innovations into three types, based on their ability to support IS core (Type I), administrative core (Type II), or technical core (Type III). See Swanson (1994) for details.

2.3. IT Effect: Negative Impact of IT Use on Firm Size

We offer three plausible explanations of the *IT effect*, i.e., the negative impact of IT use on firm size: the labor substitution effect, the coordination structure effect, and the outsourcing effect. The *labor substitution effect* simply refers to the production of output with fewer people due to the use of IT. During the approximately 50 years since the advent of computerization, the most fundamental impact of IT has been the ability to substitute for existing tasks. This concept, described as the first-order effect by Malone and Rockart (1991), results in increased operational efficiency. To justify these IT applications, IS executives can appeal to the conventional investment rationale, because the benefits basically operate through the parameters of the existing structures and render a linear extension of production resources. While this offers a straightforward explanation of the IT impact, the labor substitution effect of IT has been wrought with controversy over the years. Empirical evidence that links IT to employment has not delivered on predictions of wholesale elimination of jobs (Cyert and Mowery 1987). The impact is even less clear, with arguments ranging from job reduction, to evidence of upgrading job skills with new roles in organizations (Bresnahan et al. 2002, Malone and Rockart 1991). Therefore, it is difficult to make a compelling case for the IT effect based on labor substitution alone. In fact, while labor substitution was the major theme in the early days of computerization when most IT investment was aimed at automating transaction processing and clerical work, it can be argued that most organizations have moved well beyond this first-order effect and have absorbed the influence of coordination structure and outsourcing effects, as described next.

The *coordination structure effect* refers to the implementation of new coordination-intensive structures made possible by the advent of IT. Malone and Smith (1988) argued that many historical changes in firm structures can be explained by changes in technology that enable the economization of coordination costs. The spectrum of IT applications, collectively known as coordination technologies, has begun to transform organizations and industries into "coordination-intensive" structures (Malone 1988, Malone and Rockart 1991). By streamlining the way processes are organized and managed both within and across organizational boundaries, increasing the span of control, and reducing levels in the hierarchy, companies have reduced expensive coordination costs and created more responsive structures (Hammer and Stanton 1999, Hammer 2001). However, it is the differential impact of IT on two subcategories of coordination costs that will determine the coordination structure effect on size. Coordination costs can be divided into two subcategories: internal coordination costs and external coordination costs. Internal coordination costs include all costs incurred for managerial decision-making, accounting, planning, and control processes. External coordination costs represent the costs of coordinating external relationships with suppliers and customers such as marketing, purchasing, and advertising activities. Because both internal and external coordination costs include information-intensive activities, such as gathering information, communicating, and making decisions, IT is particularly useful for facilitating these kinds of activities. However, if IT reduces internal coordination costs more than external coordination costs, we would expect a greater interest in taking on more activities in-house. If, in contrast, IT reduces external coordination costs more than internal coordination costs, then we would expect firms to buy from the market, thereby reducing firm size (Brynjolfsson et al. 1994, Malone et al. 1987). Malone and colleagues argued that the latter argument is more likely (Malone 1987, Malone et al. 1987, Malone and Smith 1988). For example, Malone and Smith (1988) suggested that while the division of labor and knowledge in classical organizational designs depends on coordination through the managerial hierarchy, IT will change these coordination mechanisms and reverse the trend toward the creation of larger firms. Furthermore, Pinsonneault and Kraemer (1993) also found that new coordination structures have been linked to a reduction of people in middle management in cases in which IT decisions are centralized (Pinsonneault and Kraemer 1993).[5]

Finally, the *outsourcing effect* is often informed by transaction cost economics (TCE).[6] The outsourcing effect considers the influences of IT on external coordination costs. Malone and colleagues argued that by reducing the costs of coordination activities with external organizations, IT can make buying things externally more attractive to firms. If more outsourcing occurs, thus we would expect a decrease in the average number of employees per firm. We believe that this expectation can be supported by the following reasons. First, it is likely that unit (or marginal) costs of external coordination are often greater than those of internal coordination (Malone and Rockart 1991;

[5] See the next paragraph for additional explanations for the argument that IT leads to smaller firms by reducing external coordination costs more than internal coordination costs.

[6] A full treatment of TCE would require consideration both of production costs and coordination costs (Malone et al. 1987). However, our primary focus here is on coordination costs that would be influenced more by IT (cf. Brynjolfsson et al. 1994, Malone et al. 1987). To distinguish coordination costs from production costs, we define coordination costs as costs incurred to coordinate nonproduction activities inside the firm and with suppliers and customers.

Williamson 1981, 1985). The costs of finding suppliers, negotiating contracts, and paying bills often make external coordination more expensive than coordinating the same activities internally (Brynjolfsson et al. 1994, Williamson 1985). Transactions with external parties often require more negotiation and coordination than those with internal parties. Thus we would expect that firms would try to reduce external coordination costs more than internal coordination costs by investing in IT ceteris paribus. Second, this expectation is consistent with empirical results of previous studies, which are unequivocal in their assertion that the effect of IT on external coordination costs is stronger than that on internal coordination costs (Brynjolfsson et al. 1994, Dewan et al. 1998, Hitt 1999). Brynjolfsson et al. (1994) provided some empirical evidence that IT investment is correlated with a decrease in firm size, which indicates IT might have a greater effect on external coordination than on internal coordination. Dewan et al. (1998) and Hitt (1999) found a strong negative relationship between IT and vertical integration, and a weaker positive relationship between IT and diversification. These findings indicate that "IT is associated with decreases in internal and external coordination costs and that the effect of IT on external coordination costs is stronger and more consistent" (Hitt 1999, p. 145). Third, it is important to realize that a good proportion of IT investment in internal coordination (e.g., supplier databases and inventory and scheduling systems) directly reduces external coordination costs, while the reverse is almost never true. Therefore, it appears that the disproportionate reductions in external coordination costs are a more powerful explanation of economywide changes in firm sizes than are the reductions in internal coordination costs (Kling et al. 2001). Accordingly, we explicitly recognize the mediating role of coordination in explaining the impact of IT use on firm size in the right half of our research model (Figure 1) and postulate that the *IT effect* is as follows:

Part or all of the negative impact of IT on firm size is transmitted through a reduction in coordination costs.

3. Research Variables and Methodology

Before delving into the research variables and methodology, it is necessary to explain certain basic parameters of the research model such as the unit of analysis and the time lag interval. While Brynjolfsson et al. (1994) used industry-level data on IT investment, we use more detailed firm-level data on IT use to test our research model. The results of our firm-level study should provide additional insight into the dynamics of the relationship between IT and firm size by tracing the cause and effect of coordination costs as mediating variables in this relationship.

Given the paucity of longitudinal research on the relationship between IT and firm size, it is difficult to find a rigorous basis on which to establish the time lags between variable measurements. However, Brynjolfsson et al. (1994) found that firm size is a function of IT investment lagged for two and three years. Hitt et al. (2002) also showed that it takes about two years to install enterprise systems, indicating even longer for the systems to affect firm size. Furthermore, most of longitudinal research in other discipline areas has used one-year lag between variable measurement times that would be sufficiently short to capture key events and sufficiently long to permit the hypothesized causal processes to take place among key variables (cf. Van de Ven and Walker 1984, Weill 1992). Therefore, we employ both of one-year lag and two-year lag between our key variables. While the one-year lagged model represents the sequential relationship among firm size, IT use, and coordination costs over a period of five years, the two-year lagged model represents the relationship over a period of nine years. The one-year lagged model proposes that it takes two years for IT use to lead to a decline in firm size. In the two-year lagged model, it is proposed that there are four-year lag between IT use and firm size. We believe that the two-year lag among key variables would be sufficiently long to permit the impacts to take place among them. We obtain data regarding a set of manufacturing firms over nine years from 1989 to 1997.[7]

3.1. Variable Measures and Data Sources

Our main research variables are IT use, firm size, and coordination costs. In addition, control variables such as diversification, vertical integration, sales, non-IT use, and research and development (R&D) expenditure are employed for our firm-level analysis. The variables used in this study are summarized in Table 1, along with their surrogate, source, and deflator.

3.1.1. IT Use. As a surrogate of IT use, we employ both of IT (flow) spending and IT stock. To measure the IT spending, we use annual IT budget data provided by *InformationWeek* (IW) that were used by previous studies (e.g., Hitt 1999, Ray et al. 2009). Since 1991, IW magazine has annually provided data regarding IT budgets and a list of 500 significant

[7] The time period of the study is reflective of a period where there was steady increase in IT investments that preceded the anomalies of the dot com boom and bust. Therefore, it reflects a reasonable period to test the lagged model. For our study, manufacturing is particularly interesting because of the harsh technical demands of manufacturing coordination that brings many different groups and activities together and because of the constant experimentation taking place with new forms of coordination (Kling et al. 2001).

Table 1 Data Sources and Variable Measures

Variable	Surrogate	Source	Deflator*
IT use (IT): *IT spending*	IT budget	CI survey	Deflator for computer systems (Gordon 1990) and index of total compensation for IT labor expenses
IT use (IT): *IT stock*	$\sum_{r=0}^{t}(1-\delta)^r \mathrm{IT}_{t-r}$ (Berndt et al. 1995)	CI survey	Deflator for computer systems (Gordon 1990) and index of total compensation for IT labor expenses
Firm size (size)	Number of total employees	Compustat	Not deflated
Coordination costs (CC)	SG&A expenses (excluding R&D)	Compustat	Producer price index for intermediate materials, supplies and components
Non-IT spending (NIT)	Net capital expenditures	Compustat	GDP implicit deflator for fixed investment
Non-IT capital (NITC)	Net property, plant and equipment (PPE)	Compustat	GDP implicit deflator for fixed investment
Sales (SA)	Net sales	Compustat	Industry gross output price deflators of BEA
R&D (RD)	R&D expense	Compustat	Producer price index for intermediate materials, supplies and components
Diversification (DI)	Diversification index	Compustat	Not deflated
Vertical integration (VI)	Vertical industry connection (VIC) index	BEA and Compustat	Not deflated

*Using these deflators, variables are converted to constant 1992 dollars.

IT users.[8] This data set is compiled in an annual survey by the Computer Intelligence (CI) Corporation, a market research company that surveys IT chief managers to collect data on central IT budgets and expenditures. The IT budget is defined as corporatewide capital and operating expenditures for IS and services. We obtained 688 observations of IT spending for 277 manufacturing firms for the five-year period from 1991 to 1995. Since IT spending data are needed at the third year in our one-year lagged model, we collected data on other variables for the firms having IT spending data over the nine-year period from 1989 to 1997 from the Compustat database.[9] In addition to the flow measure of IT use, we also use IT stock as another surrogate of IT use. Since stocks are the ultimate result of the accumulation of the relevant flows, we calculate IT stock by accumulating the IT spending. To do this, we apply the perpetual inventory method that has been used in many economics and marketing studies (e.g., Berndt et al. 1995, Fischer et al. 2010). Thus we define the cumulative IT spending (i.e., IT stock), S_t, at year t as

$$S_t = (1-\delta)S_{t-1} + F_t$$
$$= \sum_{r=0}^{t}(1-\delta)^r F_{t-r}$$

where F_t is IT budget at year t, and δ is the yearly depreciation rate. To estimate the depreciation rate δ, it is assumed that the period of depreciation of IT capital is three years. For the analysis of IT stock, we include only those firms that have at least three consecutive years of IT budget data.

3.1.2. Firm Size. We measure firm size using the total number of employees (cf. Blanchflower et al. 1991, Blau et al. 1976, DeLone 1981). This measure of firm size enables us to analyze the IT effect as well as the size effect. Gurbaxani and Shi (1992) argued that IT can lead to shifts in a firm's make versus buy decisions (vertical firm size) as well as in the scope of the customer markets (horizontal firm size) in which it participates by reducing external coordination costs. While sales (revenues) are related to only the horizontal size, the number of employees encompasses both the vertical size and horizontal size.

3.1.3. Coordination Costs. We define coordination costs as the costs incurred to coordinate nonproduction activities inside the firm and with suppliers and customers. This definition of coordination costs has been employed by many studies (cf. D'Aveni and Ravenscraft 1994; Mitra and Chaya 1996; Shin 1997, 1999; Strassmann 1997, 1999; Bharadwaj 2000;

[8] IT budget alone might not provide a complete picture of corporate IT spending because IT managers may not hold the purse strings for all corporate IT expenditures. The central IT budget might not include spending on IT by departments other than the IS department. It is likely that the IT expenditures by non-IS departments, which are not reflected in the central IT budget, are not significantly large. Therefore, IT budget is used as a measure of IT spending in our study.

[9] To use a different deflator for IT labor expenditure, we extracted the IT labor expenditures from the total IT budget. Thus, the IT labor spending is calculated from the Computerworld data as the total IT budget multiplied by the fraction of the budget spent on IS staff. And the IT labor spending is deflated using the Index of Total Compensation (cf. Dewan and Min 1997). The other portion of the IT budget is deflated using the deflator for computer systems (cf. Gordon 1990). The total IT spending is calculated by adding the IT labor spending and the other IT spending portion. Notably, Computerworld did not provide data on the fraction of the budget spent on IS staff for all our sample firms. Therefore, we use the industry average value of the Computerworld data for our sample firms with missing data on the fraction. We additionally deflated the total IT spending using the GDP deflator. In this case, we obtained similar results. Thus, our results were insensitive to IT deflators.

Ray et al. 2009).[10] To construct the measure of coordination costs, selling, general, and administrative (SG&A) expenses are obtained from Compustat database (Poston and Grabski 2001; Ray et al. 2009; Shin 1997, 1999; Strassmann 1997, 1999). SG&A expenses in Compustat database are defined as all commercial expenses of operation (such as, expenses not directly related to product production) incurred in the regular course of business pertaining to the securing of operating income. According to Generally Accepted Accounting Principles (GAAP), SG&A expenses can be divided into selling expenses and general and administrative expenses (Hansen 1990). Selling expenses include all costs incurred in performing sales activities such as salaries and commissions of salespeople, advertising, warehousing, customer service, and shipping. General and administrative expenses include overall business expenditures, such as the salary of the president, legal fees, general accounting, and research and development. Given the definition of SG&A expenses, coordination costs can be measured by SG&A expenses (Strassmann 1999).

As mentioned above, coordination costs can be divided into two subcategories—internal coordination costs and external coordination costs (Brynjolfsson et al. 1994). The itemized SG&A expenses in the *Compustat User's Guide* delineate well into one of the two subcoordination costs (see Appendix C). Strassmann (1999) found that firms incur SG&A expenses in the process of managing, planning, promoting, and coordinating their organizations for effective delivery of goods and services to customers. After much experimentation, then he argued that SG&A is the best representation of the costs of information management (i.e., coordination) that are available from public sources (Strassmann 1999, p. 1). This also indicates that SG&A is an appropriate surrogate for coordination costs. Furthermore, SG&A expenses have been used as a measure of coordination costs in prior IS studies that attempted to measure coordination costs using readily accessible financial data (e.g., Francalanci and Maggiolini 1999; Poston and Grabski 2001; Ray et al. 2009; Shin 1997, 1999; Strassmann 1997, 1999). Recently, for instance, Ray et al. (2009) used SG&A as a measure of coordination costs in their *Information Systems Research* study. They suggested that SG&A reflects the selling and administrative costs incurred to coordinate activities inside the firm and with suppliers and customers, and thus is an aggregate measure of coordination costs (Bharadwaj 2000, D'Aveni and Ravenscraft 1994, Mitra and Chaya 1996, Poston and Grabski 2001).

We measure coordination costs by subtracting research and development (R&D) expenses from SG&A expenses because the R&D expense represents all costs that relate to the development of new products. We then readjusted the adjusted SG&A expenses to avoid a double counting of the IT budget in SG&A expenses.[11] Because the Compustat database provides only an aggregate amount of SG&A (i.e., not all of the itemized SG&A expenses are available from the database, except for some itemized expenses such as R&D expense, advertising expense, depreciation, etc.), the readjusted surrogate for coordination costs does not allow us to separate them into internal and external coordination costs. As mentioned in our theoretical framework, however, our thesis posits that the decrease in firm size by IT reflects labor substitution, coordination structure, and outsourcing effects, where in the latter two cases, IT has a greater effect on external than internal coordination costs.

3.1.4. Control Variables. Through the review of previous studies, diversification, vertical integration, sales, non-IT use, and R&D expense are selected to be controlled for in examining the bidirectional relationships between IT and firm size. Because we are using a panel of data from different industries over different periods, we also control for industry effects and year effects (Greene 2003).

[10] It should be mentioned that while Brynjolfsson et al. (1994) and Malone et al. (1987) define coordination costs as the costs incurred to coordinate both of production and nonproduction tasks, we define our coordination costs as costs related to only nonproduction activities. Therefore, our coordination costs are likely to be understated. However, we believe that compared with coordination costs in nonproduction, the coordination costs due to production (overhead costs) are relatively small. According to Strassmann (1997), the overhead costs account for about 15% of SG&A, on the average (p. 59). Also, the overhead costs and coordination costs in nonproduction have same relationship with firm size and IT. Therefore, we believe that the omission of overhead costs does not significantly bias our results.

[11] While capital expenditures related to IT are recorded as fixed assets (e.g., equipment), operating IT expenditures are reported as SG&A expenses. Therefore, coordination costs measured by SG&A and non-IT spending measured by capital expenditures should be adjusted by subtracting the operating IT expenses and capital IT expenses, respectively. Because data on the level of allocation of IT budget to capital IT expenditures were not available, we assumed that the level of allocation for capital IT expenditures is two-third (i.e., one-third to operation expenditures). This means that if the total IT spending goes to capital IT expenditures, then the capital IT expenditures will be depreciated into SG&A over three years. Accordingly, we have allocated the one-third of the IT budget to operating IT expenditures (SG&A) and the rest of the IT budget to capital IT expenditures. And then we have subtracted both of the operating IT expenditures and the depreciation of the capital IT expenditures from SG&A to avoid the double counting of them. To check whether our results were affected by the level of the allocation, we have performed a sensitivity analysis for two extreme cases: (1) a case of allocation of total IT budget into capital expenditure (i.e., 0% to SG&A); and (2) a case of allocation of total IT budget into operating expenditure (i.e., 100% to SG&A). In addition to these two extreme cases, we have also done an additional sensitivity analysis for the one-fifth allocation ratio case (i.e., 20% to SG&A). We have found the results were stable across the four cases.

The scope variables, such as diversification and vertical integration, are often correlated with the scale (number of employees) of the firm (Dewan et al. 1998). For example, larger firms tend to be more diversified, more vertically integrated, and have more output (sales). The effect of IT on the scale variable might be confounded by the variation in scope variables and other scale variables (Dewan et al. 1998, Hitt 1999). Therefore, to isolate the effects of IT on firm size, it is important to control for scope and other scale variables.

Further, previous studies have found that diversification, vertical integration, and output of the firm are related to IT investment (Dewan et al. 1998, Hitt 1999). Dewan et al. (1998) and Hitt (1999) have found that diversification leads to an increase in coordination requirements across multiple lines of business units, and subsequently to a higher demand for IT investment. However, more vertically integrated firms have been shown to have less IT. Thus, a lower level of vertical integration leads to a higher level of IT investment. Dewan et al. (1998) also found that a higher level of output (sales) requires greater IT investment.

Diversification. Diversification refers to the extent to which a firm operates in multiple lines of business. The entropy measure is used to calculate the extent of diversification in our study. This measure takes into account the number of industries in which a firm operates and the relative importance of each industry's sales (Hoskinsson et al. 1993, Palepu 1985). This index has a lower limit of zero (i.e., a single-business company) but no upper limit. Data for computing the entropy measure of diversification are obtained from Compustat Business Segment database for our sample firms.

Vertical Integration. We employ Maddigan's vertical industry connection (VIC) index as the measure of vertical integration. It measures the proportion of economic processes carried out within the firm (Balakrishnan and Wernerfelt 1986, Dewan et al. 1998, Hitt 1999). The minimum value of VIC is 0, which indicates that the firm is only producing products in one industry, or that the firm is involved in several industries but no industry serves as either an input or an output to another (Maddigan 1981). The upper limit of the value of VIC is 1. The VIC index is constructed from the input-output matrix for the United States (Lawson 1997a, b). The matrix is based on a 97-industry classification scheme, roughly corresponding to the two-digit SIC classification (Dewan et al. 1998, Santhanam and Hartono 2003). For each firm, Compustat Business Segment data are used to classify each segment into BEA industries. We calculate the VIC index for each firm following the methodology of Maddigan (1981).

Other Control Variables. In addition to diversification and vertical integration, we control for the effect of sales. Standard production function reasoning suggests that a higher level of output would require greater IT input, for a given level of other inputs (Dewan et al. 1998). *Sales* are often used as a proxy for the gross output of a firm (Dewan et al. 1998) and are correlated with the size (number of employees) of the firm. Since our primary focus is on structural (coordination) aspects of the firm, we control for sales.

We also control for the effects of non-IT use and R&D expense on firm size and IT use. These variables have been used as control variables for IT investments or coordination costs in previous studies (Brynjolfsson et al. 1994, Dewan et al. 1998, Hitt 1999, Shin 1997). Like IT use, *non-IT use* is also measured as non-IT spending and non-IT stock. Non-IT spending is calculated by net capital expenditure. Capital expenditure represents cash outflow or funds used for additions to the company's property, plant, and equipment (PPE). Non-IT stock is measured by net PPE. For a given level of output, non-IT capital can be substituted with IT capital (Dewan et al. 1998). Also, it is likely that non-IT spending is positively related to firm size. On the other hand, some Schumpeterian researchers suggested that large firms are large because of previous innovative successful R&D activities (Jarrell 1983). Accordingly, we assume that R&D activities increase firm size. IT investment would also be a result of R&D activities. One aspect of R&D activities involves staying up to date on innovations and new technological developments, including new IT, and adopting them when appropriate (Daft 1995).

Finally, we include dummies for the two-digit SIC submanufacturing industries in our estimation models to allow broad *industry* groups to have different mean levels of IT spending, firm size, and coordination costs. We also employ indicators for each *year* in the sample period to account for possible macroeconomic trends that might have influenced our response variables. To neutralize the effects of inflation, all variables that are measured in dollar terms—IT use, coordination costs, R&D expenses, non-IT use, and sales—are converted from current dollars to constant 1992 dollars using the appropriate price deflator for each of the variables (see Table 1).

3.2. Methodology

The data for manufacturing industries over the period of nine years are pooled and corrections are made for potential simultaneity, multicollinearity, and heteroskedasticity. We also transform size, IT use, coordination costs, R&D expenses, non-IT use, and sales into natural logarithms.

3.2.1. Empirical Models. To estimate the size and IT effects in our conceptual model (Figure 1), we adopt the testing scheme for mediating effect suggested by Venkatraman (1989). According to Venkatraman (1989), we formulate the following set of equations:[12]

$$\begin{aligned}\mathrm{IT}_{it+2} = {}& \alpha_0 + \alpha_1 \mathrm{SIZE}_{it} + \alpha_2 \mathrm{CC}_{it+1} + \alpha_3 \mathrm{NIT}_{it+1} + \alpha_4 \mathrm{DI}_{it+1} \\ & + \alpha_5 \mathrm{VI}_{it+1} + \alpha_6 \mathrm{SA}_{it+1} + \alpha_7 \mathrm{RD}_{it+1} \\ & + \alpha_8 \mathrm{Industry}_{it+2} + \alpha_9 \mathrm{Year}_{it+2} + \varepsilon_{it+2}, \qquad (1)\end{aligned}$$

$$\begin{aligned}\mathrm{CC}_{it+1} = {}& \beta_0 + \beta_1 \mathrm{SIZE}_{it} + \beta_2 \mathrm{DI}_{it} + \beta_3 \mathrm{VI}_{it} + \beta_4 \mathrm{SA}_{it} \\ & + \beta_5 \mathrm{Industry}_{it+1} + \beta_6 \mathrm{Year}_{it+1} + \varepsilon_{it+1}, \qquad (2)\end{aligned}$$

$$\begin{aligned}\mathrm{SIZE}_{it+4} = {}& \gamma_0 + \gamma_1 \mathrm{IT}_{it+2} + \gamma_2 \mathrm{CC}_{it+3} + \gamma_3 \mathrm{NIT}_{it+3} \\ & + \gamma_4 \mathrm{DI}_{it+3} + \gamma_5 \mathrm{VI}_{it+3} + \gamma_6 \mathrm{SA}_{it+3} + \gamma_7 \mathrm{RD}_{it+3} \\ & + \gamma_8 \mathrm{Industry}_{it+4} + \gamma_9 \mathrm{Year}_{it+4} + \varepsilon_{it+4}, \qquad (3)\end{aligned}$$

$$\begin{aligned}\mathrm{CC}_{it+3} = {}& \eta_0 + \eta_1 \mathrm{IT}_{it+2} + \eta_2 \mathrm{DI}_{it+2} + \eta_3 \mathrm{VI}_{it+2} + \eta_4 \mathrm{SA}_{it+2} \\ & + \eta_5 \mathrm{Industry}_{it+3} + \eta_6 \mathrm{Year}_{it+3} + \varepsilon_{it+3}, \qquad (4)\end{aligned}$$

where

IT_{it} = the natural log of IT use for the *i*th firm in year *t*,
SIZE_{it} = the natural log of firm size for the *i*th firm in year *t*,
CC_{it} = the natural log of coordination costs of the *i*th firm in year *t*,
NIT_{it} = the natural log of non-IT use for the *i*th firm in year *t*,
DI_{it} = diversification index (i.e., entropy measure) for the *i*th firm in year *t*,
VI_{it} = vertical integration (i.e., VIC index) for the *i*th firm in year *t*,
SA_{it} = the natural log of sales for the *i*th firm in year *t*,
RD_{it} = the natural log of R&D for the *i*th firm in year *t*,
$\mathrm{Industry}_{it}$ = a dummy for each submanufacturing industry where the *i*th firm in year *t*,
Year_{it} = a dummy for the year for the *i*th firm, and
ε_{it} = an error term with a zero mean.

While Equations (1) and (2) are formulated to investigate the size effect, Equations (3) and (4) are specified to examine the IT effect. In these equations, we assume that except for the industry and year effects, all other control variables affect the dependent variables after one year.[13] We expect the signs of the estimated coefficients for testing our hypotheses to be:

- $\alpha_2 \cdot \beta_1 > 0$ ($\alpha_2 > 0$ and $\beta_1 > 0$), indicating a *positive size effect*: As firms grow, their coordination activities (costs) increase, and subsequently IT use increases to reduce the increased coordination costs;
- $\gamma_2 \cdot \eta_1 < 0$ ($\gamma_2 > 0$ and $\eta_1 < 0$), indicating a *negative IT effect*: The increased use of IT reduces coordination costs, and eventually, firm size decreases;
- $\alpha_1 > 0$, indicating a direct effect of firm size on IT use; and
- $\gamma_1 < 0$, indicating a direct effect of IT use on firm size.

To test the statistical significance of size effect and IT effect, an approximation of the *t*-value provided by Sobel (1982) is used (Venkatraman 1989). Regarding the size effect, for instance, we calculated the following *t*-value: $t = (\alpha_2 \cdot \beta_1)/\sqrt{(\alpha_2^2 \cdot S_{\beta 1}^2 + \beta_1^2 \cdot S_{\alpha 2}^2)}$, where S refers to the standard error of estimates.

3.2.2. Estimation Methods. We estimate, respectively, equations using IT spending and IT stock as IT use. At the same time, we perform the estimation of equations with one-year lag and two-year lag. The exogenous variables may be jointly determined with endogenous variables. For example, managers aiming to minimize coordination costs choose both the firm size and IT use by considering the levels of the other (Brynjolfsson et al. 1994). R&D and sales may be also jointly determined. Therefore, their inclusion might introduce simultaneity bias (Maddala 1992). In addition, all of the variables in this study are measured with some error. Because the solution to both the simultaneity bias and the measurement errors is instrument variable estimation (Pindyck and Rubinfeld 1991), we estimate the coefficients in our empirical models using 2SLS, which is one of two methods commonly used to implement instrumental variable estimation. Our set of instruments for the one-year lagged model includes one-year lagged values of the endogenous variables plus all other exogenous variables, following the work done by Dewan et al. (1998).[14]

Furthermore, we obtain the variance inflation factor (VIF) to detect the presence of multicollinearity in

[12] These equations could be derived by extending and rewriting the Cobb-Douglas (log-log) production function because the main variables, including exogenous variables and endogenous variables, are transformed into natural logarithms. The Cobb-Douglas production function is characterized by the equation ln Output = constant + a_1 ln IT + a_2 ln Capital + a_3 ln Labor. Our equations could be obtained by transposing ln IT to the left-hand side (or by replacing ln Output with ln Size), replacing the constant term by a linear combination of the other variables, replacing ln Labor by ln CC, and adding the error term (cf. Dewan et al. 1998).

[13] This is for the one-year lagged model. For the two-year lagged model, control variables are assumed to affect the dependent variables after two years.

[14] We assume that IT_{t+2} and Size_{t+4} are endogenous variable and other variables are exogenous variable. Treating CC_{t+1} and CC_{t+3} as endogenous or exogenous does not make a significant difference. For the two-year lagged model, two-year lagged values of the endogenous and exogenous variables are used as instrument variables.

Table 2 Sample Characteristics

Variable	Min	Max	Median	Mean	SD	*N*
IT spending (IT)	0.000	4,444.760	67.900	180.980	381.610	688
IT stock (IT)	5.000	27,000.000	386.270	946.560	2,013.650	257
Firm size (Size)	450	756,300	17,748	35,976	63,754	1,303
Coordination costs (CC) = (SGA − R&D)	41.320	23,210.730	459.100	1,146.410	2,097.720	951
Non-IT spending (NIT)	0.540	17,025.450	150.050	502.830	1,251.050	1,282
Non-IT capital (NIT)	16.500	65,732.680	968.700	2,868.600	6,472.020	1,294
Sales (SA)	31.590	148,700.840	2,896.650	7,379.800	14,688.010	1,306
R&D (RD)	0.550	7,542.400	76.940	300.490	708.020	1,006
Vertical integration (VI)	0.000	0.890	0.001	0.055	0.143	1,094
Diversification (DI)	0.000	2.260	0.690	0.665	0.520	1,094

Note. Dollar figures are in millions of constant 1992 dollars.

the initial regressions. It was found that the VIF of sales was more than 10 and the highest among VIFs of other variables. To overcome multicollinearity problems, therefore we normalized sales by total asset. The use of the normalized sales variable brought VIFs of all variables much below 10. In addition to the multicollinearity, we also check for heteroskedasticity problems in our regressions. Since the time series and cross-sectional observation are pooled, the potential problems of heteroskedasticity may have been introduced. When we found heteroskedasticity, we applied the weighted least squares (WLS) correction technique. We performed the WLS procedure by using error term variance as weight, which is suggested by Neter et al. (1990). Finally, as might be expected in time-series regressions, serial correlation can be presented in our regressions. However, Durbin-Watson (DW) statistics for all equations in the regressions exhibited no serial correlations.[15] Therefore, no correction was applied for the serial correlations. We use the results from the corrected regressions to test our hypotheses.

4. Results

Basic descriptive statistics for the raw data employed in the data analysis are shown in Table 2. The distribution of all variables, except for diversification, is skewed. Natural logarithm transformation of the variables alleviated the skewness of their distributions. The statistics for firm size suggest that firms in the sample are large, with an average employment of 35,976 people.

4.1. Results for the Bidirectional and One-Year Lagged Model

The 2SLS estimates for Equations (1)–(4) for the bidirectional and one-year lagged model using IT spending and IT stock are summarized in Table 3.[16] The signs of the coefficients of key variables are consistent with those predicted. The coefficient (α_1) of firm size in Equation (1) using IT spending ($p = 0.005$) and IT stock ($p = 0.041$) is positive and significant, respectively. This result indicates the direct impact of firm size on IT use. The coefficient (α_2) of coordination costs in Equation (1) using IT spending ($p < 0.000$) and IT stock ($p = 0.001$) is positive and significant, respectively. And the coefficient (β_1) of firm size in Equation (2) using IT spending ($p = 0.016$) and IT stock ($p = 0.001$) is also positive and significant, respectively. Therefore, the size effect ($\alpha_2 \cdot \beta_1$) mediated by coordination costs using IT spending ($p = 0.016$) and IT stock ($p = 0.006$) is positively significant. These results indicate that firm size affects IT use directly and indirectly through coordination costs, indicating *a partial mediational size effect model* (cf. James and Brett 1984, Venkatraman 1989). The partially meditational size effect model means that an increase in coordination activities is one of main factors that drive an increase in IT use. This implies that the presence of coordination costs is necessary but not sufficient for explaining the effect of firm size on IT spending.

Unlike the partially meditational size effect model, the IT effect model is found to be completely mediated by coordination costs. Hence, the coefficient (γ_1) of IT use in Equation (3) using IT spending and IT stock is not significant, indicating that the direct impact of IT use on firm size does not exist. However, the coefficient (γ_2) of coordination costs in Equation (3) using IT spending ($p < 0.000$) and IT stock ($p < 0.000$) is significantly positive and the coefficient (η_1) of IT use in Equation (4) using IT spending ($p < 0.000$) and IT stock ($p = 0.012$) is significantly negative, respectively. Therefore, the IT effect ($\gamma_2 \cdot \eta_1$) mediated by coordination costs using IT spending

[15] We also obtain DW statistics for second-order autocorrelation in all equations. The obtained DW statistics for second-order autocorrelation exhibited no significant correlation.

[16] The subscript j in Equations (1)–(4) is $t + 1$, t, $t + 3$, and $t + 2$, respectively. Unstandardized coefficients are provided in tables of the results.

Table 3 **Results of 2SLS Estimation for One-Year Lagged Model**

	IT spending				IT stock			
	Size effect		IT effect		Size effect		IT effect	
	Equation (1)	Equation (2)	Equation (3)	Equation (4)	Equation (1)	Equation (2)	Equation (3)	Equation (4)
Variable	IT Use_{t+2}	Coordination $Costs_{t+1}$	Firm $Size_{t+4}$	Coordination $Costs_{t+3}$	IT Use_{t+2}	Coordination $Costs_{t+1}$	Firm $Size_{t+4}$	Coordination $Costs_{t+3}$
Independent variables								
Firm $Size_t$	0.232***	**0.132****			0.474**	**0.378*****		
	(2.83, 7.0)	(2.42, 1.7)			(2.08, 6.3)	(3.49, 3.9)		
Coordination $Costs_{t+1}$	**0.408*****				**0.888*****			
	(4.59, 4.4)				**(3.61, 4.6)**			
IT Use_{t+2}			−0.017	**−0.128*****			0.073	**−0.072****
			(−0.35, 5.8)	(−4.05, 1.3)			(1.65, 7.2)	(−**2.60**, **1.3**)
Coordination $Costs_{t+3}$			**0.309*****				**0.726*****	
			(4.25, 4.5)				**(5.63, 2.9)**	
Control variables								
Non-IT Use_j	0.298***		0.901***		0.334**		0.070	
	(5.13, 4.3)		(6.92, 3.7)		(2.10, 3.7)		(1.38, 2.6)	
$Diversification_j$	−0.057	0.209*	0.289***	−0.063	−0.270	0.775***	0.504***	−0.028
	(-0.72, 1.8)	(1.68, 1.7)	(5.16, 1.4)	(−0.81, 1.6)	(-1.41, 1.5)	(4.05, 1.7)	(4.93, 3.9)	(-0.31, 1.7)
Vertical $Integration_j$	−0.441*	0.620**	−0.662*	0.109	−0.080	2.283***	−0.332	2.215***
	(−1.89, 1.7)	(2.23, 1.8)	(−1.93, 3.0)	(0.42, 1.8)	(-0.10, 2.3)	(3.69, 2.7)	(−1.33, 2.3)	(4.01, 1.1)
Normalized $Sales_j$	5.410***	9.421***	5.754***	2.738**	10.712***	12.206***	5.001***	3.816***
	(4.85, 1.4)	(5.10, 1.6)	(5.60, 3.1)	(2.42, 1.4)	(3.24, 1.4)	(2.89, 2.2)	(2.81, 3.3)	(2.73, 1.3)
$R\&D_j$	0.579***		0.151***		1.421***		0.650***	
	(6.25, 8.4)		(2.77, 8.5)		(8.21, 8.4)	(6.72, 8.1)		
Adjusted R^2	0.840	0.540	0.810	0.530	0.870	0.520	0.860	0.480
No. of observations	296	296	296	296	104	104	104	104
DW	1.920	2.100	2.010	2.210	1.820	1.940	1.810	1.900
Size and IT effects	0.054**		−0.040***		0.335***		−0.052***	
	($t = 2.14$, $p = 0.016$)		($t = -2.93$, $p = 0.002$)		($t = 2.51$, $p = 0.006$)		($t = -2.36$, $p = 0.009$)	

Notes. The subscript j in Equations (1)–(4) is $t+1$, t, $t+3$, and $t+2$, respectively. The numbers in parentheses refer to t-value and VIF.
$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

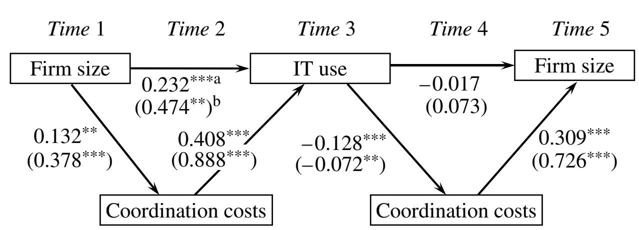
($p = 0.002$) and IT stock ($p = 0.009$) is negative and significant, respectively. These results indicate that IT use at year 3 leads to smaller firm sizes at year 5 by decreasing coordination costs at year 4. Thus, we find that a *complete mediational relationship* exists in the IT effect model. This finding suggests that the outsourcing effect (through coordination costs) rather than the substitution (direct) effect explains the impact of IT on firm size.

The results of the estimation for our bidirectional and one-year lagged model can be summarized as a partially meditational size effect model and completely meditational IT effect model, as shown in Figure 2. These results are consistent with our expectation and provide evidence for the mediating role of coordination costs and the duality of IT in organizational change.

4.2. Results for the Bidirectional and Two-Year Lagged Model

The estimation results of the two-year lagged model are summarized in Table 4. The key results are entirely consistent with those of the one-year lagged model, except for the insignificant direct effect of firm size on IT stock. While the coefficient of firm size in Equation (1) using IT spending is positive and significant ($p = 0.016$), the coefficient of firm size in Equation (1) using IT stock is positive but insignificant. The coefficient of coordination costs (α_2) in Equation (1) using IT spending ($p < 0.000$) and IT stock ($p = 0.001$)

Figure 2 **Summary of Results of Bidirectional and One-Year Lagged Model**



$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.
[a]indicates the path coefficients using IT spending and [b]refers to the path coefficient using IT stock.

Table 4 Results of 2SLS Estimation for Two-Year Lagged Model

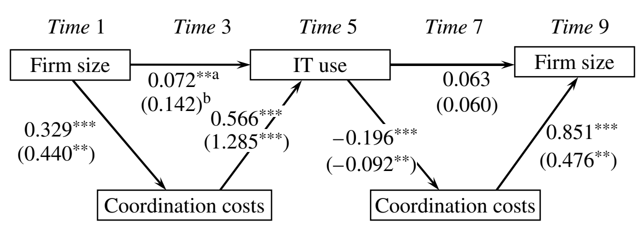
	IT spending				IT stock			
	Size effect		IT effect		Size effect		IT effect	
	Equation (1)	Equation (2)	Equation (3)	Equation (4)	Equation (1)	Equation (2)	Equation (3)	Equation (4)
Variable	IT Use$_{t+4}$	Coordination Costs$_{t+2}$	Firm Size$_{t+8}$	Coordination Costs$_{t+6}$	IT Use$_{t+4}$	Coordination Costs$_{t+2}$	Firm Size$_{t+8}$	Coordination Costs$_{t+6}$
Independent variables								
Firm Size$_t$	0.072** (2.46, 6.2)	**0.329*** (3.87, 2.0)**			0.142 (0.52, 5.9)	**0.440** (2.48, 3.5)**		
Coordination Costs$_{t+2}$	**0.566*** (6.82, 3.7)**				**1.285*** (3.71, 4.5)**			
IT Use$_{t+4}$			0.063 (0.65, 8.0)	**−0.196*** (−3.93, 1.1)**			0.060 (1.18, 5.4)	**−0.092** (−2.22, 2.3)**
Coordination Costs$_{t+6}$			**0.851*** (9.22, 3.1)**				**0.476** (2.55, 6.8)**	
Control variables								
Non-IT Use$_j$	0.281*** (4.39, 7.6)		0.296*** (3.45, 4.3)		0.361 (1.61, 3.9)		0.423*** (3.52, 8.2)	
Diversification$_j$	0.057 (0.88, 5.4)	0.221 (0.91, 2.3)	0.407*** (4.82, 1.3)	−0.110 (−0.96, 1.1)	−0.326 (−1.29, 1.5)	0.358 (0.94, 2.9)	0.037 (0.33, 3.2)	−0.044 (−0.26, 2.1)
Vertical Integration$_j$	−1.137*** (−5.16, 3.2)	0.995** (2.45, 1.8)	−1.702*** (−4.68, 1.7)	0.854** (2.51, 1.2)	−0.778 (−0.70, 2.7)	1.994*** (2.98, 2.4)	−0.273 (−0.55, 2.8)	2.588*** (5.08, 1.3)
Normalized Sales$_j$	9.242*** (9.36, 2.5)	8.181*** (2.72, 1.4)	3.818** (2.41, 1.7)	2.740** (2.20, 2.3)	3.947*** (2.87, 1.2)	7.887*** (2.76, 2.6)	5.053** (2.23, 3.1)	3.414** (2.38, 1.4)
R&D$_j$	0.691*** (14.33, 5.1)		0.568*** (6.72, 8.1)		1.650*** (6.78, 8.2)		0.351** (2.60, 8.0)	
Adjusted R^2	0.840	0.430	0.860	0.470	0.880	0.530	0.890	0.550
# of observations	103	103	103	103	49	49	49	49
DW	1.830	1.910	1.830	2.030	1.940	1.930	1.820	2.160
Size and IT effects	0.186*** ($t = 3.37$, $p < 0.000$)		−0.162*** ($t = -3.62$, $p < 0.000$)		0.565** ($t = 2.06$, $p = 0.021$)		−0.044** ($t = -1.67$, $p = 0.048$)	

Notes. The subscript j in Equations (1)–(4) is $t+2$, t, $t+6$, and $t+4$, respectively. The numbers in parentheses refer to t-value and VIF.
$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

is positive and significant, respectively, and the coefficient of firm size (β_1) in Equation (2) using IT spending ($p = 0.000$) and IT stock ($p = 0.018$) is positive and significant, respectively. Accordingly, it is found that the size effect mediated by coordination costs ($\alpha_2 \cdot \beta_1$) is positive and significant for IT spending ($p < 0.000$) and IT stock ($p = 0.021$), respectively. The findings in the two-year lagged model also imply that the presence of coordination costs is necessary but not sufficient for explaining the effect of firm size on IT spending, indicating *a partial mediational size effect model* (cf. James and Brett 1984, Venkatraman 1989).

In addition to the size effect, the indirectly negative IT effect ($\gamma_2 \cdot \eta_1$) is also found to be significant for IT spending ($p = 0.000$) and IT stock ($p = 0.048$), respectively. The direct effect of IT use using IT spending and IT stock on firm size is not significant. These results are also entirely consistent with the IT effect in the one-year lagged model. Thus, a *completely mediational relationship* also exists in the IT effect model with two-year lags. The results of the estimation for our bidirectional and two-year lagged model are summarized in Figure 3. We believe that these results in the two-year lagged model provide further convincing evidence to support our expectations.[17]

Figure 3 Summary of Results of Bidirectional and Two-Year Lagged Model



$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.
[a]indicates the path coefficients using IT spending and [b]refers to the path coefficient using IT stock.

[17] To ensure the mediating effect of coordination costs between IT use and firm size, we have additionally estimated the size and IT effects without coordination costs. We have found that except for the IT stock effects, all results confirm that coordination costs function as a mediator. See Appendix D for details.

5. Discussion and Conclusion

Our study has drawn on a range of different theories to explicate the complex relationship between IT and organizational changes. These include information processing perspective (Galbraith 1977), coordination theory (Malone 1988), TCE (Williamson 1981), and structuration theory (Orlikowski 1992). Based on these theories, we have formulated a bidirectional and time-lagged relationship between IT and firm size into an integrated model in which the relationship is mediated by coordination costs. We find a sequential interaction between IT and firm size, which is partially and completely mediated by coordination costs. Our findings corroborate theoretical guidance from the various theories listed above (see Table 5). Table 5 demonstrates how our empirical findings support the various theories.

Our study empirically confirms a variance-based bidirectional and time-lagged relationship between IT and organizational change. The empirical testing of such relationships is challenging and potential limitations (including the use of accounting measures) should be considered in interpreting the results and deriving conclusions. We have carefully considered the effect of each possible limitation on the results. In addition, we have taken actions or made assumptions to eliminate or mitigate these problems, giving our research results a high level of robustness (see Table 6).

5.1. Research Contributions

The contribution of this study to IS research can be understood from two perspectives. First, we believe we have broadened the positivist tradition of IS research that has often been limited to assuming unidirectional causality and using cross-sectional data. These limitations are related to the often misleading conclusions that could be derived from simple correlation data. Noteworthy theories regarding IT and organizational change are likely to be formed from intellectual perspectives that rest on broad disciplinary or ideological assumptions (Kling et al. 1992). One such intellectual perspective is the emergent or structuration perspective on IT-organization interaction (Jones and Karsten 2008, Markus and Robey 1988, Orlikowski 1992, Orlikowski and Robey 1991). Incorporating organizational and microeconomic theories in our bidirectional and time-lagged research model, we found that IT use is both an antecedent and a consequence of organizational change. This is consistent with the structuration perspective and provides empirical evidence of its core precepts (see Table 5).

Table 5 Empirical Findings of Our Study and Theoretical Guidance

Theories	Theoretical guidance	Findings of this study	Main references
Structuration theory	*Bidirectional and time-lagged effect*: IT use is both an antecedent and a consequence of organizational change.	The duality of IT with firm size was found in model partially or completely mediated by coordination costs.	DeSanctis and Poole (1994), Jones and Karsten (2008), Orlikowski (1992), Orlikowski and Robey (1991)
Information processing perspective/coordination theory	(1) *Size effect*: Part or all of the positive impact of firm size on IT use is transmitted through an increase in coordination costs.	A part of the positive impact of firm size on IT use was transmitted through an increase in coordination costs (a partial meditational size effect).	Galbraith (1977), Gremillion (1984), Grover et al. (1997), Malone (1988)
Production theory/ coordination theory/ TCE	(2) *IT effect*: Part or all of the negative impact of IT on firm size is transmitted through a reduction in coordination costs.	All of the negative impact of IT on firm size was transmitted through a reduction in coordination costs (a complete meditational IT effect).	
Production theory	—*Labor substitution effect*: IT substitutes for labor.	Direct impact of IT on firm size was found.	Berndt and Morrison (1995), Bresnahan et al. (2002), Brynjolfsson et al. (1994), Cyert and Mowery (1987), Osterman (1986)
Coordination theory	—*Coordination structure effect*: IT enables firms to implement coordinative intensive structure that is affordable to smaller in their size.	IT reduced coordination costs by implementing coordinative-intensive structure and then firm size decreased.	Malone (1988), Malone and Rockart (1991), Malone and Smith (1988), Hammer and Stanton (1999), Pinsonneault and Kraemer (1993)
TCE	—*Outsourcing effect*: IT reduces more external coordination costs, which results in a reduction in firm size.	IT reduced external coordination costs and then firms afforded more outsourcing, indicating a reduction in firm size.	Brynjolfsson et al. (1994), Gurbaxani and Whang (1991), Williamson (1981)

Table 6 Limitations of the Methods

Limitation	Possible effects on results	Actions taken or assumptions made to mitigate the threats
Measurement of coordination costs: (1) We measure coordination costs using the accounting measure of SG&A expenses that cannot be separated into internal and external components of coordination costs. (2) SG&A does not capture agency costs and opportunistic holdup. (3) SG&A does not include coordination costs due to production.	(1) We are unable to compare the impact of IT on internal coordination costs with that of IT on external coordination costs. We cannot directly demonstrate the IT effect. (2) We cannot analyze the impacts of the agency costs on firm size or IT use. (3) We cannot analyze the impacts of production overhead on firm size or IT.	(1) We adjust SG&A costs to avoid including noncoordination items (R&D) and to avoid double-counting. We acknowledge that smaller firm size could be due to efficient coordination structures. We also present arguments and prior empirical studies supporting that IT has a bigger impact on external coordination than on internal coordination. (2) There is positive association between agency costs and firm size. And IT can be used to reduce the agency cots (Gurbaxani and Whang 1991). As a result, we argue that the inclusion of the agency costs in our measure of coordination costs is expected to augment the impacts of coordination costs on firm size and IT spending. (3) We explicitly address the definition of coordination costs. We define our coordination costs as costs related to only nonproduction activities. Therefore our coordination costs are likely to be understated. However, we believe that the overhead costs related to product production (i.e., coordination costs in production) may not be as large as coordination costs in nonproduction.
Measurement of IT use: (1) IT use can be measured as IT (flow) spending or IT stock. (2) IT budget can be recorded as capital expenditure (i.e., non-IT capital) or operating expenditure (i.e., coordination costs).	(1) IT (flow) spending cannot capture the existing IT infrastructure. The IT use measured as IT spending may be understated in terms of its impacts on coordination costs and firm size. (2) Our results may be dependent on the level of allocation of IT budget into capital expenditure and operating expenditure.	(1) IT spending and IT stock, respectively, are used in our estimation of empirical models. We find that both IT spending and IT stock yield the same results. (2) We assume that one-third of the IT budget goes to SG&A and the rest of the IT budget goes to fixed assets. We also perform several sensitivity analyses by using different levels of the allocation. We find that the results are stable across the different levels of the allocation.
Use of panel data set: It could introduce the potential problems of simultaneity, heteroskedasticity, and autocorrelation.	The statistical problems may lead to inconsistent estimates.	We use instrument variables estimation (i.e., 2SLS) to correct the simultaneity problem. We check multicollinearity effects by calculating the VIF index. Also, we normalize sales by total asset and find that there are no significant multicollinearity problems. A weighted 2SLS by error term variance is used for mitigating the heteroskedasticity problem. Finally, no corrections are conducted for autocorrelation because significant serial correlation does not exist.
Length of time lag: We assume that there are one-year or two-year lags between variables in our bidirectional and time-lagged model.	Our results could be affected by using different time lags.	We justify the use of one-year lags by citing previous studies that use the one-year lagged model. We find that one-year lagged model has strong support by our data set. Moreover, we also test the two-year lagged model and found that the results of the two-year lagged model are similar to the one-year lagged model, indicating that there is a four-year lag in IT impact on firm size. Compared with the results of prior studies, we think that the four-year lag is long enough to IT impact.

Second, the present study provides an extension of previous studies toward a cumulative tradition of research through empirical evidence. Several researchers have identified the role of coordination costs in linking IT to changes in firm size (Brynjolfsson et al. 1994, Gurbaxani and Whang 1991, Malone and Rockart 1991). However, none of the previous empirical studies have incorporated coordination costs into the examination of the relationship between IT and firm size. Our study found a mediation relationship between IT and firm size through coordination costs, which is consistent with the inferences made in previous works by Brynjolfsson et al. (1994), Dewan et al. (1998), and Hitt (1999). This is a significant step toward understanding why and how the increasing use of IT is related to changes in firm size.

5.2. Implications and Directions for Research

One important implication of our results is that the increasing use of IT may be driven by the demand for coordination activity. We found that the direct impact and the indirect impact of firm size on IT via coordination costs are significantly positive. This implies that among the many reasons why larger firms tend to use IT more, the facilitation of coordination activities may be a critical reason. This supports the information processing perspective of the organization (Galbraith 1977). On the other hand, the finding of a complete mediation relationship in the IT effect model implies that coordination costs are the most critical factor that drives the impact of IT on firm size. This suggests that coordination costs should be incorporated as a critical variable in future research on the link between IT and organizational change. However, the construction of a better proxy for coordination costs should take precedence. The organizational literature might offer some guidance as it makes similar coordination arguments and uses alternative proxies like *C*-level executive changes, middle versus operational-level managers, geographic distribution of subsidiaries, etc.

Second, this study focuses on the mediation relationship between IT and firm size. While size is a critical variable that defines the boundary conditions of a firm, it needs refinement to better elucidate structural manifestations. It would be interesting to relate the mediation relationship to the impacts of IT on other organizational changes. For example, one could examine the mediation relationship between IT and other structural characteristics, such as process-oriented structures, span of control, and formalization. Future research could also examine *how* coordination costs mediate the relationship between IT and organizational performance such as profitability and productivity. Furthermore, the moderating effects of coordination costs on the bidirectional relationships between IT and other organizational changes could be also investigated.

Third, our treatment of IT as a generic variable could benefit from future work. For instance, many IT investments today are infrastructural and focus on not only reducing coordination costs, but also providing a platform for IT-business innovations. Some IT investments (e.g., CAD/CAM for concurrent engineering) are geared toward facilitation of production as well as coordination activities. Other investments might vary in their degree of specificity to a given industry. Therefore, questions pertaining to IT investment types and their effects on size, internal versus external coordination costs, structural characteristics, options for innovation, first-mover versus follower effects, and performance (Melville et al. 2004) may provide rich avenues for further research. Such research might also benefit from other theoretical perspectives (e.g., agency theory, property rights) that can contribute to the nomological network.

Finally, our data are limited to the manufacturing sector and the period from 1989 to 1997. Thus, findings from the present study may not necessarily be applicable to other industries and other periods. Future studies should attempt to reexamine and validate our dual-causality models using data sets for other industries and other periods.

5.3. Implications for Practice

The spectrum of IT applications, collectively known as coordination technologies, has begun to transform organizations and industries into coordination-intensive structures, where IT investment can no longer be justified by conventional criteria such as ROI and new IT-enabled products and services. Findings from our study have demonstrated that IT investment is a response to excessive coordination costs and that making this investment would normally lower coordination costs, leading to a smaller workforce. This suggests that coordination costs are a critical link between IT investments and the complex and continuing cycles of IT-enabled structural changes. The critical implication is that today's top-performing organizations must not only be strategically competitive, but also structurally competitive. Without a coordination-intensive structure, an organization will very rapidly lose its ability to respond to changes in a timely manner (Haeckel and Nolan 1993, Straub et al. 2004).

In recent years, we have seen many organizations achieve smaller sizes while evolving toward more coordination-intensive structures, called hybrid structures or network organizations (cf. Tapscott et al. 2000). This trend is likely to continue and may even accelerate as Internet technology enables greater levels of coordination within and between organizations, reduces the cost of purchasing, affords better management of supplier relationships, streamlines logistics and inventory, and reaches new and existing customers more effectively. Advances in IT, such as the Internet, may not only alter the way we do business and create value, but also change the organizational structure itself. Our findings support this expectation.

The fact that the structural manifestations of IT operate through coordination costs suggests that effective recognition and management of these costs are important to the facilitation of new structural forms. Organizations need to carefully and explicitly assess their structural competitiveness, including coordination costs and the role of IT investment on these costs. This includes the evaluation of the role of IT in facilitating communication, brokerage, and integration within and between organizations.

The IT effect observed in the panel data corresponds to a dramatic increase in the outsourcing of business processes and functions during the periods of this study. Since that time, outsourcing has continued unabated, as companies farm out nonstrategic aspects of their firms to inshore and offshore vendors. As the Internet infrastructure continues to evolve toward a seamless, ubiquitous, efficient, and global utility, the ability to manage these external relationships will be made more efficient. The challenges will be to determine what portions of the business to outsource; how to manage a network of coordination-intensive relationships; how to establish (strategic) network centrality within these relationships; and as a consequence, how to create a leaner and more nimble organization. This has particular implications for firms operating in an economy that is beginning the transition from an era of large enterprises to an era of organizational forms that exploit the resources of small suppliers (Brynjolfsson et al. 1994).

5.4. Conclusion

Some have questioned the strategic value of IT in the face of its growing ubiquity (Carr 2003). As companies struggle to make sense of their IT investments, it has never been more important to better understand the complex relationship between IT and the organization and how it can result in the creation of unique capabilities. This study has attempted to empirically examine dual causality and longitudinal effects, and to reconcile different theoretical perspectives. We hope this work can act as a catalyst, leading to a better understanding of the relationship between IT and organizations, with the ultimate goal of robust prescriptions for successful structural changes.

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Appendix A

To confirm our study's contribution, we contrast in Table A.1 our study with those of Brynjolfsson et al. (1994), Dewan et al. (1998), and Hitt (1999). As Table A.1 shows, Dewan et al. (1998) and Hitt (1999) did not test the association between IT and coordination costs nor the relationship between IT and firm size (total number of employees). Dewan et al. (1998) tested the unidirectional impacts of organizational characteristics on IT use. Hitt (1999) tested cross-sectionally the bidirectional relationships between IT and vertical integration or diversification. He did not perform the examination of the longitudinal relationship between them. Brynjolfsson et al. (1994) did not incorporate coordination costs as a mediator into their model. They tested only the direct impacts of IT on firm size.

In summary, to provide a more complete and general model for the relationship between IT and firm size, our study extends and complements previous studies in the following three areas:

- We empirically test the bidirectional model that consists of size effect model and IT effect model (see Figure 1). The two submodels are based on the technological imperative perspective and the organizational imperative perspective, respectively. No previous studies in the IS area have tested the integrated (bidirectional) model;
- We empirically test the time-lagged impacts. The related studies (except for Brynjolfsson et al. 1994) have not examined the time-lagged effects; and
- We empirically test the mediating effect of coordination costs. No related studies have empirically examined the mediating effect.

Appendix B

To make a more convincing argument on our study's contributions, we have searched for previous studies on the relationship between IT and firm size. In Table B.1, we have summarized the previous studies and compared them

Table A.1 Summary of Brynjolfsson et al. (1994), Dewan et al. (1998), and Hitt (1999) Studies

Study	Unit of analysis	Data set	Dependent variable	Key independent variable	Use of firm size as total number of employees	Use of lagged variable	Addition of mediator
Brynjolfsson et al. (1994)	Economy-wide	BEA data, COMPUTAT	Size	Lagged IT capital	Yes	Yes (only IT and non-IT)	No
Dewan et al. (1998)	Firm level	Computerworld data, COMPUSTAT	IT capital	Sales, related diversification, unrelated diversification, VI	No	No	No
Hitt (1999)	Firm level	Computer intelligence InfoCorp data, COMPUSTAT	Vertical integration,	IT cost share	No	No	No
			Diversification	IT cost share	No	No	
			IT cost share	Diversification, vertical integration	No	No	
Our study	Firm level	IW data, COMPUSTAT	IT use$_{t+2}$	Firm size$_t$, coordination costs$_{t+1}$	Yes	Yes	Yes
			Coordination costs$_{t+1}$	Firm size$_t$			
			Firm size$_{t+4}$	IT use$_{t+2}$, coordination costs$_{t+3}$			
			Coordination costs$_{t+3}$	IT use$_{t+2}$			

Table B.1 Empirical Research on the Relationship between IT and Firm Size

Study	Theory	Methodology; sample (period)	Dependent variable: measure	Independent variable: measure	Level of analysis	Type of analysis	Direction of causality	Impact	Use of mediator
Empirical research on the impact of IT on firm size: technological imperative									
Hoos (1960)	Organization theory	Multicases; 19 firms in multi-industries (NA)	Size: number of middle managers	IT: computerization	Firm	Cross-sectional	Unidirectional	Negative	No
Lee (1964)	Organization theory	Case; a major shoe manufacturer (1955, 1962)	Size: clerical and managerial manpower	IT: computer installation	Firm	Longitudinal	Unidirectional	Positive	No
Whisler (1970)	Organization theory	Multicases; 20 insurance firms (NA)	Size: number of clerks, middle managers, and top managers	IT: computerization (computer expense; number of functions computerized)	Firm	Cross-sectional	Unidirectional	Negative	No
Blau et al. (1976)	Organization theory	Survey; 110 diverse manufacturers (1973)	Size: number of employees	IT: automation of functions	Firm	Cross-sectional	Unidirectional	Positive	No
Crowston et al. (1986)	Organization theory	Case; an electronic manufacturer (NA)	Size: number of line middle managers, staff specialists, and total employees	IT: computer conference system	Firm	Cross-sectional	Unidirectional	Negative	No
Osterman (1986)	Economics theory of production	Secondary data; 20 industries (1972, 1978)	Size: employment of clerks, nondata entry clerks, managers, and others	IT: Total amount of main computer memory in industry; wage; output	Firm	Cross-sectional	Unidirectional	Positive	No
Blanchflower et al. (1991)	Economics theory	Survey; 948 British establishments (1984)	Size: total establishment employment	IT: introductions of new microelectronic plant and equipment	Firm	Cross-sectional	Unidirectional	Negative	No
Berndt and Morrison (1995)	Labor substitution theory	Secondary data; all manufacturing and services industries (1976–1989)	Size: number of production and nonproduction workers	IT: High-tech office equipment capital stock	Industry	Cross-sectional	Unidirectional	Positive	No
Berndt et al. (1991)	Labor substitution theory	Secondary data; two-digit SIC industries	Size: number of production and nonproduction workers	IT: High-tech office equipment capital stock	Industry	Cross-sectional	Unidirectional	Positive	No
Machin and Wadhwani (1991)	Economics theory	Survey; 721 British establishments (1984)	Size: total establishment employment	IT: introductions of new microelectronic plant and equipment	Firm	Cross-sectional	Unidirectional	Positive	No
Pinsonneault and Kraemer (1993)	Organization (contingency theory)	Case; a natural gas firm (1984–1991)	Size: middle management	IT: extent of automation	Firm	Longitudinal	Unidirectional	Positive or Negative	No
Brynjolfsson et al. (1994)	Labor substitution theory; TCE	Secondary data; all manufacturing and services industries (1976–1989)	Size: employees per establishment; employees per firm; sales per firm; value added per firm	IT: IT capital	Industry	Cross-sectional; time lagged	Unidirectional	Negative	No

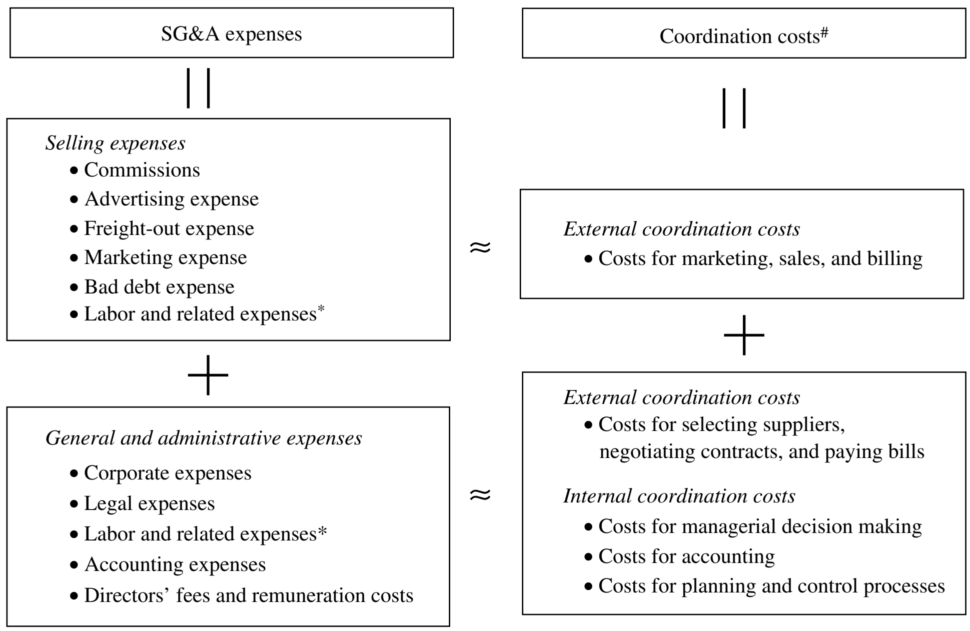
Table B.1 (cont'd.)

Machin (1996)	Economics theory	Panel data; 16 U.K. manufacturing industries (1982–1989), 402 U.K. establishment (1984, 1990)	Size: employment shares of nonmanuals in industry sample; employment shares of six skill groups in plant-level sample	IT: Introduction of microcomputers	Industry and Plant	Cross-sectional	Unidirectional	Positive	No
Pinsonneault and Kraemer (1997)	Organizational change; reinforcement politics	Survey; 155 city governments (NA)	Size: number of middle managers	IT: IT penetration (i.e., extent of automation)	Organization	Cross-sectional	Unidirectional	Positive or Negative	No
Empirical research on the impact of firm size on IT: organizational imperative									
Klatzky (1970)	Organization theory	Survey; 50 state employment agencies (NA)	IT: extent of automation	Size: total number of personnel	Organization	Cross-sectional	Unidirectional	Positive	No
DeLone (1981)	Management theory	Survey; 74 Los Angeles manufacturing firms (NA)	IT: computer use: external, total EDP, hardware, installation	Size: number of employees	Firm	Cross-sectional	Unidirectional	Positive	No
Turner (1982)	Organization theory	Survey; 38 mutual savings banks (1978)	IT: IT investment intensity	Size: index consisting of total bank assets, net income, and the number of full-time equivalent staff	Firm	Cross-sectional	Unidirectional	No	No
Gremillion (1984)	Technology innovation	Multicases; 66 administrative units of the U.S. Forest Service (1981)	IT: computer system use	Size: acreage; ranger districts; budget; timber harvest; recreation use; range use; supervisor level; staff size	Organization	Cross-sectional	Unidirectional	No	No
Harris and Katz (1991)	Organization theory	Secondary data; 650 life insurance firms (1983–1986)	IT: IT investment intensity	Size: premium income	Firm	Cross-sectional	Unidirectional	Negative	No
Grover et al.(1997)	IS innovation	Survey; 313 senior IS executive (NA)	IT: adoption of IS	Size: revenue; number of employees	Firm	Cross-sectional	Unidirectional	Positive	No
Lai and Guynes (1997)	Organization theory; IS innovations	Survey; 161 MIS directors of the BusinessWeek 1,000 companies (NA)	IT: ISDN adoption	Size: annual sales; number of employees	Firm	Cross-sectional	Unidirectional	Positive	No
Rai and Bajwa (1997)	Innovation theory	Survey; 210 top computer executives (1992)	IT: EIS adoption status; EIS adoption level	Size: number of total employees; Number of full-time employees in IS department	Firm	Cross-sectional	Unidirectional	Positive	No
Empirical research on the bidirectional relationship between IT and firm size									
Our Study	Organization theory; TCE	Secondary data; 277 manufacturing firms (1986–1997)	IT: IT budget; IT capital	Size: total number of employees	Firm	Longitudinal	Bidirectional	Positive and Negative	Yes

Appendix C

Figure C.1 shows the itemized expenses of SG&A provided by *User's Guide* for Compustat file and their relation with external and internal coordination costs. As shown in Figure C.1, while selling expenses are related to external coordination costs, general and administrative expenses capture internal coordination costs. This indicates SG&A can be a surrogate for coordination costs.

Figure C.1 Itemized SG&A Expenses and Internal and External Coordination Costs



*Labor expenses could be related to both internal and external coordination activities.
#We define coordination costs as costs incurred to coordinate *nonproduction* activities inside the firm and with suppliers and customers.

to our study. As Table B.1 shows, the empirical examination of bidirectional relationship between IT and firm size has never been attempted. Accordingly, we believe that the empirical examination of our bidirectional and time-lagged model has a cumulative contribution in the IS area.

Appendix D

To assure the mediating effect of coordination costs, we additionally estimated the size and IT effects without coordination costs (cf. Baron and Kenny 1986). Hence, we dropped coordination costs from Equations (1) and (3) and then estimated the modified equations. The direct size and IT effects without coordination costs are summarized along with those with coordination costs in Table D.1. According to Baron and Kenny (1986), in Table D.1, the mediating effect of coordination costs can be confirmed when (A) is greater than (B) and (C) is greater than (D) in each of the two lagged models, respectively. Except for the results of IT

Table D.1 Effect of Firm Size (IT Use) on IT Use (Firm Size) Without and With Coordination Costs

Model		IT spending		IT stock	
One-year lagged model	(A)	Effect of size on IT w/o CC 0.384*** ($t = 5.00, p = 0.00$)	Effect of IT on size w/o CC −0.399*** ($t = -9.37, p = 0.00$)	Effect of size on IT w/o CC 0.876*** ($t = 3.71, p = 0.00$)	Effect of IT on size w/o CC 0.035 ($t = 1.54, p = 0.13$)
	(B)	Effect of size on IT with CC 0.232*** ($t = 2.83, p = 0.00$)	Effect of IT on size with CC −0.017 ($t = -0.35, p = 0.73$)	Effect of size on IT with CC 0.474** ($t = 2.08, p = 0.04$)	Effect of size on IT with CC 0.073 ($t = 1.65, p = 0.10$)
(A)–(B)		0.152	−0.382	0.402	−0.070
Two-year lagged model	(C)	Effect of size on IT w/o CC 0.094*** ($t = 2.74, p = 0.00$)	Effect of IT on size w/o CC −0.181** ($t = -2.00, p = 0.05$)	Effect of size on IT w/o CC 0.339 ($t = 1.14, p = 0.26$)	Effect of IT on size w/o CC −0.005 ($t = -0.10, p = 0.92$)
	(D)	Effect of size on IT with CC 0.072** ($t = 2.46, p = 0.02$)	Effect of IT on size with CC 0.063 ($t = 0.65, p = 0.52$)	Effect of size on IT with CC 0.142 ($t = 0.52, p = 0.61$)	Effect of IT on size with CC 0.060 ($t = 1.18, p = 0.25$)
(C)–(D)		0.022	−0.244	0.197	−0.065

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

stock effect on size (see the last column in Table D.1), all results confirm that coordination costs function as a mediator. For example, in the one-year lagged model, the estimated coefficient (0.384) of the size effect on IT spending without coordination costs is greater than the estimated coefficient (0.232) with coordination costs. Thus, the direct size effect on IT spending without coordination costs is reduced when coordination costs are included, suggesting a mediating effect of coordination costs.

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