EXAMINATION OF A PATH MODEL RELATING INFORMATION TECHNOLOGY INFRASTRUCTURE WITH FIRM PERFORMANCE

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INTRODUCTION

The value of information technology (IT) to modern organizations has become an important and recurring topic for discussion and debate (Bharadwaj 2000; Melville, Kraemer, and Gurbaxani 2004; Santhanam and Hartono 2003). Both the academic and practitioner trade literatures report that enterprises purportedly use IT to improve productivity, enhance profitability, and reduce costs (Mukhopadhyay, Lerch, and Mangal 1997); to enable new ways of planning, organizing, and controlling (Sabherwal and Chan 2001); to support existing business strategies (Chan, Huff, Barclay, and Copeland 1997); to gain competitive advantage (Byrd and Turner 2001); and to improve customer service, enhance product and service quality, and integrate supplier and customer operations (Luftman, Lewis, and Oldach 1993). Yet, there are many questions still remaining surrounding the relationship between IT and firm performance.

In this study, we draw on the resource-based view (RBV) (Barney 2001) of the firm as well as the IT-performance literature to investigate the mechanisms through which IT impacts organizational performance by examining the direct and indirect impact of IT at both the intermediate and organizational levels. The RBV is associated with the notion that resources and capabilities in an organization

that are difficult to imitate and that are valuable can give a company a competitive advantage in the marketplace. Barau and Mukhopadhyay (2000) suggest that many more studies should investigate the impact of IT on intermediate functional and operational measures such as internal operations, customer services, supplier interactions, or mass customization and not just directly on high level measures such as total cost of operations and profitability. Ravichandran and Lertwongsatien (2005) further contend that such intermediary performance measures should provide more conclusive results when related to intermediate-level performance measures as opposed to aggregate measures of firm performance. In following this suggestion in this study, we investigate the relationships among IT infrastructure, logistics information systems (LIS's) impact, and firm performance.

An IT infrastructure is defined in the study as the shared IT resource consisting of a technical physical base of hardware, software, communications technologies, data and core software applications, and a human component of skills, expertise, and knowledge that combine to create IT services that are typically unique, or at least distinctive, to an organization (Byrd and Turner 2000). LIS's in the study are defined as IT applications that are specifically used to support the supply chain functions such as order processing, production plan and process control, warehouse management, supplier relationships, distribution and transportation management, sales and price management, and consumer service and customer management (Narasimhan and Kim 2001). This study explores the impact of these IT applications on supply chain functions. The firm performance measures used in this study are return on assets (ROA) and total cost of operations (TCO).

One of the distinctive features of this study is the measure of the impact of LIS's on supply chain functions. Past research has recommended that to get a more accurate determination of the impact of IT on functions in an organization, researchers must relate the IT applications as closely to these functions as possible (Barua, Kriebel, and Mukhopadhyay 1995). The measures of LIS impact in this study are "direct" measures of the effect of these IT applications on supply chain functions such as order processing, production planning and process control, supplier relationships, customer management, among others. The term "direct" is used to convey that the effects of LIS's (as perceived by Chief Information Officer (CIO) respondents in our study) on supply chain functions are the actual measures used instead of using an implied relationship between IT and supply chains functions as proposed in earlier studies (Narasimhan and Kim 2001; Sanders and Premus 2005).

THEORETICAL CONSIDERATIONS

Information Technology Performance Literature

Two distinct research streams have emerged in the study of the relationship between IT and firm performance (Barua and Mukhopadhyay 2000). One stream uses production economics as an analysis tool (Brynjolfsson and Hitt 1996; Loveman 1994; Roach 1991), and the other stream focuses more on the "process-oriented" model of IT value (Byrd and Turner 2001; Cron and Sobol 1983; Harris and Katz 1991; Weill 1992). Results from early studies in both streams had generally found no significant relationship between IT and firm performance (Loveman 1994; Roach 1991; Weill 1992). More recent studies in both streams, however, have shown a positive relationship between IT and firm performance (Barua and Lee 1997; Bharadwaj, Bharadwaj, and Konsynski 1999; Hitt and Brynjolfsson 1996; Lee and Barua 1999; Menon, Lee, and Eldenberg 2000; Mukhopadhyay, Rajiv,

and Srnivasan 1997; Narasimhan and Kim 2001; Rai, Patnayakuni, and Patnayakuni 1997; Sanders and Premus 2005).

These more positive results in recent studies have been attributed to more accurate and focused measures that feature "types" of IT instead of simply lumping all IT into one measure, and to exploring the relationships of IT with intermediate performance variables that may be "closer" from a causal standpoint than overall firm performance measures. Intermediate measures such as IT effects on internal operations, customer service, and inventory levels might be more accurately determined than simply considering the effects on overall firm performance. Two thorough reviews of these results are found in Melville, Kraemer, and Gurbaxani (2004) and Barua and Mukhopadhyay (2000).

As illustrated by these and other studies, there has certainly been progress in our understanding of the relationship between IT and firm performance. Scholars are working diligently to explain how, why, and when different types of IT improve organizational effectiveness and performance. However, significant challenges have made it difficult to understand the nature of the relationship between IT and firm performance. First, there is still the need for better measures of the IT construct itself (Brynjolfsson 1993). Second is the possible indirect nature of the impact of IT in the organization. IT may have a direct effect on firm performance, or it may affect intermediate variables with effects propagating through organizational processes and, ultimately influencing firm performance (Barua, Kriebel, and Mukhopadhyay 1995; Melville, Kraemer, and Gurbaxani 2004). Intermediate variables are associated with the primary activities such as inbound logistics, operations, outbound logistics, marketing and sales, and service of an organization while firm performance variables include measures like ROA and TCO (Barua, Kriebel, and Mukhopadhyay 1995). Barua, Kriebel, and Mukhopadhyay noted that IT is likely to have first order effects on the intermediate variables. Further, these intermediate variables would, in turn, have an influence on the firm performance measures.

As researchers, we have only started to examine IT effects at this level. Many past studies have examined IT spending and its relationship with firm performance and have found that IT does have a positive impact (Brynjolfsson and Hitt 1996; Menon, Lee, and Eldenburg 2000). While IT spending is a useful measure, it does not allow for the isolation of the impact of IT on individual organizational activities such as logistics. Such studies have only recently started to appear in the literature (Banker, Bardhan, Chang, and Lin 2006; Sanders and Premus 2005). To fully understand the specific role of IT in enhancing organizational performance, more intermediate-level studies must be done.

Resource-Based View of IT

The RBV has long provided researchers with a theoretical framework to determine the combination of resources that will enable sustainable competitive advantage and lead to superior business performance. Wade and Hulland (2004, p. 109) define resources as "assets and capabilities that are available and useful in detecting and responding to market opportunities or threats." Assets are defined as anything tangible or intangible the firm can use in its processes for creating, producing, and offering its products (goods and services) to a market; whereas capabilities are repeatable patterns of actions in the use of assets to create, produce, and offer products to a market. Assets can serve as inputs to a process, or as the outputs of a process. In contrast, capabilities "transform inputs into outputs of greater worth." The competitive advantage that is gained comes from an integrated assembling of firm-specific assets and capabilities into resources that are *Economica*lly valuable, relatively scarce, causally ambiguous, difficult to imitate, and socially complex (Teece, Pisano, and Shuen 1997).

An organization's IT infrastructure shares most of these characteristics and can be a source of competitive advantage (Piccoli and Ives 2005; Wade and Hulland 2004). A *superior* IT infrastructure is composed of assets (communications quality, hardware/operating systems (OS) quality, data quality) and capabilities (IT skills, business application integration) that are integrated to work closely together and serve as a sound foundation for organizational software applications that support business functions and activities. A superior IT infrastructure would be a conduit to deliver accurate, timely, relevant, reliable, and complete information to business functions throughout an organization. Such an IT infrastructure would integrate many of the business software applications and enable them to share information among themselves. A superior IT infrastructure would also have a knowledgeable and skilled IT workforce that has excellent technical and operational capabilities and is extremely responsive to end-users.

The impact of LIS's in this study is a measure of the effectiveness of using IT to support the functions in the supply chain. Thus the measure, LIS's impact, reflects how IT and the underlying supply chain functions are effectively integrated and combined to produce needed logistics services. Barney (1991) notes that the interweaving of IT applications into the processes of business functions, such as logistics, can provide improvement in overall firm performance and give an organization a sustainable competitive advantage over the long-term. A high impact of LIS's on supply chain functions should suggest the creation of specialized resources for the logistics of a firm and the potential for better performance.

CONCEPTUAL MODEL AND RESEARCH HYPOTHESES

Figure 1 presents the conceptual model developed for this study. Specifically, the model explores the influence of IT infrastructure on an intermediate variable, LIS's impact, and the effects of both of these variables on two firm level organizational performance variables, ROA and TCO. Size is included in the model as a control variable.

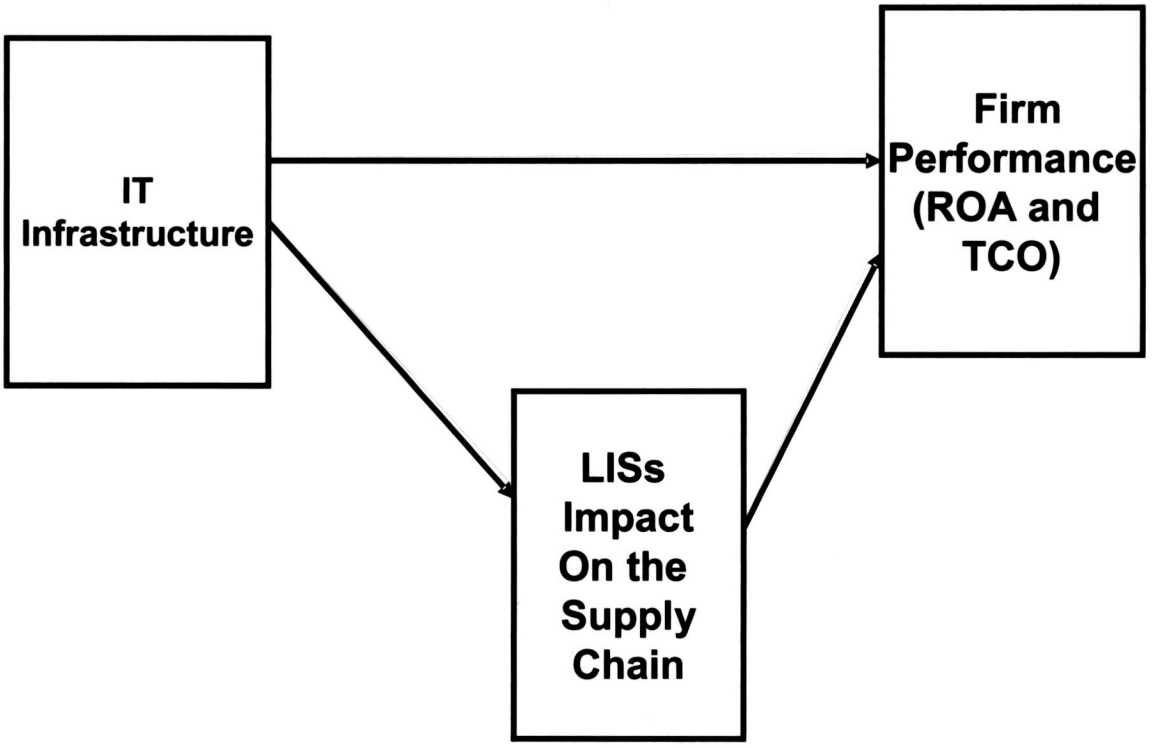
A superior IT infrastructure has been shown to have value that is not easily duplicated by rivals in some industries, and has helped companies in those industries to become market leaders (Melville, Kraemer, and Gurbaxani 2004; Piccoli and Ives 2005; Weill and Broadbent 1998; Weill, Subramani, and Broadbent 2002). Weill, Subramani, and Broadbent (2002, p. 58) affirm the critical value of a superior IT infrastructure by stating: "Once a company's (IT) infrastructure is in place, there is a potential payoff: Competitors need long lead times to emulate the new business initiatives that the infrastructure enables."

The more the resources of an IT infrastructure leverage each other and provide a superior foundation for difficult to duplicate business initiatives, the higher the value it will bring to the organization (Melville, Kraemer, and Gurbaxani 2004; Narasimhan and Kim 2001; Weill, Subramani, and Broadbent 2002). Although an individual asset, or even a capability, of an IT infrastructure may be easily duplicated or imitated, there is evidence that when various IT assets and capabilities are integrated appropriately they form an entity that yields unique characteristics (Bharadwaj 2000; Byrd and Turner 2001; Duncan 1995; Piccoli and Ives 2005; Wade and Hulland 2004; Weill and Broadbent 1998; Weill, Subramani, and Broadbent 2002). Duncan (1995, p. 168) writes "one firm's (IT) infrastructure may make strategic innovations in business processes feasible, while the characteristics

of competitors' infrastructure may likewise cause their inability to imitate the innovations rapidly enough to mitigate the first mover's advantage." For example, retailers like Sears have been trying to challenge Wal-Mart but simply have not been able to match the superior IT infrastructure that has allowed Wal-Mart to continue to add innovative business processes. Sears and other retailers have access to the same IT assets and, to a large extent, the same IT capabilities as Wal-Mart but simply have not been able to assemble the assets and capabilities together in such a way to duplicate Wal-Mart's superior IT infrastructure.

FIGURE 1

THE CONCEPTUAL MODEL FOR THIS RESEARCH



IT: Information Technology
LISs: Logistics Information Systems
ROA: Return on Assets
TCO: Total Cost of Operations

Hypotheses for the Conceptual Model

The most direct task of an IT infrastructure is to act as a foundation for organizational IT business applications like LIS's. In providing a foundation for LIS's, a superior IT infrastructure acts as an effective mechanism to bolster these IT applications to better support the logistics functions in the supply chain (Narasimhan and Kim 2001, Weill, Subramani, and Broadbent 2002). High quality data

management and data delivery of a superior IT infrastructure enhance the impact of LIS's by providing accurate, relevant, timely, and complete information. Supply chain functions described earlier (e.g., order processing, supply relationships, customer management) all benefit from the use of such information that is delivered through LIS's utilizing a superior IT infrastructure (Autry, Griffis, Goldsby, and Bobbitt 2005; Narasimhan and Kim 2001).

A superior IT infrastructure also provides an integrative foundation to allow LIS's to communicate and coordinate information among these IT applications and thus increase the impact on supply chain functions. The increase in information sharing capability of LIS's is directly related to the extent to which critical and proprietary information is shared among supply chain participants (Li, Ragunathan, Ragunathan, and Rao 2006) and the impact of these systems on the supply chain functions (Sanders and Premus 2005).

Lastly, a superior IT infrastructure will have stellar IT personnel with excellent technical and organizational skills to implement, maintain, and support the LIS's in the organization. Highly knowledgeable and skillful IT workers would be able to help integrate the capabilities of the LIS's deep into the supply chain functions and thus increase the impact of these systems (Byrd and Turner 2001). IT personnel of a superior IT infrastructure would be better able to work with logistics personnel to match the capabilities of the LIS's more closely with their needs and produce IT applications with much more impact.

The combination of an integrative foundation that provides the channels for accurate, reliable, timely, complete, and relevant information and that is supported by a knowledgeable and skillful IT workforce is a powerful mechanism that would enhance the impact of any organizational IT application including LIS's. This argument leads to our first hypothesis:

H_1: A superior IT infrastructure positively affects the impact of logistics information systems (LIS's) in large firms.

An IT infrastructure provides a foundation for the delivery of business applications and services throughout an organization (Weill and Broadbent 1998). This implies that IT infrastructure might affect firm performance in ways above and beyond that provided through its support of LIS's. Although empirical evidence examining the relationship between the IT infrastructure and firm performance has been mixed, in most cases, the relationship has been positive. Narasimhan and Kim (2001) found that a superior IT infrastructure was related to the value creating activities of a company such as improving productivity and performance, enabling new ways of managing and organizing, and enhancing the ability to develop new businesses to serve existing and new customers. Sanders and Premus (2005) explored the relationship between IT capability, of which the IT infrastructure is a major component, and firm performance and reported a strong positive relationship between the two. The finding in Sanders and Premus is similar to those of Bharadwaj (2000) and Santhanam and Hartono (2003). One of the few empirical studies that did not show a positive relationship between IT infrastructure and a measure of firm performance, in this case, competitive advantage, was a study by Bhatt and Grover (2005). However, the overwhelming evidence is that a superior IT infrastructure will have a significantly positive effect on firm performance including overall financial measures like ROA and TCO. Thus the next hypotheses are:

H_{2a}: A superior IT infrastructure will significantly increase the return on assets (ROA) in large firms.

H_{2b}: A superior IT infrastructure will significantly decrease the total cost of operations (TCO) in large firms.

Logistics channels and supply chains are increasing in complexity with longer chains and more partners (Bardi, Raghunathan, and Bagchi 1994). Bardi, Raghunathan, and Bagchi wrote: "The LIS employed by a company determines the efficiency and competitiveness of the company in the marketplace. The ability to optimize logistics costs and service levels is affected by the LIS... The implementation of a LIS is motivated by a number of objectives including service optimization, cost optimization, information integration, and customer linking. A LIS is a critical link in the provision of service performance measurements and the achievement of customer logistics service satisfaction" (p. 72).

As noted by Bardi, Ranghunathan, and Bagchi (1994) and supported by other researchers, when LIS's have a high positive impact on the supply chain functions, it is reasonable to expect that the performance of these functions will be correspondingly high as well (Bardi, Ranghunathan, and Bagchi 1994; Kent and Mentzer 2003; Narasimhan and Kim 2001; Rai, Patnayakuni, and Seth 2006; Sanders and Premus 2005; Straub, Rai, and Klein 2004; Wisner 2003). High performance in the supply chain functions has been shown to have a positive effect on firm performance (Autry, Griffis, Goldsby, and Bobbitt 2005; Sanders and Premus 2005). These IT-enabled supply chain functions should allow companies to increase the efficiency and effectiveness of material and financial flows through the organization and substantially affect its performance (Autry, Griffis, Goldsby, and Bobbitt 2005; Marquez, Bianchi, and Gupta 2004). The resulting performance effects should include both a reduction in overall costs and a better return on assets used by the organization. Therefore, the following two hypotheses result from this argument:

H_{3a}: A high impact of LIS's on supply chain functions will lead to a significant increase in return on assets (ROA) in large firms.

H_{3b}: A high impact of LIS's on supply chain functions will lead to a significant decrease in total cost of operations (TCO) in large firms.

Size is used as a control in this study. Many past organizational studies have demonstrated that size can make a difference in the effects of IT in an organization (Harris and Katz 1991). One reason might be that larger firms typically have more slack resources to more effectively utilize IT in ways that smaller firms can not match (Grover, Fiedler, and Teng 1997). Size has been shown to have an effect in organizational studies that ranged from executive compensation to internal organizational demography to IT (Dobrev and Carroll 2003; Grover, Fiedler, and Teng 1997). According to the results of past organizational studies, size should have a positive effect on the relationships in this study.

RESEARCH METHODOLOGY

Content Validity for the IT Factors

To develop items for the factors in the study, an extensive content analysis of a twenty year period of the IT literature was performed. We searched databases that contain periodical indices in business and social science (ABI/INFORM and Wilson Social Science Directory, respectively) using

terms as suggested above (e.g., IT infrastructure) along with results oriented IT terms like information systems (IS)/IT capability, IS/IT performance, IS/IT productivity, and IS/IT success. We also reviewed top academic journals (*Information Systems Research, MIS Quarterly, Journal of MIS, Communications of the ACM, Decision Sciences, and Management Science*) specifically for years not contained in the indices. Scholarly books and monographs that had the stated criteria in their titles were also included.

Using the sources from the literature, explicit characteristics of each factor were extricated and noted. Three MIS faculty members reviewed the lists in an iterative fashion until agreement was reached on the characteristics of the factors. They were not further involved in the study. The characteristics provided the foundation for items used on the measurement instrument developed in the second round of the research methodology. Our objective was to determine various aspects of each IT factor and to represent them in the questionnaire. Table 1 includes a sampling of the literature that was used in creating the items and factors in our study.

TABLE 1

SAMPLING OF LITERATURE FOR FACTORS AND THEIR ITEMS USED IN THE STUDY

CONSTRUCTS	AUTHORS
IT Infrastructure	
Hardware/OS (HDO) Communications Systems (COM) Business Application Integration (INT)	Hamilton and Chervany (1981a, 1981b) Lewis, Snyder, and Rainer (1995) Miller and Doyle 1987 Miller (1993) Wilson (1993)
Data Quality (DAQ)	Bailey and Pearson (1983) Slevin, Stieman, and Boone (1991) Zmud (1978)
IT Department Skills and Knowledge (ITD)	Cheney and Lyons (1980) Green (1989) Harkness, Kettinger, and Segars (1996)
Impact from IT Use IT Impact on Inbound (ITB) IT Impact on Operations (IOP) IT Impact on Outbound (IOB)	Hamilton and Chervany (1981a, 1981b) Porter and Millar (1985) Rayport and Sviokla (1995) Venkatraman (1994) Wilson (1993)

Pre-Test

We performed a pre-test with seven faculty members and eight Ph.D. students at a large university in the southeastern US. We asked them to complete our questionnaire and then to review and comment on both its content and appearance. The respondents' comments on the questionnaire were

reviewed and appropriately consolidated into the instrument. For example, we dropped two questions from the "hardware/OS" factor because their comments indicated that they did not fit very well. We also revised the overall format in line with their suggestions.

Pilot Test

We contacted several large IT intensive companies to help pilot test the instrument. A contact person in each participating firm was asked to distribute the pilot test packet to IT managers in their firms. The pilot test packet included a cover letter explaining the research objectives, the questionnaire, and a stamped, return-addressed envelope. The IT managers included IT project managers, IT functional managers (e.g., application development, database management) and senior IT managers. Participants were asked to complete the instrument and to provide comments regarding the wording of the items, especially understandability and lack of ambiguity (Kerlinger 1986). Additionally, we asked the participants to comment on the overall appearance and organization of the instrument.

The responses from the pilot study suggested only minor cosmetic changes. No additional questions were dropped. Since there were only minor changes suggested and with the further review of two other university faculty members, the instrument was deemed ready to be sent to a large sample to gather data to evaluate the validity and reliability of the instrument and evaluate our research model. One of these faculty members continued to be involved in the study. The items for each IT factor used in this paper are shown in Table 2.

TABLE 2

LIST OF ITEMS USED IN THE STUDY

Code	ITEMS IN QUESTIONNAIRE
Heading	***The following statements describe the efficiency with which the information technology development and operations process use assigned resources (equipment, staff, materials, money) to provide information technology to your firm. Please CIRCLE THE NUMBER that best reflects the degree to which you disagree or agree with each statement.***
HDO1	Hardware and operating systems are available for use 24 hours per day, 7 days a week.
HDO2	Hardware and operating systems response time are adequate to keep users satisfied.
HDO3	Hardware and operating systems exhibit high degree of reliability.
HDO4	Hardware and operating systems uptime are comparable to available user time.
COM1	Communications systems are available for use 24 hours per day, 7 days a week.
COM2	Communications systems response times are adequate to keep users satisfied.
COM3	Communications systems exhibit high degrees of reliability.
COM4	Communications systems uptimes are comparable to available user time.
INT1	Business applications software is readily available to users.
INT2	Business applications software is integrated across all functional areas within the business unit to enable data exchange.
INT3	Data is fully integrated between business applications.
INT4	Communications systems are integrated (data/text/image/video) to enable efficient internal organizational interactions.

TABLE 2 (cont.)

Heading	***The following statements describe those characteristics of information produced by information technology that potentially impact decision making in your firm. Please CIRCLE THE NUMBER that best reflects to which you disagree or agree with each statement.***
DAQ1	Users receive reports in a timely manner (for decision making).
DAQ2	Users receive accurate information output (for decision making).
DAQ3	Users receive complete (thorough) information output (for decision making).
DAQ4	Users receive relevant information output (for decision making).
DAQ5	Users receive reliable information output (for decision making).
DAQ6	Data integrity is maintained throughout the organization.
Heading	***The following statements describe the extent to which the information technology department contributes to facilitating your firm's achievement of its goals. Please CIRCLE THE NUMBER that best reflects the extent to which you disagree or agree with each statement.***
ITD1	Present information technology department staff resources are adequate to meet our current operational and development needs.
ITD2	Information technology department staff responds to users requests for assistance in a timely manner.
ITD3	Information technology department services evolve to meet your firm's changing needs and capabilities.
ITD4	Information technology department personnel have superior technical capabilities.
ITD5	Information technology department planning supports your firm's ability to keep up with changing technology.
ITD6	Business continuity/disaster recovery plans adequately protect your firm's resources.
ITD7	Data security is adequate for protecting the integrity and safety of your firm's resources.
Heading	***The following statements refer to the impact information technology has had on your firm's activities such as buying raw materials, selecting suppliers, operations, marketing, and sales. Please CIRCLE THE NUMBER that best reflects the extent to which information technology has impacted the following:***
ITB1	Impact of information technology on activities associated with purchasing inputs (raw materials) required by the firm.
ITB2	Impact of information technology on interacting and coordinating activities with suppliers.
ITB3	Impact of information technology on reducing costs of switching to alternative suppliers.
ITB4	Impact of information technology on receiving, storing, and disseminating inputs to the product (e.g., material handling, warehousing).
IOP1	Impact of information technology on transforming inputs into the final product (e.g., cutting, assembly).
IOP2	Impact of information technology on improving your firm's products and processes (e.g., R&D).
IOP3	Impact of information technology on general management activities (e.g., planning, accounting, finance, legal).
IOP4	Impact of information technology on coordinating different activities such as purchasing, order processing, marketing, and production.

TABLE 2 (cont.)

IOB1	Impact of information technology on interacting and coordinating with customers.
IOB2	Impact of information technology on marketing your firm's final products (e.g., advertising, promotion).
IOB3	Impact of information technology on collecting, storing, and distributing the final product to your firm's customers (e.g., order processing, scheduling).
IOB4	Impact of information technology on providing service to maintain or enhance the value of the product (e.g., maintenance notices, upgrades).

Note: HDO, COM, INT, ITD, DAQ anchored on 7-point Likert scale from "Strongly Disagree" to "Strongly Agree." ITB, IOP, IOB anchored on 7-point Likert scale from "Not Much" to "Extensively."

Data Collection

The companies used in this study were a subset of a larger group of companies we surveyed for a larger study. For the original sample of companies, we compiled a mailing list of top computer executives from the *Directory of Top Computer Executives*. Due to the difference in profit motive for profit and non-profit firms, we eliminated all public hospitals, public educational institutions, governmental agencies, and other non-profit organizations from consideration as sample participants. We felt that for-profit firms were the more appropriate population for our initial examination of the IT constructs because of the strong demand for overall performance in that type of company. About 3,000 companies in the Directory were qualified according to these criteria.

Once the population was decided upon, we generated random numbers for each firm and the firms were sorted in ascending numerical order. The qualified population of about 3,000 firms was divided into homogeneous strata based on industry type and placed in each type in ascending numerical order. The number of entries needed from each industry category to achieve a sample size of 1,000 firms, yet maintain the population proportion of the Directory, was calculated. We selected entries for the mailing list by starting with the first entry per industry category and continuing down the list until the desired number of entries was obtained. Thus, a proportional, stratified random sample of fairly large, for-profit firms was developed and utilized.

This study used the "key informant" methodology. This methodology uses the individual identified as the most knowledgeable about the phenomenon of interest in the study. They are chosen for this specific reason. These individuals provide information about the aggregated unit of analysis by reporting the properties of the entire unit instead of their own personal attitudes and behaviors (Segars and Grover 1998). The organizational individual chosen as the key informant in this study was the top information executive typically called the chief information officer (CIO) in most firms although this executive might have other names such as vice president of information systems or similar titles. This individual is extremely knowledgeable about all the IT assets and capabilities in the organization including those associated with the IT infrastructure and logistics.

Three mailings of our research instrument were made to the CIOs. A total of 225 completed questionnaires were returned from the three mailings, approximately a third of the total from each mailing. This resulted in a response rate of 22.5% of the original 1000 firms targeted. Chi-square analysis of the industry distribution of the respondents showed no difference from the industry distribution of all the firms in the population of 3,000 of the largest firms in the United States. We also

divided the respondents into three groups based on the timing of their responses. Since the respondents fell into fairly equal groups based on their response to the first, second, or third mailing, this was relatively easy to do. ANOVA analysis showed no difference among the three groups on any of the IT factors used in the study and on size. These two tests suggested an absence of non-response bias in the returned questionnaires relative to the overall sample.

Sub-Sample from COMPUSTAT

Of the 225 responding organizations in our survey, 104 of the companies were found in the COMPUSTAT database. The COMPUSTAT database carries financial data for a 20-year period on many of the publicly traded companies in the US. Of the 104 companies, we found financial data on 94 companies (the other had data that were marked as NA or not available). The two financial measures used in this study are ROA and TCO. ROA is often used by researchers as measure of overall firm performance because it incorporates measures of both firm profitability and efficiency (Barua, Kriebel, and Mukhopadhyay 1995; Bharadwaj 2000; Weill 1992). Following other studies that have used ROA as a measure of firm performance, we propose that the performance benefits of a superior IT infrastructure and a high impact LIS are likely to include aspects of both increased efficiency and greater profitability.

TCO is a measure that consisted of the summation of the selling, general, and administrative costs (SGA) and the cost of goods sold (COGS) divided by sales. The ROA and TCO measures used in this study are the averages of the three years immediately following the year the primary data was collected, respectively. The reason that we used the three year window immediately following the year of data collection is that there is evidence that existing large-scale IT resources like IT infrastructure are not likely to change radically over a short time period like a three year period and will have an enduring impact for at least that time frame (Brynjolfsson, Malone, Gurbaxani, and Kambil 1994; Wade and Hulland 2004; Weill, Subramani, and Broadbent 2002).

We standardized the averaged performance measures by using the companies in the same respective four-digit SIC industry code as each of our sample companies. A z-score for each measure was calculated for each company in our sample using the other companies in that company's industry as references to determine how well the sample company performed within its own industry. The use of four-digit SIC codes is well accepted in organizational studies as a way to standardize for industry effects (Byrd and Marshall 1997). Wade and Hulland (2004) note this sense of comparativeness, that is, assessing performance relative to key competitors, has not been emphasized by researchers using the RBV as a theoretical foundation.

To increase the generalizability of the results of our study, we performed an ANOVA comparing the COMPUSTAT set of companies (94 companies) with the set of companies that were not used found in COMPUSTAT (131 companies) using each IT factor (e.g., hardware/OS, data quality) as the criterion variable. We found no statistical difference between the two sets of companies on any of the IT measures (p-values from .128 to .728). We did, however, find a difference between the size of the COMPUSTAT set and the remaining firms from the original sample on both sales and number of employees (p-values of .026 and .032, respectively). From this analysis, we acknowledge that the firms in the sub-sample (COMPUSTAT) group are significantly larger than the set of companies not found in COMPUSTAT.

The demographics for the sample of 94 firms used in this study are presented in Table 3. The Chief Information Officer (CIO) or the Information Services Director completed 85% of the survey questionnaires. Other respondents identified themselves as vice presidents of IT, vice presidents of information systems, general managers of IT, and global vice presidents of information services. More than 62% of the firms had at least $1 billion in sales with a similar percentage of companies employing more than 5,000 people. The sample consisted of 32% manufacturing firms, 14% retail/ wholesale firms, 10% financial firms, and about 5% insurance companies, with lower percentages of other types of firms.

TABLE 3

CHARACTERISTICS OF THE STUDY SAMPLE

Characteristics of the Respondent	Sub-Sample in COMPUSTAT (%)
I. Average number of years worked in the company	14.5
A. Job Title:	
Chief Information Officer	41.5
Information Services Director	43.6
Other	14.9
II. Characteristics of the Company	
A. Number of Employees	
Between 251 and 1,000	3.2
Between 1,001 to 5,000	35.1
Over 5,000	61.7
B. Gross Revenue (in millions)	
$50 to $250	6.2
$251 to $500	11.7
$501 to $1,000	19.3
Over $1,000	62.8
C. Industry Group	
Manufacturing	31.9
Insurance	5.3
Health Services	4.3
Financial	9.6
Retail/Wholesale	13.8
Utilities	2.1
Other	26.6

RESULTS

Correlations for the measures used in the study are given in Table 4. The reliability and validity for the measures are discussed next.

Reliability

The reliabilities of all the measures were acceptable with values well over .70 for all the measures with many in the .8 and .9 ranges. Reliability is related to the degree that measures are error-free and was measured through Cronbach's alpha. Reliabilities are given in Table 5.

Validity

Since the sample size is relatively small compared to the scholarly recommendation to use a 10:1 ratio of sample size to number of parameters estimated, the convergent validity for each latent variable was assessed separately using a confirmatory factor analytic model (Bollen 1989; Nunnally and Bernstein 1994). This method was also used in Chatterjee, Grewel, and Sambamurthy (2002). The results from the analyses showed all measures exhibited convergent validity.

Discriminant validity is assessed by the pairing of all possible combinations of the latent factors in confirmatory factor analytic models (Anderson and Gerbing 1988). This method was used by Segars and Grover (1998) and Chatterjee, Grewal, and Sambamurthy (2002). The results for discriminant validity revealed that all measures are distinct from any other thus that the measures of the instrument demonstrated discriminant validity. The validity for the second-order factors was assessed through the significance of the relationships between first-order and second-order factors (Segars and Grover 1998). Validity results are shown in Table 5.

TABLE 4

CORRELATIONS OF THE FIRST ORDER

	HDO	COM	INT	DAQ	ITD	ITB	IOP	IOB
HDO	1.00							
COM	.59**	1.00						
INT	.36**	.45**	1.00					
DAQ	.37**	.42**	.46**	1.00				
ITD	.39**	.42**	.53**	.47**	1.00			
ITB	.14**	.24**	.30**	.17*	.28**	1.00		
IOP	.24*	.24**	.23**	.19**	.28**	.71**	1.00	
IOB	.18**	.26**	.38**	.23**	.30*	.59**	.53**	1.00

Note: * denotes significance at the .05 level.
** denotes significance at the .01 level.

TABLE 5

MEASUREMENT MODELS: CONFIRMATORY FACTOR AND RELIABILITY ANALYSES

Measurement Model	Range of Standardized Factor Loadings	GFI	NFI	CFI	Reliability Cronbach's Alpha	RMSEA	Adjusted χ^2
Hardware/OS	.68-.87	.99	1.0	1.0	.89	.075	< 4
Communications Quality	.82-.92	.99	.99	.99	.93	.070	< 4
Business Applications Integration	.50-.96	.99	.96	.96	.85	.080	< 4
Data Quality	.71-.91	.94	.92	.93	.88	.034	< 4
IT Department Quality	.51-.70	.96	.99	.96	.84	.081	< 5
IT Impact on Inbound	.60-.97	.99	.99	.99	.89	.070	< 2
IT Impact on Operations	.62-.85	.93	.98	.99	.83	.053	< 2
IT Impact on Outbound	.60-.70	.99	.99	.99	.84	.052	< 2

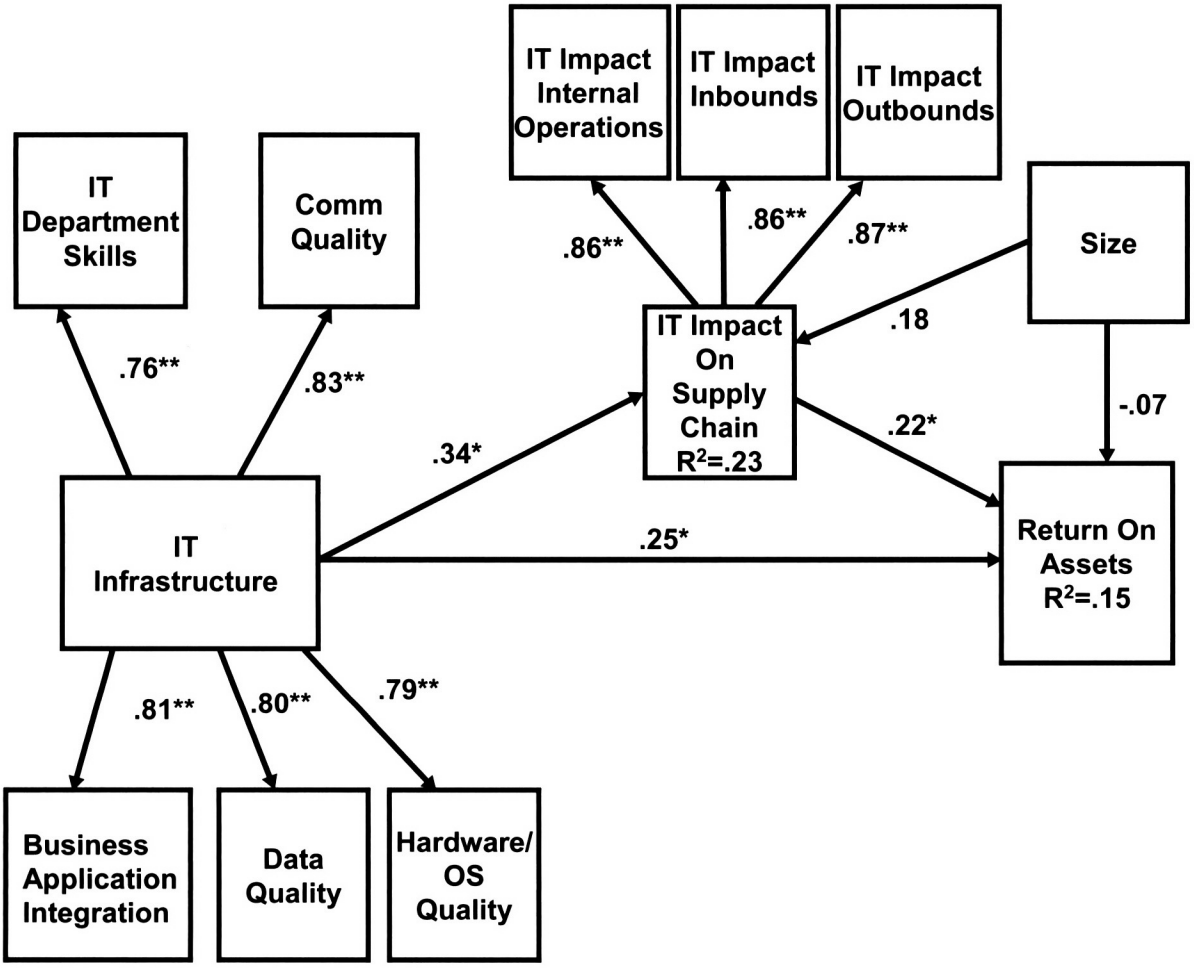
Results of Hypothesis Testing

In our analysis, we ran two models, shown as Figures 2 and 3, with ROA and TCO, respectively, as the financial measures. In PLS, the statistical significance of the paths was determined by using bootstrap resampling. We completed two runs of 1000 resamples for the model runs. Hypothesis 1, proposed that a superior IT infrastructure will positively affect the impact of logistics information systems (LIS's) was supported at the .05 level. The beta value for the relationship is .34 with an R^2 of .23.

A superior IT infrastructure also had a direct effect on ROA and TCO above and beyond the effects through LIS's impact thus supporting hypotheses 2a and 2b with beta values of .25 and -.32, respectively. Hypothesis 3a, which proposed that a high impact of LIS's on supply chain functions will significantly impact a firm's ROA was supported with a beta value of .22. Hypothesis 3b was also supported at the .05 level with a high impact of LIS's on supply chain functions significantly and negatively related to TCO with a beta of -.21. The total R^2 for the impact on ROA was .15. The total R^2 for the two IT variables on TCO was .20. Size did not seem to make a difference in our model since all relationships in both model runs were not significant.

FIGURE 2

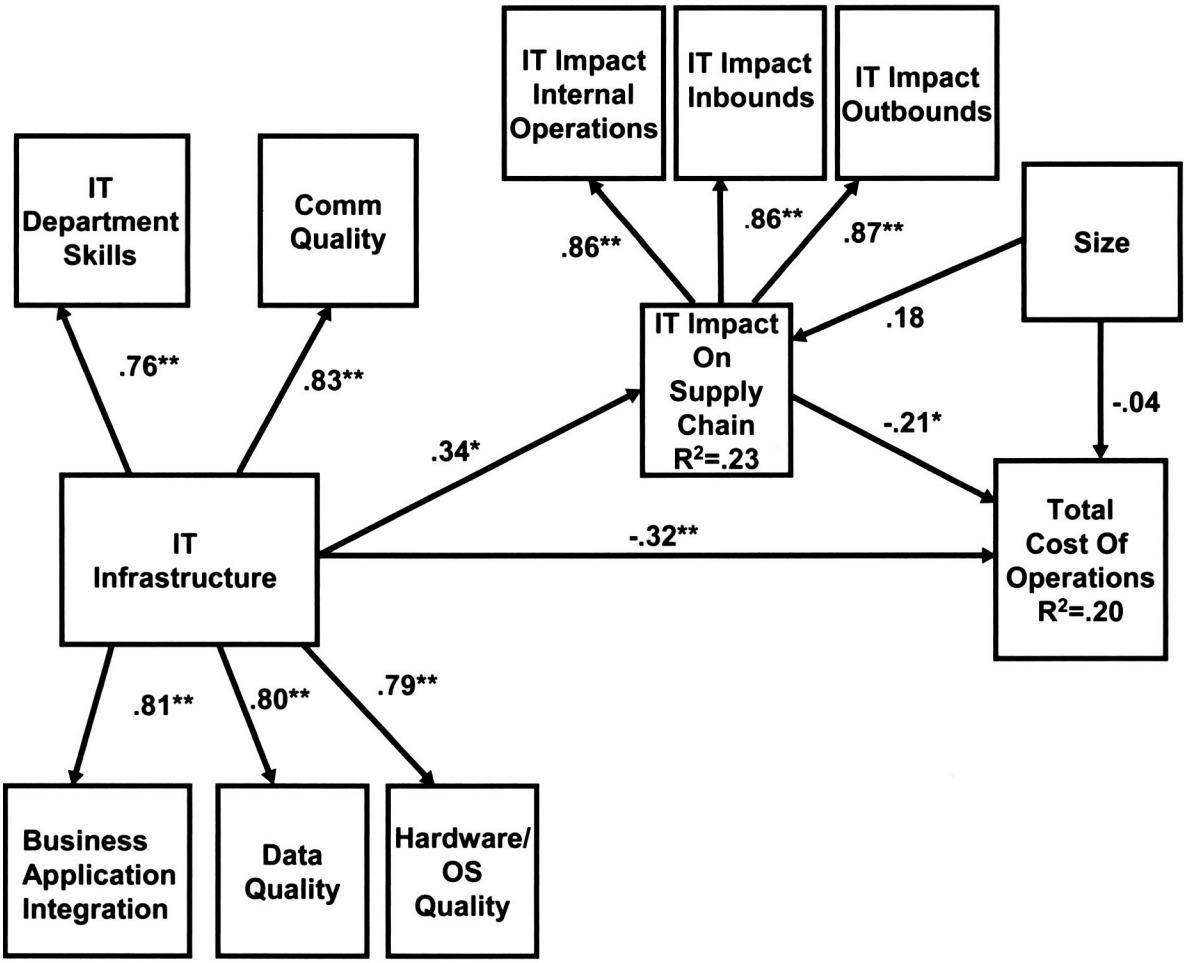
RESULTS OF PLS FOR RETURN ON ASSETS (ROA)



Significance Key
** .01 Level
* .05 Level

FIGURE 3

RESULTS OF PLS FOR TOTAL COST OF OPERATIONS (TCO)



DISCUSSION

Using the RBV, our study examined the direct and indirect influence of IT on firm performance. We proposed and investigated the role of an IT resource, the IT infrastructure that was shown to have an enabling effect on another organizational resource, LIS's impact, which is defined as the effect of IT applications that are specifically used to support the supply chain functions, and a direct influence on two measures of firm performance, ROA and TCO. We characterized the IT infrastructure as a combination of IT assets like hardware and software and IT capabilities like IT skills and business application integration. We argued that IT infrastructure may lead to better intermediate performance as well as better overall organizational performance. Likewise, the impact of LIS on supply chain functions yielded positive benefits by increasing ROA and decreasing TCO.

The firm performance measures in this study were represented by three year averages of ROA and TCO. The three year averages provide some evidence of a moderate term effect of IT infrastructure and LIS's. In order for an IT capability to provide a competitive advantage, the performance advantage has to be sustained over some period of time. A key question for determining if a capability gives a competitive advantage or not according to the RBV is what length of time is appropriate for an advantage to be maintained for it to be a "sustained" competitive advantage? Is it three years, five years, ten years, or even more? This issue of the length of time is seldom discussed by RBV researchers. This is an issue that needs to be discussed more in the research literature especially in future RBV studies. The results of this study give some support that IT infrastructure and LIS's have effects over a three year time period. Although these results do not provide definitive evidence that IT infrastructure and LIS's provide "sustained" competitive advantage, they do suggest that these IT capabilities may play a primary role in providing this type of an advantage in large firms similar to those in our study.

This study shows that when IT infrastructure is characterized as a single organizational capability consisting of hardware and software along with IT human skills and knowledge that it makes up a very powerful organizational resource, one that is likely to yield a competitive advantage. Not only does the IT infrastructure contribute directly to the intermediate variable in this study, the impact of LIS's, it also has an influence directly on the organizational performance measures used in this study above and beyond that through the intermediate variable. This finding is a major contribution because some previous studies have reported that IT infrastructure may not offer a competitive advantage because it can be easily duplicated (Mata, Fuesrt, and Barney 1995). The results here really bring that previous notion into doubt.

We believe that the concept of IT infrastructure may have been too narrowly conceptualized in earlier studies. An IT infrastructure is not just the hardware, software, and data that other IT applications are built on. The IT infrastructure consists of these elements plus the human elements of IT knowledge and skills of the workers in, and associated with, the IT function (Byrd and Turner 2000). When these assets (hardware, software, and data) and capabilities (IT skills and knowledge, IT practices) are complementary, they can form a very strong powerful organizational resource. Two factors are said to be complementary if one raises the value of the other and vice versa (Barua and Mukhopadhyay 2000). This could indeed be what is happening with IT infrastructure in this study. When both sets of factors, hardware, software, and data on one hand and IT skills, knowledge, and practices on the other hand, are both rated highly by the CIO respondents, the result is a capability that is extremely valuable to an organization.

This study opens up the "black box" of other IT investment studies, like Brynjolfsson and Hitt (1996), of IT usage, and investigates the effects of IT where they occur in an organization (Barua, Kriebel, and Mukhopadhyay 1995). Barua and Mukhopadhyay (2000, p. 76) state the importance of this feature clearly: "One potential limitation of most of the preceding studies (like Brynjolfsson and Hitt) is they considered IT in the abstract in terms of the levels of investment. Given that there are many types of IT application areas (e.g., manufacturing, logistics, sales, and marketing), using the total IT investment figure may not be particularly useful in obtaining an accurate estimate of IT impacts. One alternative approach, therefore, will be to study the application of a technology in different contexts and to derive more meaningful results." The advantage of the approach used in our study is that more accurate and more precise impacts can be evaluated and determined than is pos-

sible if aggregate IT investment figures are utilized. The value of the earlier aggregate IT investment studies was that they showed that IT had a positive influence on firm performance. However, they did not give an indication of just how this influence was manifested. Our study, which is more specific and addresses at least one of the intermediate effects (Barua, Kriebel, and Mukhopadhyay 1995), is a typical example of the type of studies we now need to do to gain insights and better understanding of how IT brings value to an organization. The intermediate variable in our study was the impact of LIS's.

The impact of LIS's also proved to be a valuable capability for the organizations in this study. High evaluations of the impact of LIS's are linked to higher ROA and a decrease in TCO. These resources show that IT applications associated with the logistical functions of an organization are key to providing value from the IT investments of a firm. The impact of the LIS's in this study includes influences on internal operations, inbound logistics, and outbound logistics in the firms that responded to our survey. The importance of these logistical activities and their link to competitive advantage has been endorsed and accepted for over twenty years (Porter 1985). The impact of IT on these logistical activities seems to be positive and make it even more likely that they will lead to a competitive advantage in organizations where this impact is indeed high.

Managerial Implications

The findings of this study suggest that firm executives should realize that the most value is likely to accrue when the technical and human IT resources are appropriately combined. For value to be created, the technical IT resources must be well managed by IT personnel. This might also imply that these managers should not just automatically outsource for human IT skills and services since synergy between the technical resources and human resources are more likely to occur if the human IT skills are inside the organization.

Our study also provides evidence that investment in IT applications specifically used to support supply chain functions can lead to an advantage. This study differs from many others that investigated the value of IT in supporting core supply chain functions by presenting a broader scope than these other studies. Auramo, Kauremaa, and Tanskanen (2005) point out that the results from past supply chain studies are diminished because of their narrow scope. They cite examples such as estimating the dollar value of EDI in automotive manufacturer-component supplier-relationships (Mukhopadhyay, Kekre, and Kalathur 1995), and the performance of an ERP after a year of operation (McAfee 2002). Our measure of supply chain capability is much broader in scope in the sense that it considers many of the processes of a typical supply chain and found value when these processes are enabled by IT.

Oftentimes, as indicated to some extent by our findings, IT-enabled business processes can be a source of competitive advantage to adopting firms. For example, Dell's IT-enabled supply chain model took many years to develop and to dominate its market. It has taken many years for Dell competitors to come close to matching its IT infrastructure. However, for many years, Dell enjoyed greater profits than all of its competitors primarily because of its IT-enabled supply chain (Magretta 1998).

Limitations and Future Research

Like all studies examining extremely complex organizational phenomena, this study had several limitations. For one, the sample consisted of very large US corporations, generally members of the

Fortune 2000. Therefore, it might be difficult to generalize the results here to small and medium sized firms. In the same way, it might be problematic to generalize the findings to foreign corporations, large or small. Finally, on the same note, the findings might not apply to large or small public organizations. Future researchers should create samples using one of these types of firms in their research projects and compare their findings with ours.

Even though we used two different data sources for the IT variables and financial measures, we still only used one respondent from each organization for the IT data. Although the single respondent was a high-level IT executive in most cases, this can still cause problems. Multiple informants from each organization are always an ideal, but rarely practical, in actual studies targeting very high-level executives. The fact that we used COMPUSTAT for the financial data lessened this limitation. Still, the use of a single informant, regardless of how highly placed, can introduce some bias and should be considered in interpreting study results. Future studies may focus on collecting data from two or three high level IS and business executives and triangulating their data.

Although we used two firm performance measures, ROA and TCO, that represent key firm performance metrics from a causality point of view, other firm measures could have been investigated and probably should be in future studies. A single study can simply not examine every option since such a study would quickly grow out of hand. Studies relating IT infrastructure and other IT capabilities to different financial and non-financial performance measures should be done in the future so that cumulative research knowledge in this stream can be amassed.

The lack of support for size may show that the relationships considered in our model are fairly consistent across relatively large organizations. For size to have an impact, the differences in the size of the firms may have to be greater. Future studies might contrast small and medium size firms with large firms similar to the ones in this study to determine if size truly makes a difference in the relationships examined in this study.

CONCLUSION

As organizations continue to invest in IT to support and enhance core organizational processes, understanding how these investments enhance competitive advantage and lead to positive firm performance has become an important topic. It is widely recognized that, while some firms realize significant benefits from their IT investments, other firms are less successful at garnering value from their technology investments. In our study, we draw from the resource-based theory to examine the underlying mechanisms through which IT investments influence a firm's competitive position. Specifically, we examined the direct and indirect relationships from a superior IT infrastructure to the impact of LIS's used to support supply chain activities, to the effects on total cost of operations and return on assets. All paths were significantly related to appropriate downstream variables. A superior IT infrastructure was shown to be directly related to both firm performance measures, and also indirectly through an intervening variable, LIS's impact. The use of firm performance variables from a different data source, COMPUSTAT, adds to the significance of our results. We encourage other researchers to look inside the "black box" of the relationship between IT and firm performance so that a cumulative stream in this very important area can be realized.

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