Efficiency or Innovation: How do Industry Environments Moderate the Effects of Firms’ IT Asset Portfolios?

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Abstract

Firms invest in a variety of information technologies and seek to align their IT asset portfolios with two key performance outcomes: efficiency and innovation. Existing research makes the universalistic assumption that both outcomes will always be realized through firms’ IT asset portfolios. There has been limited research on the conditions under which firms’ IT asset portfolios should be more oriented toward efficiency or innovation. Here, we argue that the nature of the industry where a firm competes will have a significant moderating effect on the links between firms’ IT asset portfolios and efficiency or innovation outcomes. Using panel data that covers a wide range of industry environments, we find that at lower levels of dynamism, munificence and complexity, IT asset portfolios are associated with a greater increase in efficiency. In contrast, in environments with higher levels of complexity, IT asset portfolios are associated with a greater increase in innovation (i.e., development of new products and processes, and exploration of growth opportunities). These results provide insights about how firms could realize strategic alignment by tailoring their IT asset portfolios toward an efficiency or innovation focus.

Keywords: Efficiency, Innovation, Exploitation, Exploration, IT Asset Portfolio, IT Value, Competitive Environment, Dynamism, Munificence, Complexity
INTRODUCTION

The alignment of information technology (IT) management and business strategy continues to be a priority and a challenge in organizations (Luftman, Kempaiah, and Rigoni, 2009). Luftman and Kempaiah (2007; also, Ward, Daniel, and Peppard, 2008; Westerman and Hunter, 2009) argue that the ability of executives to assess and communicate how their firms’ IT investments benefit specific business goals is important for enhancing alignment. As a case in point, Curley (2004) describes the ongoing efforts at Intel to develop a dashboard of business goals that could be used as benefits for justifying IT investments. Managers are encouraged to identify the appropriate business goals and make the case for IT investments accordingly. It is clear that advances in the practice of IT management have sought to develop frameworks and methodologies for linking IT investments with specific business goals and benefits. However, the existing research has yet to provide commensurate descriptive or prescriptive evidence about how and when IT investments enable specific business outcomes.

In particular, the business strategies of firms involve two distinctive processes of exploitation and exploration (e.g., March 1991; Levinthal and March 1993). During exploitation, firms use their existing knowledge to enhance organizational efficiency (Benner and Tushman 2003). On the other hand, during exploration, firms search for new knowledge, develop new products and services for emerging customers and markets and enhance their innovation performance (Benner and Tushman 2003). Therefore, firms invest in IT to improve the efficiency of their existing operations by substituting labor, reducing inventory, or by eliminating waste. Here, IT value is achieved through exploitation, i.e., by performing existing activities more efficiently. Transaction processing systems (TPS) are a classic example of this type of IT (Sabherwal and Chan 2001). Alternatively, firms invest in IT to achieve innovation by supporting the
development of new products and processes. For example, market scanning and interpretation
systems are used to identify new products and services, and discover underserved markets
(AnalysisTeam 2005).\textsuperscript{1} In this way, IT value is achieved through exploration i.e., by developing
new products and services to serve underserved markets.\textsuperscript{2}

Existing empirical research has demonstrated that investments in IT are associated with
increased firm output (Brynjolfsson and Hitt 1993, 1996; Lichtenberg 1995; Barua and Lee
1997; Lee and Barua 1999; Menon et al. 2000) and enhanced financial and market performance
(e.g., Mahmood and Mann 1993; Kettinger 1994; Hitt and Brynjolfsson 1996; Bharadwaj et al.
1999; Bharadwaj 2000; Zhu 2002). Recent research also provides evidence that investments in
IT enhance organizational innovativeness (Kleis, Chwelos, Ramirez, and Cockburn, in press).
Other scholars have argued that the enterprise-level impacts of IT should be measured through
intermediate (i.e., process) level metrics (e.g., inventory turnover ratio) (Barua et al. 1995;
Kohli and Devaraj 2003; Ray et al. 2005; Banker et al. 2006; Tallon and Kraemer 2006).
However, the IT value literature largely focuses on overall firm performance with limited
attention being paid to the efficiency or innovation outcomes associated with the exploitation and
exploration processes. Further, research makes the implicit assumption that IT is associated
universally with an increase in all the measures of performance. Given the plurality of business
performance measures, managerial intuition suggests that firm’s IT investments might be

\begin{itemize}
\item \textsuperscript{1} This efficiency-innovation classification of IT-enabled value creation is also analogous to the implications of IT for efficiency and effectiveness as proposed in Melville et al.
\item \textsuperscript{2} It is clear that both exploitation and exploration are associated with innovation, albeit of different types. As indicated above exploitative innovations involve incremental improvements in existing products and processes that build on existing technologies. However, exploratory innovations are aimed at developing and entering into new product market domains using radical innovations that involve acquiring and developing new knowledge (Baum et al. 2000; Benner and Tushman 2002; He and Wong 2004; Gupta et al. 2006). In this paper, we use the term \textit{efficiency} to refer to exploitative innovation and use the term \textit{innovation} to refer to explorative innovation.
\end{itemize}
differentially associated with efficiency or innovation under the different contexts of industry environment or business strategy. Existing empirical research, however, does not provide evidence of such contingent effects.

Further, while most studies of the business value of IT have focused their attention on either the stock of IT investments made by a firm (Brynjolfsson and Hitt, 1996; Bharadwaj, Bharadwaj, and Konsynski, 2000; Kleis et al., in press) or their investments in specific IT applications (Mukhopadhyay, Surendra, and Srinivasan, 1997; Banker, Bardhan, Chang, and Ling, 2006), there is a recent realization that a portfolio perspective may be more appropriate. Aral and Weill (2007) identify four different types of systems in a firm’s IT asset portfolio – infrastructural, transactional, informational, and strategic IT systems, and describe how they contribute differently to efficiency and innovation. Ross and Beath (1996) describe different long-term and short-term goals in a firm’s IT asset portfolio and describe how firms can balance their portfolio across these goals. A common theme in these conceptualizations is that firms can enhance strategic alignment through their IT asset portfolio because they have to address multiple performance objectives, not all of which might be achievable through similar actions or investments.

Therefore, this research examines the relationship between firms’ IT asset portfolios and the performance outcomes associated with efficiency or innovation. Further, we test a contingency theory whereby we propose that firms’ IT asset portfolios are related to efficiency or innovation outcomes in different industry environments. This contingency perspective is motivated by the IS-business strategy alignment literature (e.g., Sabherwal and Chan 2001), which suggests that managers should align their IT goals with business strategies and objectives; and, the structure–conduct–performance paradigm (e.g., Porter 1985; Domowitz 1986), which suggests that an
industry’s structure influences the behaviors and performance of the firms in that industry. Recent literature has also emphasized the role of the firms’ competitive environments in moderating the impact of IT on firm-level productivity and performance (e.g., Berndt and Morrison 1995; Morrison 1997; Stiroh 2002; Hitt and Brynjolfsson 1996; Chiasson and Davidson 2005; Melville et. al. 2004; Melville et al. 2007). However, few studies have specifically examined how environmental characteristics moderate the performance outcomes associated with IT asset portfolios.

Our study uses a multi-industry panel data to examine how environmental characteristics influence the impact of IT asset portfolio in achieving efficiency and innovation. Following the strategy literature (e.g., Dess and Beard 1984; Keats and Hitt 1988), we characterize a firm’s industry environment in terms of the dynamism, munificence and complexity. Our analysis suggests that the environment does moderate the impact of IT asset portfolio on efficiency and innovation. Specifically, we find that in less dynamic, munificent, and complex industry environments, IT asset portfolios are associated with a greater increase in operational efficiency in the form of greater increase in inventory, payables, and receivables turnover, and a greater decrease in selling and administrative costs. In contrast, in more complex environments, IT asset portfolios are associated with a greater increase in innovation in the form of greater increase in R&D intensity, new product and process patents, and market-valued innovation (captured by residual Tobin’s Q). These results suggest that managers should tailor their IT asset portfolios toward exploitation processes for efficiency or exploration processes for innovation, depending on the nature of their firm’s industry environment.
The rest of this paper is organized as follows. First, we develop our conceptual model and research hypotheses. Next, we describe the data and the operationalization of the variables. Finally, we present the empirical analyses and discuss the implications of our research.

**CONCEPTUAL MODEL AND HYPOTHESES**

A recent theme in the studies of firms’ IT investment behaviors is that they can enhance strategic alignment through their IT asset portfolios (Aral and Weill, 2007; Ross and Beath, 1996). We extend these ideas by explicitly linking the IT asset portfolio with the two core value-creating processes of exploration and exploitation. Exploitation IT investments are aimed at enhancing the operational efficiency of customer side, supplier side, and administrative and operational processes. Examples of exploitation IT investments include transaction processing systems such as point of sale systems. On the other hand, exploration IT investments are aimed at enhancing innovation by accelerating the development of new product and process innovations. Examples of exploration IT investments include collaboration systems and product data management systems for supporting innovation. Though Ross and Weill (2002) argue that the level of investment in IT itself is a strategic decision, we propose that an equally important managerial challenge is how the IT asset portfolio should be allocated among exploitation and exploitation initiatives. Existing studies have not examined how firms should tradeoff between designing IT asset portfolio for efficiency or innovation, especially when they may be constrained by the fact that their overall level of investments are inadequate for enabling all the potential IT initiatives. We argue that decisions about the relative levels of IT investments in exploitation and exploration initiatives will be influenced by the characteristics of the industry where a firm operates and the imperatives to align the IT asset portfolio and business strategy with those environmental characteristics.
Prior research finds that the industry environment ‘explains’ a significant proportion of the variance in firm performance (e.g., McGahan and Porter 1997, 2002; Misangyi 2006; Hawawini et al, 2003). For example, Mauri and Michaels (1998) report that the environmental factors have a strong influence on the R&D and advertising investments made by firms in an industry. The strategy literature characterizes a firm’s industry environment in terms of its dynamism, munificence and complexity (e.g., Dess and Beard 1984; Keats and Hitt 1988). Dynamism refers to the volatility and unpredictability of the changes in various environmental variables that a firm has to deal with (Keats and Hitt 1988). For instance, industries with higher uncertainty in demand are more dynamic. Munificence refers to the opportunity for growth within an industry (Dess and Beard 1984). Industries with a higher sales growth rate are more munificent. The complexity of the environment arises from the number and diversity of external entities a firm has to deal with – the larger the number and heterogeneity of the entities (e.g., competitors), the more complex the environment. For instance, complexity is associated with greater levels of competitive rivalry in an industry.

Organizational learning theories suggest that, in more stable environments, the pursuit of exploitation leads to superior financial performance, whereas, in more unstable environments, the pursuit of exploration leads to superior financial performance (e.g., March 1991; Levinthal and March 1993; Jansen et. al. 2006). Therefore, we argue that firms in less dynamic, munificent and complex environments may use IT to focus more on improving the efficiency of their existing processes, whereas firms in more dynamic, munificent and complex environments may use IT to focus more on searching for new business opportunities. Below, we explore how environmental characteristics moderate the effects of the IT asset portfolio on operational
efficiency and on new product and process innovation. Figure 1 presents a graphical representation of our conceptual model.

Firms face lower levels of dynamism in industries with enduring technologies and stable and predictable consumer preferences. Here, they can produce and sell homogeneous products in larger volumes and achieve economies of scale. Munificence refers to the opportunities for growth in the industry. There are fewer growth opportunities in less munificent environments. Though firms in these industries are likely to face less competition from new entrants, they face aggressive competition from other incumbents. Thus, they strive to eliminate waste, reduce costs, and increase the efficiency of their operations to maintain profitability. The complexity of the environment arises from the number and diversity of external entities a firm has to deal with. Competition is one of the salient aspects of a complex environment. A concentrated industry may have a less complex environment because a few firms dominate the industry. Porter (1980) argues that, in concentrated industries, the “leader or leaders can impose discipline and play a coordinative role (p. 18).” In a concentrated, i.e., in a less complex industry, each firm knows its
competitors and how they will behave, so that there is less uncertainty about the nature of the competitive interactions. Also, if there are few new firms with new resources and capabilities, the competitive interactions would be more predictable, as the incumbent firms would know their competitors and their likely behaviors (Thomas 1996).

Industry environments with lower levels of dynamism, munificence, and complexity allow firms to pursue relatively enduring strategies and compete through operational efficiencies and incremental innovations (Tushman and Anderson 1986). Firms compete by following intensive planning and control that is oriented toward cost reduction and improvements in operational efficiency. They build information systems for maintaining control over existing operations and seek to grow with incremental improvements in products and processes rather than through radical innovations to explore new product and/or market opportunities.

In less dynamic, munificent and complex environments, a firm’s IT asset portfolio should support the pursuit of exploitation and enhancement of operational efficiency. Barua et. al (2004) suggest that IT resources are associated with supplier and customer side informational capabilities, where supplier- (customer-) side informational capabilities improve information sharing and coordination with suppliers (customers). These informational capabilities should positively impact operational performance. Thus, firms may use their IT asset portfolio to improve the efficiency of their customer side, supply side, and administrative and operational processes. The objective of customer-side informational capabilities is to reduce the cost of serving customers. For example, GE uses an integrated system to support web, call center, and retail activities to reduce costs and improve the efficiency of customer service operations (Patton 2006). On the supply side, firms may use EDI systems to reduce shipment errors (Srinivasan et al. 1994). Similarly, firms may rely on Collaborative Planning, Forecasting, and Replenishment
(CPFR) tools to decrease inventory levels and reduce stock outs (Lee 2002). These supplier-side informational capabilities improve the efficiency of the operational and supply side processes.

In less dynamic, munificent, and complex environments, firms may also focus their IT asset portfolio on administrative and financial management systems, where the objectives are to monitor and control operations, improve asset allocation and utilization, and reduce cost and eliminate wastage. For example, Dow Chemicals adopted enterprise systems to reduce costs by streamlining financial control and administrative processes (Davenport 1998).

These arguments suggest that firms operating in less dynamic, munificent, and complex industry environments usually pursue efficiency in their operations. Of course, some firms may choose to go counter to the industry norm and follow a differentiation approach through innovation in less dynamic, munificent, and complex industry environments (Smith et al, 2001). Such a strategy would be consistent with the competitive approach taken by prospectors (Miles and Snow, 1978). However, our conceptual arguments suggest that most firms are likely to follow the industry norm and pursue efficiency in less dynamic, munificent, and complex industry environments. Therefore, we propose that firms in such environments will direct more of their IT asset portfolio toward exploitation initiatives relative to exploration initiatives. As a consequence, their IT asset portfolio is more likely to be weighted toward the pursuit of efficiency. We state our formal hypothesis as:

$H1a$: In less dynamic industry environments, the level of investments in the IT asset portfolio will have a greater impact on efficiency.

$H1b$: In less munificent industry environments, the level of investments in the IT asset portfolio will have a greater impact on efficiency.

$H1c$: In less complex industry environments, the level of investments in the IT asset portfolio will have a greater impact on efficiency.
When a firm operates in more dynamic environments, it faces significant unpredictability regarding its customers’ tastes and preferences and its production and service technologies. Changes in technologies and customers’ needs and preferences compel firms to change their strategies (D’Aveni 1994; Tushman and Anderson 1986; Brown and Eisenhardt 1997). Thus, competition in dynamic industries – sometimes referred to as hypercompetition (D’Aveni 1994) – is based on radical innovation, where firms compete by introducing new products and services and by identifying and expanding into new areas of opportunity. In such environments, firms value being the “first in” to new product and market areas, and strive to respond rapidly to early signals concerning areas of opportunity.

A munificent environment has a high growth rate, and it offers a variety of avenues for business expansion and profits. However, munificent environments attract competitors who may bring new assets and capabilities. Thus, munificent environments motivate incumbents to seek new product and process innovations and realize growth opportunities instead of being preempted by new entrants or rivals.

Complex environments are characterized by heterogeneous actors and many inter-organizational connections and interactions. Keats and Hitt (1988) argue that the organizational information processing requirement increases with the number and heterogeneity of the industry members (such as competitors). Thus, in a more complex environment, there are more competitors, and it is difficult for a firm to predict its competitors’ actions. Similarly, when competitors have very diverse resources and capabilities, complexity increases as firms may
compete in unique and unpredictable ways. In such environments, firms need to be very agile and respond to competitive moves to stay ahead of the competition.

In more dynamic, munificent, and complex environments, firms focus on identifying and pursuing new product and market opportunities. They use aggressive market research and R&D to develop radically new products and significantly better processes. In these environments, competitive interactions occur through R&D/patent races and new product and process innovations, where firms frequently redefine and enter into new markets. In order to locate the new areas of opportunity, firms develop and maintain the capacity to survey a wide range of environmental conditions, trends, and events. They also seek alliance relationships to gain access to resources and capabilities that would enable them to take advantage of emerging opportunities (Powell, et. al. 1996; Brown and Eisenhardt 1997). The goal is to grow through radical product and process innovations and market development, rather than through increased efficiency in the existing operations.

In more dynamic, munificent, and complex environments, a firm’s IT asset portfolio should support exploration by enabling the development of new product and process innovations. Dey et al. (2010) describe three mechanisms through which IT contributes to innovation: (i) knowledge management – IT contributes to the management of knowledge (e.g., technological/scientific knowledge, customer needs, competitive and regulatory information, etc.) used in innovation production, (ii) innovation production – IT enables critical elements of the innovation production process including opportunity identification, concept development, and innovation design, and (iii) interorganizational coordination – IT enables coordination between the focal firm and the external innovation partners.
As an example of knowledge management, firms may invest in CRM systems to capture customer preference information so that each customer can be provided with a unique product. For example, Ritz-Carlton uses a CRM system to collect customer preference information to provide each customer with a customized room (Berinato, 2002). Such CRM systems also allow firms to mine their data warehouses to identify new demand and to cross- or up-sell new products and services. With regards to innovation production, firms may invest in environmental scanning and decision support systems to perform “what if” analysis to explore and analyze new areas of opportunity. Such systems also enable firms to identify organizations with complementary resources and capabilities so that the firm can overcome gaps in its resource portfolio and take advantage of emerging opportunities. For example, Oracle’s PartnerNetwork system is used to attract and manage different types of partners to support its expansion into new markets (Cordon, et. al. 2003). Similarly, IT applications may be used to reduce the cycle time for developing new products. BMW, for example, uses computer-aided design (CAD) system to reduce product development time (Thomke 2001).

IT can facilitate interorganizational coordination in different ways. Firms may invest in collaborative technologies to improve responsiveness and creativity in new product development. As an illustration, P&G uses IT systems to collaborate with outside scientific networks for R&D projects, in order to develop more new products (Huston & Sakkab 2006). A firm may use IT to respond to its environmental dynamism, munificence, and complexity by searching, identifying, and coordinating with a changing set of suppliers. Gosain et al. (2004) find that through the modular design of interconnected processes and structured data connectivity, IT-enabled supply chains provide the flexibility to support changes in orders (offering flexibility) as well as the ability to partner with different supply chain players (partnering flexibility). For instance, in the
electronics industry, firms use B2B exchanges (e.g., Converge) to search and coordinate activities with a changing set of suppliers (Lee 2002).

As discussed above, it is likely that in more dynamic, munificent, and complex industry environments, firms will pursue organizational innovations. However, some risk-averse firms may pursue efficiency in operations even in more dynamic, munificent, and complex industry environments (Smith et al, 2001). Such a strategy would be consistent with the competitive approach taken by *defenders* (Miles and Snow, 1978). However, we propose that most firms are likely to pursue innovation in more dynamic, munificent, and complex industry environments. They are likely to weight their IT asset portfolio more toward exploration initiatives relative to exploitation initiatives. Thus, we propose the following hypotheses:

- **H2a:** In more dynamic industry environments, the level of investments in the IT asset portfolio will have a greater impact on innovation.
- **H2b:** In more munificent industry environments, the level of investments in the IT asset portfolio will have a greater impact on innovation.
- **H2c:** In more complex industry environments, the level of investments in the IT asset portfolio will have a greater impact on innovation.

**DATA AND VARIABLES**

Data for this research were combined from four primary sources. First, we derived a proxy for the level of investments in the IT asset portfolio from the *CI Technology Database* from Harte-Hanks. This database contains information about IT infrastructure in over 500,000 sites in the United States and Canada. The information in the database covers 10 key IT areas, including personal computers, servers, networking, software, storage, and managed services. Second, we obtained firm-level measures from the COMPUSTAT database. 10-K reports were also used in collecting firm level data. We also used the COMPUSTAT segment database to calculate industry-level environmental variables such as dynamism, munificence and complexity. Third,
we collected the number of patents applied for each year from the National Bureau of Economic Research (NBER). Fourth, we obtained data from the Bureau of Economic Analysis (BEA) to derive a set of industry-level instrument variables. Our panel dataset contains 1023 observations, which cover 341 unique firms over a 3-year period from 2003 to 2005. All of these firms are Fortune 1000 companies.

**IT Asset Portfolio.** We operationalized level of investments in the IT asset portfolio as the ratio of a firm’s IT stock to its total assets. Our measure combines different prevailing approaches toward the measurement of a firm’s IT stock (e.g., Hitt and Brynjolfsson 1996; Chwelos et al. 2010). Brynjolfsson and Hitt (1996) derived the IT hardware capital as the total number of mainframe systems times the price index for mainframe systems. The IT productivity literature has used a single price index to calculate the IT hardware capital (e.g., Hitt and Brynjolfsson 1996; Brynjolfsson et al. 2003; Dewan and Min 1997). This approach implicitly applies the mainframe price index across all types of IT hardware, including non-mainframe technology. Regarding software, the IT productivity literature uses three times of IT labor expense as a proxy for the IT capital related to software, training and labor expense.

Chwelos et al. (2010) improved the existing approach in two ways. First, using hedonic regression, they derived the implicit prices for a wider set of IT hardware components (e.g., IBM mainframe, non-IBM mainframe, minicomputers, PCs, LAN, etc.). Compared with the prior approach which mainly used the price indices of PC and central processor, this approach provides more accurate estimates of the relative contribution of different hardware components. Second, they deflated PCs and other IT hardware separately using distinct/appropriate quality-adjusted price indices. As noted by Chwelos et al. (2010) and Gordon (2006), the advantage of

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3 We focus on this sample period to avoid the dot-com crash.
this approach, over the prior approach of using a single price index for all IT components, is that it accounts for the more rapid price decrease of PCs than that of the other IT components. Thus, we adopt the Chwelos et al. (2010) approach by using their implicit prices to calculate the nominal value of IT hardware for each year, and then deflate the nominal values of PCs and other IT components by using the appropriate price indices (to account for the price and quality changes over time). We used the PC price index and the price index for Computers and Peripheral Equipment from BEA to deflate PCs and other IT components.

Consistent with the IT productivity literature (e.g., Hitt and Brynjolfsson 1996; Dewan and Min 1997), we estimated the IT stock on software, staff and training as three times of IT labor expense. We calculated IT labor expense by multiplying the number of IT employees by industry-specific average compensation and deflate it using the Index of Total Compensation Cost from BLS. The total value of IT stock is the sum of the stock value of IT hardware and three times of IT labor expense. We divided the IT stock value by total assets and use the resulting ratio as a measure of firms’ level of investment in the IT asset portfolio.

Environmental Characteristics. We followed the existing literature (e.g., Dess and Beard 1984; Keats and Hitt 1988; Palmer and Wiseman 1999) and used multiple indicators for dynamism, munificence, and complexity. Dynamism is measured as the volatility in industry sales.

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4 Another key reason that we need approaches like Chwelos et al. (2010) is that the CI database no longer provides a continuous IT Capital measure.

5 Chwelos et al. (2010) use distinct but constant implicit prices for each component of IT hardware to estimate the total IT stock values, and then deflate the IT stock values using appropriate IT price indices. The rationale for using distinct but constant implicit prices is that the change in the price of IT systems is mainly attributable to the change in quality, rather than a change in the nominal value. For example, using data from Berndt and Rappaport (2001), they find that the nominal price change of PC over 1987-1998 is only 2.1%.

6 The robustness checks using two or four times the labor cost as the estimate for IT stock on software, staff and training, produces qualitatively similar results.
and volatility in industry operating income (Keats and Hitt 1988). Munificence is measured as
growth in industry sales and growth in industry operating income (Dess and Beard 1984).

Following the extant literature (e.g., Keats and Hitt 1988; Palmer and Wiseman 1999), we
measured the growth and volatility of industry sales using a two-step procedure. First, the natural
logarithm of the total sales of four-digit NAICS industries was regressed against an index
variable of years, over a period of five years. Then the antilog of the regression coefficient was
used as the measure for sales growth, and the antilog of the standard error of the regression
coefficient was used as the measure for sales volatility. The intuition is that the regression
coefficient captures the growth rate of sales, and the standard error of the regression coefficient
captures the unpredictability (i.e., volatility) of the sales growth rate. The same approach was
used to derive the growth rate and volatility of industry operating income.

Following the prior literature (e.g., Dess and Beard 1984; Keats and Hitt 1988), we adopted
three indicators to measure complexity. The first indicator reflects Grossack's (1965) dynamic
measure of industry concentration and is a regression of current-year market shares of all firms
in a given industry upon their shares 5 years ago. The reciprocal of the regression coefficient
indicates the decrease or increase of monopoly power in the industry and is used as one measure
of complexity. A large value of this measure (i.e., a small regression coefficient) signifies a loss
of market share and a decrease in monopoly power of large firms due to the growth of smaller
firms, the entry of new firms, or some combination of such factors, that makes the environment
more complex. On the other hand, a small value of this measure (i.e., a large regression
coefficient) signifies a trend toward dominance by fewer firms, making the environment less
complex (Keats and Hitt 1988). The second indicator of complexity is the 4-firm concentration
ratio and it is measured as the ratio of the total sales of the top four firms in an industry to the
total industry sales. Higher values indicate lower complexity (since the environment is
controlled by fewer competitors). The third indicator of complexity is the Herfindahl index of
concentration (Finkelstein and Boyd 1998). Again, the higher the value of this index, the lower
the degree of complexity.

Using the COMPUSTAT Segment database, we first calculated these environmental
indicators for each four-digit NAICS industry. Then, we calculated the aggregate indicators for
each firm, i.e., if a firm participates in multiple industries, each of the firm’s environmental
indicators (say, sales volatility) is the weighted aggregate of the corresponding environmental
variable (i.e., industry sales volatility) of all the industries the firm participates in, where the
weights are the shares of its sales in each four-digit NAICS industry the firm participates in.

In order to validate the psychometrics of our measures, we conducted a principal component
analysis (PCA) of the indicators used for the three constructs. The pattern of factor loading
supports the existence of the three dimensions corresponding to dynamism, munificence and
complexity (Table 1). A subsequent confirmative factor analysis (CFA) supported the overall
validity of the 3-factor model (Chi-square=34.71; GFI=0.99; CFI=0.97; NFI=0.96). The
Cronbach Alphas for the 3 factors are above 0.65 (dynamism=0.68; munificence=0.66;
complexity=0.73), suggesting acceptable reliability (Dess and Beard 1984). The standardized
factor scores of these three factors are used as the measures of dynamism, munificence, and
complexity for each firm.

**Efficiency and Innovation.** Our measures of efficiency capture firms’ ability in managing
their supplier relationships, internal operations, and customer relationships. They reflect the
intermediate process metrics that have been argued to be important in assessing the ways in
which IT investments impact overall firm performance (Barua et al., 1995). We used four
measures of efficiency: (i) payables turnover, measured as cost of goods sold divided by total payables, (ii) inventory turnover, measured as cost of goods sold divided by the total value of inventory (Hitt et al. 2002), (iii) receivables turnover, measured as sales divided by the value of receivables (Hitt et al. 2002), and (iv) selling and administrative cost, measured as selling, general & administrative cost divided by sales (D’Aveni and Ravenscraft 1994; Mitra and Chaya 1996; Bharadwaj 2000). Payables turnover captures the efficiency in managing supplier relationships since a high level of payables increases procurement cost (Deloof 2003). Inventory turnover captures the efficiency in converting inventory into finished goods, and thus reflects the efficiency in managing the operations and material flow in the organization. Receivables turnover reflects the efficiency in managing customer relationships and in turning receivables into cash. Selling and administrative cost reflects the costs incurred to coordinate activities inside the firm and with suppliers and customers, and thus is an aggregate measure of administrative cost (D’Aveni and Ravenscraft 1994). By virtue of their properties, greater efficiency is reflected in higher values of payables turnover, inventory turnover, and receivables turnover, whereas a lower selling and administrative cost ratio also reflects greater efficiency.

Our measures of innovation are rooted in the nature of the innovation process and are another significant type of intermediate metrics that explain how IT investments affect overall firm performance. Hagedoorn and Cloodt (2003) propose that research and development activity (often measured as R&D intensity) leads to patents (often measured in terms of patent counts) that ultimately lead to new product introductions. As the market learns about a firm’s R&D activity, patents, and new product introductions, it responds to this information through valuations of the firm’s assets that are reflected in the market value of that firm (e.g., Tobin’s Q). Therefore, we used three measures of innovation that reflect this portrayal of the innovation
process. First, we adopted R&D intensity (i.e., R&D expenditure divided by sales) as a measure of firms’ innovation activities in search of new product and process innovations. Second, we adopted the (the log value of) total number of patents applied by a firm as a measure of the outcome of the firm’s innovation activities. The number of patents was collected from the National Bureau of Economic Research (NBER). Third, we used residual Tobin’s Q as the market level measure of firms’ innovation and exploration performance. Tobin’s Q (i.e., the ratio of a firm’s market to book value) is widely used as a proxy for firms’ intangible assets (Fama and French 1992; Chan et al. 2001). This intangible asset is attributed to the value created by firms’ innovation and exploration activities. However, a firm’s Tobin’s Q can be improved through operational efficiency (e.g., cost reductions) as well as by improving innovation and exploration activities. Therefore, we removed the variance in Tobin’s Q caused by efficiency improvements by running a regression of Tobin’s Q on inventory turnover, payables turnover, receivables turnover, and selling and administrative cost. We used the residual as a measure of the firm’s innovation performance.

We used R&D intensity as one of the measures of innovation. However, a criticism of this measure is that it is an input measure rather than a measure of innovation output (Hagedoorn and Cloodt 2003). Though it is true that R&D investment in a given year is a measure of R&D input, successful R&D input in the prior years will increase the commitment and allocation to R&D in future years. Thus R&D investment not only reflects current input, but it also represents the success of prior years’ R&D efforts (Hagedoorn and Cloodt 2003). Similarly, R&D inputs affect innovation performance in terms of generating new ideas, models, and blueprints many of which will lead to patents and new products (Griliches 1998). Thus, we used R&D Intensity as one measure of innovation performance.
The second measure, patent count, is a common measure of innovation. Closely related to patents, citation counts is an alternative measure of innovation. An advantage of the citation-weighted patents is that they capture the ‘value’ of each patent, whereas raw patent counts treat each patent the same (Hall et al. 2005). However, the citation based measure suffers from truncation bias because, at any point in time, the data reflects citations received till that point in time (Hall et al. 2005). Since it may take many years for a patent to receive all of the citations that reflect its true value, citation data are a weak measure of innovation for recent patents (Zhao 2009) and citation-based analysis is not useful for evaluating current innovations (Hall et al. 2005). Given that our data is from 2003-2005, we believe that patent count is a better measure of innovation for our period/dataset.

Tobin’s Q is often used as a measure of firms’ knowledge assets and innovation output. For example, Hall et al. (2005) and Zhao (2009) find that R&D intensity, patent counts, and patent citations have a significant impact on firms’ Tobin’s Q. Similarly, Fosfuri and Giarrantana (2009) study the duopoly competition between Coca-Cola and Pepsi and find that a firm’s product innovation increases its Tobin’s Q, and rival firm’s product innovation negatively affects its stock market performance. Thus, this study provides a very clear rationale for using Tobin’s Q as a market based measure of innovation. IS researchers have also argued that IT can increase intangible assets by enabling innovation and supporting the exploration of growth opportunities. Brynjolfsson and Hitt (2003) surveyed IS managers in Fortune 500 firms and found that four out of the five top reasons for IT investment are related to intangible assets, and innovation and exploration activities (e.g., improving customer service, improving quality, improving timeliness.

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7 Hall et al. (2005) also indicate that patent-related measures cannot win a horse race with R&D intensity as a measure of firm’s intangible value and innovation. This is because optimizing firms can quickly increase (or decrease) their R&D intensity in response to R&D success (or failure). This contrasts with the average two years from application to securing a patent (Hall et al. 2005) and many more years to receive the citations that reflect the true worth of a patent.
and targeting new customers). Stiroh (2002) found that IT investments are associated with the exploration of growth opportunities at the industry level. Thus, (Residual) Tobin’s Q is our third measure of innovation.

**Control Variables.** We included variables to control for firm, year, and industry effects. First, we included firm-level control variables that have been used in prior research. Several studies (e.g., Hitt and Brynjolfsson 1996) suggest that firm-level characteristics such as capital investment, debt-to-equity ratio, and market share affect firm performance. Therefore, we include capital investment (measured as total invested capital as a percentage of total assets), debt-to-equity ratio (measured as book value of total liabilities divided by the book value of total equity), and market share (measured as firm sales as a percentage of industry sales at the primary four-digit NAICS industry level) as control variables. We also used the natural logarithm of total number of employees ($EMP$) as a control for firm size. Second, firm’s R&D capital and brand strength may increase its intangible value (and increase its Tobin’s Q). Therefore, we included R&D capital (measured as the five-year average R&D expenditure divided by sales) and advertising capital (measured as the five-year average advertising expenditure divided by sales) as firm-level controls in the residual Tobin’s Q model. Third, we used three binary dummy variables to control for the year effect. Finally, a set of dummy variables were used to control for firms’ primary industry (based on the 4-digit NAICS code) so as to take into account other unobserved industry effects (e.g., regulation). Table 2 summarizes the definition of variables used and table 3 provides descriptive statistics and the correlations between these variables.

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8 It may be expected that manufacturing industries are systematically different from service industries in terms of efficiency and innovation. We also conduct a robustness check using a set of dummies indicating seven industry groups: Manufacturing (with NAICS code starting with 3); Construction, Mining, Utilities (with NAICS code starting with 2); Wholesale, Retail Trade and Transportation (with NAICS code starting with 4); Information, Finance and Professional Services (with NAICS code starting with 5); Education and Healthcare (with NAICS code starting with 6); Entertainment, Accommodation and Food Services (with NAICS code starting with 7); and Other
EMPIRICAL ANALYSES

The Model. We used the following set of models to test the hypotheses:

Dependent Variable $Y_{it}$ (of Efficiency or Innovation)

$$Y_{it} = \beta_0 + \beta_1 \text{IT}_{i,t-1} + \beta_2 \text{Dynamism}_{i,t-1} + \beta_3 \text{Munificence}_{i,t-1} + \beta_4 \text{Complexity}_{i,t-1}$$

$$+ \beta_5 \text{IT}_{i,t-1} \times \text{Dynamism}_{i,t-1} + \beta_6 \text{IT}_{i,t-1} \times \text{Munificence}_{i,t-1} + \beta_7 \text{IT}_{i,t-1} \times \text{Complexity}_{i,t-1}$$

$$+ \sum \text{Firm Controls}_{i,t-1} + \sum \text{Year Dummies}_{i,t-1} + \sum \text{Industry Dummies}_{i,t-1} + \epsilon_{i,t-1} \quad (1)$$

In expression (1), all the dependent variables were lagged by one-year after the independent variables (i.e., IT asset portfolio in year $t$, improves efficiency/innovation in year $t + 1$). These models allow us to examine the impact of the IT asset portfolio on efficiency and innovation. The coefficients of the interaction between level of investment in the IT asset portfolio and industry characteristics capture the moderating effects of industry characteristics. We mean-centered the variables involved in the interaction terms to reduce the multi-collinearity problem and simplify the interpretation of the coefficients (Cohen et al. 2003).

We employed 3SLS estimation for the model due to two main issues. First, prior studies (Dewan et al. 1997; Hitt 1999) suggest that firms’ investments in their IT asset portfolio are not exogenous, but are influenced by other firm and industry characteristics. As a consequence, the simultaneity bias makes OLS estimation inappropriate. Hausman tests also show that the IT asset portfolio is endogenous. Second, since efficiency and innovation variables may be correlated, we need to address the cross-equation error correlation.

Services and Public Administration (with NAICS code starting with 8 and 9). The results show that compared with service industries, manufacturing industries in general have higher efficiency and innovation. However, the general pattern of relationship between industry characteristics and efficiency and innovation outcomes are consistent across manufacturing and service industries.
In 3SLS, the first stage is used to estimate the endogenous variable, i.e., IT asset portfolio. The instrument variables we used included the previous-year’s level of investments in the IT asset portfolio and a set of industry variables used in the literature (e.g., Hitt 1999), such as industry-level IT capital ratio (from the *Current-Cost Investment in Private Nonresidential Fixed Assets Table* from BEA), industry-level tax ratio (from BEA’s GDP-by-Industry tables), industry-level operating surplus (from BEA’s GDP-by-Industry tables), industry-level material-energy input ratio (calculated using BEA’s Value-Added-by-Industry tables), industry-level service-energy input ratio (calculated using BEA’s Value-Added-by-Industry tables), and industry-level import and export value (from BEA’s industry Input-Output Use tables). These industry-level variables are considered as exogenous to firms and influence firms’ level of investments in its IT asset portfolio (Bartelsman et. al. 1999; Hitt 1999). We used weighted values for all industry-level instrument variables. That is, an instrument variable was calculated for each industry the firm participates in, weighted by the firm’s sales in that industry. In the second stage of the 3SLS estimation, the predicted cross-equation error covariance matrix is obtained from an OLS estimation of each model. In the third stage, the cross-equation error covariance matrix is used for a joint generalized least squares (GLS) estimation of all equations, as in *seemingly unrelated regression* (SUR). This approach takes into account the cross-equation error correlation among different efficiency and innovation models.¹

We used Huber-White robust estimators to account for non-independent variance within repeated observations of the same firm. We conducted OLS estimation with White test for each individual equation, and found no heteroskedasticity problem. We also checked the Variance Inflation Factors (VIFs) of all the independent variables. None of the VIFs exceed 10, suggesting that there are no severe multicollinearity problem (Cohen et al. 2003).

¹We also tried fixed-effect estimation and random-effect estimation and obtained qualitatively similar results.
Results

Efficiency Models. Table 4b presents the results of the analysis. We discuss the efficiency models first. As indicated in Table 4b, the coefficient of the $IT \times Dynamism$ interaction is significant in all the models. The negative and significant coefficients of the $IT \times Dynamism$ interaction in the Inventory Turnover model ($p<0.01$), the Payables Turnover model ($p<0.01$), and the Receivables Turnover model ($p<0.01$) suggest that the level of investment in the IT asset portfolio has a greater impact in improving the efficiency of inventory management, supplier relationship management and customer relationship management in less dynamic environments than in more dynamic environments. In the Selling and Administrative cost model, the coefficient of the $IT \times Dynamism$ interaction is positive and significant ($p<0.01$), suggesting that the impact of IT asset portfolio in decreasing selling and administrative cost is larger in less dynamic environments than in more dynamic environments. These results are consistent with hypothesis H1a.

Table 4b also shows that the coefficients of the $IT \times Munificence$ interaction are negative and significant in the Payables Turnover model ($p<0.01$) and the Receivables Turnover model ($p<0.05$). This suggests that the IT asset portfolio has a greater impact in enhancing payables and receivables turnover in less munificent environments than in more munificent environments. These results provide support for hypothesis H1b. In the selling and administrative cost model, the coefficient of the $IT \times Complexity$ interaction is positive and significant ($p<0.01$), suggesting that the impact of IT asset portfolio in decreasing selling and administrative cost is larger in less complex environments than in more complex environments. This result provides support for hypothesis H1c.
In general, Table 4b provides evidence that environmental dynamism, munificence, and complexity moderate the relationship between IT asset portfolio and operational efficiency. Figure 1a illustrates the impact of IT asset portfolio on inventory turnover at different levels of dynamism (with all other variables at their means). When dynamism is medium (i.e., at its mean value of zero), an increase in level of the IT asset portfolio by 1 standard deviation from the mean (i.e., change from 0.07 to 0.19) leads to an increase in inventory turnover by just 0.05 (i.e., from 17.88 to 17.93). At a lower level of dynamism (i.e., one standard deviation below its mean), an increase in level of investment in the IT asset portfolio by 1 standard deviation from the mean leads to an increase in inventory turnover by 2.08 (i.e., from 17.84 to 19.92). This means that in less dynamic environments, an increase in the investment in the IT asset portfolio is associated with a greater improvement in inventory turnover.

Similarly, Figure 1b illustrates the impact of the IT asset portfolio on selling and administrative cost at different levels of dynamism (with all other variables at their means). At medium levels of dynamism (i.e., at its mean 0), an increase in level of investment in the IT asset portfolio by 1 standard deviation from the mean (i.e., change from 0.07 to 0.19) leads to a decrease in selling and administrative cost by just 0.04 (i.e., from 0.29 to 0.25). At lower levels of dynamism (i.e., one standard deviation below its mean), an increase in the level of investment in the IT asset portfolio by 1 standard deviation from the mean leads to a decrease in selling and administrative cost by 0.09 (i.e., from 0.3 to 0.21). This suggests that in less dynamic environments, an increase in the IT asset portfolio is associated with a greater decrease in selling and administrative cost.
Innovation Models. Table 4b also presents the results of the analysis on innovation models. The coefficients of the \( IT \times \text{Dynamism} \) and \( IT \times \text{Munificence} \) interactions are only marginally significant in the Patent model but are not significant in the other two models. Thus the analysis does not provide clear support for hypothesis H2a and H2b. However, the coefficients of the \( IT \times \text{Complexity} \) interactions are positive and significant in the R&D intensity \((p<0.05)\), Patent \((p<0.01)\), and the Residual Tobin’s Q model \((p<0.01)\). These results suggest that IT asset portfolio is associated with greater increase in R&D activities, new product and process development outcomes (i.e., the number of patents), and increase in the intangible value of firms in more complex environments than in less complex environments. These findings provide support for hypothesis H2c.

Figure 2a illustrates the impact of IT asset portfolio on patents at different levels of complexity (with all other variables at their means). When complexity is medium (i.e., at its mean 0), an increase in level of investment in the IT asset portfolio by 1 standard deviation from the mean (i.e., change from 0.07 to 0.19) leads to an increase in the patent measure by just 0.14 (i.e., the log value increases from 0.46 to 0.60). When complexity is high (i.e., one standard deviation above its mean), an increase in level of investment in the IT asset portfolio by 1 standard deviation from the mean leads to an increase in the patent measure by 0.27 (i.e., the log value increases from 0.57 to 0.84). This suggests that in more complex environments, an increase in the IT asset portfolio is associated a greater increase in new product and process development patents.

Similarly, Figure 2b illustrates the impact of IT asset portfolio on residual Tobin’s Q at different levels of complexity (with all other variables at their means). At medium level of
complexity (i.e., at its mean 0), an increase in the level of investment in the IT asset portfolio by one standard deviation from the mean (i.e., change from 0.07 to 0.19) leads to an increase in residual Tobin’s Q by just 0.04 (i.e., from 0 to 0.04). At high level of complexity (i.e., one standard deviation above its mean), an increase in the level of investment in the IT asset portfolio by 1 standard deviation from the mean leads to an increase in residual Tobin’s Q by 0.11 (i.e., from 0.1 to 0.21). This means that in more complex environments, increases in the IT asset portfolio are associated with a greater increase in intangible value and innovation.

**DISCUSSION AND CONCLUSION**

The existing literature suggests that IT creates value by increasing productivity (see e.g., Brynjolfsson and Hitt 1996; Barua and Lee 1997; Menon et al. 2000; Bharadwaj et al. 1999; Bharadwaj 2000), innovation (Kleis et al, in press), and firm and process level performance (see e.g., Barua et al. 1995; Mukhopadhyay et al. 1997; Devaraj and Kohli 2003; Banker et. al. 2006; Tallon and Kraemer 2006). However, compared with the external environmental factors, internal organizational factors (e.g., synergy, knowledge sharing, IT and non-IT capabilities, etc.) have received more attention in the literature (e.g., Melville et al. 2004; Wade and Hulland 2004; Tanriverdi 2006). Our study brings environmental factors into consideration by examining how the environment moderates the salience of different IT-enabled value creation processes. While Melville et al. (2007) examined the moderating influence of the environment on the impact of IT on productivity, our research proposes and provides empirical evidence regarding how the industry environment moderates the impact of IT asset portfolio on organizational efficiency and innovation.  

10 Following McGahan and Porter (1997), we also run a 3SLS analysis without including environmental variables and their interaction with IT. We compare the system weighted $R^2$ values for the models with and without environmental variables, and use an F-test to test the significant of the difference, to assess the importance of the environment. The $R^2$ for the model without the environmental variables is 0.31, and the F-test is significant...
efficiency of operations in less dynamic, munificent and complex industry environments. At the same time, IT asset portfolio is associated with a greater increase in new product and process innovations and exploration of growth opportunities in more complex environments. Before discussing the implications of our research, it is important to examine some of its limitations.

First, consistent with the strategy literature, our analysis modeled the competitive environment in terms of the dynamism, munificence and complexity. However, there might be questions about how well this model of environment describes the role of the industry in moderating the effects of IT asset portfolio on efficiency and innovation. For example, we study the industry environment as being exogenous. In some cases, it is likely that the strategic use of IT might influence the industry environment. Therefore, future research should also study how IT may influence the industry environment\(^1\). Further, our study focuses on the generalizable aspects of different industries and ignores their idiosyncratic aspects. For example, firms in different industries may use IT differently to realize efficiency/innovation outcomes. Thus, it is important to study how IT is used differently across specific industries, e.g., the retailing (Palmer and Markus 2000) or insurance industry (Harris and Katz 1991). Such studies can provide insights about the effects of unique industry factors, above and beyond our research. Finally, our operationalization of the industry environment captures the objective characteristics of each industry’s dynamism, munificence, and complexity. Theories of managerial cognition suggest that managers perceive different levels of dynamism, munificence, and complexity, even when they operate in the same industry. Thus, the perceived industry environment might vary even more across firms than the objective environment in our study. Data limitations preclude our

\( p<0.01 \). This suggests that environmental variables as a whole have a significant impact on the efficiency and innovation.

\(^1\) We thank an anonymous reviewer for this point.
ability to incorporate perceived industry characteristics in this study, and they could be the focus of future research. However, we speculate that the perceived environments would only exaggerate the observed effects, while still providing support for our results.

Second, it is likely that the firm’s competitive strategy also moderates the impact of IT on efficiency and innovation. Similarly, firms have varied capabilities to use IT to achieve efficiency and/or innovation (e.g., Bharadwaj 2000; Ray et al., 2005). Thus, future research should incorporate industry environments and firm capabilities jointly to extend our analyses and results.

Third, the IT asset portfolios required for improving efficiency are likely to differ from those required to enable innovation. Data limitations preclude us from disaggregating the firms’ IT asset portfolios into specific assets for exploration and exploitation. Future research should extend our research by isolating the specific IT assets for exploration and exploitation. For instance, Weill and Broadbent (1998) suggest that IT assets can be classified into infrastructural, transactional, informational, and strategic technologies. Aral and Weill (2007) find that transactional technology is associated with cost reduction, strategic technology is associated with increase in revenue from new products, and infrastructural technology improves business performance in the long run. Thus, firms in more stable environments could emphasize transactional and informational technology, whereas firms in more unstable environments would emphasize infrastructural and strategic technologies. Further research is needed to test these hypotheses to extend our findings.

Fourth, we used patent counts as one measure of innovation without weighting them for citations. Though citation-weighted patent counts have some limitations, they allow researchers to incorporate the ‘value’ of each patent (Hall et al., 2005). However, citation information is not
available for the period under investigation in this study. Future studies may examine how the
environment moderates the impact of IT asset portfolio on citation-weighted measure of patents.

Patents, in general, are limited as a measure of innovation because different industries have
different patenting norms, and firms within the same industry may choose not to patent
innovations for strategic reasons. Our study uses patents as one measure of innovation, while
using two other measures, including the R&D intensity and Residual Tobin’s Q. Future research
should explore more IT-specific measures of innovation. Notwithstanding these limitations, our
research makes significant contributions to theory and practice.

**Theoretical Implications.** Though existing research has provided evidence that IT
contributes to a range of organizational performance indicators, including efficiency and
innovation, most studies assume that these effects are universalistic. Drawing upon
organizational learning theory perspective of the existence of exploitation and exploration
processes, we argue that firms’ IT asset portfolios should support exploitation and exploration
initiatives, depending on the environmental context of the firm. In other words, given the
constraints on the level of IT investment, managers make decisions about the relative allocation
of IT assets between exploitation and exploration initiatives. Our theoretical model argues that
managers would align their firms’ IT and business strategy to their industry environment through
their IT asset portfolio allocation decisions between exploitation and exploration initiatives.

Our results demonstrate that at lower levels of dynamism, munificence and complexity, the
primary role of the IT asset portfolio lies in enabling exploitation initiatives and enhancing
efficiency. In contrast, at higher levels of complexity, the primary role of the IT asset portfolio
lies in enabling exploration initiatives and enhancing innovation performance. These results
extend the prevailing insights about IS-business strategy alignment (Chan et al, 1997; Sabherwal
Our results provide evidence that managers should focus their attention on increasing exploitation-oriented IT initiatives in less dynamic, munificent, and complex industry environments and on increasing exploration-oriented IT initiatives in more complex industry environments. Further, we suggest that IS - business strategy alignment may not be reflected in overall firm level measures of performance. Instead, they are reflected more precisely in the operational efficiency and innovation measures of performance that are aligned with the business strategy and industry context of the organization.

We had proposed (in H2a and H2b) that in more dynamic and munificent industry environments, IT asset portfolio is likely to be associated with greater increase in innovation. However, the empirical analysis does not provide clear support for these hypotheses. This suggests that increases in uncertainty and growth opportunities may not be associated with increase in IT-enabled innovation performance. While more research is needed in this area, managers should be cautious in increasing exploration-oriented IT initiatives in more dynamic and munificent industry environments. However, complexity implies greater industry competitiveness. Our results suggest that enhanced levels of competitiveness motivate firms to seek innovation opportunities through their IT asset portfolio. Therefore, managers should explore innovation opportunities through their IT assets when their firms operate in more competitive industry environments.

**Managerial Implications.** Our findings have important managerial implications. First, managers evaluating the returns from their IT investments need to take into account the specific environments they operate in. It is likely that in specific environments IT investments pay off on certain dimensions of performance, but not on other dimensions of performance. An arbitrary choice of performance measure that ignores the moderating effects of the environment, may lead
managers to inaccurate conclusions regarding the payoff from their investments in IT. For example, Table 5 suggests that in less complex environments, an increase in the investments in IT asset portfolios by one standard deviation from the mean leads to a decrease in selling and administrative cost by 11% (from .33 to .22). However, this investment may not increase residual Tobin’s Q. Thus, in less complex environments, IT asset portfolios pay off according to efficiency measures of performance but may not pay off according to the innovation measures of performance. In contrast, in more complex environments, a similar increase in the investment in the IT asset portfolio is associated with an 11% increase in residual Tobin’s Q (from 0.1 to .21) but the selling and administrative costs may not decrease. Therefore, in more complex environments, investments in the IT asset portfolios pay off according to innovation measures of performance, but may not pay off according to efficiency measures of performance. Thus, managers should choose performance measures that account for the environmental context of their firm while evaluating and justifying the investments in IT. An arbitrary choice of performance measure may lead to misleading conclusions about the payoff from IT.

The second key managerial implication of this study is about the alignment of the IT asset portfolio with business strategies and goals in different environments. Since the IT asset portfolio required to enable efficiency are likely to be different from that are required to support innovation, firms need to commit their IT asset portfolio to focus on specific goals that are aligned with the business strategy and environmental context of the firm. In less dynamic, munificent, and complex environments, the use of IT to reduce the cost of operations and become more efficient supports firms’ cost-leadership strategies. In contrast, in more complex or competitive environments, the use of IT to facilitate new product and process development supports the differentiation/exploration strategies. Thus, firms in more complex environments
may weight their IT asset portfolios toward strategic and infrastructural systems whereas firms in
more stable environments may emphasize the transactional and informational components of
their IT asset portfolio. The implication here is that understanding the moderating influence of
the environment on IT-enabled value-creation can help managers build IT asset portfolios that
produce positive returns.
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Note: *Sales growth (sales volatility)* is the antilog of the regression coefficient (the standard error of the regression coefficient) from a regression of industry sales (log values) against an index variable of years over a 5-year period. Similarly, *income growth (income volatility)* is the antilog of the regression coefficient (the standard error of the regression coefficient) from a regression of industry operating incomes (log values) against an index variable of years over a 5-year period. Dynamic concentration is the reciprocal of the regression coefficient from a regression of markets shares of all firms against their market shares 5 years ago. *4-firm concentration* is the ratio of the total sales of the top four firms in an industry to the total industry sales. Herfindahl index of concentration is as in Finkelstein and Boyd (1998).
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<td>1.50</td>
<td>1.02</td>
<td>Compustat</td>
<td>Bharadwaj et al. (1999)</td>
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<td>Number of Patents</td>
<td>Natural logarithm of the number of patents granted each year</td>
<td>0.46</td>
<td>0.66</td>
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<tr>
<td>Employee</td>
<td>Natural logarithm of total employees</td>
<td>7.63</td>
<td>3.46</td>
<td>Compustat</td>
<td>Hitt &amp; Brynjolfsson (1996)</td>
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<tr>
<td>Capital investment</td>
<td>Capital investment divided by total assets</td>
<td>0.58</td>
<td>0.18</td>
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<tr>
<td>Debt-to-equity</td>
<td>Total liabilities divided by total equity</td>
<td>0.45</td>
<td>2.19</td>
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<tr>
<td>Market share</td>
<td>Sales divided by industry total sales at 4-digit NAICS level</td>
<td>0.09</td>
<td>0.13</td>
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</tr>
<tr>
<td>IT intensity</td>
<td>Total IT capital divided by total assets</td>
<td>0.07</td>
<td>0.12</td>
<td>CI database</td>
<td>Chwelos et al. (2007); Hitt &amp; Brynjolfsson (1996)</td>
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### Table 3: Descriptive Statistics

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<td>7. Patents</td>
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<td>8. Tobin’s Q</td>
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<td>-0.02</td>
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<td>0.01</td>
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<td>12. Market Share</td>
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<td>13. Dynamism</td>
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<td>0.12</td>
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<td>-0.01</td>
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<td>-0.01</td>
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<td>14. Munificence</td>
<td>-0.01</td>
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<td>0.01</td>
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<td>0.06</td>
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<td>15. Complexity</td>
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Note: (1) Pearson coefficients are reported; (2) Coefficients higher than 0.6 or lower than -0.6 are significant at the 0.05 level. Coefficients higher than 0.08 and or lower than 0.08 are significant at 0.01 level.
Table 4a. Impact of IT on Efficiency and Innovation (The Base Model)

<table>
<thead>
<tr>
<th></th>
<th>Inventory Turnover</th>
<th>Payables Turnover</th>
<th>Selling and Admin Cost</th>
<th>Receivables Turnover</th>
<th>R&amp;D Intensity</th>
<th>Patents</th>
<th>Residual Tobin’s Q</th>
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</thead>
<tbody>
<tr>
<td>IT Intensity</td>
<td>0.009</td>
<td>0.064</td>
<td>-0.063**</td>
<td>0.037</td>
<td>0.023</td>
<td>0.070**</td>
<td>0.049†</td>
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<tr>
<td>Dynamism</td>
<td>0.044</td>
<td>-0.004</td>
<td>0.006</td>
<td>0.003</td>
<td>0.034</td>
<td>0.023</td>
<td>0.053†</td>
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<tr>
<td>Munificence</td>
<td>-0.020</td>
<td>0.021</td>
<td>-0.028</td>
<td>-0.007</td>
<td>-0.029</td>
<td>0.040</td>
<td>-0.002</td>
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<tr>
<td>Complexity</td>
<td>0.019</td>
<td>-0.019</td>
<td>-0.038</td>
<td>0.046†</td>
<td>0.140**</td>
<td>0.121**</td>
<td>0.084*</td>
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<tr>
<td>Employee</td>
<td>-0.204**</td>
<td>-0.379**</td>
<td>-0.042</td>
<td>0.051</td>
<td>-0.255*</td>
<td>0.768**</td>
<td>-0.242*</td>
</tr>
<tr>
<td>Capital Investment</td>
<td>0.002</td>
<td>0.064†</td>
<td>0.053†</td>
<td>0.041</td>
<td>0.039</td>
<td>-0.073**</td>
<td>0.194*</td>
</tr>
<tr>
<td>Debt-to-Equity</td>
<td>0.003</td>
<td>0.001</td>
<td>-0.007</td>
<td>0.018</td>
<td>-0.003</td>
<td>-0.028</td>
<td>0.024</td>
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<td>Market Share</td>
<td>-0.044†</td>
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<td>-0.019</td>
<td>0.001</td>
<td>0.061†</td>
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<td>R&amp;D Stock</td>
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<td>0.209**</td>
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Industry dummies and year dummies are included. System Weighted $R^2=0.322$; System Weighted MSE=0.999; DF=6949

Table 4b. Impact of IT on Efficiency and Innovation (The Full Model)

<table>
<thead>
<tr>
<th></th>
<th>Inventory Turnover</th>
<th>Payables Turnover</th>
<th>Selling and Admin Cost</th>
<th>Receivables Turnover</th>
<th>R&amp;D Intensity</th>
<th>Patents</th>
<th>Residual Tobin’s Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT Intensity</td>
<td>0.002</td>
<td>0.031</td>
<td>-0.072**</td>
<td>0.013</td>
<td>0.018</td>
<td>0.072†</td>
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<td>Dynamism</td>
<td>0.038</td>
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<td>-0.002</td>
<td>0.035</td>
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<td>Munificence</td>
<td>-0.023</td>
<td>0.029</td>
<td>-0.023</td>
<td>-0.004</td>
<td>-0.028</td>
<td>0.038</td>
<td>-0.001</td>
</tr>
<tr>
<td>Complexity</td>
<td>0.020</td>
<td>-0.014</td>
<td>-0.044</td>
<td>0.049†</td>
<td>0.137**</td>
<td>0.116**</td>
<td>0.081*</td>
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<tr>
<td>IT× Dynamism ($\beta_5$)</td>
<td>-0.083**</td>
<td>-0.101**</td>
<td>0.101**</td>
<td>-0.107**</td>
<td>0.031</td>
<td>0.044†</td>
<td>0.041</td>
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<tr>
<td>IT× Munificence ($\beta_6$)</td>
<td>0.006</td>
<td>-0.093**</td>
<td>0.010</td>
<td>-0.051†</td>
<td>0.019</td>
<td>0.045†</td>
<td>0.013</td>
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<tr>
<td>IT× Complexity ($\beta_7$)</td>
<td>-0.004†</td>
<td>0.027</td>
<td>0.135**</td>
<td>0.018</td>
<td>0.073*</td>
<td>0.064**</td>
<td>0.082**</td>
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<td>Employee</td>
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<td>-0.375**</td>
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<td>0.051</td>
<td>-0.254*</td>
<td>0.767**</td>
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<td>Capital Investment</td>
<td>-0.003</td>
<td>0.061†</td>
<td>0.057†</td>
<td>0.038</td>
<td>0.038</td>
<td>-0.073**</td>
<td>0.194*</td>
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<tr>
<td>Debt-to-Equity</td>
<td>0.003</td>
<td>-0.001</td>
<td>-0.010</td>
<td>0.017</td>
<td>-0.004</td>
<td>-0.028</td>
<td>0.023</td>
</tr>
<tr>
<td>Market Share</td>
<td>-0.039</td>
<td>0.044</td>
<td>-0.041</td>
<td>-0.028</td>
<td>-0.025</td>
<td>-0.007</td>
<td>0.053</td>
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<td>0.203**</td>
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Industry dummies and year dummies are included. System Weighted $R^2=0.333$; System Weighted MSE=0.999; DF=6949

Note: (1) Standardized coefficients are reported; (2) $p<0.1$, $p<0.05$, $p<0.01$.
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<th>Increase in IT by one standard Deviation from the Mean</th>
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<th>High Complexity</th>
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<td>Selling and Administrative Cost</td>
<td>Decreases from 0.33 to 0.22</td>
<td>Increases from 0.25 to 0.28.</td>
</tr>
<tr>
<td>Residual Tobin’s Q</td>
<td>Decreases from -0.10 to -0.12</td>
<td>Increases from 0.1 to 0.21</td>
</tr>
</tbody>
</table>
Figure 1a. IT’s Impact on Inventory Turnover

Figure 1b. IT’s Impact on Selling and Admin Cost

Figure 2a. IT’s Impact on Patents

Figure 2b. IT’s Impact on Residual Tobin’s Q