A THEORETICAL AND EMPIRICAL INVESTIGATION OF THE ROLE OF FIRM TECHNOLOGY INVESTMENTS AND SOURCING PRACTICES IN BUSINESS INNOVATION

by

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Dedication

I dedicate this work to my parents, Dr. Plammoottil Varghese Cherian and Mrs. Kunjoonjamma Cherian, for sacrificing so much to give an undeserving son every opportunity he could hope for and for continuing to be perfect role models of what he hopes to become.

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Finally, to my wife, Gina, I owe a tremendous debt. Getting a doctoral degree is intended to be an individual exercise, but in my case it was anything but. Gina may not have run any regressions or written any of the words in this document, but make no mistake about it; this dissertation would not have been completed had it not been for what she *did* do. She left everything she had known to allow me to pursue this dream. She left a job and friends she loved to come to a place that was foreign to her and in which I could offer little support. She gave me the time I needed to devote to this program and patiently dealt with its ups and downs. She saw me at some of my lowest moments, helped me pick up the pieces and, like a skilled coach, motivated me to continue. It would be fitting to share this degree with her but that's not exactly possible; instead, I'll love and support her as she has me and forever thank God for giving me the privilege of sharing life with such a marvelous woman.

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Abstract

The core thesis of my dissertation is that the information technology and sourcing practices of firms affect how innovative those firms are in the long run. In the first chapter of my dissertation I develop a theoretical model of firm-level innovation that asserts that firms can exploit strategic, organizational and technological levers to encourage innovation. The model I build leverages findings from prior management and MIS research. I then utilize the Interpretive Systems View of Organizations (Daft & Weick, 1984) to understand how information technology and firm sourcing practices specifically might affect firm-level innovation and define a research agenda that proposes a set of research questions to guide this area of inquiry.

In the second chapter I explore a subset of the research questions defined in Chapter 1 by exploring how IT investments affect a firm's ability to innovate. I develop hypotheses suggesting both direct and indirect (through increasing returns to R&D investment) effects of IT investment on innovative output in high-tech firms. I test my hypotheses on an unbalanced panel of large US high-tech firms from 1998 - 2003 with patent, financial and IT investment data compiled from the US Patents & Trademarks Office, COMPUSTAT and *Informationweek* surveys. I find strong support for the direct effects of IT investment on innovative output but not for a positive indirect effect. These findings contribute to the existing literature on the business value of information systems by identifying another significant way in which IT investments add value to firms.

In the third chapter I evaluate whether externally-facing IT investments and different types of sourcing practices are associated with higher levels of innovation in high-tech firms. I test my hypotheses on an unbalanced panel of large US high-tech firms from 2003 - 2007 with patent, financial, sourcing and IT investment data compiled from the US Patents & Trademarks Office, COMPUSTAT and *Informationweek* surveys. I find support for customer-facing IT investments being associated with higher innovative output but not supplier-facing IT investments. Additionally I find that business process outsourcing is associated with higher levels of firm innovation while IT outsourcing is not.

CHAPTER 1: INFORMATION TECHNOLOGY, OUTSOURCING AND INNOVATION – AN INTERPRETIVE SYSTEMS VIEW

1.1.INTRODUCTION

What makes some firms more innovative than others? This has been the subject of inquiry for scholars in economics, public policy and the management sciences for some time (Ahuja 2000; Roper et al 2008; Schumpeter 1942). Innovation is touted as the life-blood of economic activity and one of the most effective ways in which firms are able to achieve an advantage over their competitors. The ability to generate new ideas and to commercialize them remains one of the primary goals of economic activity, and research into the true determinants of firm innovative capacity remain valuable.

Numerous research studies have identified predictors of innovation asking the question of what specific firm characteristics, and in what combination, affect the ability of firms to create innovative output (Henderson & Cockburn 1996; Lieberman 1987; Owen-Smith & Powell 2004; Schwartzman 1976). Earlier studies have shown that market power (Baldwin & Scott 1987; Cohen & Levin 1989; Schumpeter 1942), firm size (Lieberman 1987), research and development (R&D) expenditures (Hall et al 1984; Hausman et al 1984; Pakes & Griliches 1980) and various network characteristics (Ahuja 2000; Owen-Smith & Powell 2004; Shan et al 1994) are all associated with better innovative performance in firms.

Recently, scholars have started to examine the relationship between IT capabilities (Han & Ravichandran 2006; Pavlou & El Sawy 2006; Joshi et al 2010), IT organizations (Saldanha & Krishnan 2011) and innovation performance. Additionally, as both business processes and information technology are hypothesized to be relevant to innovation processes (Prahalad & Krishnan 2008), the innovation implications of these phenomena remain under-studied.

In this chapter I begin to address these gaps in the literature by identifying research questions related to the phenomenon of innovation. I do this by proposing a conceptual model of innovation in firms and then viewing it through the lens of the Interpretive Systems View (ISV) of organizations (Daft & Weick 1984). The Interpretive Systems View posits that organizations are open systems that obtain, interpret, process and share information from their environments for strategic decision-making purposes. Additionally ISV suggests that systematic variation in an organization's information processing mechanisms can influence organizational outcomes. Considering the specific organizational outcome of *innovative performance* (focusing on a firm's ability to generate new products), I argue below that a firm's IT capabilities and knowledge sourcing methods (including engaging in outsourcing) will significantly influence a firm's innovative performance.

In the next section I review some of the literature from two relevant streams of research: (1) prior studies of the business value of information technology (IT) and (2) prior studies of innovation. My goal in doing so is to frame the work of this dissertation in the larger context of management research and to motivate an interest in evaluating *innovation* as a measure of the business value of information technology. Following the literature review, I describe in greater detail some foundational concepts: (1) a conceptual model of firm-level innovation and (2) the Interpretive Systems View of organizations. I then identify a series of research questions motivated by viewing the conceptual model of innovation through the lens of ISV.

1.2. LITERATURE REVIEW

In this section I highlight theoretical and empirical insights drawn from prior research on the business value of information technology and on innovation. I review prior studies of the business value of information technology, seeking to place this study in the context of other studies of IT business value. I then provide a review of empirical findings with respect to innovation as this is the phenomenon I seek to explain.

1.2.1. Prior Studies of the Business Value of Information Technology

There has been a great deal of interest in measuring the value of information technology investments over the last few decades. During that time, IT spending has increased overall and IT managers not surprisingly have been under a significant amount of pressure to justify their budgets. Many initial studies attempting to assess the true business value of IT came to the conclusion that IT did not make any significant contributions to firm performance or productivity. Brynjolfsson reviewed many of the initial studies and provided four reasons as to why the so-called "productivity paradox" existed (Brynjolfsson 1993). These reasons included (1) measurement problems, (2) lags between IT investment and IT impact, (3) output redistribution and (4) mismanagement of IT resources. A later study by Brynjolfsson and Hitt provided compelling evidence that IT in fact did contribute to firm performance significantly (Brynjolfsson & Hitt 1996). Later studies have confirmed the conclusion that the productivity paradox has disappeared and that IT investments do in fact affect firm performance. These studies have been performed at various levels of analysis and I briefly summarize these studies here for context.

At the lowest level, researchers have examined the impact of IT at the *process* level within firms. Mithas et al conceptualized business value in terms of customer satisfaction and demonstrated that investments in a CRM application led to increased customer satisfaction (Mithas et al. 2005). Devaraj and Kohli evaluated IT impact in the healthcare industry and emphasized the importance of complementary investments in business process re-engineering in order to realize IT investment benefits (Devaraj and Kohli 2000). Barua and Lee directly addressed the issue of IT productivity at the level of business units within manufacturing firms (Barua and Lee 1997). They found a strong relationship between IT investment and strategic business unit productivity.

A number of studies have been performed at the *industry* level and above. Stiroh observed that multi-factor productivity only increased for the computer-producing sector (and not for computer-using sectors) in an analysis of sectoral aggregate data from 1947 to 1991 (Stiroh 1998). Dewan and Kraemer looked at country-level data and found that IT capital expenditures are correlated with higher GDP in developed countries (Dewan and Kraemer 2000); however, for underdeveloped countries they do not find significant returns to IT investments. In the IT business value literature one will also find a number of studies demonstrating the importance of complementary investments and intangible assets to the realization of IT business value. Bresnahan et al (Bresnahan et al. 2002) and Brynjolfsson et al (Brynjolfsson et al. 2002) demonstrated the relationship between IT investments and organizational capital. In a similar manner, Francalanci and Galal examined IT productivity in the life-insurance industry and found that the composition of the labor force interacted with IT to impact productivity (Francalanci and Galal 1998).

At the *firm* level, Hitt and Brynjolfsson evaluated three potential measures of IT benefits: (1) productivity, (2) consumer surplus and (3) profitability (Hitt and Brynjolfsson 1996). They found that IT capital investments are correlated with productivity and consumer surplus, but not with profitability. This study provided evidence of the poor measurement issues described above and demonstrated that IT benefits are primarily realized in productivity and consumer surplus measures. Others have addressed this measurement issue specifically by using the forward-looking Tobin's q as a measure of IT benefits and found a significant association between IT expenditure and Tobin's q (Bharadwaj et al. 1999). Dos Santos et al investigated various types of IT investments (innovative vs. non-innovative) and the effect of announcements of such investments on firm market value (Dos Santos et al. 1993). They found that only announcements of innovative IT investments were positively related to firm market value. Finally, Brynjolfsson and Hitt used a production function approach on firm-level data to demonstrate that the gross marginal product for computer capital investments was quite high and that the gross marginal product for IT labor was at least as high as that for non-IT labor in their data set (Brynjolfsson and Hitt 1996).

More recently scholars have turned to examining *innovation* as a firm performance outcome of interest and have started to explore the relationship between various IT constructs and firm innovative performance. Han and Ravichandran examined the direct and indirect effects of IT investments on innovative output in manufacturing firms (Han & Ravichandran 2006). In that study the authors did not find evidence for a direct effect of IT investment but did find a positive and significant indirect effect of IT investment with R&D expenditures. In chapter 2 of this dissertation I present results that complement this work in addressing the gap in the IT literature with respect to innovation by further examining the innovation implications to high-technology firms of IT investments. I extend earlier research by focusing my examination on high-technology industries – industries that are very information and R&D intensive and for whom patenting is more likely a useful proxy of innovative activity. I address this further in the methodology section below. More recently, scholars have identified a relationship between organizational aspects of the CIO function (e.g. level of CIO involvement in new product development processes) and a firm's propensity to innovate (Saldanha & Krishnan, 2011).

1.2.2. Prior Studies of Innovation

As firm-level innovation is my phenomenon of interest, I now review prior research on the antecedents of innovation in firms. I focus on the studies that are most relevant to the question I seek to address and refer the reader to recent review articles for a more complete treatment (Ahuja 2008; Gilbert 2006).

One of the earliest suggested predictors of firm innovative output is *firm size* (Schumpeter 1942). The Schumpeterian argument is that larger firms are better positioned to pursue R&D intensive industrial strategies that ultimately result in innovative output. The empirical evidence for this assertion has, at best, been mixed. While some studies have supported the notion that firm size is positively associated with innovative output (Lieberman 1987; Schwartzman 1976) others have not (Graves & Langowitz 1993; Halperin & Chakrabarti 1987). Arguments for an effect of firm size typically suggest that larger firms are able to achieve greater returns to scale or have the freedom to finance risky projects while arguments against this effect often deal with the potentially stifling effect of bureaucracy on innovation (Ahuja 2008). Despite the mixed empirical results, most innovation researchers agree that firm size should be controlled for in one way or another.

A number of studies have examined the relationship between *R&D expenditures* and firm innovative output (Pakes & Griliches 1980; Hausman et al 1984; Hall et al 1984). The evidence suggests that R&D investment is positively associated with firm innovative output (as measured by patenting activity). In evaluating this relationship, some have proposed that since patents typically are filed very early in the R&D process, there are in fact an input into (and not an output of) R&D processes. Robust analysis of large sample panel data has not supported this claim and instead has suggested that the relationship between R&D and patenting is either contemporaneous or at most lagged by one year (i.e. greater one-year lagged R&D is associated with higher patent counts) (Hall et al 1984).

Many studies have demonstrated the value of *collaborative networks* in fostering innovation. Schilling and Phelps (2007) demonstrated that membership in alliance networks that were highly clustered and with high reach (short average path lengths to a wide range of firms) was correlated with greater firm innovative output. Earlier studies examined the role of direct and indirect ties on firm innovative output and found that both are correlated with innovation (Ahuja 2000).

A number of articles have also examined the role of *knowledge spillovers* in the innovation process. Singh (2005) examined knowledge diffusion patterns in collaborative networks and found that, while intra-regional and intra-firm knowledge spillovers were common, knowledge diffusion was largely determined by interpersonal networks. Owen-Smith and Powell (2004) distinguished proprietary channels of information from open conduits of information between firms and examined how knowledge accessibility affected the reach of innovation benefits within collaborative networks. Some recent publications have investigated the role customers may play in the innovation process, suggesting that firms can reap innovation benefits by co-creating products and services with their customers (Prahalad & Krishnan 2008; Sawhney et al. 2005).

1.3. INNOVATION PROCESSES IN HIGH-TECH MANUFACTURING FIRMS

Having reviewed relevant literature from IT research and from prior studies of innovation, we now turn our attention to discussing the *innovation process* itself for our goal in this chapter is to thoughtfully consider how IT might affect this process and, in turn, strengthen a firm's ability to create new products. "Innovation" in common usage can refer to many things. While many scholars currently are studying innovation in services, organizational forms and processes, in this dissertation I focus exclusively on innovations in manufactured *products* i.e my focus is on the **new product development (NPD) process**. While there conceptually may be some overlap between product innovation and other types of innovation (e.g. with respect to idea generation, filtering), I focus exclusively on products for two primary reasons. First, most prior studies of innovation have focused on product innovation. As evaluating the role of information technology and outsourcing on innovation processes remains a relatively new area of inquiry, it is important to ground this work as closely as possible to the existing literature on innovation. Second, studying product innovation is attractive from a methodological standpoint because the patenting regime provides a useful way for researchers to measure a firm's innovative output. This measure is not without certain limitations, nevertheless patent counts have been considered by many researchers across disciplines to be a useful proxy for product innovation (Griliches 1990; Hall et al 1984; Hausman et al 1986).

To set the stage for understanding the new product development process it will be useful to consider anecdotal examples of what we mean when we discuss product innovation. First consider an example from the computing industry in which large mainframe computers of the 1960's and 1970's led to the development of the "personal" desktop computers of the 1980's which further led to the development of laptops and, more recently, tablet PCs and netbooks. The innovation in computing largely resulted in greater processing power and storage being provided in smaller and more portable packages and consequently in a significantly richer set of functionality available to the consumer. These innovations were themselves driven by other innovations (e.g. in semiconductors, processors, hard drives) and enabled innovations in other products (e.g. in software and services dependent on computing power).

Another example could be drawn from the pharmaceutical industry's efforts to develop drugs to treat heartburn and gastroesophageal reflux disease (GERD). In that case, antacids (e.g. Rolaids, Tums) developed earlier in the 20th century gave way to H2-antagonists (e.g. GlaxoSmithKline's Tagamet) in the 1990's due to improved efficacy and the ability to proactively prevent the development of heartburn. These H2-antagonists in turn led to the development of proton pump inhibitors (e.g. Takeda's

Prevacid or AstraZeneca's Nexium) which additionally were able to heal esophageal damage due to frequent heartburn. In addition to the innovations in drug efficacy, pharmaceutical companies have been provided innovations with respect to dosing (e.g. extended release tablets) and formulations (gelcaps, tablets, thin strips) to accommodate a wide array of consumer preferences.

I now will discuss a prototypical new product development process which I propose is representative of new product development processes at high-tech manufacturing firms. The utility of this discussion is that it will enable us to thoughtfully consider where and how IT investments and capabilities might affect innovation processes. Throughout the discussion I will apply each conceptual process to an example of new product development in the pharmaceutical industry to add a real world perspective that should help clarify the concepts.

1.3.1. Internal New Product Development Processes

New product development within high-tech manufacturing firms is focused on identifying prospects for new products for the firm and to refine and develop those prospects to such a degree that they can be commercialized by the firm. This can result in the introduction of wholly new products all together (e.g. the launch of a new drug in a new therapeutic area for a pharmaceutical company) or can result in the improvement of existing products (e.g. a new formulation of an existing drug on the market). While the R&D organization is tasked with identifying and developing future commercial products for the firm, it is very dependent on other parts of the organization to complete its mission. In particular, R&D organizations often collaborate with Marketing functions to incorporate market-based assessments (e.g. the market size of a potential diabetes drug) along with technical feasibility analyses (e.g. have new biological targets for treating diabetes been identified) to determine the best targets for research and development.

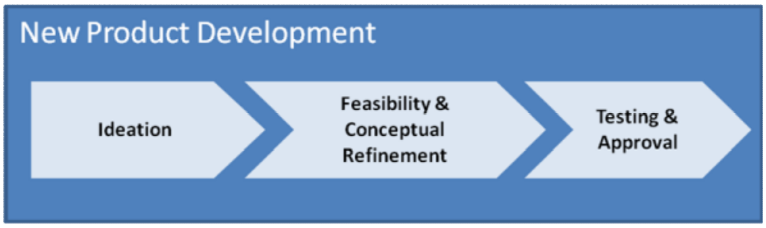

Figure 1. A Prototypical NPD Process at High Tech Manufacturing Firms

Consider the conceptual model of new product development proposed in Figure 1. All new product development processes at high-tech manufacturing firms will have some sort of ideation process in place. At a pharmaceutical company this might correspond to "drug discovery" within the R&D organization whereas at an aerospace company this might correspond to "product concept design" within the product engineering function. It is during this stage of the NPD process that prospects for product innovations (where incremental or new products) are proposed and initially tested by the firm. The next stage of the process will focus on a refined set of prospective products which have passed the primary criterion for new product development. During this stage the prospects will be rigorously tested to determine whether further development and commercialization is in fact feasible. In our prototypical pharmaceutical company this would correspond to early stage toxicology analysis and Phase I and II clinical trials to establish a baseline level of safety and efficacy for a proposed diabetes drug. Candidates that pass this level of analysis move on to the final stage of the NPD process during which candidates are subjected to a more formalized series of testing and manufacturing process development to ensure final readiness for product launch. We will now consider each one of these processes in turn.

1.1.1.1 Ideation

The ideation process within R&D encompasses the earliest stages of product development that deal with generating, assessing and validating ideas for further development.

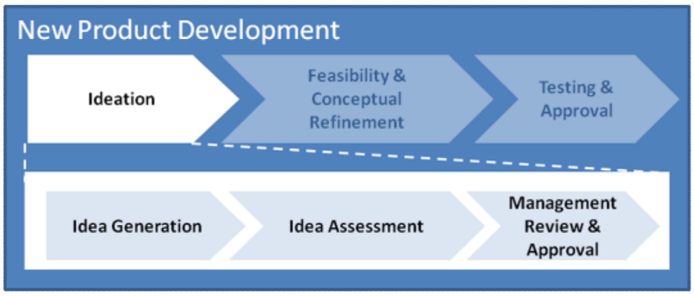

Figure 2. The NPD Ideation Process

During the idea generation process, firms will search the space of possible product development options to determine which preliminary ideas pose the greatest potential for commercial development. I will refer to this set of potential ideas as a firm's "idea pipeline." Conventional wisdom would suggest that conducting broad searches at this early stage would be fruitful as the firm is likely to encounter a broad and varied set of ideas for product development. A counterargument, however, would suggest that being too broad could subject the firm to information overload which could result in good ideas being missed due to high levels of noise in the idea pipeline.

As ideas are generated by engineers, scientists and new product development teams, firms should have in place mechanisms for assessing the viability of each discrete idea in the idea pipeline. This typically will involve a preliminary assessment of the technical viability of the idea as well as some consideration of the market potential of the idea. Continuing our pharmaceutical example from above, a newly identified biological target for diabetes might be screened against a library of the firm's existing chemical compounds to see if the firm possesses any compounds that demonstrate some level of efficacy against the target. Even if the target is deemed technically viable, an assessment of the potential size of the market for the drug might lead the firm to forego further work on the product. This, in fact, is the case with a number of "orphan diseases" that affect relatively few individuals and, hence, are not deemed as economically viable targets by some pharmaceutical companies.

Once an idea has passed preliminary viability and market potential assessments it will then typically proceed through a stage gate review process during which firm leadership will incorporate other factors into the assessment of the idea. These factors could include the potential product's fit with the overall firm strategy (e.g. "Does the firm already create products for the diabetes therapeutic area?"), knowledge of competitor actions (e.g. "Is a competitor close to seeking approval of a similar drug?"), regulatory concerns (e.g. "Is the FDA placing greater scrutiny on diabetes drugs due to recent adverse event cases?") and organizational considerations (e.g. "Is our sales force knowledgeable enough about diabetes to influence physician prescribing practices if we successfully launch this drug?"). Ideas the make it through this stage of the process pass through to the next phase of evaluation.

1.1.1.2 Feasibility & Conceptual Refinement

During the Feasibility & Conceptual Refinement process, new product development teams will focus their attention on a smaller set of robust ideas that have managed to make it through the first stage. It is during this stage that a higher level of rigor is applied to each prospective new product to ensure that it is worth continued investment by the firm for development.

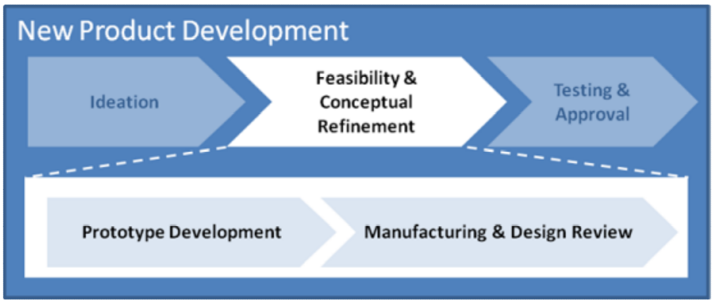

Figure 3. The NPD Feasibility & Conceptual Refinement Process

This stage typically begins with the development of a set of prototypes for further analysis and development. In the pharmaceutical context, we might imagine that at this point the firm has settled on a base chemical structure for its proposed diabetes drug and that now it will develop a series of "prototypes" of the final product in the sense that it will iteratively refine this base chemical structure to improve the products safety and efficacy profile.

Additionally during this phase, new product development teams will begin collaboration with commercial manufacturing teams to plan for product launch. The extent to which this collaboration is pursued at this stage will vary significantly across industries, but it is reasonable to expect high-tech manufacturing firms to perform some level of manufacturing assessment during this stage of the new product development process. Design insights discovered during the evaluation of prototypes are then typically reviewed by design teams and senior leadership to assess the viability of each product to move forward in the development process.

1.1.1.3 Testing & Approval

The final stage of the new product development process is focused on incorporating final improvements into the product design and collecting the objective evidence needed to commercially launch the product.

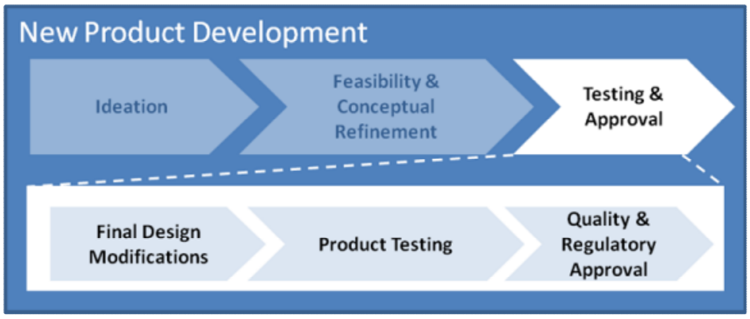

Figure 4. The NPD Testing & Approval Process

This stage of the NPD process allows product teams to incorporate feedback from earlier testing efforts to further refine products before more formalized and complex testing efforts are undertaken. This phase will include the completion of the most comprehensive battery of tests the product likely will be subjected to before commercial launch. In regulated industries, this phase will provide NPD teams with the opportunity to collect the objective evidence needed to convince regulatory authorities that the candidate product is ready for approval. In less regulated industries, this phase provides an opportunity for modifications and evaluation of adherence to both firm and industry quality standards.

Continuing the pharmaceutical example we have been considering in this section, this phase of work would be more focused on conducting clinical trials to evaluate efficacy and safety of the drug on a large sample of patients to give the pharmaceutical company (and regulatory authorities) as good a sense as is reasonably possible before product launch of the drug's pharmaceutical profile. While product modifications are possible during this stage of development, they are generally costly and may result in significant rework.

1.4. THE INTERPRETIVE SYSTEMS VIEW OF ORGANIZATIONS

Having reviewed a model of innovation, I now seek to view the innovation process through the lens of the Interpretive Systems View of Organizations (Daft & Weick 1984). In this section I provide the necessary background on ISV and review its key assumptions. In the section that follows, I discuss the implications of ISV for innovation research and, in particular, how ISV motivates a set of research questions around the role played by information technology and outsourcing in the innovation process.

ISV proposes a model of an organization as an open system faced with the challenge of interpreting and acting upon information gathered from its environment. Daft & Weick describe four major interpretation modes that organizations might adopt based upon their beliefs about the analyzability of the environment and on how active the organization prefers to be with respect to gathering information from the environment. These interpretation modes help predict the ways in which organizations scan their environment for information, formulate interpretations of the information, and ultimately make strategic decisions based upon these interpretations.

Underlying these predictions are four key assumptions about the ways in which organizations interact with their environment:

1. Organizations are open social systems that form ***information gathering*** mechanisms to learn from their environment.

2. Organizations have cognitive systems and memories and develop ***information sharing*** mechanisms to facilitate the collective interpretation process.

3. Organizations develop ***information channeling*** mechanisms to share organizational interpretations.

4. Systematic ***variation in interpretation processes*** can occur, and this variation ***may influence organizational outcomes***.

Information gathering mechanisms are primarily targeted at dealing with the uncertainty that is characteristic of a firm's external environment. These mechanisms can help organizations detect relevant trends, learn about competitor actions, identify new technological developments of interest, identify potential markets for their products, etc.. Information sharing mechanisms operate largely *within* the organization, on the other hand. These mechanisms help managers process gathered information and develop shared interpretations internally. Information channeling mechanisms help managers make known to the wider organization strategic decisions based on their collective interpretations of the gathered information.

The fourth assumption says that systematic variation in an organization's ability to interpret information may influence organizational outcomes. Daft and Weick conclude that "systematic variations occur based on organization and environmental characteristics, and the interpretation process may in turn influence organization outcomes such as strategy, structure and decision making" (Daft & Weick 1984). ISV assumes the existence of the information processing mechanisms described above; from the perspective of IS research, understanding how systematic variation in these mechanisms pertains to IT investments and IT capabilities is of paramount importance.

1.5. AN INTERPRETIVE SYSTEMS VIEW OF NEW PRODUCT DEVELOPMENT PROCESSES

In this section I discuss research questions that emerge from taking an interpretive systems view of the innovation process. These questions may serve as a starting point for future research aimed at understanding the role information systems play in the innovation process. Indeed, some of these questions form the bases for the subsequent chapters in this dissertation, which explore how IT investments and firm sourcing practices affect a firm's ability to innovate.

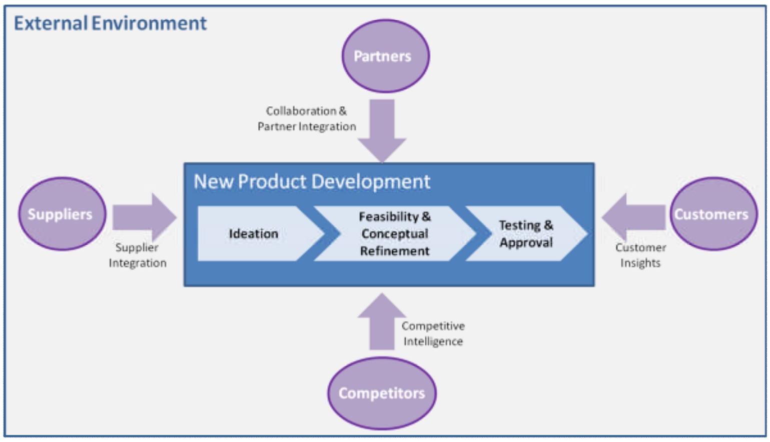

Figure 5. NPD Process External Environment

1.5.1. Information Gathering & Innovation

The information gathering mechanisms assumed by ISV are likely to be relevant to firm innovative activity as new product development processes become increasingly externalized. As shown above, NPD processes can be highly dependent on robust access to external information sources and require the firm to identify and consume large, complex amounts of information. ISV suggest that firms should aggressively gather information from their external environment to influence firm outcomes.

One such source of external information for firms can arise from the strategic partners the firm chooses to interact with. A key strategic decision for firms in recent years has been whether or not to engage in outsourcing (Whitaker et al 2006). Initially engaging in outsourcing (contracting business functions to external entities) was expected to provide firms with cost benefits that would directly impact profits. Subsequently, as outsourcing firms have further developed expertise and service offerings they have now come to be viewed as sources of competitive advantage beyond mere cost-benefits. The degree to which firms are able to leverage cost benefits and competitive advantage through outsourcing arrangements may impact the firm's ability to innovate, suggesting the following research question:

RQ1: Do sourcing decisions affect a firm's ability to generate innovative output?

Another key external source of information for firms can be information gleaned from customers themselves. Insights into customer desires and preferences remains a panacea for product developers, but mechanisms now exist for better capturing customer preferences. Scholars encourage firms to view customers not merely as purchasers of their products but rather as co-creators in the innovation process (Prahalad & Ramaswamy 2004; Prahalad & Krishnan, 2008) who provide a valuable perspective on how products should be shaped. This suggests the following research question:

RQ2: Are investments in customer-facing IT systems associated with greater levels of innovation?

NPD teams are increasingly dependent on connections with suppliers during the product development process. Suppliers can provide a different perspective on new product development by alerting firms to changes in key components (e.g. changes in the components used to make the screen on a mobile phone). Additionally, suppliers can provide focal firms with critical operational information (e.g. constrained capacity, unavailability of key items) that can influence product design decisions and affect product development timelines. I hypothesize that these connections are most relevant during the Testing & Approval stage of the NPD process as NPD teams work with suppliers to refine and finalize manufacturing processes and scale up production capacity for commercial launch. This suggests the following research question:

RQ3: Are investments in supplier-facing IT systems associated with higher levels of innovation?

1.5.2. Information Sharing & Innovation

ISV suggests that it not only is important to *gather* information from the external environment; the firm must also develop sophisticated capabilities to *process* and *share* information to influence firm outcomes. Throughout the new product development process, external sources of information provide the raw material for innovation. Once this information is within the focal firm, what mechanisms and capabilities will best enable the firm to capitalize on the information? Information Technology investments are known to confer a number of capabilities to firms that are likely to facilitate information processing including: coordination and communication (Hitt 1999; Malone et al 1987) collaboration (Finholt & Olson 1997) and information sharing (Kumar 2009).

These benefits of using IT, when applied to the specific organizational outcome of *innovation*, suggest the following research questions:

RQ4: Is aggregate IT investment associated with higher levels of innovation?

RQ5: What types of IT investment are associated with higher levels of innovation?

At this point in the innovation process, information has been collected from both external and internal sources and now teams of knowledge workers work together to collectively make sense of it and use it strategically. During this phase it is most likely that the *information sharing* mechanisms assumed by ISV will be most relevant. Recall that these mechanisms are purported to enable teams to develop shared interpretations of the collected information and to iteratively recombine and refine this information to enable the generation of new products.

R&D is a very knowledge-intensive process (Sheck et al 1984) and consequently will require significant IT-enabled knowledge management capabilities to process the large volumes of information created, suggesting the following question. In discussing the capabilities conferred to firms through IT usage, McAfee mentions experimentation capacity as a capability conferred by a certain class of IT systems (McAfee 2006). While traditional studies of the economic impact of IT investments have examined general investments in hardware and software, an entire class of advanced information systems specific to R&D remains to be investigated. Using advanced information systems (such as high-throughput screening systems in pharmaceutical drug discovery or advanced simulation systems in automotive design) will significantly increase a firm's experimentation capacity, thereby supporting the early stages of the innovation process. This suggests the following related question:

RQ6: What is the nature of the relationship between R&D investment and IT investment with respect to innovation?

During the Ideation and Feasibility & Conceptual Refinement stages of the NPD process, NPD teams are frequently collaborating with external partners to identify, develop and refine new product ideas. As such, NPD teams will have to share complex sets of data and analyses with partners to enable the rigorous filtering of ideas that must occur to focus firm resources on the most promising prospects. As researchers collaborate, it will be critical for them to develop shared understandings of the data and observations they share with each other. How might information systems help facilitate that process (or could they be a hindrance?)? The complexity and amount of information that firms must handle at this stage is expected to be quite high, so systems that facilitate knowledge management will be very relevant. Additionally, the degree to which information systems enable collaborate teams to process and develop shared interpretations will be important to the ability of these teams to innovate. The information sharing aspect of the transformation phase and its emphasis on collaborative innovation suggests a set of research questions specific to this phase.

RQ7: Do information systems facilitate collective sensemaking in the innovation process and, if so, by what mechanisms?

1.5.3. Information Channeling & Innovation

Finally, ISV also suggest that develop mechanisms to effectively *channel* information throughout the firm will impact organizational outcomes. Firms these days are faced with far more data than they are able to meaningfully consume. In such an environment it is important to ensure not only that the firm obtains access to the right information but also that this information makes its way to the people who are best positioned to capitalize on it for the firm. Additionally, innovation enabling information may not be consumable in the same ways by all levels of an organization. Technologies that enable firms to draw actionable insights from information and promote transparency of information across disparate business units will likely provide the capabilities needed to enable this type of information channeling. These suggest the following research questions:

RQ8: Are investments in information channeling IT systems (e.g. ERP systems, knowledge management systems) associated with higher levels of innovation?

RQ9: What types of information systems best enable collaboration in innovation processes?

1.6.SUMMARY OF RESEARCH QUESTIONS

Here I summarize the research questions that I have proposed as a research agenda to guide investigations of information technology investments, firm sourcing practices and innovation. For each question I additionally identify whether it is addressed in a later chapter of this dissertation or is proposed as an area of future research.

Table 1: An Interpretive Systems View of Innovation - A Proposed Research Agenda	
Information Gathering: focused on capabilities that enable the firm to gather data from external sources	
Research Question	**Notes**
RQ1: Do sourcing decisions affect a firm's ability to generate innovative output?	Addressed in Chapter 3 of this dissertation

RQ2: Are investments in customer-facing IT systems associated with greater levels of innovation?	Addressed in Chapter 3 of this dissertation
RQ3: Are investments in supplier-facing IT systems associated with higher levels of innovation?	Addressed in Chapter 3 of this dissertation
Information Sharing/Processing: focused on capabilities that enable the firm to convert raw data into useful information	
Research Question	**Notes**
RQ4: Is aggregate IT investment associated with higher levels of innovation?	Kleis et al (2012) suggest a relationship between IT capital stock and innovation; in Chapter 2 I address this question by measuring the effect of actual firm IT expenditures on innovation
RQ5: What types of IT investment are associated with higher levels of innovation?	Addressed in Chapter 2 of this dissertation
RQ6: What is the nature of the relationship between R&D investment and IT investment with respect to innovation?	Addressed in Chapter 2 of this dissertation
RQ7: Do information systems facilitate collective sensemaking in the innovation process and, if so, by what mechanisms?	Future Research
Information Channeling: focused on capabilities that enable the firm to be transparent by sharing useful information throughout the organization	
Research Question	**Notes**
RQ8: Are investments in information channeling IT systems (e.g. ERP systems, knowledge management systems) associated with higher levels of innovation?	Joshi et. al (2010) associate knowledge management capabilities with innovation; future research should explore the relevance of other information channeling IT systems to the innovation process
RQ9: What types of information systems best enable collaboration in innovation processes?	Future Research

1.7. CONCLUSION

In this chapter I have described the theoretical motivation for this dissertation. First I have reviewed prior studies of the business value of information technology and of innovation. In addition to reviewing relevant prior empirical studies of innovation, I have also proposed a generalized version of the new product development process that guides innovation at high-tech manufacturing firms. I then developed a set of research questions relating to information technology investments, firm sourcing practices and innovation motivated by the Interpretive Systems View of Daft & Weick. I propose that these research questions form a compelling research agenda within management research and set out to address a subset of those questions in Chapters 2 and 3 of this dissertation.

CHAPTER 2: DO INFORMATION TECHNOLOGY INVESTMENTS ENABLE INNOVATION IN HIGH-TECH FIRMS? AN EMPIRICAL ANALYSIS.

2.1. INTRODUCTION

In this chapter, I begin to empirically address some of the research questions identified in the last chapter. In particular, in this chapter I address the following research questions:

RQ4: Is aggregate IT investment associated with higher levels of innovation?

RQ5: What types of IT investment are associated with higher levels of innovation?

RQ6: What is the nature of the relationship between R&D investment and IT investment with respect to innovation?

While the research on innovation is voluminous, I find that very little attention has been paid to the question of whether information technology (IT) investments affect a firm's ability to innovate. IT scholars have for decades published studies demonstrating the unique contributions IT investments make to firm performance and the various ways in which IT investments create firm value. Typical firm performance metrics (e.g. productivity) are influenced by a number of value-creating factors including revenue growth (from sales of new and/or existing products) and operational efficiencies and give us a good view of the affect of IT investments on aggregate firm performance. As numerous subsequent studies of the business value of information systems have shown (e.g. Mithas et al 2005), examining effects of IT investment at more granular levels can be useful in demonstrating the magnitude of IT's contribution to firm value. *Innovation* is distinct from total firm productivity in that innovative output refers to the portion of a firm's annual production that results from *new value creation* i.e. new and/or improved products. Innovation is a knowledge-intensive process often requiring significant coordination and collaboration between employees and partner firms (Ahuja 2000; Owen-Smith & Powell 2004). Understanding the relationship between IT investment and firm-level innovation is vital to our overall understanding of how IT contributes to firm value. While a great deal of attention has been paid to assessing the value effects of IT investments in many regards, innovation has largely been ignored.

This chapter begins to fill that gap. Building on recent efforts (Han & Ravichandran 2006; Kleis et al 2012) to evaluate the impact of IT investment on innovation, I evaluate my hypotheses concerning the relationship between IT investment and firm-level innovation in high-technology manufacturing industries using an unbalanced panel data set with 148 observations of 63 firms in high-technology management industries over the years 1998 – 2003. These knowledge-intensive industries, that tend to patent their innovations (Schilling & Phelps 2007), include aerospace equipment, automotive bodies & equipment, chemicals, computer & office equipment, household audiovisual equipment, medical equipment, petroleum refining & products, pharmaceuticals, semiconductors, telecommunications equipment, and measuring & controlling devices. I find that IT investment is strongly associated with innovative output for firms operating in these industries over this time period. Contrary to my expectations, I further find that innovation returns to IT investment are higher (lower) for firms with lower (higher) levels of R&D expenditures, suggesting that IT capabilities may confer upon resource constrained firms the ability to compensate for lower R&D investment. I also find that IT investment in R&D-specific systems, in *new* IT systems and in long-lasting IT assets are associated with higher levels of innovation, strongly suggesting that IT capabilities play a role in enabling innovation processes.

The remainder of this chapter is organized as follows. In the next section I develop my hypotheses concerning the effects of IT investment on firm innovative output. In the following section I discuss in detail the methods employed in building the data set and estimating the econometric models. I then conclude with a discussion of the findings, implications, limitations and possible extensions.

2.2.BACKGROUND & HYPOTHESES

My goal in this study is twofold. First, I adopt *innovation* as a measure of IT business value. The impact of IT investment on firm outcomes has been well studied in the IS literature, but only recently have scholars begun to evaluate the effects of information technologies on innovation production (Joshi et al 2010, Klies et al 2012, Saldanha & Krishnan 2011). Second, I wish to empirically evaluate the direct and indirect effects of IT investments on innovation in high-technology firms. The predictors of firm level innovation have been well studied in the economics, public policy and management literature, but IT investments and practices have received little attention as potential predictors of innovation or input factors in innovation production functions. I believe that given the increasing level of digitization in every aspect of a firm's business model ranging from R&D, design and customer connection, the capacity of a firm to reconfigure resources and leverage R&D investments may depend on the level of its IT investments and the quality of its technology architecture.

2.2.1. Aggregate IT Investment & Innovation

I now turn to a consideration of the IT resource and its potential effects on firm-level innovation. In doing so I seek to identify ways in which IT investments may affect innovation processes within a firm and develop a research model, a schematic of which is presented in Figure 1.

IT investments provide firms with enhanced *coordination* and *collaboration* capabilities. Innovation processes typically rely on input from many, often distributed, players each performing tasks relevant to the process. This creates a strong need to coordinate activities amongst the participants in the innovation process. Similarly, innovation is very often dependent on interactions between distributed employees and partners. Prior research has demonstrated the importance of such ties that go beyond the boundaries of the firm to innovation processes (Ahuja 2000; Owen-Smith & Powell 2004). IT investments have been shown to enhance coordination and communication amongst employees and with partners (Hitt 1999; Malone et al 1987). Furthermore, IT investments can facilitate robust collaboration between distributed members by enhancing communication (Finholt & Olson 1997) and facilitating the development of trust (Bos et al 2002). Because IT enables the development of robust coordination and collaboration capabilities, all of which are vital to innovation processes, I expect the following:

H1: Higher levels of aggregate IT investment will be associated with higher levels of firm innovative output.

2.2.2. IT enablement of R&D processes

Next I consider the role IT investments may play in enhancing R&D processes. R&D expenditures have been found to be positively associated with innovative output (Pakes & Griliches 1980). With respect to R&D, I consider the *knowledge management* capabilities provided by IT investments. Innovation processes are known to be very R&D intensive (Hall et al 1984) and R&D is a very knowledge intensive process (Sheck 1984). Innovators create and evaluate large bodies of data that provide the building blocks for future commercial products. Consider an example from the pharmaceutical industry. It is well known that pharmaceutical drug development is very risky and time-consuming. Companies typically synthesize thousands of compounds in order to get one marketable drug. Identifying a marketable drug can take years of expensive clinical trials and can require overcoming numerous regulatory hurdles. On average, if a company synthesizes 10,000 compounds (i.e. drug candidates) it can expect that 10 of those will be suitable for clinical experiments and that one might become a marketable drug. (Sheck et al, 1984). A key challenge for pharmaceutical companies, therefore, is to search through the information space of possible drug candidates to identify those that might be most likely to succeed. Managing this data and providing employees with the capabilities to sift through it to extract useful information will be a key determinant of innovative success. IT investments facilitate knowledge management capabilities in firms (Alavi & Leidner 2001). As larger R&D programs are likely to involve data on multiple product candidates and more data for each candidate, they likely will benefit from robust IT capabilities to help manage the complexities associated with large-scale research programs. Consequently, I hypothesize that:

H2a: Innovation returns to R&D investment will be higher for firms with higher levels of aggregate IT investment

H2b: Higher levels of R&D-specific IT investment will be associated with higher levels of innovative output

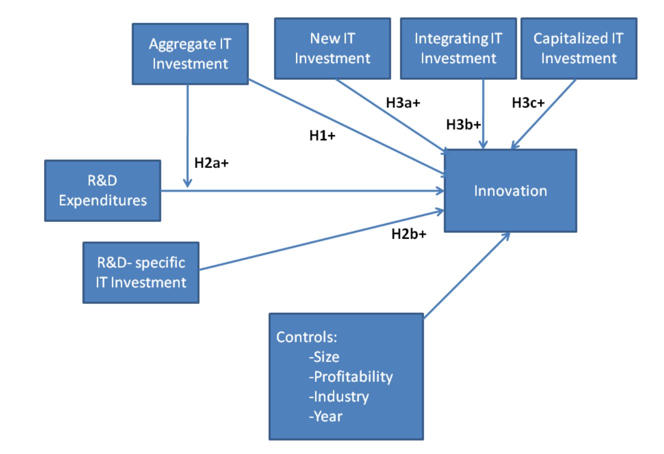

Figure 6. IT & Innovation Research Model

2.2.3. New IT Capabilities, IT Assets & Innovation

I now wish to propose hypotheses that deal with IT investment at a lower level. A firm's IT budget can be segmented into the amount spent on developing *new* IT systems, on *maintaining* existing IT systems and on *integrating* existing IT systems. Investments in new IT systems extend a firm's IT capabilities. On the other hand, IT investment in maintaining existing systems allows a firm to continue to use existing IT capabilities. Firms are facing growing informational and competitive challenges (Chesbrough 2003;

Prahalad & Krishnan 2008). One way in which firms can deal with such challenges is by implementing IT systems that provide new IT capabilities that adequately reflect the firm's evolving environment. Firm IT capabilities can evolve to changing environmental conditions faced by firms (Wade & Hulland 2004; Kohli & Melville 2009). A firm's ability to innovate is intimately related to its ability to sense changes in its environment (e.g. shifting customer preferences) and to leverage a flexible IT architecture to respond appropriately. On the other hand, firm investments targeted at maintaining existing IT systems more likely reflect IT capabilities from prior firm contexts. As innovation is hypothesized to be dependent on anticipating and responding to changes in a firm's context, I do not expect that investment in maintaining existing IT capabilities will be associated with higher levels of innovation. IT investments targeted at facilitating integration of IT systems should help existing IT systems perform better. Having flexible and integrated IT systems can help firms deal with environmental instability and flux (Prahalad & Krishnan 2008). These suggest the following hypotheses with respect to types of IT investment:

H3a: Higher levels of investment in NEW IT systems will be associated with higher levels of innovative output.

H3b: Higher levels of investment in INTEGRATING IT systems will be associated with higher levels of innovative output.

Another way to segment IT investments, is to consider whether the investment confers short-term or long-term benefits to the firm. IT investments that create a long-term asset from which the firm can extract benefits are categorized as *capitalized IT expenditures* in a firm's IT budget. These types of IT investments can extend a firm's IT capabilities (Wade & Hulland 2004), and capabilities can enable firms to deal with new informational challenges (Eisenhardt & Martin 2000), suggesting the following hypothesis:

H3c: Higher levels of CAPITALIZED IT investment will be associated with higher levels of innovative output.

2.3. RESEARCH DESIGN & METHODOLOGY

In this section I describe the methods I used to test the hypotheses described above. I first discuss in detail the data sources I used to build my data set and then define variables I constructed to measure the theoretical constructs identified in the last section. Finally I turn to a discussion of the econometric methods I used to estimate the econometric model and to test my hypotheses.

I began by constructing an unbalanced panel of U.S. firms for the period 1998 to 2003. The panel includes large U.S.-based firms that operate in any of 11 high-technology manufacturing industries including: aerospace equipment (standard industrial classifications (SICs)): 3721, 3724,3728, 3761, 3764, 3769; automotive bodies & parts (3711, 3713, 3714); chemicals (281-, 282-, 285-, 286-, 287-, 288-, 289-); computer & office equipment (3571, 3572, 3575, 3577); household audiovisual equipment (3651); medical equipment (3841, 3842, 3843, 3844, 3845); petroleum refining & products (2911, 2951, 2952, 2992, 2999); pharmaceuticals (2833, 2834, 2835, 2836); semiconductors (3674); telecommunications equipment (366-), and measuring & controlling devices (382-). I focused my inquiry on these industries because prior research has suggested that despite the shortcomings of patents as a measure of innovation, patents are more likely to be a useful proxy for innovation in the high-technology industries listed above (Levin et al 1987; Schilling & Phelps 2007).

2.3.1. Data Sources

I obtained data on the variables of interest in the following ways. In order to obtain information on IT expenditures, the sample was restricted to firms that had participated in the annual *Informationweek 500* surveys conducted between 1998 and 2003. These surveys are circulated annually to large US-based firms, most of which are *Fortune 500* firms as well. Data from the *Informationweek 500* surveys has been used in a number of prior IS studies (Bharadwaj et al 1999; Han & Ravichandran 2006; Rai et al 1997; Santhanam & Hantoro 2003). The *Informationweek 500* surveys ask for details on a number of information technology practices for each firm, including its level of IT investment.

I supplemented the survey data with financial data from COMPUSTAT. Specifically firms from the data set were matched to COMPUSTAT records and I extracted data on firm revenues, assets, profitability, and R&D expenditures from the database. In some cases, the required financial data was not available in COMPUSTAT. In those cases I examined firm SEC filings for the years of interest to obtain the necessary financial data.

I use patents as a proxy for firm-level innovation and obtained patent count data from the U.S. Patent & Trademark Office (USPTO). I obtained patent data from the US only for two reasons. All of the firms in the sample are large US-based high tech firms and it is likely that a large proportion of their patenting activity occurs within the US. Second, as patenting regimes can vary significantly across nations, including the frequency with which patents are granted and the level of protection provided by patents, I limited my data to US patents only to be able to consistently compare patent counts across firms and years (Ahuja 2000). After compiling the data and restricting the sample as described here, I was able to test my hypotheses on 148 observations of 63 firms over the years 1998 – 2003. Descriptive statistics on the sample can be found in Table 1.

Table 2. Descriptive Statistics

	Observations	Mean	Std. Dev.	Min	Max
Patents	148	187.86	356.51	0	1956
R&D Expenses (millions)	148	1120	1660	18.8	7100
Revenue (millions)	148	19,300	35,100	834	184,000
Net Income (millions)	148	1280	2040	-3940	10,500
IT Expenses (millions)	148	543	1060	12.5	9490

Researchers have commonly used two methods to assemble patent counts in prior studies: (1) assemble yearly counts of patents *granted* (i.e. successful patents) to the firm in a given year and (2) assemble yearly counts of successful patents *applied* for by the firm in a given year (i.e. counts of patents applied for in a given year that were ultimately granted). Note that both counts are limited to applications that ultimately were granted by the USPTO; data on patent applications that were not successful or are still under review typically is not made available to the public. Prior research has suggested that patent *application* counts are the better measure to use with respect to innovation because the point at which a firm applies for a patent represents a time closer to the point at which the firm believes it has created successful innovative output. Consistent with prior research, I acquired yearly counts of successful patent applications for use.

2.3.2. Variable Construction

As my data set includes data from many sources, I now define the specific ways in which I constructed each variable. A summary of the variable definitions is provided in Table 2.

PATENTS*:* I measure a firm's yearly innovative output as a count of the number of ultimately successful patent applications filed by the firm in that year. As an example, suppose that Firm X applied for 15 patents in the year 1999, 5 of which were granted in 2001, 3 in 2002 and 2 in 2003. Further suppose that the remaining 5 patents were not granted by the USPTO. I would assign this firm a patent count of 10 for the year 1999 because it was at that time that the firm believed it had successful innovative output, and my intention is to identify the role of information technology investments in enabling that output.

Though very widely used, patent counts have been criticized as a measure of innovation. In particular, it has been noted that there are non-innovative reasons for which a firm might submit a patent application. For example, some firms file defensive patents i.e. patents for inventions they do not necessarily intend to develop but rather wish to prevent a competitor from developing. Further not all innovations are necessarily patented by firms. I address this potential shortcoming methodologically by restricting the sample to firms operating in industries for which patents are considered to be a good proxy for innovative activity. Despite these shortcomings, patents are widely considered to be a useful measure of innovative activity at firms because they require external validation of the firm's output (Griliches 1990). Additionally, empirical studies of the validity of patents have shown that patent counts are closely correlated with the introduction of new products into the market (Comanor & Scherer 1969) and with sales growth (Scherer 1965). Consistent with many prior studies of innovative output (Ahuja 2000; Han & Ravichandran 2006; Owen-Smith & Powell 2004; Schilling & Phelps 2007), I use patents as a proxy for firm-level innovation.

RDEXP: This variable represents the natural log of the firm's RD expenditures. As patents are very likely related to a firms research and development activities, it is important to control for this effect in order to assess the independent contribution of my variable of interest (IT investment). Consistent with prior research, I lag R&D expenditures by one year relative to patent application counts (Hall et al 1984).

ITEXP: The IT expenditure variable represents the natural log of the firm's *aggregate* IT expenditures based on the firm's response in the *Informationweek 500* survey. I evaluated IT expenditures lagged one year prior to patent application counts to assess the effect of lagged IT investments on innovative activity.

RDITEXP: This IT expenditure variable represents the natural log of the firm's IT expenditures devoted to *R&D-specific information systems* based on the firm's response in the *InformationWeek 500* survey. As with the other IT expenditure variables, this variable is lagged one year prior to patent application counts.

NewITEXP: This IT expenditure variable represents the natural log of the firm's IT expenditures devoted to *new* IT projects (i.e. towards implementing new IT systems) based on the firm's response in the *InformationWeek 500* survey. As with the other IT expenditure variables, this variable is lagged one year prior to patent application counts.

MaintITEXP*:* This IT expenditure variable represents the natural log of the firm's IT expenditures devoted to *maintenance* IT projects (i.e. towards maintaining the firms existing IT systems) based on the firm's response in the *InformationWeek 500* survey. As with the other IT expenditure variables, this variable is lagged one year prior to patent application counts.

IntegITEXP*:* This IT expenditure variable represents the natural log of the firm's IT expenditures devoted to *integration* IT projects (i.e. towards better integrating the firms existing IT systems with each other) based on the firm's response in the *InformationWeek 500* survey. As with the other IT expenditure variables, this variable is lagged one year prior to patent application counts.

CapITEXP*:* This IT expenditure variable represents the natural log of the firm's IT expenditures categorized as *capitalized IT expenditures* (i.e. those investments the firm believes will create an IT asset that will benefit the firm beyond one-year) based on the firm's response in the *InformationWeek 500* survey. As with the other IT expenditure variables, this variable is lagged one year prior to patent application counts.

OperITEXP*:* This IT expenditure variable represents the natural log of the firm's IT expenditures categorized as *operating IT expenditures* (i.e. those investments the firm believes will create benefits to the firm with the year of expenditure) based on the firm's response in the *InformationWeek 500* survey. As with the other IT expenditure variables, this variable is lagged one year prior to patent application counts.

REVENUE*:* This variable represents the natural log of the firm's revenue. Although there is disagreement as to the direction of the effect of firm size on innovation, there is widespread agreement that firm size will be associated with innovative output. I control for firm size in a manner consistent with prior studies by using revenue as a proxy for the size of the firm.

PROFIT*:* This variable represents the return on assets for the firm in the given year. Prior studies have suggested that firm performance is associated with innovative effort and output (Cameron et al 1987; Staw et al 1981) and scholars have agreed that this construct is an important predictor of innovativeness in firms (Ahuja 2008). I control for this by using one-year lagged return on assets as a proxy for firm performance.

INDUSTRY*:* This binary variable (one for each industry in the sample) indicates the industry to which the firm belongs. Prior research has suggested that patenting propensities can vary across industries. I control for this by including this dummy variable in my econometric models.

YEAR*:* This binary variable represents the year of each observation. I include this variable to control for any year to year fluctuations in patenting activity (e.g. diminished processing capacity at the USPTO) that are beyond the control of the firm.

Table 3. Chapter 2 Variable Definitions

Variable	Definition	Source
$PATENTS_{it}$	Count of successful patent application counts for firm *i* in time *t*.	US Patent & Trademark Office
$RDEXP_{i,t-1}$	ln(R&D Expenditures) for firm i in time *t-1*.	COMPUSTAT
$ITEXP_{i,t-1}$	ln(IT Expenditures) for firm *i* in time *t-1*.	*Informationweek 500* Survey
$ITEXP_{i,t-1}$	ln(IT Expenditures) for firm *i* in time *t-1*.	*InformationWeek 500* Survey
$RDITEXP_{i,t-1}$	ln(R&D-specific IT Expenditures) for firm *i* in time *t-1*.	*InformationWeek 500* Survey
$NewITEXP_{i,t-1}$	ln(IT Expenditures on new IT projects) for firm *i* in time *t-1*.	*InformationWeek 500* Survey
$MaintITEXP_{i,t-1}$	ln(IT Expenditures on maintenance IT projects) for firm *i* in time *t-1*.	*InformationWeek 500* Survey

IntegITEXP $_{i,t-1}$	ln(IT Expenditures on integration IT projects) for firm *i* in time *t-1*.	*InformationWeek 500* Survey
CapITEXP $_{i,t-1}$	ln(capitalized IT Expenditures) for firm *i* in time *t-1*.	*InformationWeek 500* Survey
OperITEXP $_{i,t-1}$	ln(operating IT Expenditures) for firm *i* in time *t-1*.	*InformationWeek 500* Survey
REVENUE $_{it}$	ln(Revenue) for firm *i* in time *t*.	COMPUSTAT
PROFIT $_{i,t-1}$	Return on Assets for firm *i* in time *t-1*.	COMPUSTAT
INDUSTRY $_{i}$	Dummy variable indicating the industry to which firm *i* belongs	COMPUSTAT

2.3.3. Empirical Methods

The traditional Ordinary Least Squares (OLS) assumptions of homoskedasticity and normally distributed errors are violated with count data, and the OLS estimator will therefore be biased. An estimation method that accounts for the discrete, non-negative nature of count data is more appropriate in this case. Poisson regression models have been widely used to address this issue and are appropriate for count data. A limitation of the Poisson regression model is that it assumes that the expected mean and variance for the dependent variable are the same. Patent application counts often suffer from *overdispersion* in that the variance of patent application counts typically exceeds the mean. As can be seen in the summary statistics table (Table 1), this appears to be the case in my sample as well. An estimation method that better allows for overdispersion of the count variable is the negative binomial regression model (Hausman et al 1984). In these regression models, the probability of observing a particular count value (e.g. k) follows a negative binomial distribution:

$$\Pr(y_i = k \mid x_i) = \frac{\Gamma(k+\alpha^{-1})}{k!\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu_i}\right)^{\alpha^{-1}}\left(\frac{\mu_i}{\alpha^{-1}+\mu_i}\right)^{k}$$

With the probability function specified, estimation proceeds via maximum likelihood. As mentioned above, I add industry and year variables as well to control for industry and time specific effects. To take advantage of the longitudinal aspect of my data set and to address potential unobserved heterogeneity, I use the generalized estimating equations (GEE) population averaged estimator (Zeger et al 1988). All regression results in this proposal were generated using this estimation approach unless otherwise indicated. Additionally, to correct for potentially heteroskedastic errors, all regressions employ Huber-White standard errors (White 1980).

2.4.RESULTS

In this section I present results using the methods above on my data set. In each table below, I start by estimating a base model that does not include my IT variables of interest and then proceed to add the relevant variables to the model to obtain parameter estimates.

Table 4: Aggregate IT Investment and ITxRD

	(1) Base Model	(2) IT Expenditures	(3) IT x R&D
R&D Expenses$_{i,t-1}$	0.251*** (0.018)	0.191 (0.104)	2.676*** (0.000)
Revenue $_{i,t}$	0.579*** (0.001)	0.522*** (0.000)	0.594*** (0.000)
Return on Assets i,t-1	0.813 (0.301)	0.827 (0.254)	0.666 (0.348)
IT Expenses $_{i,t-1}$		**0.138* (0.081)**	**2.737*** (0.000)**
IT Expenses $_{i,t-1}$ x R&D Expenses $_{i,t-1}$			**-0.130*** (0.001)**
Intercept	-14.929*** (0.000)	-14.980*** (0.000)	-76.733*** (0.000)
Industry Controls	Yes	Yes	Yes
Year Controls	Yes	Yes	Yes

Wald chi-squared	807.43	688.71	1499.38
Prob > chi-squared	0.000	0.000	0.000
Observations	148	148	148
Firms	63	63	63

p values in parenthesis; * significant at 10%; ** significant at 5%; *** significant at 1%

Model 1 serves as baseline for comparison and for docking my work with earlier empirical studies of innovation. Consistent with prior research, I find that one-year lagged R&D investments show a strong positive relationship with firm innovative output. This result provides a measure of confidence that the innovation processes being evaluated in my data set are similar to those from prior research on innovation. Similarly, I find a significant association between firm size (as measured by revenues) and innovation and industry controls (results not shown). Proceeding from this base model, I evaluated the direct and indirect effects of IT investment on firm innovative output.

I hypothesized that lagged IT expenditures would be positively associated with firm patenting activity. As shown in Table 3, I find support for this hypothesis (H1) in my sample. I further hypothesized that the effect of IT expenditures on innovative output would be higher for firms with higher levels of R&D investment. I do not find support for this hypothesis (H2a) in my sample. In fact, my data suggests quite the opposite: that innovation returns to IT investments are higher for firms with lower R&D investments. I provide an interpretation of this surprising finding in the discussion of results below.

Table 5: R&D Specific IT Investments

	(4) Base Model	(5) IT Expenditures	(6) R&D Specific IT
R&D Expenses$_{i,t-1}$	0.662*** (0.000)	0.596** (0.001)	0.638*** (0.000)

Revenue $_{i,t}$	0.181 (0.461)	0.050 (0.857)	-0.106 (0.663)
Return on Assets i,t-1	0.420*** (0.002)	0.404*** (0.002)	0.397*** (0.006)
IT Expenses $_{i,t-1}$		**0.216** **(0.176)**	**0.153** **(0.296)**
R&D-specific IT Expenses $_{i,t-1}$			**0.200**** **(0.020)**
Intercept	-12.219*** (0.000)	-11.939*** (0.000)	-11.438*** (0.000)
Industry Controls	Yes	Yes	Yes
Year Controls	Yes	Yes	Yes
Wald chi-squared	902.53	683.62	817.17
Prob > chi-squared	0.000	0.000	0.000
Observations	61	61	61
Firms	36	36	36

p values in parenthesis; * significant at 10%; ** significant at 5%; *** significant at 1%

The findings with respect to R&D specific IT investments are presented in Table 5. In this case I hypothesized the higher levels of R&D-specific IT investment will be associated with higher levels of innovative output (H2b). In this data set I find this hypothesis to be confirmed, suggesting that such investments help firms extract greater value from their R&D processes.

Table 6: New, Maintenance & Integration IT Investments

	(7) Base Model	(8) IT Expenditures	(9) New, Maint. & Integ. IT Expenditures
R&D Expenses $_{i,t-1}$	0.258** (0.028)	0.209* (0.088)	0.246** (0.032)
Revenue $_{i,t}$	0.575*** (0.000)	0.445*** (0.002)	0.431** (0.034)
Return on Assets i,t-1	0.438 (0.630)	0.381 (0.652)	0.515 (0.521)
IT Expenses $_{i,t-1}$		0.200** (0.034)	
NEW IT Expenses $_{i,t-1}$			**0.167****

			(0.025)
MAINTENANCE IT Expenses $_{i,t-1}$			**0.011** **(0.869)**
INTEGRATION IT Expenses $_{i,t-1}$			**-0.018** **(0.808)**
Intercept	-14.930*** (0.000)	-14.640*** (0.000)	-14.158*** (0.000)
Industry Controls	Yes	Yes	Yes
Year Controls	Yes	Yes	Yes
Wald chi-squared	1154.42	632.74	984.88
Prob > chi-squared	0.000	0.00	0.000
Observations	135	135	135
Firms	61	61	61

p values in parenthesis; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 6 presents the results of evaluating different types of IT investment and their effect on firm patenting. Model 9 shows the particular results of interest indicating that, in particular, investment in new IT projects appears to be correlated with higher patenting activity. This provides support for H3a, suggesting that firms that develop new IT capabilities further enable their innovation efforts. However, I do not find support for my hypotheses (H3b) that spending on integration IT projects would be associated with higher innovative output.

Table 7: Capitalized vs. Operating IT Investments			
	(10) Base Model	(11) IT Expenditures	(12) Cap. & Oper.. IT Expenditures
R&D Expenses $_{i,t-1}$	0.431*** (0.006)	0.385*** (0.011)	0.419*** (0.006)
Revenue $_{i,t}$	0.505** (0.015)	0.355 (0.135)	0.344 (0.153)
Return on Assets i,t-1	0.254** (0.036)	0.245** (0.028)	0.242 (0.033)
IT Expenses $_{i,t-1}$		**0.220*** (0.005)**	

CAPITALIZED IT Expenses $_{i,t-1}$			**0.141** (0.033)**
OPERATING IT Expenses $_{i,t-1}$			**0.031 (0.571)**
Intercept	-16.570*** (0.000)	-16.258*** (0.000)	-15.492*** (0.000)
Industry Controls	Yes	Yes	Yes
Year Controls	Yes	Yes	Yes
Wald chi-squared	895.22	603.38	950.43
Prob > chi-squared	0.000	0.00	0.000
Observations	93	93	93
Firms	47	47	47

p values in parenthesis; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 7 presents the results of evaluating the effect of capitalized and operating expenses on firm patenting activity. Model 12 shows support for H3c, specifically that higher levels of capitalized IT investment (which confer long-lasting IT benefits to the firm) are correlated with higher levels of innovative output.

2.5.DISCUSSION

Table 8: Chapter 2 Summary of Results	
H1: Higher levels of aggregate IT investment will be associated with higher levels of firm innovative output.	Supported
H2a: Innovation returns to R&D investment will be higher for firms with higher levels of aggregate IT investment	Not Supported
H2b: Higher levels of R&D-specific IT investment will be associated with higher levels of innovative output	Supported
H3a: Higher levels of investment in NEW IT systems will be associated with higher levels of innovative output.	Supported
H3b: Higher levels of investment in INTEGRATING IT systems will be associated with higher levels of innovative output.	Not Supported
H3c: Higher levels of CAPITALIZED IT investment will be associated with higher levels of innovative output.	Supported

2.5.1. Implications for Research

The primary contributions of this chapter are the findings that suggest a correlation between IT investment and firm patenting in high-tech firms. In particular, I find that aggregate IT investment (H1), R&D-specific IT investment (H2b), New IT Investment (H3a) and Capitalized IT Expenditures (H3c) are associated with greater patenting activity for firms in my data set. These findings suggest that, as with other firm performance measures, IT plays a critical role in a firm's ability to innovate. IT investments confer upon firms enhanced knowledge management, coordination and collaboration capabilities that should allow employees and teams to enhance both the quality and quantity of their output. These results complement earlier studies of the business value of information systems and widen the breadth of impact of IT investments on organizational performance.

The finding in model 3 regarding the interaction of IT investment and R&D investment, with respect to innovative output, is curious. I expected to find a positive and significant effect consistent with earlier research but instead found a negative and statistically significant effect. This implies that in my sample the marginal effect of increased IT investment was greater for firms with smaller R&D budgets. This could mean that IT investments confer upon resource challenged firms capabilities that allow them to compensate for lower levels of R&D investment. Alternatively it could be that there are different investment practices followed by firms with different R&D budgets. For example, if firms with larger R&D budgets tend to invest more in *physical* R&D assets (e.g. laboratory space) while firms with smaller R&D budgets tend to invest in *information* R&D assets (e.g. advanced information systems, computational modeling systems) then the result I have obtained would be explained. Future research can help to explain this finding in greater detail.

2.5.2. Implications for Practice

These findings have significant implications for IT practitioners in addition to researchers. While there has been substantial interest in overall IT investment and innovation, little insight has been available as to *how* IT dollars should be invested to maximize innovative output. This work begins to fill that gap. In particular, I find that IT investments targeted at building *new* IT capabilities are associated with higher levels of innovation. Similarly I find that *asset-creating* IT investments (i.e. IT investments that are capitalized) are associated with greater innovation. These findings suggest that IT managers operating in business contexts where maximizing innovation is a primary strategic firm objective should consider strategically expanding their IT capabilities through focused IT investments. Additionally support for H2b (*higher levels of R&D-specific IT investment will be associated with higher levels of innovative output*) suggests that the same managers should also consider R&D enabling IT-investments as they plan their operating budgets. Firms operating in contexts where other objectives take precedence (e.g. reducing operational costs) will not necessarily benefit from these types of investments and should rather let the primary strategic objectives guide their IT investment decisions.

The finding that innovation returns to IT investment are greater for firms with lower levels of R&D investment suggests that IT and R&D investments may be substitutes. This suggests that firms with smaller R&D programs may in fact be able to compensate for their lower R&D investment by making wise IT investments. In this sense information technologies can be viewed as a "great enabler" in the sense that they allow firms to expand other firm capabilities (e.g. R&D experimentation capacity) through enabling technology investments.

2.5.3. Limitations & Extensions

In this chapter I have attempted to examine specific firm IT investments to assess which types of IT investments are correlated with higher levels of innovative output. In doing so I have assumed that R&D expenses and IT expenses truly measure different constructs, but in theory an overlap between these two components is possible. Think of an example in which a firm is implementing an IT system to support the R&D function. Since the R&D unit is ultimately purchasing the system their budget could reflect the expense. Since the IT department is providing many of the resources needed to implement the system, the expense of implementing the system could also be reflected in the IT budget. If an overlap between these two expenses exists it would introduce measurement error into my econometric models and could bias my results. To address this potential concern I interviewed current and former executives from firms within my sample to assess how likely such an overlap is in practice. Their responses are included in Appendix 1 and suggest that such overlap between IT and R&D budgets is unlikely to actually occur in practice.

I also have speculated above that when firms *capitalize* IT expenses they do so when they believe the investment is creating a long-lasting asset for the firm. In order to confirm whether in practice IT executives categorized their expenses in this manner I asked the same executives questions related to how they make the decision to capitalize. These responses are also included in Appendix 1 and suggest that while firms tightly control which expenses are allowed to be capitalized and that these generally follow firm interpretations of common accounting rules (e.g. FASB standards), capitalized IT expenses are typically associated with asset-building activities.

One limitation of this study has to do with the firms included in the *Informationweek 500* survey sample. Though there is a good deal of overlap in the firms included from year to year, firms are chosen for inclusion based on the subjective criterion that they are considered to be leaders with respect to their usage of information technology investments. These firms are likely to be more aggressive than the average firm in their IT investment and adoption practices. Prior research has suggested that the financial performance of such IT leader firms may significantly differ from that of non-IT leader firms as well (Bharadwaj 2000; Santhanam & Hartono 2003). The degree to which the sample is skewed towards leader firms may affect the generalizability of my results.

Additionally, while offering compelling evidence of the existence of a direct effect of IT investment on firm innovative performance, this chapter does not specifically evaluate the *mechanisms* by which IT capabilities affect innovation processes positively. Does IT specifically enhance the knowledge management, coordination, collaboration or other capabilities of the firm and, if so, to what degree? Are there organizational complements that are vital to the ability of firms to extract innovation value from IT investments? These and other related questions provide opportunities for IS scholars to continue to understand the critical ways in which IT investments create firm value and affect innovation.

2.6.CONCLUSION

In this chapter I provide empirical evidence for a direct effect of IT investment on firm innovative output. I developed hypotheses concerning the relationship between different types of IT investment and firm innovative activity. I also discussed methodological considerations relevant to the estimation of econometric models using count data and, using those methods, demonstrated support for the effect of IT on innovative output. In particular, I found that aggregate IT investment and specific IT investments aimed at supporting R&D processes are associated with greater innovative output. I further find that IT investment in extending firm IT capabilities (by investing in NEW IT systems) and in developing long-lasting IT capabilities are associated with greater innovative output. Taken together, these findings provide compelling evidence for a relationship between a firm's IT capabilities and innovative productivity. This chapter contributes to the IS literature by suggesting another significant way in which IT investments add value to firms and provide opportunities for IS researchers to understand the mechanisms by which IT investments enable firm-level innovation.

CHAPTER 3: THE INNOVATION IMPLICATIONS TO FIRMS OF EXTERNALLY-FACING IT INVESTMENTS AND FIRM SOURCING PRACTICES

3.1.INTRODUCTION

For the third chapter of my dissertation I maintain my focus on elucidating determinants of firm-level innovation but focus my inquiry on how the focal firm interacts with its external environment and what innovation implications those interactions drive. I specifically examine two types of firm interactions with its external environment: (1) making investments in externally-facing IT systems and (2) engaging in outsourcing.

Why should we expect these two types of interactions to affect a firm's ability to innovate? In both cases the relationship is suggested by the Interpretive Systems View of the firm as discussed in Chapter 1 of this dissertation. Specifically the ISV posits that a firm's ability to generate positive firm performance outcomes (in this case, driving higher levels of innovation within the firm) are critically dependent on its ability to understand, learn from and react to its external environment (Daft & Weick 1984). IT systems are key enablers of a firm's ability to understand its external environment. Customer Relationship Management (CRM) systems, for example, provide firms with the ability to capture, disseminate and act upon information related to its customers. This information can be tactical in nature (e.g. physician detailing information used by pharmaceutical sales representatives) but can also be related to the firm's products (e.g. field observations of physician complaints about pharmaceuticals / medical devices). I specifically evaluate the innovation implications of firm investments in *customer-facing IT systems* and *supplier-facing IT systems* in this chapter.

While in the case of externally facing IT systems it is the ability for the firm to *process* knowledge about its external environment that is likely to be valuable, with respect to outsourcing it is gaining *access* to useful information that is most likely to be related to enabling innovation as are the cost-savings that can be accrued from outsourcing relationships. In this chapter I propose a mechanism by which firms who engage in outsourcing may achieve a competitive advantage by benefitting from "weak ties" (Ahuja 2000) with other firms through a shared outsourcing firm. In this sense outsourcing firms, because of their increasingly central position in firm networks, may unintentionally become knowledge brokers by learning, adapting and sharing valuable information (e.g. best practices) from firms that choose to partner with them. Specific research questions I address in this chapter include:

RQ1: Do sourcing decisions affect a firm's ability to generate innovative output?

RQ2: Are investments in customer-facing IT systems associated with greater levels of innovation?

RQ3: Are investments in supplier-facing IT systems associated with higher levels of innovation?

In the remainder of this chapter I develop hypotheses concerning the relationship between externally-facing IT investments, outsourcing and innovation and describe the empirical strategy for testing these relationships.

3.2.BACKGROUND & HYPOTHESES

3.2.1. Externally-Facing IT Investments & Innovation

In the previous chapter I performed analyses that segmented firm IT investments in various ways (e.g. capitalized vs. operating IT expenses, new vs. maintenance IT expenses). In this section I focus specifically on externally-facing IT investments to develop hypotheses motivated by the Interpretive Systems View relating these investments to firm innovation. I define "externally-facing" IT investments as those investments the firm makes in information technologies focused on gathering, processing and channeling information regarding the firm's external environment. In chapter 1, section 1.5 I discussed how innovation processes are enabled by robust access to external information sources. Specifically, I propose that implementing IT systems that help firms better understand their customers will enable firm-level innovation.

Customer-facing IT systems (e.g. CRM systems) enable the firm to collect, process and disseminate information gleaned from its customers throughout the firm. While in the past firm's might have developed new products in silos or with limited access to end consumers, firms now are very interested in incorporating customer input early in the new product development lifecycle to leverage customer insights for co-creation (Prahalad & Ramaswamy 2004; Prahalad & Krishnan 2008). One way in which this kind of co-creation can happen is for customers to provide input on their desired outcomes (e.g. the problems they wish a new product would solve) and firm R&D teams can focus their efforts on designing products to meet those needs (Ulwick 2002). Additionally, customers can provide feedback to the firm on existing products that can be leveraged to improve future versions of a product. IT systems that help firms collect and process this type of customer input are expected to provide firms with the ability to accelerate new product development.

While customer-facing IT systems are expected to be particularly useful in innovation *idea generation* processes, supplier-facing IT systems may be useful further in the new product development process. As a product idea matures, R&D teams shift focus towards rapid prototyping and design refinement. Robust connections with suppliers may be valuable during this stage of product development because firms can effectively collaborate with their suppliers to improve the design of products. In addition to design information, firms may also benefit by having insight into key *operational* parameters at their suppliers. Manufacturing efficiency becomes more important as firms scale the production of new product candidates. The degree to which firms have visibility into supplier's production capacity and the status of outstanding order / transactions can affect the firm's ability to manage its R&D supply chain. Consider an example from the pharmaceutical industry. As a new pharmaceutical drug candidate progresses in the pipeline, the pharmaceutical company has to scale product of the drug to provide adequate supply for the clinical studies it must complete to attain FDA approval. Failure to maintain an adequate stock of investigational drug product can lead to delayed clinical trial results, FDA submissions and, in the case of blockbuster drugs, potentially millions of dollars in lost revenue. Supplier-facing IT systems that could enable the company to perceive and react to threats in its R&D supply chain can enable innovation processes by providing visibility into supplier capacity.

For the reasons listed above I suggest the following hypotheses related to externally-facing IT investment and innovation:

H4a: Higher levels of investment in customer-facing IT systems will be associated with higher levels of innovative output.

H4b: Higher levels of investment in supplier-facing IT systems will be associated with higher levels of innovative output.

3.2.2. Outsourcing & Innovation

There are a number of reasons to expect that engaging in outsourcing should enable firms to be more innovative. In this section I present my rationale for expecting a relationship and suggest specific hypotheses to be tested. I evaluate the innovation implications to firms of engaging in two types of outsourcing: business process outsourcing (BPO) and information technology outsourcing (ITO). In engaging in BPO, firms decide to outsource one or many IT-intensive business processes (e.g. human resources, accounting) to an external vendor. In ITO, firms outsource all or part of their information technology operations (e.g. helpdesk, server/network management) to an external vendor. There are two primary reasons for expecting that firms that outsource will be more innovative. The first reason has to do with firm resources. Firms often choose to engage in outsourcing to pursue cost benefits. In addition to cost benefits, engaging in outsourcing may confer other resource advantages to firms (Whitaker 2006). When such benefits are realized, rational firms would be expected to redirect those resources towards core business activities. In high-technology industries, developing new products is a core business activity and below I propose some mechanisms by which engaging in outsourcing might free up firm resources for innovative activities. The second reason is knowledge based. I argue below that engaging in outsourcing exposes firms to new sources of knowledge. These come in the form of access to knowledge workers at the outsourcing firm and, indirectly, to knowledge from disparate and proximate industries.

3.2.2.1 Resources for Innovation

I propose that engaging in outsourcing enables firm-level innovation by affecting the levels of three types of critical firm resources. First, outsourcing can confer *monetary resource benefits* to firms by lowering costs for key business functions (Whitaker et al 2006). While firms could use such monetary resources for any purposes, it is likely that rational firms will direct at least some of these resources towards core business activities to enhance firm performance. Second, outsourcing can affect innovation by conferring *cognitive resource benefits* to the focal firm. Employees of firms that engage in outsourcing theoretically should be able to focus their mental effort on core business activities by reducing (or eliminating) time spent on non-core activities. Third, outsourcing can enable innovation by conferring *labor resource benefits* to the focal firm. While the second line of reasoning addresses the quality of employee engagement with core business problems, this one addresses quantity. Specifically, firms that effectively outsource non-core business tasks should be able to reassign more employees to focus on core business activities. Having these monetary, cognitive and labor resource benefits conferred by outsourcing should positively affect a firm's ability to innovate,

3.2.2.2 Access to New Sources of Knowledge

Prior research has shown that both direct (e.g. strategic alliances) and indirect (e.g. access to information from a partner's partner) ties promote innovation, though to varying degrees (Ahuja 2000; Owen-Smith & Powell 2004). While engaging in outsourcing, focal firms establish direct ties to outsourcing vendors, but additionally establish indirect ties to (a) other outsourcing vendors and (b) other firms that use the same vendor. From a network standpoint, outsourcing firms can be viewed as highly centralized nodes in information networks. Effectively they function as weigh-stations for information that could be a source of competitive advantage to client firms. The extent to which such information moves in outsourcing firm networks and the value which the information carries can directly affect the innovation effects on focal firms of engaging in outsourcing.

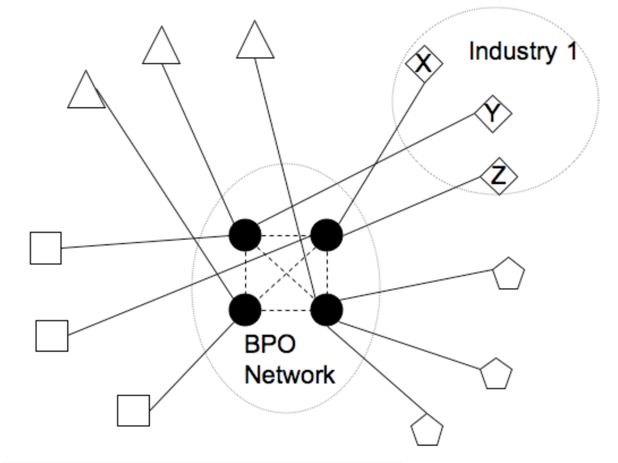

Figure 7: Outsourcing Networks & Indirect Ties

In Figure 3, the centralized shaded circles represent outsourcing firms and the outer white shapes represent focal firms (different shapes represent firms in different industries). Nodes X, Y and Z represent competing firms within the same industry who do not have information sharing agreements established with each other. All three of the firms engage in outsourcing and firms X and Z use the same outsourcing firm. In this network structure, firms X and Z have indirect ties to each other through their common outsourcing firm. Indirect ties have been shown to be a source of information that drives innovation (Ahuja, 2000) suggesting that firms that use outsourcing firms will experience higher rates of innovation.

Taken in combination, the resource benefits and access to new knowledge sources provided to firms engaging in outsourcing suggest the following hypotheses:

H5a: Engaging in business process outsourcing (BPO) will be associated with higher levels of innovative output.

H5b: Engaging in information technology outsourcing (ITO) will be associated with higher levels of innovative output.

3.3.METHODOLOGY & DATA

In this section I describe the methods I used to test the hypotheses described above. I note for the reader that this chapter utilizes the same methods and data sources of the previous chapter, but focuses on different independent variables of interest (BPO and ITO) during a different time frame (2003 – 2007) during which the *InformationWeek 500* surveys collected data on firm outsourcing activities. In this section I focus primarily on the differences in methodology that are unique to this chapter and refer the reader to section 2.3 for a more detailed discussion of the methods used in both chapters 2 and 3.

As in chapter 2, I restricted my sample to large U.S.-based firms that operate in any of 11 high-technology manufacturing industries including: aerospace equipment (standard industrial classifications (SICs)): 3721, 3724,3728, 3761, 3764, 3769; automotive bodies & parts (3711, 3713, 3714); chemicals (281-, 282-, 285-, 286-, 287-, 288-, 289-); computer & office equipment (3571, 3572, 3575, 3577); household audiovisual equipment (3651); medical equipment (3841, 3842, 3843, 3844, 3845); petroleum refining & products (2911, 2951, 2952, 2992, 2999); pharmaceuticals (2833, 2834, 2835, 2836); semiconductors (3674); telecommunications equipment (366-), and measuring & controlling devices (382-). I focused my inquiry on these industries because prior research has suggested that despite the shortcomings of patents as a measure of innovation, patents are more likely to be a useful proxy for innovation in the high-technology industries listed above (Levin et al 1987; Schilling & Phelps 2007).

3.3.1. Variable Construction

As my data set includes data from many sources, I now define the specific ways in which I constructed each variable. A summary of the variable definitions is provided in Table 7.

PATENTS*:* I measure a firm's yearly innovative output as a count of the number of ultimately successful patent applications filed by the firm in that year. As an example, suppose that Firm X applied for 15 patents in the year 1999, 5 of which were granted in 2001, 3 in 2002 and 2 in 2003. Further suppose that the remaining 5 patents were not granted by the USPTO. I would assign this firm a patent count of 10 for the year 1999 because it was at that time that the firm believed it had successful innovative output, and my intention is to identify the role of information technology investments in enabling that output. Consistent with many prior studies of innovative output (Ahuja 2000; Han &

Ravichandran 2006; Owen-Smith & Powell 2004; Schilling & Phelps 2007), I use patents as a proxy for firm-level innovation.

RDEXP*:* This variable represents the natural log of the firm's RD expenditures. As patents are very likely related to a firms research and development activities, it is important to control for this effect in order to assess the independent contribution of my variable of interest (IT investment). Consistent with prior research, I lag R&D expenditures by one year relative to patent application counts (Hall et al 1984).

CustomerITEXP*:* This IT expenditure variable represents the natural log of the firm's IT expenditures devoted to *customer-facing* IT projects based on the firm's response in the *InformationWeek 500* survey. As with the other IT expenditure variables, this variable is lagged one year prior to patent application counts.

SupplierITEXP*:* This IT expenditure variable represents the natural log of the firm's IT expenditures devoted to *supplier-facing* IT projects based on the firm's response in the *InformationWeek 500* survey. As with the other IT expenditure variables, this variable is lagged one year prior to patent application counts.

ALLOUT*:* This binary variable indicates whether a firm engaged in either business process outsourcing or information technology outsourcing in a particular year and is based on the firm's response in the *InformationWeek 500* survey. A "1" indicates that the firm did engage in BPO and/or ITO during the year while a "0" indicates that it did not.

BPO*:* This binary variable indicates whether a firm engaged in business process outsourcing in a particular year and is based on the firm's response in the

InformationWeek 500 survey. A "1" indicates that the firm did engage in BPO during the year while a "0" indicates that it did not.

ITO: This binary variable indicates whether a firm engaged in information technology outsourcing in a particular year and is based on the firm's response in the *InformationWeek 500* survey. A "1" indicates that the firm did engage in ITO during the year while a "0" indicates that it did not.

REVENUE: This variable represents the natural log of the firm's revenue. Although there is disagreement as to the direction of the effect of firm size on innovation, there is widespread agreement that firm size will be associated with innovative output. I control for firm size in a manner consistent with prior studies by using revenue as a proxy for the size of the firm.

PROFIT: This variable represents the return on assets for the firm in the given year. Prior studies have suggested that firm performance is associated with innovative effort and output (Cameron et al 1987; Staw et al 1981) and scholars have agreed that this construct is an important predictor of innovativeness in firms (Ahuja 2008). I control for this by using one-year lagged return on assets as a proxy for firm performance.

INDUSTRY: This binary variable (one for each industry in the sample) indicates the industry to which the firm belongs. Prior research has suggested that patenting propensities can vary across industries. I control for this by including this dummy variable in my econometric models.

YEAR*:* This binary variable represents the year of each observation. I include this variable to control for any year to year fluctuations in patenting activity (e.g. diminished processing capacity at the USPTO) that are beyond the control of the firm.

Table 9: Chapter 3 Variable Definitions		
Variable	Definition	Source
$PATENTS_{it}$	Count of successful patent application counts for firm *i* in time *t*.	US Patent & Trademark Office
$RDEXP_{i,t-1}$	ln(R&D Expenditures) for firm i in time *t-1*.	COMPUSTAT
$CustomerITEXP_{i,t-1}$	ln(IT Expenditures on customer-facing IT projects) for firm *i* in time *t-1*.	*InformationWeek 500* Survey
$SupplierITEXP_{i,t-1}$	ln(IT Expenditures on supplier-facing IT projects) for firm *i* in time *t-1*.	*InformationWeek 500* Survey
$ALLOUT_{i,t-1}$	Binary variable indicating whether firm *i* engaged in any type of outsourcing in time *t-1*.	*InformationWeek 500* Survey
$BPO_{i,t-1}$	Binary variable indicating whether firm *i* engaged in business process outsourcing in time *t-1*.	*InformationWeek 500* Survey
$ITO_{i,t-1}$	Binary variable indicating whether firm *i* engaged in information technology outsourcing in time *t-1*.	*InformationWeek 500* Survey
$REVENUE_{it}$	ln(Revenue) for firm *i* in time *t*.	COMPUSTAT
$PROFIT_{i,t-1}$	Return on Assets for firm *i* in time *t-1*.	COMPUSTAT
$INDUSTRY_i$	Dummy variable indicating the industry to which firm *i* belongs	COMPUSTAT

3.3.2. Empirical Methods

This chapter utilizes the same dependent variable (patent application counts) as chapter 2 and therefore requires the same empirical approach focused on the nuances of count data models. A more detailed discussion of empirical considerations when estimating count data models is included in section 2.3. Here I simply note that, as in chapter 2, the results presented in this chapter utilize a negative binomial specification that is appropriate for count data models with overdispersion of the dependent variable. As in the previous chapter, I use the generalized estimating equations (GEE) population averaged estimator (Zeger et al 1988) to take advantage of the panel nature of my data set. Additionally, to correct for potentially heteroskedastic errors, all regressions employ Huber-White standard errors (White 1980).

3.4.RESULTS

In this section I present results using the methods described above on my data set. Consistent with my empirical strategy from the previous chapter I begin by estimating a base model (13) using known predictors of innovation on my sample. I then add variables of interest to test my hypotheses regarding external IT investments and firm innovative output in model 14.

Table 10: Externally Facing IT Investment & Innovation		
	(13) Base Model	(14) External-IT Investment
R&D Expenses$_{i,t-1}$	0.410*** (0.002)	0.604*** (0.001)
Revenue $_{i,t}$	0.428*** (0.006)	0.427 (0.120)
Return on Assets i,t-1	0.294 (0.812)	0.188 (0.420)
IT Expenses $_{i,t-1}$		**0.019 (0.889)**
CustomerITEXP $_{i,t-1}$		**0.182** (0.029)**
SupplierITEXP $_{i,t-1}$		**-0.276*** (0.007)**
Intercept	-13.411*** (0.000)	-15.637*** (0.000)
Industry Controls	Yes	Yes
Year Controls	Yes	Yes

Wald chi-squared	644.25	667.73
Prob > chi-squared	0.000	0.000
Observations	65	65
Firms	34	34

For the outsourcing models I follow a similar procedure. I start by estimating a base model that does not include my outsourcing variables of interest. I then add a variable (ALLOUT) that indicates whether the firm has engaged in any type of outsourcing in the previous year. I further explore the outsourcing phenomenon by looking at business process (BPO) as opposed to information technology (ITO) outsourcing.

Table 11: Outsourcing & Innovation

	(15) Base Model	(16) Outsourcing	(17) BPO / ITO
R&D Expenses$_{i,t-1}$	0.578*** (0.000)	0.693*** (0.000)	0.414** (0.016)
Revenue $_{i,t}$	0.125 (0.456)	0.122 (0.504)	0.233 (0.644)
Return on Assets i,t-1	0.154 (0.564)	0.047 (0.964)	0.068 (0.489)
IT Expenses $_{i,t-1}$		**0.053** **(0.741)**	**0.249** **(0.240)**
ALLOUT $_{i,t-1}$		**0.198** **(0.117)**	
BPO $_{i,t-1}$			**0.369**** **(0.031)**
ITO $_{i,t-1}$			**0.001** **(0.994)**
Intercept	-9.493*** (0.000)	-13.608*** (0.000)	-12.336*** (0.000)
Industry Controls	Yes	Yes	Yes
Year Controls	Yes	Yes	Yes
Wald chi-squared	799.42	904.18	626.95
Prob > chi-squared	0.000	0.00	0.000
Observations	79	79	79
Firms	40	40	40

p values in parenthesis; ***** significant at 10%; ****** significant at 5%; ******* significant at 1%

Model 15 serves as a baseline for comparison and for docking my work with earlier empirical studies of innovation. Proceeding from this base model, I evaluated the effect of engaging in outsourcing on firm patenting activity. Model 16 shows that engaging in outsourcing is associated with greater levels of firm patenting. Model 17 examines this issue at a lower level by looking at the specific effects of business process outsourcing and information technology outsourcing on firm innovative activity.

3.5.DISCUSSION

Table 12: Chapter 3 Summary of Results

H4a: Higher levels of investment in customer-facing IT systems will be associated with higher levels of innovative output.	Supported
H4b: Higher levels of investment in supplier-facing IT systems will be associated with higher levels of innovative output.	Not Supported
H5a: Engaging in business process outsourcing (BPO) will be associated with higher levels of innovative output.	Supported
H5b: Engaging in information technology outsourcing (ITO) will be associated with higher levels of innovative output.	Not Supported

3.5.1. Implications for Research

I find mixed support for my arguments that externally-facing IT investment is associated with higher levels of innovation. While investments in *customer-facing* IT systems appear to be associated with higher levels of innovation, investments in *supplier-facing* IT systems are in fact *negatively* associated with innovation in my sample. Scholars have proposed that customers can be co-creators of new products (Prahalad & Krishnan 2008, Sawhney et al 2005) by providing insights and feedback that can influence the ultimate design of new products. This finding suggests that information technologies are able to provide firms with access to customer information that is useful to innovation processes. In this way, focused IT investments may provide firms with the ability to better analyze customer information from their external environment and thereby improve firm outcomes. This finding is consistent with the Interpretive Systems View and gives insight into what *technologies* are useful in gathering, processing and disseminating this information throughout organizations. Future research should be directed at better understanding the mechanisms behind this and at identifying what *information* specifically is valuable in addition to firm innovation processes.

Earlier in this chapter I proposed that customer-facing IT systems are likely to be more related to early-stage "idea generation" parts of new product development processes while supplier-facing IT systems are more likely to be relevant at later stages of the NPD process where execution is of greater importance. Curiously, I found that investments in supplier-facing IT systems are *negatively* associated with innovative output in this sample. While the Interpretive Systems View suggests that information about a firm's external environment should be useful to improving firm performance outcomes, this finding suggests that certain types of external information may be more valuable than others. In this case it could be that for the firms in this sample customer information was more useful for enabling new product development processes than was supplier information.

With respect to firm sourcing practices I find that engaging in outsourcing is associated with higher levels of innovation for firms in my sample. This finding is also consistent with the Interpretive Systems View in that it suggests that the more connected firm's are to external firm networks, the more able they are to improve the specific firm performance outcome of innovation. As discussed above, outsourcing firms are increasingly developing more sophisticated capabilities and are able to provide client firms with benefits beyond mere cost savings. I have speculated above as to what the mechanism for this type of benefit might be but have not been able to directly study that mechanism in this sample. Future research should be directed at elucidating the mechanisms behind this observation. Examining various types of outsourcing I find that business process outsourcing is associated with higher levels of innovation while information technology outsourcing is not. This suggests that not all outsourcing arrangements provide firms with the same types of benefits and that future research should be aimed at better understanding how these benefits vary.

3.5.2. Implications for Practice

These findings are relevant to practitioners in addition to researchers. The finding that customer-facing IT investments are positively associated with innovation suggests that firms seeking to drive new product development might benefit from evaluating their IT capability in this regard and, where needed, making targeted IT investments to improve it. As noted in the discussion of results for the second chapter, these investments should only be expected to be useful for firms operating in contexts where innovation is a primary strategic objective. Firms going through periods in which other strategic objectives (e.g. expanding market share for existing products, reducing costs) are primary will not necessarily benefit from these kinds of targeted investments unless the IT capabilities they provide are found to be related to those particular strategic objectives.

With respect to outsourcing, there are some important implications for practice. The findings presented here suggest that, consistent with predictions of scholars (Whitaker et al 2006), engaging in outsourcing can provide firms with benefits beyond cost savings. It would be naïve, however, to use this finding alone to make a decision to outsource internal firm processes. The decision of whether or not to outsource is complicated and should be influenced by a number of factors beyond implications to innovation. Additionally, firms have to seriously consider the organizational and human resource implications of engaging in outsourcing to appreciate the potential overall impact of the decision on firm performance. This study has been able to demonstrate that, for firms who have made the decision to outsource for various reasons, additional, and perhaps unintended, benefits may accrue as a result of engaging in outsourcing.

3.5.3. Limitations & Extensions

The limitations of this study are consistent with some of the limitations discussed in chapter 2. Specifically, the firms in my sample are *leaders* in their respective industries with respect to leveraging information technologies for business value. As discussed in chapter 2, this presents challenges with extrapolating these results beyond the types of firms studied here. Firms that are not as sophisticated as the firms in this sample are at extracting value from their IT investments are much less likely to experience the innovation-enabling benefits of IT investments suggested in this work.

Additionally, while offering evidence for a positive relationship for both customer-facing IT investments and engaging in outsourcing with firm-level innovation, this chapter does not specifically evaluate the *mechanisms* by which these benefits accrue. Moving beyond what technologies are valuable to an understanding of what *information* is valuable will be very useful to both researchers and practitioners. Similarly, with respect to outsourcing, it is vital that the mechanisms proposed here for how innovation benefits are generated through outsourcing arrangements be studied in greater detail. In particular, while I speculate that firms engaging in outsourcing may be able to reduce their operational costs and then redirect these resources towards innovation-generating activities, I have not been able to actually assess whether and to what degree this actually occurs. These and other related questions provide opportunities for management scholars to continue to understand the ways in which IT investments and firm sourcing practices create firm value and affect innovation.

3.6. CONCLUSION

In this chapter I have studied the effects of externally-facing IT investments and outsourcing on innovation. I find that while customer-facing IT investments are associated with higher levels of innovation but that supplier-facing IT investments are not. I also examined whether engaging in business process outsourcing and information technology outsourcing is associated with higher levels of innovative activity. I develop hypotheses surrounding this relationship suggesting that resource and knowledge benefits from outsourcing should enable firms to be more innovative. My results from evaluating these hypotheses on a panel data set of large US-based high tech firms suggests that engaging in BPO is associated with greater innovative output, while engaging in ITO is not.

APPENDIX 1: PERSPECTIVES FROM INDUSTRY ON IT BUDGETING

In chapter 2 of this dissertation I examine how specific firm IT investments affect firm-level innovation. In the course of that study I made some assumptions regarding how IT investments are classified by IT managers in order to better understand how IT investments create IT capabilities. Specifically I argued in chapter 2 that firms capitalize those expenses that they believe will be associated with generating an asset for the firm which will generate value over time. Similarly, as I included R&D expenses as a control in all of my models along with IT expenses, I implicitly assumed that there was no overlap between these two categories. In theory, however, an overlap is possible if the costs of implementing an IT system were recorded in *both* the R&D and IT budgets for the same firm in a given year.

In order to assess how well my assumptions regarding IT budgeting practices at large, US-based high-tech manufacturing firms matched how IT managers categorized these expenses in practice, I asked current and former IT executives from firms within my sample how they categorized these expenses. The questions and responses of these IT executives are included here.

Question	**Current Global IT Director** **Fortune 500 Pharmaceutical Company**	**Current Divisional VP IT** **Fortune 500 Automotive Company**	**Former Divisional CIO** **Fortune 500 Pharmaceutical Company**
In your organization how likely is it that	In our case the likelihood of this occurring is quite	I think it is unlikely that there is any	I suppose it is theoretically possible

there is an overlap between expenses recorded in IT budgets and expenses recorded in R&D budgets?	low. Typically IT system implementation and maintenance costs would not be reflected in any business unit budget but would be incorporated in the overall IT budget alone. Within the IT budget we manage business unit specific IT expenditures according to plan.	substantial overlap. It is possible that some expenses could be classified in either budget (e.g. business user time needed for system acceptance testing) but unlikely that there's any "double-counting" of expenses.	but I'm not aware of any instances of this kind of overlap during my time at <company X>. If anything I think it's more likely that some expenses that could be rightfully categorized as R&D expense ended up hitting our IT budget because our clients had a lot of influence over both budgets. That being said the money was ultimately coming from the same pool and would have impacted company financials similarly regardless of which budget they hit.
When creating your IT budgets, how do you decide which expenses should be capitalized and which should be left as operating expenses? Is there typically formal guidance on this or is it largely left to the discretion of each IT manager?	Corporate Finance tightly controls which expenses are capitalized and subjects substantial capitalized projects to much higher levels of scrutiny. I directed my project managers to capitalize expenses that we could confidently defend as directly related to building an IT capability. Hardware is frequently capitalized, major software purchases and, in some cases, even labor associated with building/coding the final product.	Formal guidance is given to us by the <corporate> Finance organization and all capital is centrally held and not in local department budgets. All capital allocations are tightly controlled and typically include only a narrow band of activities such as software development, software licenses, and other physical assets that finance deems as asset-creating investments.	The FASB rules on what should be capitalized are pretty clear. At <company X> at least, we had definite guidance from our accounting folks and not much discretion. I have heard the same from CIO's at other large companies. And the kind of expenditures that we are talking about are large so they do get scrutinized. Many of the rules were put in place to keep software companies from manipulating their income, but they apply to everyone.
Would you agree with the following statement and why (or why not): "In general, firms will try to	This was not true for us. As I mentioned, highly capitalized projects receive much greater scrutiny at the corporate	I would disagree with this statement. The vast majority of our expenditures are operating expense.	I think that firms will often have a preference for whether they capitalize or expense items, but

capitalize as much of their total IT budgets as they can	level so there isn't always a strong incentive to capitalize.	Since we are a capital intensive company with product development being our primary function, capital is tightly held for us on vehicle programs. Of our total IT budget, only a little bit over 10% would be capitalized annually.	those preferences will be different depending on the firms situation. During the go-go days of junk bonds and LBO's, companies that had gone private and were loaded up with debt sought out ways to avoid capital expenditures. That was one of the early drivers for data center outsourcing -- to avoid the capital requirements. On the other hand, firms with a lot of free cash flow (think Google or Microsoft) will prefer to capitalize. (While the FASB rules tell you how to treat a given type of transaction, you can often change the treatment by changing the type of transaction, as in my example of outsourcing rather than running your own equipment.)

APPENDIX 2: RANDOM EFFECTS ESTIMATES

The tables below present parameter estimates for the econometric models specified in chapters 2 using the random effects estimator.

Aggregate IT Investment and ITxRD			
	(1r) Base Model	(2r) IT Expenditures	(3r) IT x R&D
R&D Expenses$_{i,t-1}$	0.192** (0.048)	0.172* (0.090)	2.425*** (0.001)
Revenue $_{i,t}$	0.516*** (0.000)	0.4507*** (0.000)	0.446*** (0.001)
Return on Assets i,t-1	0.027 (0.534)	0.029 (0.505)	0.013 (0.756)
IT Expenses $_{i,t-1}$		**0.037** **(0.493)**	**2.350***** **(0.002)**
IT Expenses $_{i,t-1}$ X R&D Expenses $_{i,t-1}$			**-0.114***** **(0.002)**
Intercept	-14.418*** (0.000)	-14.542*** (0.000)	-57.391*** (0.000)
Industry Controls	Yes	Yes	Yes
Year Controls	Yes	Yes	Yes
Wald chi-squared	448.96	457.03	478.18
Prob > chi-squared	0.000	0.00	0.000
Observations	148	148	148
Firms	63	63	63

p values in parenthesis; * significant at 10%; ** significant at 5%; *** significant at 1%

R&D Specific IT Investments			
	(4) Base Model	(5) IT Expenditures	(6) R&D Specific IT
R&D Expenses$_{i,t-1}$	0.361* (0.063)	0.344* (0.081)	0.439** (0.019)
Revenue $_{i,t}$	0.585** (0.023)	0.461 (0.127)	0.393 (0.140)
Return on Assets i,t-1	0.013 (0.818)	0.014 (0.805)	-0.026 (0.683)
IT Expenses $_{i,t-1}$		**0.123** **(0.423)**	
R&D-specific IT Expenses $_{i,t-1}$			**0.129*** **(0.094)**
Intercept	-17.114*** (0.000)	-16.324*** (0.000)	-15.586*** (0.000)
Industry Controls	Yes	Yes	Yes
Year Controls	Yes	Yes	Yes
Wald chi-squared	237.00	246.91	266.21
Prob > chi-squared	0.000	0.000	0.000
Observations	61	61	61
Firms	36	36	36

p values in parenthesis; ***** significant at 10%; ****** significant at 5%; ******* significant at 1%

New, Maintenance & Integration IT Spending				
	(7) Base Model	(8) IT Expenditures	(9) New, Maint. & Integ. IT Expenditures	(9a) Model (9) with interaction between New IT & R&D
R&D Expenses$_{i,t-1}$	0.194 (0.130)	0.194 (0.132)	0.237* (0.069)	1.97*** (0.006)
Revenue $_{i,t}$	0.563*** (0.001)	0.551*** (0.003)	0.519*** (0.005)	0.545*** (0.003)
Return on Assets i,t-1	0.002 (0.974)	0.001 (0.980)	0.000 (0.992)	-0.015 (0.759)
IT Expenses $_{i,t-1}$		0.372 (0.748)		
NEW IT Expenses $_{i,t-1}$			**0.069** **(0.300)**	**1.98***** **(0.012)**
MAINTENANCE IT Expenses $_{i,t-1}$			**0.004** **(0.953)**	**-0.020** **(0.766)**
INTEGRATION IT Expenses $_{i,t-1}$			**-0.068** **(0.219)**	**-0.058** **(0.301)**
NEW IT Expenses $_{i,t-1}$ X R&D Expenses $_{i,t-1}$				**-0.094**** **(0.015)**
Intercept	-15.013*** (0.000)	-14.969*** (0.000)	-14.847*** (0.000)	-48.912*** (0.001)
Industry Controls	Yes	Yes	Yes	Yes
Year Controls	Yes	Yes	Yes	Yes
Wald chi-squared	399.53	401.23	413.90	420.08
Prob > chi-squared	0.000	0.00	0.000	0.000
Observations	136	136	136	136
Firms	62	62	62	62

Capitalized vs. Operating IT Expenditures			
	(10) Base Model	(11) IT Expenditures	(12) Cap. & Oper.. IT Expenditures
R&D Expenses$_{i,t-1}$	0.275** (0.035)	0.348*** (0.007)	0.348*** (0.007)
Revenue $_{i,t}$	0.476*** (0.004)	0.277 (0.156)	0.287 (0.143)
Return on Assets i,t-1	0.021 (0.718)	0.022 (0.712)	0.016 (0.779)
IT Expenses $_{i,t-1}$		**0.143*** **(0.084)**	
CAPITALIZED IT Expenses $_{i,t-1}$			**0.098** **(0.256)**
OPERATING IT Expenses $_{i,t-1}$			**0.028** **(0.750)**
Intercept	-14.656*** (0.000)	-14.140*** (0.000)	-13.714*** (0.000)
Industry Controls	Yes	Yes	Yes
Year Controls	Yes	Yes	Yes
Wald chi-squared	235.39	259.72	247.94
Prob > chi-squared	0.000	0.00	0.000
Observations	93	93	93
Firms	47	47	47

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