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An Empirical Investigation of the Relationship between Firm Information Technology Investments and Innovation

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ABSTRACT

Within the last four decades, IS and business scholars have shown a growing interest in information technology (IT) investments. As firms continue to make huge investments in IT, it is important to understand how IT provides competitive advantages to the firms. However, the direct effects of IT in creating business advantages are riddled with the productivity paradox. In this research, our goal is to examine the direct effects of IT investments on firm innovation. We believe that an investigation of this link will provide an important underlying mechanism that may explain how IT investments indirectly create performance differentials among firms. Using IT investments data from InformationWeek 500 and innovation (patents) data from the National Bureau of Economic Research (NBER), we generate hypotheses grounded in the resource-based view (RVB) of the firm. The results of the study provide support for the effect of IT investments on innovation.

Keywords IT investments, innovation, resource-based view of the firm, business advantages.

INTRODUCTION

This aim of this research is to seek the effect(s) of information technology (IT) investments on innovation. We believe that this area of inquiry is important in unraveling the underlying mechanisms through which IT investments leads to productivity and performance improvements in firms.

Among the dominant initiatives that are related to IT investments, innovation ranks among the top; and firms have been devoting more resources toward innovation for quite some time now (Ahuja 2000). As such, many managers have indicated that innovation is the engine of growth and the dominant driver of business value (Bosworth and Triplett 2000). Innovation is the process through which new business models, frameworks, products, processes, or services are thought out, developed, and brought to the market with the aim of generating economic rents while also satisfying customer needs (Dosi 1988).

Seeing such an importance of innovation, it is particularly surprising that research has not paid much attention in understanding the relationship between IT investments and innovation at the firm level. This research tries to fill this gap by empirically investigating the relationship between IT investments and innovation in firms. This is a fruitful research study because the results of the studies investigating the relationship between IT investments and firm performance are inconclusive, although a growing number of studies have found the evidence that IT indirectly enhances the productivity of the firms. Toward this end, the relationship between IT investments and innovation may provide an important intimation that may lead to business performance.

To test the relationship between IT investments and innovation, we collected IT investments data from Information Week 500 and patents data, as a measure of innovation, from National Bureau of Economic Research (NBER) for a total of 442 firms over 4-years. Our research model is shown below in Figure 1:

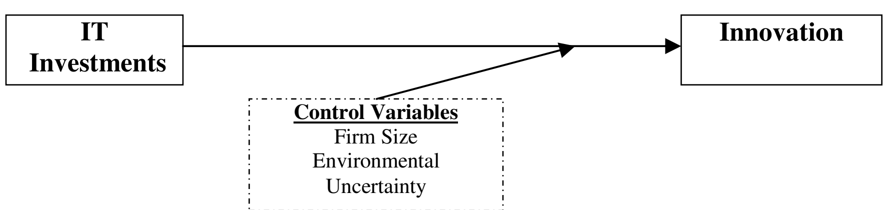

Figure 1: Research Model

THEORETICAL BACKGROUND AND HYPOTHESES

Resource based view (RBV) of the firm is currently among the dominant theories that explains the sustainable advantages of the firm (Penrose 1959; Rumelt 1984; Wernerfelt 1984). RBV presumes a firm as a collection of resources and capabilities that are geared toward generating economic rents. In general, firm resources include physical capital, financial capital, patents, technology, and workforce, while capabilities include know-how, efficient resource utilization, and learning. Rumelt (1984), notes that a firm consists of a bundle of linked and idiosyncratic resources as well as resource-conversion activities.

Barney (1991), on the other hand, argues that resources or capabilities that are the source of creating and Sustaining Competitive Advantage (SCA) must be valuable, rare, inimitable, and non-substitutable. Firms that seek to imitate the capabilities of a competitor must overcome three barriers namely; unique history of the firm, the unique history of the resource or capabilities, and causal ambiguity and social complexity (Barney, 1991). Firm history is embodied in the firm's unique past that cannot be duplicated by competitors, while the history of the resource or capabilities entails idiosyncratic processes and routines. Causal ambiguity refers to when there are no clear links between routines, resources, and the competitive advantage. Social complexity refers to various internal and external relationships that exist between the firm and stakeholders, which are difficult to codify and hence duplicate. Thus, imitators are uncertain about how a resource or a combination of resources leads to SCA, making it difficult for them to imitate the capabilities of the first-mover firm. According to Teece et al. (1997), "the strategic problem facing an innovating firm in a world of Schumpeterian competition is to identify difficult-to-imitate internal and external competences most likely to support valuable products and services."

Resource Base View Theory and Patents

A resource that has the value, rarity, non imitability and non-substitutability attributes is hard to asses, manipulate, and thus difficult to exploit (Priem and Butler 2001). Patents are a form of valuable and rare resources with enormous approbriability potential. In fact, innovative firms have been shown to outdo similar but non-innovative firms in terms of revenue from patented inventions and technologies. Patents lengthen first mover advantage by excluding rivals from using the invention without the permission of the inventor. By creating legal monopolies, patents endow the owners with superior technological sovereignty which when appropriated leads to superior performance (Markman et al, 2004). We briefly explore characteristics of a patent under the rubric of RBV.

Value

Patents have value to the firms that posses them (granted) otherwise, the firms would never bother with the processes of registering them. Of course, there are some patents that have more value than others, just as there are IS resources that are likewise. Important patents have been shown to garner more citations and also are associated with distinct innovations (Jaffe and Trajtenberg 2002). Also the number of granted patents has been associated with superior performance measured as sales revenue, and the number of patent citations has been linked to stock performance (Deng et al. 1999).

Rarity

Patents by themselves are rare in that they are unique and represent a specific invention. Apart from mergers, acquisitions or other inter-firm business arrangements, patents cannot be acquired or copied without legal ramifications. Some processes that are used in the patents development process from initial idea conception, R&D to patent grant are socially complex and are developed through on-going, firm specific investments, making them difficult for competitors to acquire or copy.

Appropriability

The exact approbriability of a specific patent might be difficult to measure but based on the specific invention, the firm possessing the patents enjoys first mover advantage. Also, some patents have been shown to have enormous rent generating capability not only in the short term but also in the long term.

Imitability

Patents have a shelf life that varies from one patent to another. However, before the shelf life has expired, patents cannot be imitated without legal consequences. Additionally, a patent entails more than observable mechanical processes but also includes socially complex resources which evolve and develop uniquely based on each organization. Patent imitations are legally protected and there are stiff penalties for infringement. Early inventions that are protected by patents are legally protected from imitations. Courts have on many occasions ruled against "imitations" by asserting that an invention whose characteristics lie somewhat outside the boundaries of a pioneer patent can still be considered an infringement (Merges and Nelson 1990). As such a patent with a high citation rate represents a stumbling block for the imitators seeking a niche in the protected domain. Thus, competitors are compelled to make huge investments in finding and developing pathways around the patented and hence legally protected inventions (Markman et al. 2004).

Substitutability

Although there might be a strategically equivalent process, model or product that is patentable and easily available to the firm and leads to equifinal results, the firm that owns the patent to the process or product is protected from substitution through patents laws. Unlike other types of resources such as IS resources, patents cannot be outsourced and the patent office examines each patent to minimize or eliminate substitutability. It is expensive and risky for competitors to develop new patents "around" the registered ones due to potential; legal ramifications. This enhances the non-substitutability of patents. The protection conferred to patents enables the inventors to develop brand names associated with the invention, the brand name continues to exist and generate rents even after the patent has expired. The drugs and chemical industries have good examples such as Tylenol®, Vicks® or Viagra®. Patent claims disclose the discoveries or patented inventions. Thus, a slightly modified technology or invention would be insufficient to replace a patented invention.

Imperfect Mobility

There is no ready market for patents and this is more so because of their intangible nature. Other resources can be easily disseminated to other firms and are hence easily mobile which is unlike the case with patents. Patents developments processes is usually aided by other firm characteristics that include external relationships, management competence, market responsiveness, and partnership relationships which are all difficult to codify and market. As such, patents as a whole have low mobility. Firms take advantage of the immobility of patents by using them as bargaining chips to acquire or access complimentary resources from external stakeholders (Lerner 1994). This can be accomplished through cross-licensing agreements which yield log terms loyalty and financial streams. Firms have also been known to "buy out" inventors whose patents threaten the status quo of the buying firm and thus suppressing substitutes.

IT Investments

There are multiple studies that have sought to extricate the complex relationship between IT investments, productivity, and performance resulting in a number of different definitions and conceptualizations of the IT investment variable. The definition and the conceptualization of IT investments vary based on whether the research data are obtained from a survey or are gleaned from archival sources (Bharadwaj, 2000; Bharadwaj et al, 1999). Broadly defined, IT investments include all the expenditures made by the firm toward computers and telecommunications resources such as hardware, software, and related services (Dedrick, Gurbaxani, & Kraemer, 2003). Elsewhere in a survey- based study, Broadbent, Weill, & St. Clair (1999, p. 181) defined IT investments as "… dollars invested in all computers, hardware, software, communications, phone, fax, data, and the people dedicated to providing IT services." Many studies have confined IT investments to hardware expenditures. However, in recent decades, firms have continued to invest heavily in software, although it is difficult to account for these investments, partly because of the lack of metrics for quantifying units of both "common" and custom software, unlike the case with packaged software (systems software).

In fact, prior to 1999, expenditures in software had been treated as an expense and not investments in the firms' books of accounts (Seskin, 1999). This study adopts the definition of IT investments that is used in *InformationWeek* (Lou, IW500, 1997), in which IT investments include all those expenditures, relating to the firm IT infrastructures, such as PCs, servers, mainframes, communications equipment, software, and other related hardware that are utilized in setting up local and wide area networks, as well as expenditures incurred toward hiring and training IT employees and providing related services.

IT Investments and Innovation

Economists and management scholars agree on the role of innovation in generating economic rents at the firm, industry, or economy level (Brynjolfsson & Schrage, 2009; Van De Ven, 1986). Firms that are persistent innovators have been demonstrated to appropriate superior economics rents compared to their competitors (Scott, Mark, & Joseph, 2008). On the other hand, IT has permeated many facets of organizations and is being utilized, for instance, to internally coordinate, control, and facilitate organizational processes and management decision-making. Externally, firms have made IT investments that enable and facilitate interactions with customers, suppliers, and other stakeholders as demonstrated in the use of customer relationship management and supply chain management systems respectively (Li, Sun, & Wilcox, 2006). These are organizational day to day processes that result from IT investments and in one way or another have a direct or indirect impact on innovations.

For example, an effective and efficient IT-enabled value chain is an indispensable firm asset that facilitates the generation and capture of ideas on new products, or processes designs, improvements on existing products, and processes as well as retirement of non-rent generating products, and processes (Li, Sun, & Wilcox, 2006) that are important innovation initiatives. Capturing and understanding valuable knowledge is a firm capability, because these ideas ultimately require being tested for their validity. These ideas also offer a firm several opportunities to identify its strengths and weaknesses. The benefits accruing from innovations are amplified when a firm integrates and aligns its business strategy with IT investment initiatives (Dedrick, Gurbaxani, & Kraemer, 2003)

Generally, innovations entail transformation of internal and external organizational processes, and IT investments play an important role in the restructuring of business processes. For instance, Francalanci and Galal (1998) reported that firms with higher number of IT workers showed higher IT investment benefits related to novel ideas compared to those with fewer IT workers. Also, Ramirez, Kraemer, & Lawler (2001) argued that firms that invested more in IT also encouraged employees to be more involved in decision-making, an initiative that ultimately brought many process innovations to the firms (Bresnahan, Brynjolfsson, & Hitt, 2002).

According to Brynjolfsson and Schrage (2009), IT has transformed the ways through which firms nowadays engage in innovations. For instance, firms rely on employees, customers, suppliers, and other stakeholders for breakthrough ideas on products, processes, or service innovations (Leonard-Barton 1995). New ideas are generated, shared, and developed through collaborative trial-and-error initiatives by different entities that supersede the Schumpeterian model of lone entrepreneurs (Schumpeter 1987). Thus, by using IT, firms can make use of industry value chain that connects the firm with customers, suppliers and other trading partners. Thus, IT can help a firm to connect diverse pools of knowledge across the firm and we hypothesize:

H1: Higher levels of IT investments will lead to higher levels of innovations.

In this study, we use firm size and environmental uncertainty as control variables because these variables are likely to provide a biased influence of IT investments on innovation. Below we show how size and environmental uncertainty affect firm innovation (Bharadwaj, 2000; Bharadwaj et al., 1999).

Firm Size, Environmental Uncertainty, and Innovation

Prior research has shown that large organizations possess slack resources that can be readily exploited in financing new projects, acquiring competent employees from competitors, or diversifying the business. Thus organizational size plays important role in fostering innovation when large firms' use slack resources in R&D capabilities as well as in the development of new products, processes, technologies, and services (Kimberly and Evanisko 1981; Zhu and Kraemer 2005). Additionally, hiring skilled people as well as partnering with professional and skilled workforce with superior technical and business knowledge places large firms in advantageous positions as compared to the smaller size firms. Thus, we hypothesize:

H2: Firm size will be positively related to firm innovations.

On many occasions, managers undertake investment decisions based on uncertain future events. For instance, managers cannot know precisely how strong or elastic the products or services demands will be, how competitors will react to the introduction of new products, services, or processes, or how the employees will react to the introduction of a new IT application (Scherer and Ross 1990). Such environments are characterized by high uncertainty and are viewed as risky, because a few erroneous decisions can lead to major problems in the firm. Therefore, we hypothesize:

H3: Higher levels of environmental uncertainty will be negatively related to firm innovations.

OPERATIONALIZATION OF THE VARIABLES

Below we provide an overview of operationalization of the variables for the study.

Measure of IT investments

IT investments in this study is measured through IT budget that represents the annual dollar figures that firms allocate or devote to the IT initiatives. The firms' annual IT budgets data were obtained from InformationWeek 500 (IW500) online archival records for the period 1994-1997. The annual IT budgets data were aggregated into various firm IT components that included hardware, software, PCs, workstations, servers, network infrastructures, employee hires, trainings, etc., invested in during the particular fiscal year.

Measure of Innovation

In this study, innovations are measured through patents granted to the firm. The granted patent confers upon the inventor the sole right to make, use, and sell that invention for a specified period of time, which is usually 20 years. Patents are classified under three main categories, namely, utility patents, design patents, and plant patents. Utility patents are granted for any inventions or discoveries of new and useful processes, machines, articles of manufacture, or composition of matter or any new and useful improvements on the aforementioned thereafter. Design patents, on the other hand, are granted for inventions of articles of manufacture that are new, original, and ornamental in design. Lastly, plant patents are granted for any invention, discovery, as well as asexual reproduction of any distinct and new variety of plant. The focus of this study is utility patents.

Patents are associated with technological advancement, a key element of economic growth, and are intended to provide an incentive that encourages firms to invest and develop ideas that are ultimately brought to the market in the form of new or improved products, services, or business processes. Patent-based innovations are knowledge-driven in that they involve the application or generation of scientific, technical, experiential, or intuitive knowledge. Patents are unique in that they allow the inventor/investor to appropriate a larger portion of the invention. They are strategic resources (Ahuja & Katila, 2004) that can be used to gunner external sources of funds or establish business relationships (Bracker, Keats, & Pearson, 1988).

An innovator's propensity to patent depends on the perceived profits from being the first to market the first technology ahead of second-generation products, the extent of required patents disclosures, the ease of reverse engineering the technology when marketed without patenting, and the protection given to the patents (Scothmer, 1991). Thus, a firm's innovativeness is shielded from imitation through legal rights of protection. By bestowing to the inventors the right to prohibit others from the practice of duplicating inventions, patents offer the strongest form of legal protection against imitation (Teece, 1998). As such, the effectiveness of patents determines the legal rights to production (Levin, Klevorick, Nelson, Winter, Gilbert, & Griliches, 1987).

Firm Size

Firm size, in this study, is computed as the natural logarithm of the annual firm sales (Chari et al. 2008).

Firm size = natural logarithm (ln) of Sales

Environmental Uncertainty

Environmental uncertainty is computed as the standard deviation of firm's net income before extraordinary items (NIBEI) in the previous five years deflated by sales in the previous year (t-1) (Kobelsky et al. 2008). The formula below illustrates how this value is computed.

$$Uncertainty_{98} = Standard\ Deviations\left(\frac{NIBEI_{97}}{Sales_{96}}, \frac{NIBEI_{96}}{Sales_{95}}, \frac{NIBEI_{95}}{Sales_{94}}, \frac{NIBEI_{94}}{Sales_{93}}, \frac{NIBEI_{93}}{Sales_{92}}\right)$$

RESEARCH METHODOLOGY

The following section explains our methods for data collection and data analysis.

Sample Selection

The population for this study comes from the manufacturing industry and the unit of analysis is the firm whose IT budget from 1994 to 1997 was reported by IW500 magazine. A firm was selected if its number of patents was also reported in the National Bureau of Economic Research Patent (NBER) patents data project (Hall et al. 2005). In other words, the sample firms consisted of both IT Budget data and patents data from 1995-2000.

Data Analysis

Following the recommendations of Hair et al. (2002) and Belsley et al. (1980) a number of tests were conducted aimed at cleaning the data as well as examining the violations of assumptions of multivariate regression analysis. For instance, in testing the presence or absence of multicollinearity, an examination of the variance inflation factors (VIFs) and tolerance values was done and they were found to be were well below the threshold value of 10 and above the 0.10 values, respectively (Belsley et al., 1980; Neter et al., 1990). In testing the violations of normality, an examination of the distribution of the variables was done and it was found that the variables were approximately normally distributed (skewness range: -0.85 to

0.73; kurtosis range -0.49-0.65). Also, the Kolomogorov-Smirnov test for normality, which indicated no deviations from normality, and the White's test (White, 1980) for heteroscedasticity that supported the constant variance assumptions were done.

Furthermore, in addition to employing a number of data transformation techniques, the values were winsorised at 5 and 95 percent levels to eliminate the influence of outliers which have been shown to be associated with Type I and Type II errors besides skewing the reliability of estimates (Osborne, 2001). The outliers were eliminated after a careful examination of Cook's D distance statistics, studentized residuals, and DFFITS as suggested by Neter et al. (1990). Finally, the correlation coefficients of the variables used in the regression analysis were evaluated and found to be low enough to signify lack of multicollinearity (rs<0.70) and thus justified simultaneous inclusion in the regression analysis.

Table 1 to Table 4 shows the descriptive statistics for the 443 observations in the sample with IT budget from 1994 to 1997 and related patents from 1995 to 2000.

Table 1: Descriptive Statistics for Firms with 1994 IT Investments

	Variables	Mean	SD	(1)	(2)	(3)	(4)	(5	(6)
(1)	ITBGT_Sls94	0.02	0.01	1					
(2)	Innov95	3.92	1.61	.57***	1				
(3)	Innov96	3.88	1.56	.64***	.95***	1			
(4)	Innov97	3.87	1.62	.62***	.94***	.98***	1		
(5)	IndUncty94	0.01	0.01	0.24**	0.20*	0.18	0.17	1	
(6)	Size94	8.82	0.79	0.20*	.40**	.37***	.33***	0.10	1

* significant at 10%; ** significant at 5%; *** significant at 1%; (two-tailed),

All variables are winsorised at 5 and 95 percent

$ITBGT\_Sls_t$ = IT budget scaled by sales as reported by firm i in year t

$Innov_t$ = natural log of number of granted patents at time t

$IndUncty_t$ = level of industry uncertainty (standard deviation of industry earnings before extraordinary items for previous 5 years scaled by sales) at time t

$Size_t$ = natural log of sales for time t

Table 2: Descriptive Statistics for Firms with 1995 IT Investments

	Variables	Mean	SD	(1)	(2)	(3)	(4)	(5)	(6)
(1)	ITBGT_Sls95	0.02	0.01	1					
(2)	Innov96	3.25	1.68	.38***	1				
(3)	Innov97	3.26	1.71	.34***	.95***	1			
(4)	Innov98	3.11	1.73	.28***	.91***	.94***	1		
(5)	IndUncty95	0.01	0.01	0.03	0.08	0.07	0.05	1	
(6)	Size95	8.60	1.01	0.05	.56***	.55***	.52***	0.08	1

* significant at 10%; ** significant at 5%; *** significant at 1%; (two-tailed),

All variables are winsorised at 5 and 95 percent

$ITBGT\_Sls_t$ = IT budget scaled by sales as reported by firm i in year t

$Innov_t$ = natural log of number of granted patents at time t

$IndUncty_t$ = level of industry uncertainty (standard deviation of industry earnings before extraordinary items for previous 5 years scaled by sales) at time t

Table 3: Descriptive Statistics for Firms with 1996 IT Investments

	Variables	Mean	SD	(1)	(2)	(3)	(4)	(5)	(6
(1)	ITBGT_Sls96	0.02	0.01	1					
(2)	Innov97	3.24	1.71	.48***	1				
(3)	Innov98	3.08	1.70	.43***	.95***	1			
(4)	Innov99	3.02	1.69	.39***	.90***	.95***	1		
(5)	IndUncty96	0.01	0.01	-.21**	-0.09	-0.08	-0.09	1	
(6)	Size96	8.63	1.11	.21**	.59***	.56***	.51***	0.12	1

* significant at 10%; ** significant at 5%; *** significant at 1%; (two-tailed),

All variables are winsorised at 5 and 95 percent

$ITBGT\_Sls_t$ = IT budget scaled by sales as reported by firm i in year t

$Innov_t$ = natural log of number of granted patents at time t

$IndUncty_t$ = level of industry uncertainty (standard deviation of industry earnings before extraordinary items for previous 5 years scaled by sales) at time t

$Size_t$ = natural log of sales for time t

Table 4: Descriptive Statistics for Firms with 1997 IT Investments

	Variables	Mean	SD	(1)	(2)	(3)	(4)	(5)	(6)
(1)	ITBGT_Sls97	0.02	0.01	1					
(2)	Innov98	3.36	1.81	.43***	1				
(3)	Innov99	3.33	1.80	.43***	.96***	1			
(4)	Innov100	3.26	1.86	.34***	.92***	.97***	1		
(5)	IndUncty97	0.02	0.01	-0.15	0.05	0.1	0.11	1	
(6)	Size97	8.70	1.09	0.13	.51***	.48***	.43***	0.08	1

* significant at 10%; ** significant at 5%; *** significant at 1%; (two-tailed),

All variables are winsorised at 5 and 95 percent

$ITBGT\_Sls_t$ = IT budget scaled by sales as reported by firm i in year t

$Innov_t$ = natural log of number of granted patents at time t

$IndUncty_t$ = level of industry uncertainty (standard deviation of industry earnings before extraordinary items for previous 5 years scaled by sales) at time t

$Size_t$ = natural log of sales for time t

The firms in this sample are weighed toward large firms with mean annual sales revenue of $8.8 billion (1994), $8.6 billion (1995), $8.6 billion (1996), and $8.7billion (1997). These values are shown in the above tables as natural logs for the *size* variable. These values are comparable to the manufacturing firms in the Standard and Poor's database of 500 firms. On average the firms in the sample spent about 2.0%, 1.8%, 2.0%, and 2.2% of their sales revenue on IT in the years 1994, 1995, 1996, and 1997, respectively.

Hypotheses Testing

To test the aforementioned research hypotheses, we used a hierarchical regression model represented by equation 1-3 below:

$$Innov_{i,t+n} = B_0 + B_1 IndUncty_{it} + B_2 Size_{it} + K \quad (1)$$

$$Innov_{i,t+n} = C_0 + C_1 IndUncty_{it} + C_2 Size_{it} + C_3\ ITBGT\_Sls_{it} + M \quad (2)$$

$$Innov_{i,t+n} = \delta_0 + \delta_1 IndUncty_{it} + \delta_2 Size_{it} + \delta_3 ITBGT\_Sls_{it} + \varphi_{it} \quad (3)$$

Where:

$ITBGT\_Sls_t$	=	IT budget scaled by sales as reported by firm i in year t
$Innov_t$	=	natural log of number of patents granted at time t to firm i
$IndUncty_t$	=	level of industry uncertainty (standard deviation of industry earnings before extraordinary items for previous 5 years scaled by sales) for firm i in year t
$Size_t$	=	natural log of sales for firm i in year t
$\varphi_{it}, \mu_{it}, \gamma_{it}$	=	independent and identically distributed error terms with zero means

Equation 1 above represents the relationship between innovation and the control variables while Equation 2 has the IT investments variable included and the empirical specification for testing these relationships is represented by equation 3. The test for the relationship between innovation and IT investments was done in two stages. In the first stage, the regression between the innovation and all the control variables was done and then in the second stage, the variable for the IT investments was included in the model. In the first step, we regressed for each year of IT investment (t) (from 1994 to 1997) with control variables (t) (from 1994 to 1997), and in the subsequent step, we included innovation (t+1) with a one year lag (from 1995 to 2000). We examined changes in values of R^2 as a result of including IT investments. The results are shown in Table 5 and Table 6.

Table 1: Relationship between IT Investments (1994-1995) and Innovation (1995-1998)

Panel A: Firms with 1994 IT Budget Data (N=66)

	Model 1-94		**Model 2-94**		**Model 3-94**	
	Innov95	Innov95	Innov96	Innov96	Innov97	Innov97
IndUncty94	22.28	7.32	18.70	1.89	19.71	2.70
	(1.44)	(0.54)	(1.23)	(0.15)	(1.18)	(0.19)
Size94	0.78	0.60	0.67	0.47	0.65	0.45
	(3.38***)	(3.00***)	(2.93**)	(2.51**)	(2.62**)	(2.12**)
ITBGT_Sls94		**68.60**		**77.06**		**77.99**
		(4.94***)		(5.99***)		(5.33***)
Adj. R-squared	**0.16**	**0.39**	**0.12**	**0.43**	**0.10**	**0.37**
Δ Adj. R-squared		**0.23*** **		**0.31*****		**0.28*****
F Value	7.32***	14.84***	5.47***	17.63***	4.48**	13.74***

Panel B: Firms with 1995 IT Budget Data(N=144)

	Model 1-95		**Model 2-95**		**Model 3-95**	
	Innov96	Innov96	Innov97	Innov97	Innov98	Innov98
IndUncty95	11.95	8.86	8.87	6.18	5.25	3.58
	(0.72)	(0.56)	(0.52)	(0.38)	(0.30)	(0.21)
Size95	0.92	0.93	0.92	0.93	0.88	0.89
	(8.25***)	(8.74***)	(8.09***)	(8.44***)	(7.53***)	(7.65***)
ITBGT_Sls95		**28.11**		**24.49**		**15.21**
		(3.97***)		(3.32***)		(1.96**)
Adj. R-squared	**0.30**	**0.37**	**0.30**	**0.35**	**0.26**	**0.28**
Δ Adj. R-squared		**0.07*****		**0.05****		**0.02****
F Value	34.72***	30.65****	33.53***	27.30***	28.63***	20.73***

* significant at 10%; ** significant at 5%; *** significant at 1%; (two-tailed)

Unstandardized regression coefficients are reported and t-values are in parentheses, two-tailed tests

i = firm

t = time in years

$ITBGT\_Sls_t$ = IT budget scaled by sales as reported by firm I in year t

$IndUncty_t$ = level of industry uncertainty (standard deviation of industry earnings before extraordinary items for previous 5 years scaled by sales)

$Size_t$ = natural log of sales for firm i in year t

All variables are winsorised at 5 and 95 percent

Table 2: Relationship between IT Investments (1996-1997) and Innovation (1997-2000)

Panel C: Firms with 1996 IT Budget Data (N=155)						
	Model 1-96		**Model 2-96**		**Model 3-96**	
	Innov97	Innov97	Innov98	Innov98	Innov99	Innov99
IndUncty96	-4.24	10.35	-2.30	10.30	-6.02	4.83
	(-0.29)	(0.77)	(-0.15)	(0.72)	(-0.39)	(0.33)
Size96	0.90	0.79	0.85	0.76	0.78	0.70
	(8.53***)	(8.25***)	(7.90***)	(7.50***)	(7.04***)	(6.53***)
ITBGT_Sls96		**66.47**		**57.40**		**49.43**
		6.02***		(4.90***)		(4.02***)
Adj. R-squared	**0.34**	**0.47**	**0.30**	**0.40**	**0.25**	**0.33**
Δ Adj. R-squared		**0.13*** **		**0.10*** **		**0.08*** **
F Value	37.21***	43.02***	31.75***	32.62***	25.48***	24.18***

Panel D: Firms with 1997 IT Budget Data (N=77)						
	Model 1-97		**Model 2-97**		**Model 3-97**	
	Innov98	Innov98	Innov99	Innov99	Innov00	Innov00
IndUncty97	10.07	20.87	19.09	30.22	22.69	31.79
	(0.53)	(1.211)	(0.98)	(1.80**)	(1.10)	(1.61*)
Size97	0.83	0.77	0.79	0.71	0.74	0.67
	(5.17***)	(5.01***)	(4.70***)	(4.60***)	(4.15***)	(3.93***)
ITBGT_Sls97		**57.49**		**58.93**		**48.18**
		(4.14***)		(4.23***)		3.10***
Adj. R-squared	**0.24**	**0.38**	**0.22**	**0.36**	**0.18**	**0.26**
Δ Adj. R-squared		**0.14*** **		**0.15*** **		**0.09** **
F Value	13.21***	16.44***	11.49***	17.75***	9.17***	8.83***

* significant at 10%; ** significant at 5%; *** significant at 1%; (two-tailed)
Unstandardized regression coefficients are reported and t-values are in parentheses, two-tailed tests

i = firm
t = time in years
$ITBGT\_Sls_t$ = IT budget scaled by sales as reported by firm I in year t
$IndUncty_t$ = level of industry uncertainty (standard deviation of industry earnings before extraordinary items for previous 5 years scaled by sales)
$Size_t$ = natural log of sales for firm i in year t

All variables are winsorised at 5 and 95 percent

RESEARCH FINDINGS AND DISCUSSION

From Table 5 and Table 6, it becomes evident that IT investment is positively and significantly (p value ranges from .01 to .001) related to innovation. For the control variables, size is found to be significantly (p<=.001) associated with innovation, while environmental uncertainty shows a positive but non-significant relationship with innovation and IT investments in years 1994, 1995, and 1996. However, corresponding to IT budget for 1997 and innovation for 1999 and 2000 (Table 6), environmental uncertainty was found to be significantly associated (at p<=.05) with innovation.

The support for hypothesis 1 illustrates that IT investment resources confer firms with the capability to test new ideas at faster speeds and at lower prices/costs. This is especially true in the present age, where, firms utilize the internet, an IT investment resource, to communicate with their customers and other stakeholders to solicit ideas and inputs on new products or processes. These communications are accomplished within short periods, at times within hours, reducing the cost and time of innovative initiatives. On the other hand, these IT-enabled capabilities make innovations, "the lifeblood of growth, more efficient and cheaper" (Brynjolfsson & Schrage, 2009, p. 1). By soliciting customers' inputs and feedback during the innovation processes, firms generate products and services that are tailored to the needs of the customers, guaranteeing wide acceptance and thus economic rents.

IT investments are also used in facilitating and organizing know-how about a firm's past projects, expertise, and routines. In addition, IT can help in coordination of knowledge among different people in the firm, especially between R&D groups by offering collaborative capability. IT investments in the form of communication tools such as networks, email, virtual meetings, blogs, and more relation-oriented tools such as wikis, and social networking can help to collaborate and work together by reorganizing and recombining the knowledge.

As expected, the relationship between size and innovation was found to be positive and statistically significant. This may be interpreted to signify that, even though news media often provide the innovative efforts of smaller firms, in reality, larger firms are more innovative. It is simply because of their large size that they do not make the headlines in popular news magazines. Larger size confers the advantages of resources and capabilities that firms have learnt overtime.

Contrary to our expectations, environmental uncertainty was not found to be statistically associated with innovation for many of the years under investigation. These results are surprising because firms in uncertain environments face more risks that inhibit their innovations as well as profitability. One rationale for these results can be advanced on the arguments that a majority of firms in sample are already competing in uncertain and dynamic environments, so there could be little variance measured through environmental uncertainty. This is because since the early 1990s, many firms have been focusing their attentions toward global competition and increasing environment uncertainty and our sample encompass data from 1994.

RESEARCH CONTRIBUTION AND LIMITATION

This study contributes to the IT payoff and related literature in a number of ways. First, researchers have long been motivated by the economic significance of IT investments in studies examining IT payoffs (Loveman, 1994). This study brings us closer to an understanding of this phenomenon by investigating the effects of IT investments on innovation, which we conjecture can lead to business advantages. In a way, we believe that IT investments may indirectly affect the performance of the firm. This study develops a theoretical framework for IT investment payoff in the context of innovation by specifically aligning the attributes of the resource-based view (RBV) theory to the innovation life cycle. The adopted research framework draws from literature on coordination and control to explain payoffs from IT investment in innovation.

In this study, the question of whether an IT investment pays-off in the context of innovation is considered to be very significant from an economical perspective. Moreover, the motivation to consider the relationship between IT investments and innovation provides researchers a firm basis that IT indirectly may lead to performance through innovation. Economists and management scholars agree on the role of innovations in generating economic rents at the firm, industry, or economy level; and firms that are persistent innovators have been demonstrated to appropriate superior economics rents compared to their competitors (Scott, Mark, & Joseph, 2008). In this respect, IT investments play a key role by spurring innovation in the firms that finally leads to business advantages.

LIMITATIONS

IT investments data are based on IT budgets and not actual IT spending, and future studies should try and address this shortcoming. The sample frame was not randomly selected and was based on a data set comprising firms that appeared in *InformationWeek* and for the most part these firms self-reported their IT budgets. As such the generalizability of these results to other firms is open to scrutiny. However, there are many studies that have adopted this data set.

The use of patents as measures of innovation may pose some limitations too. Nevertheless, there is a longstanding debate on the use of raw-patents counts as a measure of innovation output at the firm, industry or economy level (Griliches 1998). Some critics have argued that patents should not be assigned equal weights ─ weight should be assigned based on the economic value of the patent. However, researchers in management and economics have generally accepted raw-patents counts as one indicator of the innovative performance of firms as depicted by new processes, new technologies, and new products (Patel and Pavitt 1995).

REFERENCES

Available upon request from first author