ECIS 2008 Proceedings

European Conference on Information Systems (ECIS)

2008

Decreasing Returns to IT Investment? New Firm-Level Evidence from Post-Dot Com Boom 2003-2005 Period

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DECREASING RETURNS TO IT INVESTMENT? NEW FIRM-LEVEL EVIDENCE FROM POST-DOT COM BOOM 2003-2005 PERIOD

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Abstract

Given the fundamental nature of the IT-productivity link in the IS discipline, the diversity of firm-level data in terms of sources and time periods analyzed in prior research has not been very encouraging. Further, although the IT productivity paradox has been laid to rest on the basis of prior firm-level and industry-level studies, the nature of the relationship in terms of how IT returns evolve over time needs continuous investigation.

We present here the first econometric analysis of a large primary source firm-level dataset about IT investments that spans the 2003-2005 period, which is post dot-com boom and post-recession in the United States. In doing so we have extended previous firm-level work done by Brynjolfsson and Hitt (1995), Lichtenberg (1995), Hitt and Brynjolfsson (1996), and Kudyba and Diwan (2002). We not only confirm the positive and highly statistically significant relationship between IT and gross output or value-added and compute IT returns for the most recent time period, but in contrast to Kudyba and Diwan's (2002) observation about increasing returns to IT based on their analysis of the 1995-1997 Internet boom era dataset, we present evidence of an inverted U-shaped returns curve, with returns now close to what they were in the pre-Internet era.

Keywords: Productivity, IT Expenditure, Production Function

1 INTRODUCTION

The link between IT and productivity has been studied using industry level data (Stiroh, 2002) as well as firm level data (Bresnahan et al., 2002; Brynjolfsson and Hitt 1995, 1996, 2000, 2003; Dewan and Min, 1997; Hitt and Brynjolfsson, 1996; Kudyba and Diwan, 2002; Lichtenberg, 1995). Using evidence from the literature, Devaraj and Kohli (2000) point to several possible reasons behind the heterogeneity of results on the relationship between IT investments and payoff, including diversity of variables used in the different studies, the level of analysis (for example: industry level versus firm level) as well as the research design employed (e.g., cross-sectional versus longitudinal). Several more recent review and meta-analysis studies have pointed out a host of reasons behind the observed variance in the results on the IT investments-payoff link (Kohli and Devaraj, 2003; Melville et al., 2004; Piccoli and Ives, 2005). For example, industry sector or context, sample size, characteristics of data source (primary or secondary), type of dependent variable (profitability-based or productivity-based) can have an impact on IT payoff reported in the literature (Kohli and Devaraj, 2003). These recent studies have made several recommendations to improve the reliability of IT payoff studies. For example, Kohli and Devaraj (2003) suggest that future studies should analyze longitudinal or panel data that is gathered from primary data sources and that spans several periods and several firms. Given the expense, time and difficulty of gathering primary source longitudinal data for a large sample of firms, it is not surprising to find that only a few studies meet the above recommendations.

There are a few large firm-level IT productivity studies that analyze data collected from over 300 firms that span several industries and several years (Bresnahan et al., 2002; Brynjolfsson and Hitt 1995, 1996, 2000, 2003; Dewan and Min, 1997; Hitt and Brynjolfsson, 1996; Kudyba and Diwan, 2002; Lichtenberg, 1995). The diversity of datasets in terms of sources and time periods employed in these studies is not very high. For example, Bresnahan et al. (2002), Brynjolfsson and Hitt (1995, 1996, 2000, 2003), Dewan and Min (1997), Hitt and Brynjolfsson (1996), and Lichtenberg (1995) employ the same 1988-1992 dataset obtained from IDG/ComputerWorld (note: Brynjolfsson and Hitt (2003) also look at Computer Intelligence InfoCorp (CII) dataset from 1987-1994 and Lichtenberg (1995) also looks at a dataset obtained from InformationWeek). The newest firm-level data that has been analyzed is from the 1995-1997 period (Kudyba and Diwan, 2002) and it was obtained from *InformationWeek*. Industry-level data for as late as until year 2000 was analyzed by Stiroh (2002). However, no attempts have been made to gather and analyze a large sample of firm-level data from the post dot-com boom era or the post 2001-2002 US economic recession period. Post-2000 or post dom-com boom era, many observers and researchers have hypothesized the decreasing returns aspect of IT (Carr, 2004; Gordon 2000). They acknowledge the high returns to IT early on in the IT revolution, but argue that diminishing returns have quickly set in. These commentators further argue that diminishing returns applies not only to personal productivity applications such as word processing and presentation software but also to enterprise IT applications such as CRM and ERP (Carr, 2004). The high returns to IT investments during the 1995-1997 period observed empirically by Kudyba and Diwan in their 2002 *Information Systems Research* paper is consistent with the expectation of high returns with the initial adoption of IT. However, there has been little systematic empirical examination of the issue of decreasing returns to IT post dot com boom era, which was probably the golden period of the IT era, in which firms lured by the high initial returns invested heavily in IT. Importantly, most prior large sample firm-level research has looked at *IT budgets* as opposed to *actual IT expenditures*. Given that actual IT expenditures may be different from IT budgets, this distinction is an important one.

Even though the original debate about IT-productivity paradox that spurred vigorous research activity on the IT-productivity link in the 1990s has been largely put to rest (Brynjolfsson and Hitt 2000; Stiroh 2002), we believe that it behooves IS researchers to make diligent efforts to collect firm-level data from diverse sources regularly or at least after significant periods of economic growth or recession to assess how the contribution of IT to productivity or IT returns have changed over time. If similar methodology is employed to analyze newer data, it is possible to compare results with those obtained in prior studies, which use data from different sample periods.

In this paper, we attempt to address the above limitations of the current state of firm-level IT productivity empirical research and seek to meet the recommendations such as those proposed by Kohli and Devaraj (2003) which were listed above. Specifically, we construct a much newer large sample dataset which spans the post-recession 2003-2005 period and which is nevertheless similar in its construction to datasets analyzed in prior research. Importantly, most of our data (for 2003 and 2004) is about actual IT expenditures and not just IT budgets. The overall similarity in the construction of the dataset and in the variety of econometric analyses performed on the data allows us to compare results in this study with those in prior studies. Our analyses enable us to answer the following primary questions: Has the relationship between IT and productivity changed since the dot-com bubble burst? What do IT returns look like now more than a decade after the first firm-level IT productivity empirical studies were published? Given results from prior studies, how has the relationship between IT and productivity changed over time? Do we see evidence of decreasing returns to IT over the longer time horizon that includes the golden IT era (1995-2000) when the Internet first came into being on a mass scale?

We make the following contributions in this paper. We gather and analyze a large *primary source* firm-level dataset about IT investments that spans the 2003-2005 period or post 2001-2002 economic recession in the US and in doing so we extend previous firm-level work done by Brynjolfsson and Hitt (1995), Lichtenberg (1995), Hitt and Brynjolfsson (1996) and Kudyba and Diwan (2002). While previously analyzed firm-level datasets were from the pre-Internet era (for example, 1988-1992 in Brynjolfsson and Hitt (1995, 1996) and Lichtenberg (1995)) and from during the dot-com boom era (1995-1997 in Kudyba and Diwan (2002)), we assess the IT-productivity relationship and compute IT returns using data on actual IT expenditures and investments, and financial performance for more than 300 firms from a period which is post-Internet bubble and post the first economic recession of this century. Given prior firm-level results, we provide results that are consistent with the hypothesis of decreasing returns to IT. We also examine whether using IT flows versus IT stocks in the IT productivity regressions makes a material difference to the estimated IT elasticities.

2 THEORY

Our work is grounded in the economic theory of production, which has been extensively used in similar studies. According to production theory, firms transform inputs to outputs using a "technology" which is represented mathematically by a production function. The production function represents the maximum amount of output that can be produced using a given set of inputs and given "technology". Rationally-managed firms will continue to invest in an input until the last unit of input such as IT adds no more value than it costs (Hitt and Brynjolfsson, 1996). In other words, in equilibrium, marginal cost of the input equals value of the marginal output created by the last dollar invested in the input (Kudyba and Diwan, 2002) or the net marginal product of the input i.e. the additional output created for an additional unit of input minus cost of input is zero (Hitt and Brynjolfsson, 1996). The production function can be represented as Q = f(C, K, L), where Q refers to total output measured in terms of sales or value-added, C is the IT capital stock, K is the non-IT capital, and L is the non-IT labor. Note C, K and L are also referred to as factor inputs. A popular form of the production function that is often used in this type of research is the Cobb-Douglas production function shown below:

$$Q=C^{\beta}{}_{1}K^{\beta}{}_{2}L^{\beta}{}_{3}$$

Taking logs of both sides, we get

$$\log Q = \beta_1 \log C + \beta_2 \log K + \beta_3 \log L$$

The popularity of the Cobb-Douglas production function stems from its linear form (obtained by taking its logs), which allows for easy estimation of the elasticities of the factor inputs. The elasticity of a factor input is the percentage change in the output due to a one-percent increase in the factor input. In the linearized form of the Cobb-Douglas function above, β_1, β_2 and β_3 refer to the elasticities of C, K, and L respectively. We could have used a less restrictive production function specification such as the translog specification. However, as shown by Brynjolfsson and Hitt (1995), the use of the translog specification, instead of the more restrictive Cobb-Douglas specification, results in no significant differences in the estimated contribution of IT (C).

The estimated IT elasticity can be used to compute gross marginal product of IT or the rate of return on IT, which is the amount of output produced for an additional unit of IT. The relationship between IT elasticity (β_1) and gross marginal product of IT (MP_C) is as follows:

$$MP_C = \frac{\beta_1}{(C/Q)} \text{ where } (C/Q) \text{ is the factor share of IT (C) in Output (Q)}$$

3 DATA COLLECTION AND VARIABLE CONSTRUCTION

This study uses a unique dataset on IT expenditure by 347 large firms (mostly Fortune 1000 firms) during the period of 2003-2005. The data was collected by phone interviews using a questionnaire designed by the research team. The questionnaire was distributed to the firms prior to interviews. Approximately, 600 firms were contacted but many were privately owned or provided unreliable/incomplete data and were not included in the analysis dataset. The questionnaire asked the respondents to provide the replacement value of the firm's total stock of computer hardware, the total IT expenditure, the percentage of the IT expenditure classified as IT labor expenditure, the total number of information systems employees, other IT related information, and the industry in which the firm operated.

We used Compustat to obtain financial information about the 347 firms. This information included measures such as total capital, output, labor and related expenses, number of employees, and other financial data for the firm. We also obtained price indices from various sources to deflate monetary values to 2004 constant dollars. The panel has a total of approximately 850 observations (which varies depending on the model specification) out of 1041 possible observations if the panel were complete. To allow us to compare our results with those from previous studies, we closely followed the variable construction methods in Brynjolfsson and Hitt (1995) and Kudyba and Diwan (2002). Their methods have been used in several other similar studies (Brynjolfsson and Hitt, 1996; Dewan and Min, 1997; Dewan et al., 1998; Hitt and Brynjolfsson, 1996). Table 1 summarizes the definitions and the construction of the variables.

We include several flow variables such as *IT Flow,* which is the annual total IT expenditure of the firm, deflated by *Investment Price*. This is the actual expenditure incurred by the firm. Since a firm may over- or under-spend the allocated IS budget, *IT Flow* in our study is a more accurate measure of IT spending (*note that we have actual IT expenditures for 2003 and 2004, but only IT budget for 2005, as the interviews were conducted in 2005*). The summary statistics of the dataset including the factor shares are shown in Table 2.

As in previous studies, the dataset in this study also consists of large firms. The average annual sales in the sample period were $16.8 billion, and the total sales were approximately $4.6 trillion. An average firm spent $265 million annually on IT, more than a third of which were IT labor expenditures. The gross output factor shares of (non-IT) capital and labor in this dataset (36.2% and 13.8%, respectively) are much lower than those in Brynjolfsson and Hitt (1996) (97.2% and 83.3%, respectively), while IT Flow (1.58%) is approximately the same as that in the previous study (1.63%). These differences may be attributed in part to the different industry mixes of the firms in the two datasets. The dataset of this study is more balanced: approximately 18.6% of the observations are from manufacturing sector, which is the largest but not overwhelmingly dominant industry sector. Energy, Finance, and Health sectors each accounts for more than 10% of the observations. In contrast, the dataset of Brynjolfsson and Hitt (1996) was concentrated in manufacturing (the most capital-intensive industry sector in general), which accounted for approximately two-thirds of the firms in their sample. The lower factor share of labor input in this dataset may be a result of higher outsourcing of laborintensive tasks in recent times (compared to period prior to 1992) in addition to a different, more balanced distribution of industry sectors in the dataset. However, if we compare the value-added factor shares (column 4 of Table 2) of the average firm with those in Brynjolfsson and Hitt (1995), the percentages are quite similar (e.g., 11.8% for IT Stock in this study vs. 9.35% for IT Capital plus IT Labor in Brynjolfsson and Hitt (1995)). Value-added is a more reliable measurement of output and we use it here to compute gross marginal product of IT. The similarity of value-added factor shares in our dataset and the one used in several prior studies makes our results comparable to those of prior work.

Variable	Construction	Source
Gross Output	Sales (Net) (data12), which is gross sales less discounts and returned sales, deflated by industry-specific Output Price (see below)	Compustat
Value Added	Non-deflated sales minus Cost of Goods Sold (COGS) (data41) and Selling, General & Administrative expenses (SG&A) (data189), deflated by industry-specific Value Added Price (see below)	Compustat
IT Capital	The replacement value of total stock of computer hardware, deflated by Investment Price (see below)	This study
IT Stock	IT Capital plus three times IT Labor	Calculation
Capital	Net Property, Plant & Equipment (PPE) (data8), deflated by Capital Price (see below), less IT Capital	Compustat
IT Flow	Total IT expenditure, deflated by Investment Price	This study
IT Labor	Labor portion of IT Flow, deflated by industry-specific Labor Price (see below)	This study
Labor	Labor and Related Expenses (data42), when available, or estimate using industry average Wages (see below) times number of employees, deflated by industry-specific Labor Price, less IT Labor, when available	Compustat
Industry	Consolidated industry sector based on self-reported industry and the NAICS code	This study and Compustat
Output Price	Chain-Type Price Indexes for Gross Output by Industry	Bureau of Economic Analysis
Value Added Price	Chain-Type Price Indexes for Value Added by Industry	Bureau of Economic Analysis
Investment Price	Price Indexes for Private Fixed Investment by Type	Bureau of Economic Analysis
Capital Price	GDP deflator for Fixed Investment	Economic Report of the President, 2007, Table B-7
Labor Price	Employment cost index of total compensation in private industry	Economic Report of the President, 2007, Table B-48
Wages	Average earnings of workers by major industry sector	Bureau of Labor Statistics

Table 1. Variable Definitions and Construction

This dataset has several strengths. The data was gathered via phone interviews and the values were verified against those of previous years. Thus the accuracy of data is likely to be higher than that obtained from secondary sources based on questionnaire surveys. The IT Expenditure data for years 2003 and 2004 are actual expenditures as opposed to IT budget. Since a firm may over- or under-spend IT budget, the measurement errors of IT Expenditure in our dataset should be smaller than those of IS Budget which has been used in previous studies. In addition, the firms in our sample are more balanced across several industry sectors, and thus our results should be representative of a broad cross-section of the economy.

Certain limitations of the dataset should be kept in mind. The IT-related information is self-reported, and with any kind of self-reported data, there is a possibility of a bias (for example, social desirability bias) creeping in. The data may have sample selection bias. However, the relatively large sample size should mitigate the impact of the bias. Further, we used a three-year average life assumption for the IT capital stock created by IT labor; thus the IT Stock was only an approximation of IT capital. However, prior research has shown that this assumption is reasonable and that the production function estimates do not vary much when the assumption is varied from one to seven years (Hitt and Brynjolfsson,1996).

	Total $(Annual Average)			Average Firm
	(in Billions)	% Gross Output	% Value-added	(in Millions)
Sales	$4,664	100%	531%	$16,865
Value Added	$878	18.8%	100%	$3,179
IT Stock	$103	2.22%	11.8%	$373
Capital	$1,686	36.2%	192%	$6,089
IT Flow	$73.5	1.58%	8.37%	$265
IT Labor	$25.3	0.54%	2.87%	$90.9
Labor	$645	13.8%	73.5%	$2,332

Table 2. Summary Statistics (in 2004 constant dollars, N=830)

4 DATA ANALYSIS AND RESULTS

Figure 1 is a scatter plot showing the relationship between the value-added measure of firm-level productivity and IT stock, both computed relative to industry average. The plot clearly reveals a positive relationship between IT stock and productivity.

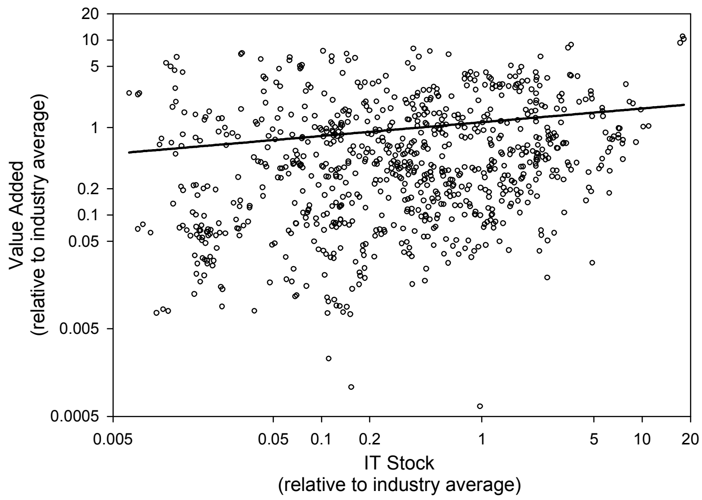


Figure 1. Value-added Productivity Measure vs. IT Stock Scatter Plot (2003-2005)

We analyzed the data using various econometric specifications: (1) year-by-year OLS estimation, controlling for industry and (2) pooled OLS, iterated seemingly unrelated regression (ISUR), and 2SLS using previous year input factors as instruments, controlling for industry and year. For each of the specifications, there are four variations: the dependent variable can be either value-added or gross output, and the IT input can be either IT stock or IT flow.

Table 3 shows the results of the year-by-year OLS regressions of value-added and gross output on IT stock and other factor inputs with industry controls. The model specification for each year t=2003, 2004, and 2005 is as follows:

$$\log Q_i = \sum_j D_j + \beta_1 \log C_i + \beta_2 \log K_i + \beta_3 \log L_i + \varepsilon$$

where $\beta_1, \beta_2, \beta_3$ are the coefficients to be estimated, Q is value-added or gross output, C is the IT stock variable, K is non-IT capital, L is non-IT labor, i is the firm, j is the industry group, D_j is a dummy variable corresponding to industry group j and ε is the residual.

In the case of value-added regressions, the IT elasticity jumped from 0.065 in 2003 to 0.127 in 2004 and 0.123 in 2005. The value-added regression IT elasticity coefficient in 2003 is significantly different from the IT elasticity coefficient in 2004 (p=0.01); however the elasticities in 2004 and 2005 are not statistically different. In the case of the gross output regressions, the coefficients are not statistically different across the different years. Importantly, across the different specifications, the coefficient for IT Stock remains positive and highly statistically significant.

	Value-added as dependent variable			Gross output as dependent variable		
	2003	2004	2005	2003	2004	2005
IT Stock (C)	.0649** (.0252)	.127*** (.0268)	.123*** (.0261)	.110*** (.0225)	.116*** (.0228)	.115*** (.0233)
Capital (K)	.670*** (.0616)	.507*** (.0735)	.609*** (.0471)	.335*** (.0417)	.304*** (.0514)	.404*** (.0452)
Labor (L)	.217*** (.0608)	.318*** (.0660)	.205*** (.0517)	.448*** (.0464)	.465*** (.0511)	.363*** (.0529)
Dummy Variables	Industry	Industry	Industry	Industry	Industry	Industry
N	284	286	262	290	289	267
R^2	98.9%	99.1%	99.1%	99.5%	99.5%	99.5%

*** p<0.01, ** p<0.05, * p<0.1; Huber/White heteroskedasticity-robust standard errors in parentheses

Table 3. Year-by-Year OLS Regressions Using IT Stock With Industry Controls

Table 4 shows the results of the pooled data OLS regression, ISUR, and 2SLS, using both industry and time controls. The pooled OLS regression model specification is as follows:

$$\log Q_{it} = \sum_t D_t + \sum_j D_j + \beta_1 \log C_{it} + \beta_2 \log K_{it} + \beta_3 \log L_{it} + \varepsilon$$

where $\beta_1, \beta_2, \beta_3$ are the coefficients to be estimated, Q is either value-added or gross output, C is the IT stock variable, K is non-IT capital, L is non-IT labor, i is the firm, t is the time period, j is the industry group, D_t is a dummy variable corresponding to time period t, D_j is a dummy variable corresponding to industry group j, and ε is the residual. For dependent variable value-added, the OLS estimation of IT elasticity is 0.107, which is not statistically different from the IT elasticity of 0.088 reported in a similar econometric regression in Brynjolffson and Hitt (1996). The gross marginal product or gross rate of return of IT stock based on IT elasticity obtained from value-added regression is 91% (=0.107/0.118), which is only marginally lower than the gross marginal product of 94.9% reported in Hitt and Brynjolfsson (1996). With gross output as a dependent variable, the IT elasticity is 0.114, which is remarkably similar to the elasticity obtained above in the value-added regression (0.107). Further, it is very close to 0.106 reported by Lichtenberg (1995).

We use ISUR (iterated seemingly unrelated regression) technique to potentially improve the estimation efficiency of our regressions. With ISUR, we estimate a system of three equations with a set of constraints that forces the estimated coefficients of certain variables to be the same across the system of equations. The system of equations is shown below:

$$\log Q_{i(2003)} = \beta_{(2003)} + \sum_j D_j + \beta_1 \log C_{i(2003)} + \beta_2 \log K_{i(2003)} + \beta_3 \log L_{i(2003)} + \varepsilon_{(2003)}$$

$$\log Q_{i(2004)} = \beta_{(2004)} + \sum_j D_j + \beta_1 \log C_{i(2004)} + \beta_2 \log K_{i(2004)} + \beta_3 \log L_{i(2004)} + \varepsilon_{(2004)}$$

$$\log Q_{i(2005)} = \beta_{(2005)} + \sum_j D_j + \beta_1 \log C_{i(2005)} + \beta_2 \log K_{i(2005)} + \beta_3 \log L_{i(2005)} + \varepsilon_{(2005)}$$

where $\beta_1, \beta_2, \beta_3$ are the coefficients to be estimated, Q is either value-added or gross output, C is the IT stock variable, K is non-IT capital, L is non-IT labor, i is the firm, j is the industry group, D_j is a dummy variable corresponding to industry group j, and ε is the residual. Note $\beta_1, \beta_2, \beta_3$ as well as the coefficients for the industry dummies are constrained to be the same across the equations. The coefficients and standard errors estimated by ISUR are unbiased provided each of the cross-section error terms is homoskedastic and uncorrelated with the input regressors. ISUR implicitly corrects for serial correlation and heteroskedasticity of error terms across years (Hitt and Brynjolfsson, 1996). In pooled OLS regressions, the latter two conditions are assumed for unbiased estimates and standard errors. As seen from Table 4, the IT stock elasticity in the value-added regression declines only marginally from 0.107 (in pooled OLS regression) to 0.0994 (in ISUR regression) whereas the IT elasticity in the gross output regression declines from 0.114 (in pooled OLS) to 0.055 (in ISUR), with marginal deterioration in the standard errors, although the standard errors for the other factor coefficients improve somewhat.

	Value-added as dependent variable			Gross output as dependent variable		
	Pooled OLS	ISUR	2SLS	Pooled OLS	ISUR	2SLS
IT Stock (C)	.107*** (.0152)	. 0994*** (.0236)	. 114*** (.0182)	.114*** (.0130)	.0556** (.0189)	.111** (.0158)
Capital (K)	.589*** (.0391)	.509*** (.0309)	.595*** (.0363)	.347*** (.0284)	.279*** (.0215)	.355*** (.0320)
Labor (L)	.252*** (.0365)	.289*** (.0346)	.244*** (.0380)	.426*** (.0302)	. 241*** (.0221)	. 430*** (.0351)
Dummy Variables	Industry & Year	Industry & Year	Industry & Year	Industry & Year	Industry & Year	Industry & Year
N	832	768	542	846	786	550
R^2	99.0%	81.6-83.4%	-	99.5%	70.2-70.4%	-

*** p<0.01, ** p<0.05, * p<0.1; Huber/White heteroskedasticity-robust standard errors (except for ISUR) in parentheses

Table 4. Regressions using IT Stock with Industry and Time controls

To eliminate the possibility of simultaneity bias or to eliminate the possibility that it is not IT that leads to higher output but higher output that stimulates higher IT investments, we perform 2SLS regressions, using the lagged values of the independent variables (IT stock, Capital and Labor) as the instruments. The 2SLS regressions show no significant change in the factor elasticities when compared to the pooled OLS regressions. The Hausman specification test does not reject the hypothesis that the estimates of IT Stock were unbiased (Hausman, 1978). Thus we can eliminate the possibility of endogeneity biases leading to high IT elasticities.

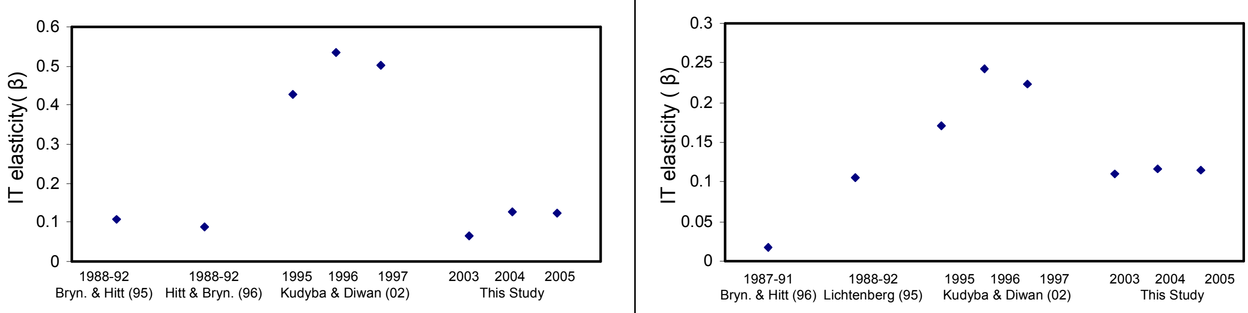
To compare our results with those of prior studies, we summarize IT elasticities in Table 5 and plot them in Figure 2. We see an inverted U-shaped curve of IT elasticities over time. While Kudyba and Diwan (2002) suggest increasing returns to IT based on comparison of results from analysis of the

1995-1997 data with those from prior studies, we provide evidence of returns having declined post Internet-boom era and reverted to previous estimates (based on the 1988-1992 data).

Source	Brynjolfsson, Hitt (1996)	Lichtenberg (1995)	Brynjolfsson, Hitt (1995)	Hitt, Brynjolfsson (1996)	Kudyba, Diwan (2002)			This study		
Factor	IT Capital	IT Capital	IT Stock[+]	IT Stock	IT Flow[++]			IT Stock		
Period	1987-91	1988-92	1988-92	1988-92	1995	1996	1997	2002	2003	2004
β^a	-	-	.109	.0883	.427	.535	.502	.0649	.127	.123
β^b	.0169[†]	.106	-	-	.171[‡]	.243[‡]	.223[‡]	.110	.116	.115

[a] Value Added as dependent variable; [b] Gross output as dependent variable; [+] Sum of IT Capital and IT Labor; [++] IS budget; [†] IT Capital and IT Labor are separate factors; [‡] IT Labor and Non-IT Labor are separate factors.

Table 5. Trend of IT Elasticities



(a) Value Added as independent variable

(b) Gross Output as independent variable

Figure 2. IT Elasticities (Value-added and Gross Output Regressions)

Following Kudyba and Diwan (2002), we also test the use of actual IT expenditures or budgets (a flow variable) instead of IT stock in the year-by-year OLS regressions. The model specification for each year t=2003, 2004, and 2005 is as follows:

$$\log Q_i = \sum_j D_j + \beta_1 \log C_{(flow)i} + \beta_2 \log K_i + \beta_3 \log L_i + \varepsilon$$

where $\beta_1, \beta_2, \beta_3$ are the coefficients to be estimated, Q is value-added or gross output, $C_{(flow)}$ is the IT flow variable or the actual IT expenditure or budget, K is non-IT capital, L is non-IT labor, i is the firm, j is the industry group, D_j is a dummy variable corresponding to industry group j and ε is the residual. Columns 2, 3, and 4 in Table 6 show that in the value-added regressions the IT elasticity jumped from 0.064 in 2003 to 0.131 in 2004 and 0.124 in 2005. Columns 5, 6, 7 in Table 6 show the estimated factor coefficients in the gross output regressions. It is interesting to see that the results *do not* change much from the results obtained when IT stock is used. The coefficients obtained using IT flow are very close to the coefficients obtained using IT stock.

	Value Added as dependent variable			Gross output as dependent variable		
	2003	2004	2005	2003	2004	2005
IT Flow (C_{flow})	.0639** (.0274)	.131*** (.0289)	.124*** (.0277)	.109*** (.0233)	.114*** (.0241)	.108*** (.0244)
Capital (K)	.671*** (.0621)	.507*** (.0732)	.610*** (.0469)	.336*** (.0411)	.305*** (.0512)	.406*** (.0446)
Labor (L)	.215*** (.0608)	.316*** (.0655)	.202*** (.0517)	.446*** (.0461)	.462*** (.0511)	.360*** (.0526)
Dummy Variables	Industry	Industry	Industry	Industry	Industry	Industry
N	284	286	262	290	289	267
R^2	98.9%	99.1%	99.1%	99.5%	99.5%	99.5%

*** p<0.01, ** p<0.05, * p<0.1; Huber/White heteroskedasticity-robust standard errors in parentheses

Table 6. Year-by-Year OLS Regressions Using IT Flow

	Value-added as dependent variable	Gross output as dependent variable
IT Flow (C_{flow})	.109*** (.0165)	.110*** (.0137)
Capital (K)	.589*** (.0392)	.348*** (.0282)
Labor (L)	.250*** (.0364)	.423*** (.0301)
Dummy Variables	Industry and Year	Industry and Year
N	832	846
R^2	99.0%	99.5%

*** p<0.01, ** p<0.05, * p<0.1; Huber/White heteroskedasticity-robust standard errors in parentheses

Table 7. Pooled OLS Regressions Using IT Flow with Industry and Time controls

Table 7 shows the results of the OLS regression on the pooled data (from all years) and it includes both industry and time controls. The model specification is as follows:

$$\log Q_{it} = \sum_t D_t + \sum_j D_j + \beta_1 \log C_{(flow)it} + \beta_2 \log K_{it} + \beta_3 \log L_{it} + \varepsilon$$

where $\beta_1, \beta_2, \beta_3$ are the coefficients to be estimated, Q is either value-added or gross output, $C_{(flow)}$ is the IT flow variable, K is non-IT capital, L is non-IT labor, i is the firm, t is the time period, j is the industry group, D_t is a dummy variable corresponding to time period t, D_j is a dummy variable corresponding to industry group j, and ε is the residual. As with the year-by-year OLS regressions, the coefficients do not change much when IT flow is used instead of IT stock in the regressions.

Overall, the above set of results indicate that the estimates do not change much when IT flow is used instead of IT stock in the regressions. The estimated IT factor coefficients remain positive and highly statistically significant. This is consistent with the findings in Kudyba and Diwan (2002).

5 DISCUSSION AND CONCLUSION

We have gathered and analyzed a large primary source firm-level dataset about IT investments that spans the 2003-2005 period, which is post 2001-2002 economic recession in the US. In doing so we have extended previous firm-level work done by Brynjolfsson and Hitt (1995), Lichtenberg (1995), Hitt and Brynjolfsson (1996), and Kudyba and Diwan (2002). To the best of our knowledge, this is the first analysis of a large sample firm-level IT investments dataset from the post Internet-boom era. Importantly, in contrast to previous studies, most of our data captures actual IT expenditures versus IT budgets. Since IT budgets are forecasted IT expenditures, they can certainly overestimate or underestimate actual IT expenditures, and hence the distinction is an important one. Further, the coverage of industries in our dataset is more balanced than that in prior research. Using a variety of econometric analyses, we have confirmed the positive and highly statistically significant relationship between IT and gross output or value-added for the most recent time period. Further, we have shown that the contribution of IT to firm-level performance measures such as value-added has not dramatically changed from what was observed in the first firm-level IT productivity studies which analyzed data from the 1988-1992 period. The similarity in construction of the dataset and in the variety of empirical analyses performed on the data has allowed us to compare results in this study with those in prior studies. In contrast to Kudyba and Diwan's (2002) observation about increasing returns to IT based on their analysis of the 1995-1997 Internet boom era dataset, we present evidence of an inverted U-shaped returns curve, with returns now close to what they were in pre-Internet-boom era. Our findings for the 2003-2005 period combined with prior published results are evidence for first increasing and then decreasing returns to IT over the longer time horizon (1988-2005).

We have shown that our results are generally robust to a variety of specifications and estimation techniques. We have also shown that use of IT flow (a measure of actual IT expenditure or IT budget) versus IT stock (a capitalized measure of IT that includes hardware capital and IT labor) does not produce a significant change in the magnitude of the estimated IT elasticities.

Given the fundamental nature of the IT-productivity link in our discipline, the diversity of sources of firm-level data analyzed in prior research has not been very encouraging. Further, though the IT productivity paradox has been laid to rest on the basis of prior firm-level and industry-level studies, the nature of the relationship needs continuous investigation especially after periods of significant economic activity or inactivity. Given the importance of understanding the potentially evolving nature of the IT-productivity relationship and the need to validate prior results from a variety of sources (secondary as well as primary) more firm-level research is called for. The difficulties of gathering a large sample of data required to conduct this type of research may explain why papers based on more recent data and diverse sources have not been forthcoming. The difficulties may however be overcome by multi-university and university-industry collaboration. Future research may include gathering a much longer time sample of data than what was analyzed in this study; it would especially be interesting to analyze a dataset spanning both an economic recession and recovery (for example: 2000-2005). Our future research efforts lie in that direction.

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