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A Firm Level Study of Information Technology Productivity by Industry Using Financial and Market Based Measures

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Abstract

Information technology productivity has been studied on a macroeconomic level, a specific application level, as well as at a firm level. None of these studies has firmly determined whether there is an absence of productivity gains despite increased information technology expenditures (often known as the Productivity Paradox). This study reviews a specific year, 1995, using publicly available InformationWeek data from their IW 500 and analyzes productivity of the firm using both market and financial based measures stratified by overall industry type. This study is to determine whether a Productivity Paradox is observed after eliminating the overall industry impact.

Keywords: information technology, information technology productivity, Productivity Paradox, economics of information systems, information systems.

Introduction

The Productivity Paradox, the concept that private industry productivity is not improving despite increases in information technology expenditures is an oft-studied concept in research literature. Generally, studies have fallen into three broad categories, macroeconomic, application, and firm level. Macroeconomic studies attempt to measure impact on the total economy. Application level studies deal with a particular application of IT in a specific company and measure the impact for this specific expenditure. The most common, firm level studies, deal with analysis of information technology at the firm or company level, measuring the impact of total IT spending on each company in a group of companies. (Peslak, 2003).

Macroeconomic studies

Many researchers have studied at the macroeconomic level and found differing results. Strassman (1999) and Berndt and Morrison (1991) found little or no gains from IT expenditures at the macro level. Clemons and Weber (1990) and Morrison (1996) did find gains.

An example of a macroeconomic study was prepared by Dewan and Kraemer (1998). The authors examine the Productivity Paradox from another perspective, by country. Up until this study all analyses had been performed on U.S. companies or U.S. multinational companies. Dewan and Kraemer examine information technology productivity across international boundaries and study data from 17 developed countries that invested significant dollars in information technology. They first review the U.S. literature and note how early studies showed no positive impact on productivity (the investment or Productivity Paradox period). More recent studies in the 1990s, however, have shown positive correlation between information technology investments and productivity (the payoff era). They also note the work of Sichel, Roach, and Strassmann who still argue that information technology productivity is not increasing. They suggest that these authors research is not "rigorous", but do note that caution still must be exercised and further research is still needed. With regard to their 17 country international study, they culled international data from IDC, Penn World tables, the International Labor Organization, and the International Monetary Fund. Their key data was gross domestic product, information technology capital, number of workers, and non-information technology capital. They use a traditional Cobb-Douglas production function and used ordinary least squares regression analysis to analyze the data. The results of the study show a positive correlation between change in information technology capital per worker vs. gross domestic product per worker, controlling for changes in non-information technology capital per worker and the number of workers. The average return on information technology capital in this study was 70.6 percent across all 17 countries while the U.S. return was 59 percent. This is consistent with the Paradox lost study by Brynjolfsson and Hitt (1996).

Daniel Sichel, the Federal Reserve Board economist, in *Computers and Aggregate Economic Growth: An Update* (1999), an article in Business Economics, attempted to review the Productivity Paradox at a macro level. He suggests there are two possible reasons for the sluggish productivity growth at the macro level. The first is a time lag effect. It simply may take time to reap the benefits of the past computer investment. The second possible reason is that the recent contribution from computers is the result of transitory factors. The transitory factors suggested by Sichel are that in recent years, computer hardware prices have dropped precipitously, resulting in more purchases and wider dissemination of technology. He suggests this rapid price decline, dissemination, and contributions to productivity may be an anomaly and may be short-lived. He studies Bureau of Labor Statistics and other government data, and estimates the growth rates of output over the time frame and the contribution from computer hardware. This analysis suggests that in the 1970s, 1980s, and early 1990s, the output growth contribution from computer hardware was extremely small, relative to other factors. Though it has significantly increased in the last few years, it still represents a small portion of output growth. He makes these estimations of the impact of output of computer capital by using a neoclassical approach. This has as its key assumption that business makes the best investment decisions, and all types of capital earn the same return at the margin.

Application level studies

Positive effects were found in specific application level studies such as Mukhopadhyay, Lerch, and Mongol (1997) and Mukhodpadhyay, Kekre, and Kalathur (1995). Offsetting these studies are ones such as Banker, Kauffman, and Morey (1990) who found no positive effects of IT expenditures. An application level manufacturing productivity analysis is presented by Kelley (1994) in *Productivity and Information Technology: the elusive connection*. Kelly performed a survey of production managers in 1987 and sampled 1612 different machinery jobs or projects. Of these 823 used programmable technology and 789 were conventional. The dependent variable was production hours. Least squares regression was used in a natural log transformation of cost of materials, number of cutting tools, volume, usage, and machinery employment variables. Controlling for product attributes and 11 other factors, the use of programmable automation cut unit production hours by 40 percent. This is not the same with all users. The most efficient are the firms with more machines per worker. This suggests that time is needed to adapt to technology and gives credence to the idea that information technology has to work its way into an organization.

Firm level studies

By far the most common study has been at the firm level but even here positive effects were found by Bharadwaj, A., Bharadwaj, S., and Knosynski, B. (1999), whereas Alpar and Kim (1990) found negative impact. Kwon and Stoneman (1995) present an empirical study on the impact of information technology investments on productivity. They use a modified Cobb-Douglas function with a different data source. Their source is a collection of three studies in the United Kingdom by CURDS in the University of New Castle upon Tyne in 1981, 1986, and 1993. The number of respondents were 1127, 848, and 343 respectively. The dates correspond to the adoption of specific information technologies. The statistics measured include total employment, research and development employment, turnover of sales, and pre-tax profit. Also from Lotus Datastream other data were obtained including fixed assets, number of employees, and value added. The authors performed ordinary least squares regression on the data. Results of the regression show that output gain does result from technology investment but the output gain is different across technologies. Specific technologies studied included numerically controlled machine tools, computerized numerically controlled machine tools, coated Carbide tools, microprocessors for processes, and microprocessors for administrative uses. The technologies reflect the manufacturing nature of the data set. One of the models reflects significant positive impact from computerized and numerically controlled machine tools. The final model predicts a 37 percent output gain from one or more of the five technologies.

Lehr and Lichtenberg (1999) analyze firm level data from the market research firm Computer Intelligence Infocorp under an NBER Sloan grant in conjunction with Compustat and Census Bureau data for the period 1977 to 1993. Their overall conclusion is that computers not only have contributed to productivity but they have excess returns in comparison to other forms of capital. They suggested that the reason for conflicting results from older data is that there are is primarily a measurement problem. Service industries use a significant amount of the computers in industry and service productivity is difficult to quantify and measure. Also computers represent a small portion of total capital so once again their impact is difficult to measure. Finally overall data itself is limited and presents an incomplete picture. For this last reason, the researchers worked with Computer Intelligence Infocorp to obtain primary level data for their analysis. Other key findings of the study included that personal computers allow greater productivity than other information technology tools, computers are complementary with skilled labor, and computers may allow inventory reductions. An interesting finding of their study is that computer productivity peaked in 1986/1987. The authors attempted to measure productivity through a Cobb-Douglas production function including output as a function of capital times labor times a technology factor. The concept would be then that raising technology would result in more productive labor and capital functions. The authors suggest this could be related to better coordination or improved technical progress. In their analysis of the impact of computer investment on productivity, there are significant positive regression coefficients for each year examined, except one, 1977. The years in 1982, 87, 86, 91, and 93 all show positive coefficients with R squared above 90 even though the early data comes from different data set than the later data. The positive coefficient in 1993 is about one-third of the coefficients shown in 1986 and 1987. The 1977, 1982, and 1987 data is from an Enterprise survey done by the Census Bureau every five years. The 1986, 1991, and 1993 data is from the marker research firm CII.

Another article is by Grover, Teng, Segars, and Fiedler (1998) in Information and Management entitled The influence of information technology diffusion and business process change on perceived productivity: the information system executives perspective. After review of the Productivity Paradox literature, the authors attempt to study productivity in a new way. The authors use non-economic firm level surveys to determine the organizational impact on the implementation of 11 specific technologies and their impact on productivity. The 11 technologies are electronic mail, expert systems, teleconferencing, electronic data interchange, executive information systems, computer aided software engineering, object-oriented programming, client/server architecture, relational database management systems, local area networks, and imaging. They then review three variables for each technology,

- Diffusion in organization or penetration.
- Perceived process change.
- Perceived productivity change.

A 36 percent response rate was received from 900 mailings. This was a study of organizations' perception of whether specific information technologies have positively affected productivity and organization. The results of the study generally show that all information technology investments have a positive impact on productivity. For electronic mail, local area networks, relational database management systems, expert systems, and imaging, the results show that process change is also necessary for productivity gains in these technologies. High penetration in organizations is necessary for high perceived productivity improvements in electronic mail, executive information systems, and electronic data interchange. The authors suggest that their more qualitative analysis supports the positive effects of information technology as demonstrated by Brynjolfsson and Hitt (1996), though they too cannot explain the past Productivity Paradox. All the technologies listed have a raw positive relationship with perceived productivity. Only client/server technology is enabled by process change. Electronic mail, relational database management systems, expert systems, imaging, and local area networks require process change for perceived productivity improvements. Teleconferencing, electronic data interchange, executive information systems, object-oriented programming, and computer aided software engineering neither require nor are enabled by process change. In short, some technologies require process change while others don't.

An article by Hitt and Brynjolfsson in 1996 is a key article in the analysis of information technology spending and its impact on business performance. 1. It is a large firm level study of information technology spending obtained from IDG for a multi-year period 1988 -- 1992. 2. It measures three different but complementary frameworks for determining the extent of the Productivity Paradox -- production productivity, business profitability, and consumer value. 3. It includes other measures as well as traditional financial measures. The authors obtained data from three different sources -- Compustat, IDG, and the Bureau of Economic Advisers. They then use a production function approach and ordinary least squares regression methodology to test their three hypotheses on the different measures of information technology productivity. In conjunction with ordinary least squares, the authors also used integrated seemingly unrelated regression and two stage least squares estimates to test error term estimates and enhance estimation efficiency. Similar results were obtained under all three regression methods. The rate of return of information technology was determined by dividing the information technology stock elasticity -- percent increase in output from a one percent increase in information technology stock -- by the ratio of information technology stock in value added. This is similar to the rate of return of information technology. Information technology stock is calculated as three times computer capital. The rate of return estimated through this computation was 95 percent. In analyzing business profitability, the authors included three methods of probability used in the past -- return on assets, return on equity, and shareholder return. Their analysis of this factor showed no evidence of increased profitability related to information technology expenditures based on these three profitability measures from their data. Finally, a measure of consumer value or surplus was created at the aggregate level. It was found that information technology investment grade created significant -- 14.5 billion dollars or 3.6 billion dollars per year -- consumer surplus over the five years of the study. Thus the three measures of information technology value showed conflicting results with profitability unaffected but strong consumer value and productivity created. Though the issue of information technology productivity, as the authors note, was far from settled in the study they did open the framework for examining the Productivity Paradox from variety of perspectives. As they note, different measures and perspectives on productivity can lead to significantly different results.

Siegel and Grilches (1992) analyze Bureau of Labor Statistics reports which show a positive impact on manufacturing productivity growth in the period 1979 -- 1987 and conclude the gains are actually less than indicated and misleading due to outsourcing to the service sector, outsourcing to foreign establishments, and the large growth in computers. These have caused errors in measurement. They attribute the large productivity gains over the period to these factors rather than a real productivity growth. Data used to perform their analysis includes the National Bureau of Economic Research productivity database from the Census Bureau, and other Census Bureau data. Errors in measurement in total factor productivity growth are cited as one of these major factors. Three sources of the mismeasurement are material price deflators, investment goods deflators, and the omission of purchased services. The investments goods deflator is especially prevalent in computers. To some extent there is also inaccuracy in industry definition and sampling procedures. After a thorough review of this data, however, the authors find that the increase in productivity in manufacturing over the time frame cannot be attributed to these noted factors. They suggest that further work is necessary to analyze the issue.

Hypothesis of This Study

This study takes as its framework the issue of conflicting conclusions on whether the Productivity paradox exists. It attempts to address the issue by separately analyzing the relationship between IT expenditures and productivity for each distinct industy sector as defined by Standard and Poor's. The information for this study came from InformationWeek 500 edition 1995 and was supplemented with financial and market data from the Compustat Standard and Poor's database. The specific hypothesis of the study was as follows.

> *Specific industry analysis will show similar positive, firm level returns from information technology investments.*

Industries were separately analyzed to determine if there have been consistent returns from different industries. The InformationWeek 500 database was sorted by general industry category. The categories are presented in Table 1.

Table 1
Industry Categories

Code	Industry	Description
10	Energy	Oil and gas and drilling equipment
15	Materials	Chemicals, gases, metals, glass, and paper.
20	Industrials	Aerospace, heavy equipment, railroads, marine
25	Consumer Discretionary	Home furnishings, appliances, clothing, hotels
30	Consumer Staples	Foods, drugs, tobacco, and drinks
35	Health Care	
40	Financials	Insurance, real estate, financial services
45	Information Technology	
50	Telecommunications services	
55	Utilities	

Each of the 10 industry categories was separately analyzed to determine if there is a difference in information technology productivity from one industry category to the next. The InformationWeek database separately analyzed each of the 12 separate performance measures shown in Table 2, grouped into the ten industry categories for the year 1995, the year of the most data points. The end result was that only eight industry categories had sufficient data points for accurate analyses. (Energy and Telecomm were excluded). For the 12 performance measures tested, the regression results were analyzed including the IT variable correlation coefficient and its significance. A p value of .05 was used as the threshold for significance of the independent variable on the dependent performance measure. A brief review of the significance of other independent variables was also noted.

Table 2
Performance Measures

Abbreviation	Measure	Type of Measure
3YR	3 Year Return	Financial
CF	Cash Flow	Financial
CFL	Log Cash Flow	Financial
EB	Earnings Before Interest and Taxes	Financial
LEB	Log Earnings Before Interest and Taxes	Financial
LMV	Log Market Value	Market
MV	Market Value	Market
PE	Price/Earnings Ratio	Market
ROA	Return on Assets	Financial
ROE	Return on Equity	Financial
ROI	Return on Investment	Financial
TOB	Tobin's q Ratio	Market

The form of the equations was as noted

Non- ratio, Non-Cobb-Douglas

Performance index (x)= a + b Current Assets +
c Total Assets+
d Total Long-term Debt+
e Total Sales+
f Total IT Budget+
g Total Non-current Assets+
h Number of Employees.

The equation was x = a + b CA+ c TA + d TLTD + e TS + f ITBUD + g TNCA + h EMP.

Non-ratio, Cobb-Douglas

Log Performance index (x)= a + b log Current Assets +
c log Total Assets+
d log Total Long-term Debt+
e log Total Sales+
f log Total IT Budget+
g log Total Non-current Assets+
h log Number of Employees.

The equation was

Log x = a + b log CA+ c log TA + d log TLTD + e log TS +f log ITBUD+ g log TNCA + h log EMP.

Ratio

Performance index (x)= a + b IT as Percent of Sales +
c Capital Intensity +
d Debt to Assets Ratio +
e Current Ratio +
f Market Share.

The equation was thus x = a + b IT + c CI + d DTA + e CR + f MS.

Results

The overall results of the analyses show that none of the factors had a majority of industries with significant correlation and none of the industries showed a majority of factors with significant correlation. The hypothesis was rejected.

> *Specific industry analyses did not show similar positive, firm level returns from information technology investments.*

At first glance there does not appear to be little if any industry effect on the Productivity paradox. The results are summarized in Table 3 that shows the correlation coefficients for IT expenditures versus the performance measures for each industry. The + or – signifies if the coefficient was positive or negative. First, none of the industries showed significant (at $p < .05$) positive and consistent returns from IT investments. For industry 20 (Industrials), four factors out of 12 were significant but three had negative correlation. The strongest positive correlation was for 25 (Consumer Discretionary) which had three factors out of twelve where IT expenditures were significant and positively correlated with the performance measure. The measures were cash flow, market value, and three year return.

Table 3
Significant coefficients in industry level multiple linear regression analysis of IW data

Measure	Number Significant out of 8	15	20	25	30	35	40	45	55
CASH FLOW	3			+		+		-	
EBIT	1		-						
MARKET VALUE	3			+				+	+
CASH FLOW LOG	1	+							
EBIT LOG	0								
MV LOG	0								
PE RATIO	2		+						+
ROA	1						-		
ROE	2		-				-		
ROI	3	+	-				-		
TOBIN’S Q	0								
3 YR RETURN	2			+			+		
Total Number significant out of 12		2	4	3	0	1	4	2	2

Also, none of the factors seemed to clearly measure productivity. The factors showing the most correlation across industries were cash flow, market value, and return on investment. But only in one, return on investment were all those coefficients positive.

But when the results are analyzed individually there are many interesting results. Specific industries do show some measurable affect from IT expenditures on common financial or market based measures. The tables below show the positive and significant factors and the performance measure with which they were significant.

Table 4
Materials sector

Y	X	Coefficient	p value
TOBIN'S Q	MARKET SHARE	-0.0000171	0.04
CF	SALES	0.2030000	0.01
EBIT	SALES	0.2340000	0.00
CF LOG	ITBLOG	0.4790000	0.04
ROE	DEBTRATIO	107.7840000	0.00
ROI	ITB%SLS	577.0660000	0.02

For the materials sector, IT budget as a percent of sales had a very significant impact on return on investment with each increase of one percent there was a corresponding 5.8 fold increase (not 580 due to decimal difference) in ROI.

Table 5
Industrials sector

Y	X	Coefficient	p value
ROE	ITB%SLS	-304.9470000	0.04
ROI	ITB%SLS	-128.7240000	0.01
ROI	DEBTRATIO	-22.3690000	0.00
ROA	DEBTRATIO	-13.8550000	0.00
MV	LTD	-2.9210000	0.00
TOBIN'S Q	DEBTRATIO	-1.4450000	0.02
EBIT	ITBUD	-0.4690000	0.03
MV LOG	LTDLOG	-0.4020000	0.00
EBIT	LTD	-0.1390000	0.02
EBIT	SALES	-0.0700800	0.01
CF	SALES	0.0689500	0.02
CF	NCA	0.1100000	0.00
EBIT	NCA	0.1120000	0.00
MV	NCA	1.6330000	0.00
MV	CA	2.1420000	0.00
PE	DEBTRATIO	228.0510000	0.05
PE	ITB%SLS	3013.1340000	0.00

In the Industrials category, ROI was significantly associated with IT budget as a percent of sales but in this sector in a negative way, with every percent increase in IT budget negatively impacting ROI by one percent. Conversely Price/earnings ratio in the Industrials sector is strongly positively associated with IT budget as a percent of sales. In this category debt ratio has a significant effect on many performance measures.

Table 6
Consumer Discretionary sector

Y	X	Coefficient	p value
MV	LTD	-1.3400000	0.00
MV LOG	SALESLOG	-0.7640000	0.02
TOBIN'S Q	DEBTRATIO	-0.6900000	0.03
MV LOG	LTDLOG	-0.2730000	0.02
EBIT	LTD	-0.1760000	0.00
TOBIN'S Q	CURRRATIO	-0.1410000	0.04
EBIT	SALES	-0.0591200	0.00
ROA	MARKET SHARE	-0.0000566	0.03
TOBIN'S Q	MARKET SHARE	-0.0000045	0.00
EBIT	NCA	0.1190000	0.00
EBIT	CA	0.1860000	0.00
MV	CA	0.8790000	0.00
MV	NCA	1.2520000	0.00
CF LOG	NCALOG	1.6120000	0.04
CF	ITBUD	3.9240000	0.00
PE	CAPRATIO	8.6740000	0.00
MV	ITBUD	20.5950000	0.01
3 YR RET	ITB%SLS	779.2160000	0.02

IT budget as a percent of sales has a high impact on a few performance measures in the Consumer Discretionary sector. Three year rate of return on sales is significant and strongly positive. Market value is positively affected as well.

Table 7
Consumer Staples

Y	X	Coefficient	p value
ROE	CURRRATIO	-84.5150000	0.04
ROI	CURRRATIO	-37.1520000	0.03
ROI	MARKET SHARE	-0.0002838	0.04
CF	EMP	2.8570000	0.05
ROI	CAPRATIO	3.9120000	0.05

The Consumer Staples category had no factors which were influenced by IT expenditures at p< .05 level. The most significant factor was capital ratio impact on ROI.

Table 8
Healthcare sector

Y	X	Coefficient	p value
TOBIN'S Q	DEBTRATIO	-7.1050000	0.04
MV	LTD	-6.8800000	0.00
MV LOG	LTDLOG	-0.4880000	0.00
EBIT LOG	LTDLOG	-0.3260000	0.02
EBIT	LTD	-0.2920000	0.00
CF	LTD	-0.2730000	0.00
ROE	MARKET SHARE	0.0001194	0.02
CF	NCA	0.1810000	0.00
EBIT	CA	0.4260000	0.03
CF	ITBUD	2.3410000	0.04
CF LOG	EMPLOG	2.4110000	0.03
MV	NCA	3.2350000	0.00
MV	CA	5.9770000	0.03
CF	EMP	33.2060000	0.00

Healthcare cash flow was affected by IT budget, with cash flow increasing at more than 2 times the expenditures on information technology. Market value was positively affected by assets but also affecting cash flow was number of employees.

Table 9
Financials sector

Y	X	Coefficient	p value
ROE	ITB%SLS	-91.6970000	0.00
ROI	ITB%SLS	-42.8210000	0.05
ROA	ITB%SLS	-24.4620000	0.01
MV LOG	LTDLOG	0.2670000	0.01
EBIT	SALES	0.5500000	0.03
3 YR RET	ITB%SLS	156.8240000	0.00
MV	EMP	186.7060000	0.01

The Financials industry sector had conflicting affects of information technology as a percent of sales. ROI, ROE, and ROA were all significant and strongly negative but three year return on sales was positive.

Table 10
Information Technology sector

Y	X	Coefficient	p value
ROA	DEBTRATIO	-46.3580000	0.03
MV	CA	-11.1260000	0.05
CF	ITBUD	-8.6750000	0.00
TOBIN'S Q	DEBTRATIO	-6.9150000	0.01
MV LOG	ITBLOG	-1.6450000	0.03
CF	LTD	-1.0690000	0.00
MV LOG	LTDLOG	-0.9880000	0.00
EBIT LOG	LTDLOG	-0.6890000	0.03
EBIT	LTD	-0.5470000	0.02
CF	SALES	-0.2970000	0.02
ROA	MARKET SHARE	0.0000621	0.02
ROI	MARKET SHARE	0.0001177	0.01
EBIT	NCA	0.4210000	0.00
CF	NCA	0.6410000	0.00
CF	CA	0.8470000	0.00
MV	ITBUD	110.8470000	0.03

The information technology sector had a strong market value impact of information technology budget, perhaps in anticipation of future profits. Statistics that measure current activity such as cash flow were negative.

Table 11
Utilities sector

Y	X	Coefficient	p value
MV	CA	-5.0000000	0.01
MV	LTD	-4.8780000	0.00
EBIT	NCA	0.1660000	0.03
MV LOG	SALESLOG	0.8570000	0.04
MV LOG	ITBLOG	0.9810000	0.02
MV	NCA	2.0270000	0.00
MV	ITBUD	79.0290000	0.00
PE	ITB%SLS	594.0850000	0.03

The Utilities industry had strong market impact of IT budget with market value and price/earnings ratio significantly impacted by IT budget dollars and IT budget as a percent of sales respectively.

Conclusion

The Productivity Paradox may be significantly influenced by industry stratification. In a number of industries, Information Technology expenditures had a significant and positive impact on firm productivity based on a common financial or market based measure. Further study needs to be performed to confirm these findings and more completely understand these industry level effects. No firm conclusions can be reached but further study is warranted.

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