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A Firm Level Study of Information Technology Productivity to Company Size Using Financial and Market Based Measures

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ABSTRACT
The Productivity Paradox, first identified by economist Robert Solow, is the concept that despite increases in information technology expenditures, productivity gains have not been recognized in industry. The author has analyzed past data and determined that over an extended number of years there is no significant and positive correlation at a firm level between information technology spending at a firm level and firm productivity as measured by a variety of market and financial based measures. Significant research has identified firm size as a factor in firm level analysis. This study measures whether stratification by firm size results in positive and significant correlations between information technology and firm level performance. The report analyzes the last year that information technology expenditures by firm were openly published. The results lead to the conclusion that for the data set analyzed there remains a Productivity Paradox since only two of sixty analyses provide significant correlation. Separate analysis by firm size does not result in significant correlation between information technology expenditures and firm productivity as measured by financial and market based dependent factors.

INTRODUCTION
In 1987, Robert Solow wrote a brief article in the New York Times that suggested that "you can see the computer age everywhere but in the productivity statistics." The main concept presented in the article was the Productivity Paradox, where increasing monies were being spent on computers and information technology, yet there were no identified gains in productivity from these increased expenditures. As a result of this article a large number of researchers began to study whether there were identifiable gains in productivity from information technology. Studies were performed at the macroeconomic level (for example, Strassman (1999), Berndt and Morrison (1991), and Morrison (1996)), the specific application level (Mukhopadhyay, Lerch, and Mongol (1997), Mukhodpadhyay, Kekre, and Kalathur (1995), Banker, Kauffman, and Morey (1990)), and at the company or firm level(Bharadwaj, A., Bharadwaj, S., and Knosynski, B. (1999), Alpar and Kim (1990), Kwon and Stoneman (1995), Brynjolfsson and Hitt (1996)). Conflicting results were obtained as a result of hundreds of studies at these different levels. Not only were there different levels where analyses were performed but there were also a variety of measures used to determine productivity. Most of these factors however focused on financial and market performance measures. This report presents brief reviews of some of these past studies and examines firm size as an influence in firm performance. The report then analyzes firm level data within these different company size levels to extend the Productivity Paradox study and determine if productivity gains for information technology productivity can be identified within similar sized firms.

MACROECONOMIC STUDIES
There have been many researchers who have attempted to find a relationship between information technology expenditures at an overall macroeconomic level with mixed results. As an example, Morrison (1996) analyzes government data and revisits the Productivity Paradox at the manufacturing industry level. Data are from the U.S. Bureau of Labor Statistics, and incorporates analysis from the Bureau of Economic Analysis and from Gorman, Musgrave, and Associates on the separation of capital stock and investment into three categories of investment. O is office, computing, and accounting machinery or information technology equipment. E is non-office durable equipment and S is structures. From this basic data, Tobin's q market value ratios of the equipment were created. The study basically analyzes data from 1972 and 1991. Tobin's q is used to measure the estimated cost benefit of the O equipment. The results of the analysis are that the marginal product of O equipment is positive but with significant differences over time in industry. There were strong returns in the 1970s but a gradual decline, though still positive in the mid-1980s, and back up again in the late 1980s. The author postulates there was over-investment in the mid-1980s but this was mitigated by lower prices in the late 1980s. The highest decline in the mid-1980s was experienced in the durable goods industry and continued into the early 1990s when non-durable goods recovered. Savings from high-tech capital come from reduced materials, not labor. In fact, high-tech capital is correlated with an increase in labor. Energy demand is somewhat mixed, with nine industries showing a positive correlation while 11 were negative.

APPLICATION LEVEL
Another approach to information technology productivity has been to analyze specific implementations and determine gains resulting from a specific application. There have been reported successes in the literature such as Banker et al. (1990) who found that Hardee's implementation of information technology point-of-sale system called Positran resulted in total savings for the chain of an estimated 2.7 million dollars.

Mukhopadhyay, Lerch, and Mongal (1997) studied the introduction of new information technology on toll collection on the Pennsylvania Turnpike and found that information technology did reduce indirect labor from 6.79 toll collectors to 5.54, and is statistically significant. There is a 15 percent increase in overall labor productivity with a 30 percent improvement in complex transactions, but no improvement in simple transactions.

FIRM LEVEL
One of the most studied areas has been analysis of information technology at the firm level. An example of this type of analysis is Lichtenberg

(1995) who uses the IDG Computerworld data, InformationWeek firm level data, as well as Compustat data for the period 1988 — 1991 to perform a firm level analysis of the productivity impact of information systems spending for this time frame. The study attempted to determine whether information systems spending and information systems labor at the firm level had a positive impact on productivity. Some of the findings of the study were that the marginal rate of substitution for information systems labor was six, that is, six employees could be replaced with one information technology employee without affecting output. He found significant excess returns with information systems capital and information systems labor. A production function was used.

The author of this paper has performed a comprehensive firm level analysis over the time period 1989-1999 using 13 different financial and market based measures and found no consistent significant and positive increases in productivity as a result of increased information technology expenditures. This study extends this analysis by separating the data set by firm size to determine whether productivity gains can be determined through the inclusion of this stratification.

FIRM SIZE

A number of researchers have determined that firm size has a significant impact on a variety of firm performance measures. Pagano and Schivardi (2003) found a significant and positive relationship between the size of a firm and its growth. They postulate that research and development have some impact on this relationship. The research relationship is explored by Stock, Greis, and Fischer (2002) who note a positive correlation between "dynamic innovation" and firm size. Orlitzky (2002) notes an impact of firm size on the confluence of social performance as well as financial performance. Firm size is even recognized as having an impact on investment timing decisions with smaller firms making quicker investment decisions (Joaquin and Khanna, 2001).

SPECIFIC ANALYTICAL TECHNIQUES AND MEASURES OF PERFORMANCE

In addition to a production function, researchers use a variety of statistical concepts and other analytical techniques to analyze their research. Brynjolfsson and Hitt (1996) use integrated seemingly unrelated regressions (ISUR) to measure the effects of the independent variables, capital, staff, and other labor, on the dependent variable output. In total there were over 1000 output observations. Gurbaxani et al. (1998) used ordinary least squares regression analysis was performed to uncover the findings. Kelley (1994) used least squares regression in her application level study.

In order to measure productivity, researchers have used a variety of measures. Following up on Bender's research, Alpar and Kim (1990) measured return on equity and the ratio of information technology expenses to total operating expenses. Many market and financial measures have been used in past studies.

KEY RESULTS

There have been conflicting results on the impact of information technology spending on firm productivity. Bharadwaj et al. (1999) developed and tested two models. The first model tested the association between the control variables and Tobin's q (firm and industry level), and the second measured the effect of information technology on Tobin's q after adjusting for the control variables. The results of the regression study for the two studies showed that information technology expenditures increased q significantly, and had a statistically significant positive correlation. The results, though positive over all the five years noted, decreased over the last few years of the study.

Alpar and Kim (1990) find that information technology reduces costs, with a 10 percent increase in information technology associated with a 1.9 percent decrease in total costs. The correlation of this was 86 percent. Information technology also reduced the amount that individuals held in demand deposits with an increase in time deposits. The authors suggest this is due to technology making the change easier for individuals.

Attewell and Rule in 1984 present a review of the literature on the effects of computers and information technology on the nature of work itself. After a thorough review of the literature (125 references), they find that there are conflicting conclusions from these disparate studies. In *The Productivity Paradox of Information Technology*, Brynjolfsson (1993) shows negative correlation between productivity and information technology. In *Paradox lost? Firm Level Evidence on the Returns to Information Systems Spending*, Brynjolfsson and Hitt (1996) found that computer investment did measurably contribute to firm level output.

Tam's hypothesis (1998) was that information technology correlates with both business performance and stock market return. The performance measures for his first hypothesis included return on equity, return on assets, and return on sales. For hypothesis two, total shareholder return and market value of the firm were used as productivity measures. The two hypotheses did not provide extremely favorable results. There were mixed results for hypothesis one with some countries showing positive correlation and others not. There was no correlation with total shareholder return, and hypothesis two was rejected.

HYPOTHESIS OF THIS STUDY

This study takes as its framework the issue of the Productivity Paradox and the conflicting and often disappointing results from information technology investments. It attempts to address the issue by separately analyzing the relationship between IT expenditures and productivity for each of six separate company size categories. The information for the study came from InformationWeek 500 edition 1995 (the last year detailed data was openly published) and was supplemented with financial and market data from the Compustat Standard and Poor's database. The specific hypothesis of the study was:

Firm size level analyses will show similar positive, firm level returns from information technology investments.

The firm size categories were individually analyzed to determine whether there have been consistent returns within each size category. The InformationWeek 500 database was sorted by firm size. The size categories are presented in Table 1.

Each of the six size categories was analyzed to determine if there were consistent and positive returns from information technology expendi-

Table 1. Size of Firm

Category	Size of firm in sales
1	greater than $50,000,000,000 in sales
2	$25-50,000,000,000 in sales
3	$10-$25,000,000,000 in sales
4	$5-$10,000,000,000 in sales
5	$1-$5,000,000,000 in sales
6	$0-$1,000,000,000 in sales

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

tures within similar sized firms. Only five of the six categories had sufficient data points for statistical analyses. Category 1 was excluded from the analyses. The firms were then analyzed based on twelve different financial and market based performance and productivity measures shown in able 2. Least squares regression was used to determine the IT variable correlation coefficient and its significance. A significance level of $p < .05$ was used as the threshold level.

Other factors were also included in the multiple linear regressions. The form of the equations was

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

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

RESULTS

The results of the analysis were that information technology expenditures did not have a significant and positive impact on firm productivity. The hypothesis was rejected.

Firm size level analyses did not show similar positive, firm level returns from information technology investments.

The result of 60 different analyses with five different firm size categories yielded only two situations (3%) where information technology related expenditures had a significant (at $p < .05$) effect on the financial or market independent variable. Those two situations are noted in table 3, where information technology expenditures had a significant and positive effect on cash flow of firms sized between \$10 and \$25 billion. The other significant factor was information technology expenditures as a percent of sales which had a significant but negative effect on the price/earnings ratio of firms sized between \$5 and \$10 billion. All analyses for market and financial based market measures as dependent variables showed no relationship with the information technology related independent variables. All of the other 58 analyses (97%) showed no significant relationships.

Table 3. Significant IT Variables

Size	Y	X	Coefficient	p value
\$10-25 billion	Cash Flow	ITBud	1.33	0.008
\$5-10 billion	PE	ITBud%	-490.911	0.027

Table 4. \$25-50 Billion in Sales

Y	X	Coefficient	p value
Cash Flow	CA	0.231	0.04
Cash Flow	NCA	0.304	0.033
EBIT	CA	0.483	0.011
EBIT	NCA	0.324	0.035

Table 5. \$10-\$25 Billion in Sales

Y	X	Coefficient	p value
Cash Flow	LTD	-0.394	0
EBIT	LTD	-0.324	0.001
Market Value	LTD	-5.608	0.001
EBIT Log	LogLTD	-0.27	0.004
MV Log	LogCA	1.108	0.015
CF Log	LogLTD	-0.571	0.002
ROA	Debt Ratio	-11.078	0.04
ROE	Debt Ratio	-34.222	0.009
Cash Flow	Sales	-0.105	0.015
EBIT	NCA	0.206	0
Market Value	NCA	2.632	0.001
EBIT Log	LogEmp	-0.228	0.048
MV Log	LogLTD	-0.396	0.008
CF Log	LogSales	1.636	0.007
Cash Flow	ITBud	1.33	0.008
MV Log	LogNCA	1.766	0.008
CF Log	LogEmp	-0.505	0.024
Cash Flow	NCA	0.217	0

Table 4 shows the significant factors for the \$25-\$50 billion sales category. Only current assets and non-current assets had a positive significant impact on two of the performance measures, cash flow and earnings before interest and taxes (profits). None of the IT factors were significant.

Table 5 illustrates many factors which were significant in this third largest firm size category. As noted, in this category, there was one factor, IT budget which had a significant and positive impact on one performance measure, cash flow. Every dollar increase in IT budget had a corresponding 1.33 dollar increase in cash flow. In this size category balance sheet items including long term debt and non-current assets had significant influence on many financial and market performance measures.

The \$5-10 billion sales category analysis uncovered a negative correlation between IT as a percent of total sales and price/earnings ratio. This is counter-intuitive in that it suggests higher IT expenditures lead to a lowered market valuation. Factors which positively affected performance were current assets and non-current assets. Sales and employees in two factors negatively affected cash flow and 3 year percentage return.

Finally, the smallest category in this study showed many significant factors but none for information technology. Again, balance sheet items predominate with long term debt having a negative and significant relationship with three productivity factors. Other balance sheet items such as non current assets, debt ratio, and current assets also were significant in some analyses.

Table 6. $5-10 Billion in Sales

Y	X	Coefficient	p value
Cash Flow	Sales	-0.115	0.01
EBIT	LTD	-0.246	0
Market Value	CA	3.902	0.002
3Yr Return	EMP	-0.366	0
CF Log	LogSales	-2.967	0
PE	ITBud%	-490.911	0.027
Cash Flow	NCA	0.107	0.001
EBIT	NCA	0.151	0
Market Value	NCA	1.01	0.029

Table 7. $1-5 Billion in Sales

Y	X	Coefficient	p value
Cash Flow	LTD	-0.121	0.001
EBIT	LTD	-0.0871	0.038
Market Value	LTD	-1.691	0.005
3Yr Return	CA	0.01484	0.01
EBIT Log	LogNCA	0.913	0.01
MV Log	LogCA	0.806	0.003
CF Log	LogLTD	-0.186	0.008
Tobin's q	Debt Ratio	-0.99	0.05
Cash Flow	NCA	0.128	0
EBIT	Sales	-0.0638	0.017
Market Value	NCA	0.98	0
3Yr Return	EMP	-0.982	0.005
MV Log	LogLTD	-0.318	0
CF Log	LogNCA	1.335	0.001
EBIT	NCA	0.107	0
MV Log	LogNCA	1.263	0.004

CONCLUSION

Overall, the results of the study suggest that firm size is not a mitigating factor in influencing the lack of productivity gains resulting from increased firm level information technology expenditures. Firm size level analyses did not show similar positive, firm level returns from information technology investments. Further study is warranted in a variety of areas to analyze other factors' influence on firm level information technology productivity.

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