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A Framework of Information Technology Productivity Studies

Alan R. Peslak
Penn State University - Worthington Scranton, 120 Ridge View Drive, Dunmore, PA 18512 USA, peslak@psu.edu

ABTRACT

One of the most studied issues in all of management science has been the Productivity Paradox, the seeming decrease in productivity that has occurred despite increased investment in information technology. But despite all the analysis, a framework for these studies has been missing. The objective of this study is to provide a structure of information technology productivity in a comprehensive fashion as well as provide a framework for further research. The study reviewed over 20 years of information productivity analyses and prepared a framework for review of these studies. The framework starts with the early identification of a productivity paradox. Three broad categories of IT studies are then categorized: overall macroeconomic studies, specific application level studies, and company or firm level studies. Other elements of the framework include a review of techniques and analytical methodology studies, the overall applicability of the production function for IT productivity, specific analytical techniques utilized, and measures of performance and productivity. Finally, there is a review of key results and the reasons proposed for the results. This framework can be utilized to further research on the specific elements of IT productivity by focusing resources on each key relevant area. The major contribution of the study is that it provides a broad comprehensive framework based on a review of the impact of information technology on firm and economic productivity. The study highlights specific methods to determine instances of higher and lower information technology productivity.

INTRODUCTION

Perhaps no topic in Information Systems has been analyzed as much as information technology productivity. For a period of nearly three decades, many researchers including Erik Brynjolfsson (1993), Cron and Sobel (1983), and Dewan and Kraemer (1998) have studied the problem of whether the huge investment in information technology (IT) has had a consistent positive impact on overall productivity in the economy. Yet despite all this attention, there is no agreement on whether IT has consistently and positively impacted productivity over the past three decades. This research develops a framework for study of this important question based on reviews of the dozens of studies.

The term Productivity Paradox was coined in 1987 with Robert Solow, the noted economist, who said that computers can be seen everywhere but in the productivity statistics (Solow, 1987). The Productivity Paradox stated that investigations in the late 1980s and early 1990s seemed to show that IT investments, by a variety of measures, were not contributing to overall productivity gains. Many studies since that time have come to different conclusions on the impact of IT investments.

Some of the questions arising from a review of the literature and that need to be answered through a research agenda include the following:

What measures of performance should be used for information technology productivity studies?
Do the measures match the reasons for the undertaking of projects?
Are financial and/or market based measures appropriate?
Are financial measures accurate measures of performance, productivity, or success?
Are market measures accurate measures of performance, productivity, or success?
What have the results been over the years?
Why do the results differ?
Have any of the proposed theories for the Productivity Paradox been empirically studied?

In order to answer these questions, a proposed analytical framework needs to be developed. This report reviews the literature briefly focusing on the major progress of research over more than 20 years with regard to IT spending and productivity. The framework for these studies includes the following components.

- Identification of the Productivity Paradox;
- Macroeconomic studies;
- Application level studies;
- Firm level studies;
- Applicability of the Production function;
- Specific analytical techniques;
- Measures of performance;
- Key results; and
- Reasons theorized for results.

IDENTIFICATION OF THE PRODUCTIVITY PARADOX

The first area of the Productivity Paradox analysis framework is recognition of the problem of increased information technology spending without corresponding productivity gains. This area focuses on a definition of information technology, determination of the history of information technology and when it was determined to be potentially non-productivity enhancing. A comprehensive review of this area can lead to a better understanding of the productivity problem and provide further avenues of analysis for the future.

There are a few early studies that did begin to recognize the issue of information technology productivity and measure its impact. The studies actually predate the concept of the Productivity Paradox triggered by the 1987 Solow article. One of the very first articles, published in 1983 by Cron and Sobel, is regarded as one of the seminal articles on IT productivity. Cron and Sobel began their study by noting that surprisingly, the growth in IT expenditures over the last 10 years was done without any analysis of the impact on the firm. In general, the results of the authors' study are somewhat mixed, with no clear-cut advantages seen from IT. Surprisingly, little work has been done extending this study.

MACROECONOMIC STUDIES

There are three ways to study the information technology productivity impact; at the macroeconomic level, at the specific application level, and at the firm level. The question of how best to measure returns from information technology has been a central issue for researchers. Attempts have been made to try to measure IT expenditures impact on the overall economy, but these studies have been overall unsuccessful in demonstrating a clear relationship between IT and productivity gains or losses. Many extraneous factors have influenced the US and world economy over the studied time periods and reliability of macroeconomic data has been suspect. Nevertheless, an attempt to measure the impact on the economy through macroeconomic variables is an extremely valuable area for further research. As noted, many attempts have been already made.

Authors who have attempted to review IT productivity at the macro level were Griliches (1995), Strassmann (1999), Dewan and Kraemer (1998), Berndt and Morrison (1995), Brynjolfsson (1993) and Morrison (1996).

Overall macroeconomic studies of information technology productivity have been plagued by uncertain data, extraneous factors, and mixed results. A clear understanding of what is included in IT, accurate macroeconomic data, and comprehensive statistics (goods and services) are necessary to further this research. An issue at the macro level is whether information technology is a significant enough factor to allow for an impact in the overall economy. This also has not been resolved by researchers. Finally, if IT has had a significant impact on the economy, when did it start and does it still continue.

APPLICATION LEVEL STUDIES

With unsuccessful results at the macro level, many researchers have attempted to view the impact of information technology at a specific application level. Many studies have been performed but the major problem with research at this level is the lack of extrapolation potential. Isolated specific successes or failures at the application level do not lend themselves to generalizations about further or other information technology expenditures. Though many studies have explored this area successfully, none have attempted to generalize from their observations. For meaningful research to come from this area, there must be general enough applications that can be repeated in other industries, and situations for meaningful conclusions to be drawn. The implementation of enterprise resource planning systems such as SAP and its large installation base perhaps offer opportunities in this area.

The other significant factor in application level studies is the effect of the studying itself. When these specific applications were studied in detail, did the mere observation produce the desired effects, or was it actually the technology. Similarly, did significant "unpaid" help from the researchers or their assistants contaminate what otherwise would have been unsuccessful projects. These areas are not addressed in the major existing application studies.

Researchers who have worked at the application level were Banker, Kaufman, and Morey (1990), Kwon and Stoneman (1995), and Mukhodpadhyay, Kekre, and Kalathur (1995).

FIRM LEVEL STUDIES

With macroeconomic data difficult to obtain and application studies not able to be generalized, one of the most studied areas of information technology productivity has been at the firm level. Owing in large part to industry publication surveys of information technology spending at the firm level, there have been numerous studies that have measured firm productivity. Adding to the allure is the availability of large amounts of financial and market data at the firm level. Its appeal is that data though self-reported seem to be generally reliable and analysis at this level could readily be extrapolated to other firms of similar characteristics. But this area as well has provided inconsistent results over the past two decades. The impact of other factors including competition, the economy, information technology trends, and the significant amount of software failures over the past two decades have proven to make easy answers much more complex. For this promising research area to yield more significant and consistent results, there must be a much more in depth review of the firms studied and include all tangible, intangible, competitive, economic, environmental, and management factors possible to eliminate all extraneous variables and truly measure the impact of changes in solely information technology.

Authors researching at the firm level have been most numerous including Alpar and Kim (1990), Bharadwaj, Bharadwaj, and Knosynski (1999), Brynjolfsson and Hitt (1998) ,Gurbaxani, Melville and Kraemer (1998), Lehr and Lichtenberg (1999) , Tam (1998), Brynjolffsson and Hitt (1996), Brynjolfsson and Hitt (1997), Grover, Teng, Segars, and Fiedler (1998), and Lichtenberg (1995).

APPLICABILITY OF THE PRODUCTION FUNCTION

Another issue is the methodology to record the impact of information technology on performance and success of the firm. Though the production function does not perhaps fully cover all the reasons for the undertaking of IT projects, it can reasonably provide a measure of output in terms of clearly measured input. Many studies both for information technology and other factors have demonstrated the utility of the production function. An issue for IT however remains the proper form of that function, namely regular, Cobb-Douglas or some other variation.

Many researchers have used the production function as the basis for their empirical studies. Alpar and Kim (1990) begin their article by discussing the basis for analysis in microeconomic theory, using a standard production function of Y equals F(X), where Y is an output and X is a series of inputs. Brynjolfsson and Hitt (1996) fit their data to a Cobb-Douglas production function. Grilches and Mairesse (1984) use a simple extended Cobb-Douglas production function after considering trans-log functions. Gurbaxani, Melville, and Kraemer (1998) use a standard Cobb-Douglas production function. Dewan and Kraemer (1998) use a traditional Cobb-Douglas production function. Lehr and Lichtenberg (1999) use a Cobb-Douglas production function.

SPECIFIC ANALYTICAL TECHNIQUES

The general standard for analytical techniques used in analysis of information technology has been various methods of multiple linear regression. It appears that this methodology is appropriate for the questions at hand, but if other non-quantitative factors are determined to be significantly influential in information technology success, then perhaps other methods will need to be examined to include this data. These issues are raised in the following section, Measures of performance. The issue is what analytical techniques should be used to determine input factors, output factors, and the relationship thereof. Brynjolfsson and Hitt (1996) , Capon, Farley, and Hoenig (1990), Hitt and Brynjolfsson (1996), De Long and Summers (1991) all used least squares regression.

MEASURES OF PERFORMANCE

Perhaps the key issue which has gone un-researched is the determination of what is the true measure of success for an information technology project. Until this area is researched, it cannot be fully determined what the proper measures of performance or success are and similarly it cannot be determined what analysis techniques to use. In past studies, researchers have used a variety of measures. Alpar and Kim (1990) measured return on equity and the ratio of information technology expenses to total operating expenses.

Berndt and Morrison in 1991 used two measures of improved economic performance — labor productivity and profitability. Within labor productivity two measures were used — output divided by labor input, and output growth minus an aggregate growth of all inputs. Profitability indices used were internal rate of return, revenue divided by operating costs, and revenue divided by total costs. Bharadwaj et al. (1999) suggest that Tobin's q (a market value measure) accounts for two aspects of performance that traditional accounting measures do not. These are future performance and intangible values. Cron and Sobel (1983) propose performance measures that are generally financial and accounting measures, and include pretax return on assets, return on net worth, pretax profits as a percent of sales, and average five-year growth. Griliches (1995) suggests there are problems of measurement for IT productivity. Initially Jarvenpaa and Ives (1990) used sales growth as a measure of success. Rai, Patnayakuni, and Patnayakuni (1997, July) develop two output measures, sales and value (labor expense), two performance measures, return on assets and return on equity, and two productivity measures, labor and administrative. The measures of productivity used by Weill (1992) include sales growth, return on assets, amount of non-production expenses per million dollars of sales, percent change in labor productivity statistic, information technology expenditures divided by total sales, and information technology investment by strategic, informational, and transactional type.

KEY RESULTS

Overall results have been mixed in terms of whether information technology has provided increased productivity for the firm or whether these expenditures have been a success or not. Clearly similar data from similar sources cannot provide so disparate results. There must be attempts to reanalyze similar studies and determine the reasons for conflicting results. Only through this analysis can it be determined what the true impact of information technology expenditures have been.

Bharadwaj et al. (1999) showed that information technology expenditures increased Tobin's 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. Banker et al. (1990) 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. 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. The return on computer capital was calculated to be 81 percent over the data set and time frame. Dewan and Kraemer (1998) found the average return on information technology capital in this international study to be 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).

REASONS THEORIZED FOR RESULTS

Finally, many researchers have attempted to determine the reasons for conflicting study results in the IT productivity arena. There has been little research to test these theories and determine their validity. As a general rule, none of these areas have been empirically studied to determine their validity. This is an area that requires extensive testing and research.

Some authors have attempted to theorize on the reasons for the Productivity Paradox. Sichel (1999) postulates two reasons for the sluggish productivity growth in the early 1980s: the time lag effect, and the possibility of a temporary anomaly. Brynjolfsson (1993) proposed four possible reasons for the early negative results when looking at information technology investments and their impact on productivity:

1. Measurement error
2. Time lag
3. Redistribution
4. Mismanagement

Mismanagement would include the result of many project failures. Many authors have decried the lack of productivity measures for the burgeoning service industry as one of the reasons for the information technology Productivity Paradox of the 1980s and early 1990s. Lehr and Lichtenberg (1999) suggested that the reason for conflicting results from older data is that there is primarily a measurement problem. Ralston (1998) also suggests much of the alleged Productivity Paradox is due to the inaccurate data.

CONCLUSION

The review of the literature shows that many of the key issues involved in this complex issue have only been partially addressed. This report has been a study of the productivity paradox, a framework for further study, a review of the literature and a call to action. Specific research can now be performed within this framework to specifically address this vital research question.

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