An Empirical Study of the Casual Relationship Between IT Investment and Firm Performance

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The promise of increased competitive advantage has been the driving force behind the large-scale investment in information technology (IT) over the last three decades. There is a continuing debate among executives and academics as to the measurable benefits of this investment. The return on investment (ROI) and other performance measures reported in the academic literature indicate conflicting empirical findings. Many previous studies have based their conclusions on the statistical correlation between IT capital investment and firm performance data of the same time period. In this study we argue that the causal relationship between IT investment and firm performance could not be reliably established through concurrent IT and performance data. We further submit that it would be more convincing to infer causality if the IT investments in the preceding years are significantly correlated with the performance of a firm in the subsequent year. Using the Granger causality models and three samples of firm level financial data, we found no statistical evidence that IT investments have caused the improvement of financial performance of the firms in the samples. On the contrary, the causal models suggest that improved financial performance over consecutive years may have contributed to the increase of IT investment in the subsequent year. Implications of these findings, as well as directions for future studies, are discussed.

INTRODUCTION

The so-called "Productivity Paradox" has created an increasing awareness of the issues that surround the question: What value does information technology add to an organization? The paradox is described as that "[the] delivered computing power in the U. S. economy has increased by more than two orders of magnitude since 1970, yet productivity, especially in the service sector, seem to have stagnated" (Brynjofsson, 1993, p. 67). Here management is faced with the dilemma: Does it pay to invest in information technology (IT) provided that there are other investment opportunities?

The case literature of the 1980s and 90s attempted to show that IT provided competitive advantages to firms by adding value across all aspects of the value chain, improving operational performance, reducing costs, increasing decision quality, and enhancing service innovation and differentiation (Applegate et al., 1996; Porter and Millar, 1985). More recent literature suggests that sustained competitive advantages can be achieved through building and leveraging key IT assets such as human resources, reusable technology and partnership between IT and business management (Ross, Beath, and Goodhue, 1996). The underlying theory is that these operational and strategic improvements as a result of effective use of IT should lead to corresponding improvements in productivity, revenue, and profits for those firms which consistently make higher investment in IT than their competitors. In the case of high-tech companies, IT often is the product or service that directly contributes to revenue and profit.

There are several empirical studies that support such arguments. Brynjolfsson and Hitt (1996) estimated that the net marginal product of IT staff is about $1.62, and that of IT capital is about 48% or better, which are at least as large as these of other types of capital investment. Mitra and Chaya (1996) showed that the firms that spent more on IT achieved lower cost of production and lower total operating cost when compared with their peers in the same industry, indicating that IT investment indeed improves operational efficiency.

However, not all studies of industry and firm level financial data have shown positive causal relationship between IT investment and improved firm performance. Morrison and Berndt (1990) found that in the manufacturing sector, every dollar spent on IT only delivered on average about $0.80 of value on margin, an indication of overspending in IT. Loveman's study (1994) of 60 business units found that IT investment has a negative output elasticity, indicating that the marginal dollar would have been better spent on other categories of capital investment. Even though such a negative impact of IT on a firm's output seems unlikely and counter-intuitive, it is consistent with the findings of Hitt and Brynjolfsson (1996). Their study of 370 firms showed that IT stock has negative impacts on firm performance measures, such as return on assets, return on equity, and total return, though the magnitude of such impact is quite small.

Closer examinations of these studies, however, revealed a flaw in the methodologies: the impact of IT on firm performance was tested using the IT capital data and the performance data of the same time period. Under such circumstances, the positive and significant correlation between IT capital variables and the firm performance variables has no inherent implication of a causal relationship, no matter how this correlation is established: whether it is through Canonical correlation, economic production functions, or t-tests. This is because one can equally reasonably argue, given the same test results, that it is the higher revenue or profit that caused the firm to spend more on IT capital, or that firms allocate more capital spending when they anticipate better financial performance in the coming years.

In this study, we investigate the impact of IT investment on firm productivity and performance using well accepted causal models based on firm level financial data. We argue that no matter what theoretical or empirical models are used, with the currently available testing techniques, it is unlikely that using concurrent IT and firm performance data would yield conclusive causal relationship between the two. We further submit that it would be more convincing to conclude that IT investment does impact firm performance if it can be shown that the IT investments in the preceding years are significantly correlated with the output level of a firm in the subsequent year, but not vice versa.

RESEARCH BACKGROUND

There is no doubt in the management and MIS literature regarding the value of information and IT in the organizational context. A major problem for senior corporate management, however, is that the "added value" that IT is supposed to deliver to a firm is difficult to discern from business financial data. This could be attributed to several causes, primarily the inability of organizations to track the return of investment in IT when the impact of such investment may cross many business processes and value chain activities. Thus, it is often difficult for IS managers to convince senior management to invest in IT projects when other capital spending opportunities exist.

What is needed is the empirical evidence at the firm level that investment in IT does provide added value to organizations. In light of this position, measuring the effectiveness of information technology has been consistently ranked as one of the most significant issues facing corporate information systems management in the 1980s and 1990s (Brancheau et al., 1996; Sethi and King, 1994). This pressure is only likely to increase with the increasingly fierce competition and the general trend of downsizing, which have forced top management to closely scrutinize any IT investment. As one top executive put it (Violino, 1998, p. 62]: "We understand that enhancing systems is critical in today's world. But we look at every system we get to make sure there's a payback." It is likely that the decision to invest in IT will be increasingly based on the comparative financial returns of IT projects, rather than reported successful IT investment experienced by other organizations.

The necessity to understand IT investment from a value-added perspective has resulted in a new research area: information technology economics. An early study in this area was by Alpar and Kim (1990) who utilized a cost function to examine the impact of IT investment on the financial performance of commercial banks. The results were mostly mixed: IT investment was found to be negatively correlated with cost, while the relationship between the IT expense ratio and the return on equity (ROE) was insignificant in six out of the eight years studied.

In the study of Mahmood and Mann (1993), the Pearson correlation and Canonical correlations were obtained between a set of six organization performance variables and a set of six IT investment variables using the *Computerworld* "Premier 100" companies[1] of 1989. Based mostly on the correlation, it was found that organizational performance measures, such as sales by total assets, market value to book value, and return on investment (ROI), were significantly positively correlated with IT investment measures, such as IT budget as percentage of revenue and percentage of IT budget for training employees. However, it was also found that IT budget as a percentage of total revenue was significantly negatively correlated to performance measures such as sales by total assets, market value to book value and ROI.

Mitra and Chaya (1996) also used the *Computerworld* "Premier 100" companies but with five-year data from 1988 to 1992. The relationship between IT investment and firm performance measures were tested using average values of at least three out of the five data points for each firm. Firms in the sample were grouped into different categories based on normalized z-scores of different operational and performance measures. Then t-tests and one-tailed Mann-Whitney tests were used to determine whether one group is different from another. It was found that high IT spenders had a lower average cost of operation than low IT spenders. It was thus concluded that high spenders on information technology achieve lower cost of production.

A different approach was taken by Barua, Kribel, and Mukhopadhyay (1995) in their study of the business value of IT. Based on the premise that a firm level analysis of IT impact may not provide meaningful guidelines to management, medium and large firms have many IT applications in each primary and supporting value chain activity for which the impacts are not uniform. A two-stage model was used in which the impact of IT was tested using intermediate variables, such as capacity utilization and inventory turnover. Then the impacts of these variables on firm performance measures, i.e., return on assets (ROA) and market share, were tested. It was found that IT capital had a significant impact on most of the intermediate variables, which in turn significantly affected firm performance measures, such as ROA and market share.

Using the IT spending data of large U. S. firms compiled by the International Data Group, Brynjolfsson and Hitt (1996) estimated the contribution of computer capital to the output of firms based on a set of economic production functions. Two major findings were that computer capital had a gross marginal product of 81% vs. 6.26% for non-computer capital, and that for every dollar spent on IS labor, the return was $2.62 on the margin vs. $1.07 on other labor and expenses. These led to the conclusion that the IT "Productivity Paradox" has disappeared by 1991 (Brynjolfsson and Hitt, 1996). In another study, Hitt and Brynjoflsson (1996) included *consumer surplus* to the list of dependent variables for studying the value of IT. Using the same economic production approach, it was found that the IT stock had contributed positively to the production output with a marginal product of 94% and that IT had created substantial consumer surplus over its investment. However, it is also found that IT stock has contributed negatively to profitability measures such as ROA and ROE, though the magnitude of such impact is very small.

The same economic production function approach was also used by Rai, Patnayakuni, and Patnayakuni (1997) in a recent study of the impact of IT investment on firm performance. Using firm level IT spending data published in *Informationweek* in 1994, coupled with other financial data found in the Compustat database, the authors estimated several production functions with different performance variables (ROA, ROE, labor productivity, and administrative productivity) as the outputs and different IT investment categories (IT capital, IT budget, client/server expenditure, staff expenditure, etc.) as the inputs. Overall, it was found that IT investments were positively associated with firm performance (ROA and ROE) and labor productivity, but not with administrative productivity.

A summary of the major studies reviewed above is presented in Table 1. Mahmood and Mann (1993, p. 102) and Brynjofsson (1993, p. 70) provide excellent reviews of some earlier studies of IT investment impact on firm performance. Overall, the literature on the IT impact on firm performance has been overwhelmingly positive. However, few of the these studies used explicit causal models, while supposedly it was the causal relationships between IT investment and firm performance that was under investigation. These studies often concluded or implied causality by asserting that IT investment impacted firm performance based on the established statistical correlation between the variables of these two factors. In essence, all that has been established in these studies is that IT investment and firm performance are *related*. It could be that the increase in IT investment has caused the improvement in firm performance. Or it could well be that the improvement in firm performance has caused the increase in IT investment. As indicated by Hitt and Brynjolfsson (1996, p. 137) "... a key assumption of the production function approach is that input 'causes' output. Yet, it may also be true that output 'causes' increased investment in inputs, since capital budgets are often based on expectations of what output can be sold." Without the explicit testing for causal relationship, the correlation-based models will not discover the true relationship between IT investment and firm performance.

Another flaw in the previous studies is the use of IT data and firm performance data of the same time periods. Causal relationships between two factors inferred from concurrent data assume instantaneous causality between the two factors. It is highly suspicious, if not unlikely, that such instantaneous causal relationship exists between IT investment and firm performance. The lagged effect of IT investment on firm performance has been suspected by Osterman (1986), Brynjolfsson (1993), and Loveman (1994), though no significant empirical evidence has emerged in the literature. On the other hand, the argument for instantaneous causality between IT investment and firm performance (e.g., Rai et al., 1997) appears rather weak.

With an understanding of the significance of the issue and the apparent limitations of previous studies, we attempt to accomplish two objectives in this study. First, to determine whether there is a causal relationship between IT investment and firm performance with explicit causal modeling techniques. If such a causal relationship is found to exist, then the second objective is to determine the direction of the causal relationship. The next section presents our research model and hypotheses.

RESEARCH MODEL AND HYPOTHESES

While many of the previous studies have provided significant insight into the issue of economic value of IT to business from different perspectives, the conclusions were almost always based on the correlation between concurrent IT-related data and performance-related data. The problem is, *correlation does not necessarily imply causation*. These correlations can be equally logically interpreted in the opposite direction.

In a system with two observable variables or vectors of variables, X and Y, in order for a researcher to claim that X causes Y, three commonly accepted conditions must hold

(Kenny, 1979, p. 3):

- *Time precedence.* Causal relations are assumed to be fundamentally asymmetric, while many statistical measures are symmetric. That is, for X to cause Y, X must precede Y in time. Although instantaneous causation is logically conceivable, it is usually difficult to observe. In fact, it is suggested that in many economic situations an apparent instantaneous causality would disappear if the economic variable were measured at more a frequent time interval (Granger, 1969).
- *Relationship.* To establish a causal-effect relationship between two variables, there must exist a functional relationship between the cause and the effect. In judging whether two variables are related, it must be determined whether the relationship could be explained by chance. Statistical methods provide a commonly accepted method of testing whether such relationship exists in the population.
- *Nonspuriousness.* For a relationship between X and Y to be nonspuriousness, there must not be a Z that causes both X and Y such that the relationship between X and Y vanishes once Z is controlled. However, a distinction must be made between a spurious variable and an intervening variable. If X causes Z, and Z in turn causes Y, then Z is called an intervening variable. In this case, the relationship between X and Y is still considered as nonspuriousness.

In line with this discussion, we argue that the causal relationship, if it exists at all, between IT investment and firm performance, could not be established with any degree of certainty using concurrent IT data and performance data with conventional statistical techniques. The commonly used models in many of the previous studies, such as simple and multiple linear regression, the economic productions models, or the structural equation models based on instantaneous causation assumption, are certainly inconsistent with the first condition, and questionable with the third condition at the best.

On the other hand, there are plenty of theoretical arguments and empirical testimonies in the literature that IT investments indeed have impact on firm performance. According to Porter and Millar (1985), the three most important benefits that IT can provide to a firm are reducing cost, enhancing differentiation, and changing competitive scope. Thus the impact of IT investment on firm productivity and financial performance can be hypothesized as follows. IT investment increases IT capital in a firm, which leads to three main results. First, improved efficiency of operation and decision making, which reduces the number of employees, other factors being equal; or more products or services can be produced or offered, other factors being equal. Second, product innovation and differentiation, which increases the market share or demand, other factors being equal. Finally, broadened competitive scope, which leads to a larger market for the product and services, other factors being equal. In any of the cases or as a combined result, the net effect of IT investment should be the increased productivity and better financial performance.

Meanwhile, it has been noted in many studies (e.g., Brynjolfsson, 1993, Brynjofsson et al., 1994; Loveman, 1994; Osterman, 1986) that it takes time to realize the effect of IT capital investment on the bottomline of firms. The logic behind this argument is convincing. The greatest benefits of any IT initiatives come not from replacing old computers with new ones or manual processes with automated ones, in which the effect of investment can be realized immediately, but from organizational and procedural changes enabled by IT, often known as business process reengineering (BPR). The effect of such changes may take years to realize (Hammer, 1990; Stoddard and Jarvenpaa (1993). There are good reasons for such lagged effect. Significant IT projects usually take years to implement. Organization structures need time to adapt in order to take advantage of the new or improved systems. Employees need time to be trained and re-skilled. Finally, customers and the market are the last of these time-delayed chain reactions to respond which ultimately determines the firm performance.

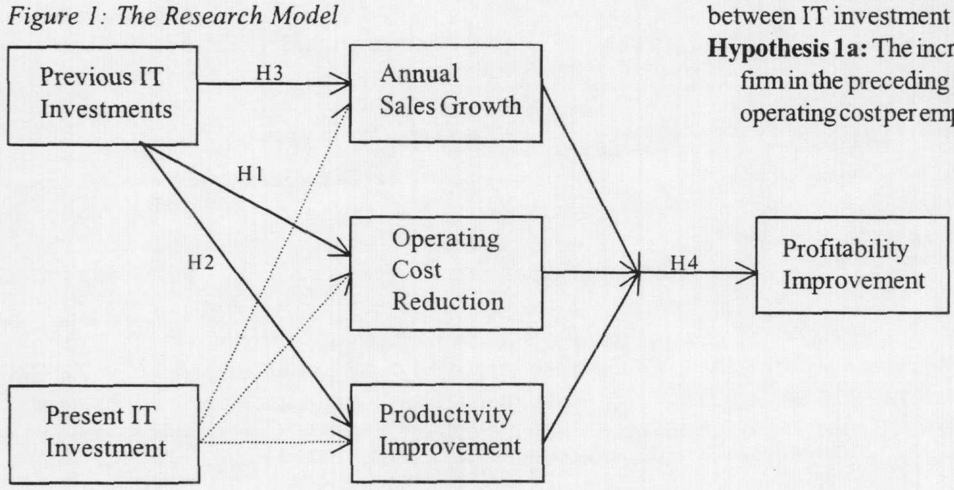
In light of the preceding argument, the following research hypotheses are developed for testing the causality between IT investment and firm performance:

Hypothesis 1a: The increase in IT investment per employee by a firm in the preceding years may contribute to the reduction of operating cost per employee of the firm in the subsequent year.

Hypothesis 2a: The increase in IT investment per employee by a firm in the preceding years may contribute to the increase of productivity of the firm in the subsequent year.

Hypothesis 3a: The increase in IT investment per employee by a firm in the preceding years may contribute to the sales growth of the firm in the subsequent year.

Figure 1: The Research Model



Hypothesis 4a: The increase in IT investment per employee by a firm in the preceding years may contribute to improvement of profitability of the firm in the subsequent year.

The preceding hypotheses can be summarized into the research model shown in Figure 1. The solid arrow lines represent the hypothesized causal relationships in this study, and the dashed arrow lines represent the causal relationships proposed in the previous studies.

Meanwhile, it is also reasonable to argue that the opposite causal relationships exist between IT investment and firm performance. That is, if a firm had experienced consecutive years of good financial performance, it would likely increase capital spending, including IT investment. Thus, the following causal relationships can be hypothesized:

Hypothesis 1b: The reduction of operating cost per employee by a firm in the preceding years may contribute to the increase in IT investment per employee of the firm in the subsequent year.

Hypothesis 2b: The increase of productivity of a firm in the preceding years may contribute to the increase in IT investment per employee by the firm in the subsequent year.

Hypothesis 3b: The sales growth of a firm in the preceding years may contribute to the increase in IT investment per employee by the firm in the subsequent year.

Hypothesis 4b: The improvement of profitability of a firm in the preceding years may contribute to the increase in IT investment per employee by a firm in the subsequent year.

We use the weaker causal relationship "contribute" rather than the stronger relationship "cause" in the hypotheses simply to reflect the fact that IT investments alone would not cause the stated effects. Many operational, technological, and economic factors play significant roles in the performance of a firm. Since we have no control over those other factors, we shall not proclaim that IT investment "causes" these stated effects even if the statistical tests show the existence of the causal relationships between IT investment and these effects.

DATA AND METHOD

Data

One of the major difficulties pertaining to economic studies of IT impact on business is to obtain reliable company IT-related data, such as IT budget, IT stock value, replacement value, and IT staff, etc.. This is because most companies, even the publicly traded ones, regard these data as private and competitive information. Without empirical validation, theories of IT impact on corporate performance or the value of IT to business competitiveness can only be regarded as hypotheses. Academic researchers have explored various avenues for firm level IT data sources. Most relied on data published in industry trade publications and databases; see Table 1 for details.

It would be extremely beneficial if different studies used the same set of data sources, so that theories and inferences could be validated utilizing different research frameworks and methodologies. Unfortunately, among these sources that have firm level IT data, only the *ComputerWorld* (CW) and the *InformationWeek* (IW) databases are publicly available. To test our hypotheses, we need a set of companies that have IT data available for at least four consecutive years. These companies must also be publicly traded on one of the three major exchanges (NYSE, AMEX, and NASDAQ) so that their financial data can be obtained using the widely available Compustat database. For this study, we use the IT data published in a high quality industry publication, *InformationWeek* (IW). IW publishes an annual list of 500 companies that it considers as the largest users of information technologies in the United States. These companies were selected based on their revenue as recorded in the Compustat database.

Like other databases, the companies in the IW 500 lists vary from year to year. In addition, the IT investment data of about half of the listed firms were either not available or estimated by the editors of IW. In order to create reliable and accurate data sets that can be used to test our causal models and hypotheses, we constructed three separate data sets, each of which contains a set of firms that have non-estimated IT data for four consecutive years. Then we matched these firms with the Compustat database and acquired other financial data for each of the firms. The characteristics of the three data sets are shown in Table 2.

It can be seen that the companies included in the three data sets have similar characteristics: they are mostly large corporations, on average, with an annual revenue of about $10 billion, and annual IT spending of about $340 million, and employing about 56,000 people. The companies are well distributed in a variety of industries, with banking, computer/electronics/telecom, and energy/natural resource having a slight lead over other groups.

Method

In order to test the causal relationships submitted in our research hypotheses, we must rely on the established causal modeling methods. Although the difficulties in and the need for causal modeling in MIS research had not been properly addressed until recently (see Lee, Barua, and Whinston, 1997), the literature in social sciences, especially econometric studies, has developed a rich body of alternative causality models for various social and economical issues. Among those, the Granger causal model (1969) exhibits the maximum compliance with the three preconditions of causality; even the instantaneous causation can be accommodated in the model. The major strength of the Granger causality model is in testing the direction of causal effect using time series data in a bivariate system (Sims, 1972; Holland, 1986), which provides an excellent statistical tool for testing the hypotheses we have formu-

Table 1. IT Data Sources Used in Previous Studies

Authors	Data Period	Data Source	Sample Size	Topic	Metrics for Performance and IT investment	Major Findings
Alpar and Kim (1990)	1979-1986	Federal Reserve Bank of New York	624 to 759, varying year to year	IT impact on competitiveness and performance	ROE and Production Cost Ratio of IT Expense to Operation Expense, Level of computer usage	Inconclusive: IT is negatively correlated to operation cost, but insignificant to ROE
Brynjolfsson, Malone, Gurbaxani, and Kambil (1994)	1976-1989	Bureau of Economic Analysis (BEA)	20 industries	IT impact on firm size IT capital per firm	Employee per firm, sales per firm, and value added per firm	IT capital is strongly negatively correlated to firm size measures
Loveman (1994)	1978-1984	Management Productivity and Information Technology (MPIT) database	60 business units of roughly 20 firms	IT impact on firm productivity and performance	Inventory adjusted sales per business unit IT capital of a firm	IT capital has zero or negative correlation to business output measures
Barua, Kriebel, and Mukhopadhyay (1995)	1978-1984	Same as above	60 business units of roughly 20 firms	IT impact on firm productivity and performance	Capacity utilization, inventory turnover, market share, Return on Assets, and etc IT capital and IT purchase, employee cost	IT capital and purchase are positively correlated to intermediate measures such as capacity utilization and inventory turnover, which in turn is positively correlated to performance measures
Mahmood and Mann (1993)	1989	ComputerWorld Premier 100 list	100 firms	IT impact on competitiveness and performance	Return on Investment, return on sales, growth in revenue, etc. IT budget as percentage of total revenue, value of IT as percentage of revenue, etc.	Results are mixed. Correlation analysis shows IT investment is positively related to performance measures, while canonical analysis results are inconclusive, both positive and negative results exist
Hitt and Brynjolfsson (1996)	1988-1992	International Data Group (IDG) annual survey database	370 firms	IT impact on firm productivity and performance	Return on Assets, Return on Equity, Gross sales and value added (Sales minus non-labor expense) IT Stock (IT capital plus IS Staff Budget)	IT stock has contributed positively to total output, however, IT stock is slightly negatively correlated to profitability measures such as ROA and ROE.
Brynjolfsson and Hitt (1996)	1987-1991	International Data Group (IDG) annual survey database	Total 367 firms average 224 firm each year in dataset	IT impact on firm productivity and performance	Output measured by total sales Computer capital and IS Staff Budget	Computer capital and IS staff budget are positively related to increase in output
Mitra and Chaya (1996)	1988-1992	ComputerWorld Premier 100 list	448 firms, varying from year to year	IT impact on firm productivity and performance	Operation and production costs, firm size IT budget as percentage of sales	Firms with higher IT investment have lower operating cost, lower production cost, higher overhead
Rai, Patnayakuni, and Patnayakuni (1997)	1994	Information Week	497 firms, 231 had IT data	Impact on firm productivity and performance	Sales, Return on Assets, Return on Equity, Sales per employee IT capital, IT budget, It staff, software	IT investment is positively related to firm output measures (sales) and profitability measures (ROE and ROA)

*Table 2: Characteristics of the Firms in the Data Sets**

DESCRIPTION	DATA SET #1	DATA SET #2	DATA SET #3
Years Covered	1990-1993	1991-1994	1992-1995
Number of Companies	56	62	42
Revenue, μ (σ), billions	10.82 (13.54)	11.19 (13.73)	12.74 (14.93)
IT Budget, μ (σ), millions	348.88 (763.76)	357.77 (759.32)	412.85 (834.03)
Employee, μ (σ), thousand	56.28 (82.64)	58.09 (83.32)	58.64 (82.53)
Firms in Industry Groups			
Aero/Auto	4	5	4
Airline/Air Freight	3	2	0
Banking	10	9	7
Chemical	3	3	3
Computer/Electronics/Telecom	6	13	8
Consumer	1	2	1
Energy/Natural Resources	9	9	6
Financial Services	5	0	1
Food	1	3	2
Manufacturing	4	3	4
Healthcare	2	3	2
Pharmaceutical	1	2	1
Publishing	3	0	0
Railroad/Transportation	1	0	0
Retailing	1	3	2
Wholesale	2	0	0

* Firms in the three data sets are not mutually exclusive, rather they overlap with each other to a fair degree. An inspection of the data sets reveals that about 50% of the companies overlap in any two adjacent data sets, and about 30% of the companies overlap in all three data sets.

lated.

Let X_t and Y_t be two time series data, the general causal model with consideration of possible instantaneous causality can be written as:

$$X_t + b_0 Y_t = \sum_{j=1}^{n} a_j X_{t-j} + \sum_{j=1}^{n} b_j Y_{t-j} + \varepsilon_t \qquad (1)$$

$$Y_t + c_0 X_t = \sum_{j=1}^{n} c_j X_{t-j} + \sum_{j=1}^{n} d_j Y_{t-j} + \eta_t$$

where ε_x and 7_t are two uncorrelated white noise error terms with zero means.

This definition of causality implies that Y causes X if some b_j is not zero, and X causes Y if some c_j is not zero. If both of these events occur, there is said to be a feedback relationship between X and Y. If b_0 is not zero, then the instantaneous causality is occurring and a knowledge of Y_t will improve the "prediction" or goodness of fit of the first equation for X_t, and vice versa if c_0 is not zero.

Substituting X and Y in the causal model with firm IT data and performance data, we can derive a set of models for testing our research hypotheses. However, before we present the causal models specific to these hypotheses, we need to define each of the variables used to represent IT investment, operating cost, sales growth, productivity, and profitability. To minimize the impact of firm size variations in our samples, it was decided that we should use per employee metrics wherever it is applicable.

IT Investments. The three data sets provide annual IT spending of each firm for four consecutive years. Instead of using the actual values, the change of the annual IT investment per employee is considered as the most appropriate measure for studying the impact of IT on firm performance, defined as follows:

$$\Delta I_t = \frac{I_t / E_t - I_{t-1} / E_{t-1}}{I_{t-1} / E_{t-1}} \qquad (2)$$

where I_t and I_{t-1} are the IT investments by the firm in year t and t-1, E_t and E_{t-1} are the number of employees of that firm in year t and t-1, and ΔI_t is the percentage change of IT investment per employee over the preceding year.

Operating Cost. If IT investment has any impact on firm performance, the operating cost should be the most sensitive area. A firm's operating cost is measured in terms of its selling, general, and administrative expenses as reported in its annual report. In this study, we are more interested in the change of operating cost than the cost itself. Therefore, we define the change of operating cost as follows:

where C_t and C_{t-1} are the selling, general, and administrative expenses in year t and t-1, and E_t and E_{t-1} are the number of employees of that firm in year t and t-1, respectively. ΔC_t is the operational cost reduction per employee.

Sales Growth. Annual sales growth rate is an important indicator of the competitiveness of a firm. If IT investment has any impact on firm performance, it should be reflected in the changes of sales from year to year. In this study, the sales growth is calculated as follows:

$$\Delta C_t = \frac{C_t / E_t - C_{t-1} / E_{t-1}}{C_{t-1} / E_{t-1}} \qquad (3)$$

where S_t and S_{t-1} are the annual sales of a firm in year t and t-1, and ΔS_t is the annual sales growth rate from year t-1 to year t.

Productivity. Labor productivity is defined in general as the output per unit time of labor. In this study, the output is measured in terms of sales, and the time unit is one year. Thus labor productivity of a firm is defined as the annual sales per employee, and the change of productivity is defined as follows:

$$\Delta S_t = \frac{S_t - S_{t-1}}{S_{t-1}} \qquad (4)$$

where S_t and S_{t-1} are the annual sales of a firm in year t and t 1, E_t and E_{t-1} are the number of employees of a firm in year t and t-1, and ΔP_t is the change of productivity of the firm from year t-1 to year t.

Profitability. A firm's profitability is measured in terms of the classic ROA (Return on Assets) and ROE (Return on Equity). Since these measures are already calculated in percentages, the annual changes of profitability are simply defined as follows:

$$\Delta P_t = \frac{S_t / E_t - S_{t-1} / E_{t-1}}{S_{t-1} / E_{t-1}} \qquad (5)$$

$$\Delta ROA_t = ROA_t - ROA_{t-1} \qquad (6)$$

$$\Delta ROE_t = ROE_t - ROE_{t-1} \qquad (7)$$

where ROA_t and ROA_{t-1} are the Return on Asset of a firm in year t and t-1, and ROE_t and ROE_{t-1} are the Return on Equity of a firm in year t and t-1.

The four pairs of research hypotheses can be tested by substituting the Xs and Ys in the Granger causality model (1) with the investment and performance variables defined in equations (2) through (7).

According to the principle of the Granger causality model, there are several possible outcomes from this set of regression equations, each of which provides some insight into the relationship between the dependent variable and independent variables:

- If b_0s or c_0s are found to be significantly different from zero, then there exists instantaneous causal-effect relationship between the change of IT investment and the change of the performance variables;
- If b_js (j = 1, 2, … n) are found to be significantly different from zero and the same is not true for c_js (j = 1, 2, … n), then it should be concluded that the change of IT investments in the previous years (ΔI_{t-j}, j=1, 2, …n) caused, or at least, contributed to, the change of the performance measures (ΔC_t, ΔS_t, ΔP_t, ΔROA_t, or ΔROE_t) in the subsequent year (t);
- If c_j's (j = 1, 2, … n) are found to be significantly different from zero and the same is not true for b_js (j = 1, 2, … n), then it should be concluded that the change of performance measures in the previous years (ΔC_{t-j}, ΔS_{t-j}, ΔP_{t-j}, ΔROA_{tj}, or ΔROE_{t-j}, j=1, 2, …n) caused, or at least, contributed to, the change of the IT investment (ΔI_t) in the subsequent year (t);
- If b_js (j = 1, 2, … n) are found to be significantly different from zero and the same is true for c_js (j = 1, 2, … n), then it should be concluded that there exists a feedback relationship between the change of IT investments (ΔI_{t-j}, j=1, 2, …n) and the change of the performance measures (ΔC_{t-j}, ΔS_{t-j}, ΔP_{tj}, ΔROA_{t-j}, or ΔROE_{t-j}, j=1, 2, … n).
- If all of b_js and c_js (j = 1, 2, … n) are found to be insignificantly different from zero, then it should be concluded that there is no relationship between the change of IT investments and the change of the performance measures.

Table 3: The Causal Relationship Between IT and Operational Cost

Parameters	Data Sets 1990-1993	1991-1994	1992-1995
	Operational Cost as the Effect		
R^2-adj	-0.0459	0.1627	0.1120
F statistic	0.6312	**3.0202	1.9335
Intercept	4.8519 (1.2325)	1.2415 (0.4125)	***9.1060 (3.3979)
a_1	-0.0853 (-0.2480)	-0.0083 (-0.0594)	*-0.4417 (-1.9457)
a_2	-0.0870 (-0.2129)	**0.3893 (2.2898)	-0.0942 (-.3434)
b_0	0.0836 (1.6596)	0.0768 (0.9193)	0.0808 (1.2834)
b_1	0.1489 (1.1798)	-0.0900 (-0.8141)	-0.0898 (-1.3426)
b_2	-0.0154 (-0.2345)	0.0729 (0.8941)	-0.0708 (-0.8610)
	IT Investments as the Effect		
R^2-adj.	0.2837	0.1535	-0.0096
F-statistic	***4.3273	**2.8865	0.9293
Intercept	3.0963 (0.2449)	0.9421 (0.1806)	9.0610 (1.0772)
c_0	0.8291 (1.6596)	0.2300 (0.9193)	0.6060 (1.2834)
c_1	0.6377 (0.5911)	***0.7139 (3.2623)	-0.5779 (-0.8897)
c_2	0.3931 (0.3058)	0.2100 (0.6804)	-0.5031 (-0.6731)
d_1	***-1.3763 (-4.0982)	-0.1912 (-1.0027)	0.0467 (0.2481)
d_2	-0.1909 (-0.9315)	-0.1552 (-1.1055)	-0.1580 (-0.6988)

Table 4: The Causal Relationship Between IT and Productivity

Parameters	Data Sets 1990-1993	1991-1994	1992-1995
	Productivity as the Effect		
R^2-adj	0.0374	0.2568	0.0731
F statistic	1.4273	***5.2165	1.6471
Intercept	2.8143 (1.0971)	4.5869 (2.0858)	10.7476 (4.1925)
a_1	0.3107 (0.3077)	-0.0727 (–0.7407)	-0.2226 (-1.5291)
a_2	0.1966 (0.7719)	***0.4988 (3.4739)	0.0951 (0.4678)
b_0	-0.0619 (-1.4358)	*0.1217 (1.9925)	*0.1143 (1.8257)
b_1	-0.1270 (-1.6106)	-0.0483 (-0.6531)	-0.0253 (–0.3766)
b_2	-0.0367 (-0.6435)	0.0696 (1.1894)	-0.0356 (-0.4753)
	IT Investments as the Effect		
R^2-adj.	0.2700	0.1159	0.0256
F-statistic	***5.0688	**2.5992	1.2158
Intercept	16.1826 (2.0148)	-0.0326 (-0.0068)	5.1805 (0.6543)
c_0	-0.6402 (-1.4358)	*0.5440 (1.9925)	*0.7413 (1.8257)
c_1	-0.8114 (-1.0553)	**0.5209 (2.6488)	-0.2804 –0.7385)
c_2	-0.4316 (–0.5252)	-0.1218 (-0.3642)	-0.1353 (–0.2608)
d_1	***-0.9298 (-4.1434)	0.0007(0.0043)	0.0671 (0.3924)
d_2	-0.2100 (-1.1533)	-0.0604 (-0.4839)	-0.1450 (-0.7639)

We can see that, compared to the conventional regression analysis used in many previous studies, including the studies using economic production models, the tests based on Granger causality model are able to eliminate the chance of confirming false causal relationship resulted from mis-specified regression models.

RESULTS

We estimated the model parameters using least-square linear regression method provided in the SAS software package based on the causality models defined in equation (1) and the three data sets as described in Table 2. The results are presented in Tables 3 through 7 in the Appendix. Notice that since we only have the data for four consecutive years, and we are using the year-to-year changes as variables, the upper limit (n) for subscript j in all the models is two (j = 1, 2). As a result, the causal relationship between the proposed cause and effect variable is tested in three consecutive years (t-0, t-1, t-2).

Since multi-year financial data are involved in the regressions, inflation becomes an important factor. Before conducting the regressions, we inflated the financial figures of the preceding years to the real dollar values of the subsequent year (t) based on the annual percentage change of implicit price deflator of the Gross Domestic Product, as published in the Survey of Current Business (U.S. Department of Commerce, 1997).

In all tables, the numbers in parentheses are the two-tailed t-statistics of the regression parameters, and the statistical significant levels are represented as: *** for $p < 0.01$, ** for $p < 0.05$, and * for $p < 0.1$.

DISCUSSIONS

The tables present a large amount of data about the estimated causality models and their associated testing statistics. To facilitate our discussion, these results are summarized in Tables 8 and 9 and organized based on the research hypotheses.

The results in Table 8 speak out loud and clear: there is no convincing evidence that IT investments in the preceding years have made any significant contribution to the subsequent changes in any of the four categories of firm performance measures: operating cost, productivity, sales growth, and profitability. The only noticeable significant b parameter is the one for the effect of IT investment on the ROA in the 1990-1993 data set ($b_1 = 0.0470$, significant at $p < 0.01$ level). The implication is that the increase of IT investment in the time period of 1991-1992 had contributed to the increase of ROA in 1993 of the firms in the data sets. However, given the overall non-significant tone of the results, this one case of significance is not enough to be considered as convincing evidence to conclude that IT investment has a positive impact on firm profitability.

On the other hand, there is clear evidence to support the hypotheses that firms budget their IT investment based on the financial performance of preceding years, especially the sales growth, as shown in Tables 9. In two out of the three data sets, either c_1 or c_2 was found to be significantly greater than zero for hypothesis H3b. Since the opposite hypothesis H3a is not true, we can conclude with a fair degree of certainty that the changes in sales growth in the preceding years had contributed to the changes of IT investment in the subsequent year: the faster the sales growth was achieved, the more money was allocated for IT investment.

Table 5: The Causal Relationship Between IT and Sales Growth

Parameters	Data Sets 1990-1993	1991-1994	1992-1995
	Sales Growth as the Effect		
R^2-adj	0.0563	0.3027	-0.1177
F statistic	1.6562	***6.2953	0.1362
Intercept	7.8706 (1.5032)	***6.9156 (4.6003)	***12.2512 (2.8656)
a_1	0.2652 (0.7117)	***0.2457 (2.9643)	0.0146 (0.0485)
a_2	0.5320 (1.6358)	***0.4640 (3.8513)	0.1064 (0.4357)
b_0	-0.1440 (-1.5658)	-0.0153 (-0.3686)	-0.0760 (-0.6748)
b_1	-0.0119 (-0.0607)	*-0.0909 (-1.9744)	-0.0454 (-0.3803)
b_2	-0.0595 (-0.4986)	-0.0115 (-0.3250)	0.0369 (0.3260)
	IT Investments as the Effect		
R^2-adj.	0.3319	0.0666	0.3071
F-statistic	***5.9859	1.8710	***4.6335
Intercept	**18.4446 (2.4261)	1.9846 (0.3493)	11.1464 (1.6599)
c_0	-0.3246 (-1.5658)	-0.1586 (-0.3686)	-0.1644 (-0.6748)
c_1	**-1.1285 (-2.0925)	***0.7302 (2.7019)	-0.3805 (-0.8699)
c_2	0.0845 (0.1687)	-0.1780 (-0.4083)	***1.3195 (4.6304)
d_1	***-1.1535 (-4.6949)	0.0912 (0.5964)	**-0.3542 (-2.1368)
d_2	-0.2724 (-1.5531)	0.0482 (0.4218)	-0.0383 (-0.2297)

Table 6. The Causal Relationship Between IT and Profitability: ROA

Parameters	Data Sets 1990-1993	1991-1994	1992-1995
	ROA as the Effect		
R^2-adj	0.0822	0.0512	0.0824
F statistic	1.9851	1.6588	1.7362
Intercept	-0.1784 (-0.3515)	0.6810 (0.7691)	0.7811 (1.2644)
a_1	0.0443 (0.3210)	**-0.3516 (-2.1276)	-0.2356 (-1.1410)
a_2	***-0.3526 (-2.6759)	**-0.5123 (-2.4413)	-0.0180 (-0.1105)
b_0	0.0078 (0.9466)	0.0110 (0.4681)	0.0169 (1.0543)
b_1	***0.0470 (2.6962)	-0.0208 (-0.7515)	0.0054 (0.3160)
b_2	0.0007 (0.0649)	0.0105 (0.4964)	0.0207 (1.0912)
	IT Investments as the Effect		
R^2-adj.	0.2256	-0.0387	-0.0134
F-statistic	***4.2052	0.5460	0.8914
Intercept	18.0419 (2.1995)	2.7491 (0.5434)	10.4976 (1.6893)
c_0	2.2439 (0.9468)	0.3558 (0.4681)	1.7697 (1.0543)
c_1	-1.6436 (-0.7065)	0.9401 (0.9680)	-0.6286 (-0.2928)
c_2	2.7118 (1.1535)	0.7795 (0.6218)	-1.7159 (-1.0431)
d_1	***-1.1368 (-4.1846)	0.1173 (0.7418)	0.0286 (0.1645)
d_2	-0.2025 (-1.0752)	0.0768 (0.6397)	-0.1483 (-0.7590)

This conclusion is further supported by the measures of goodness of fit of all linear regression models. It can be seen from Tables 3 through 7 that when IT investment is used as the effect (dependent variable) and the measures of financial performance as the causes (independent variables), most models' F-statistics are significant at $p < 0.05$ level and R^2-adj.s are at decent levels. When the measures of firm performance are used as the effect and the IT investment as the cause, most F-statistics are insignificant at $p < 0.05$ level and R^2-adj.s are very small.

We also found no evidence to support the hypothesis that there is an instantaneous causality between IT investment and firm performance, as implicitly assumed in many of the previous studies when concurrent IT data and performance data are used to test the causal relationship. According to the principle of Granger causality, if there exists an instantaneous causal relationship between IT investment and firm performance, then either coefficient b_0 or c_0 would be significantly different from zero. Examining Tables 3 through 7, none of the b_0s or c_0s are significantly different from zero at the $p < 0.05$ level. This result casts serious doubt on the research methodology that uses concurrent data for testing causal relationship between IT investment and firm performance.

It should be noted that the effect of industry differences and IT maturity levels of firms on their performance and productivity is not considered in our models and tests, due to the limitation of the data sets. Previous studies of such effect (e.g., Lovemena, 1994; Brynjofsson et al., 1994; and Mitra and Chaya, 1996) have shown mixed results.

CONCLUSIONS

We have shown, through tests using the Granger causality models and firm level data, that the hypothesized positive causal relationship between IT investment and firm performance cannot be established at acceptable statistical significant levels. On the other hand, there is clear evidence that firms had budgeted IT investment based on the financial performance of the preceding years, especially the growth rate of annual sales.

The results of this study have a number of significant implications for future studies of the economic value of IT investment. The first is that many firms, if not all, may have failed to capitalize on their investments in IT through reengineering business processes (Hammer, 1990) and other organizational changes. Year after year firms adjust, usually upward, their IT budget based on the previous year's level simply because their competitors and other members of the industry are doing the same. New versions of software and ever more powerful hardware replace the existing ones, even if they are still adequate for the applications they support. Detailed examinations of how firms actually allocate their IT budget and the subsequent changes are warranted and may shed some light on why IT investments have failed to show at the bottom line of organizations.

Second, overspending in IT by firms may be another complicating factor. Marginal analysis by Morrrison and Berndt (1990) shows that every additional $1 spent on IT only delivers $0.80 in output. This is essentially the same as the findings of two other studies (Brynjolfsson and Hitt, 1996; Hitt and Brynjolfsson, 1996) using different data sets. A recent report by Sentry Technology Group based on a survey of 16,000 large U.S. companies estimates that as much as $66 billon—nearly 10% of total IT purchases—could go into the "inefficient" IT spending category, including purchases of unused or underused hardware, software, and services (Violino, 1997a). "It has become so easy to spend a lot of money on hardware, software, and maintenance – and not necessarily see any return," said one executive (Violino, 1998, p.61). Policies and practices for better IT asset management may be another important area that has been overlooked by both practitioners and academia.

Our final concern is the issue of measurement. Although most studies of the economic value of IT, including the present one, have attempted to associate IT investment with aggregated firm per-

Table 7. The Causal Relationship Between IT and Profitability: ROE

	Data Sets		
	1990-1993	1991-1994	1992-1995
Parameters		*ROE as the Effect*	
R^2-adj	0.8627	0.3184	0.1489
F statistic	***70.1165	***6.6997	*2.4445
Intercept	2.6733 (0.8574)	**5.4298 (2.3329)	3.4128 (1.6514)
a_1	***-0.8161 (-15.6229)	*-0.3600 (-1.8349)	**-0.3017 (-2.7028)
a_2	***-0.9930 (-4.3222)	***-0.4960 (-3.3458)	-0.0008 (-0.0126)
b_0	0.0199 (0.3879)	0.0192 (0.3155)	0.0592 (1.1040)
b_1	*0.1835 (1.7117)	-0.0487 (-0.6560)	0.0329 (0.5754)
b_2	-0.0477 (-0.6906)	-0.0025 (-0.0462)	0.0406 (0.6485)
		IT Investments as the Effect	
R^2-adj.	0.2173	-0.0487	-0.0092
F-statistic	***4.0532	0.4340	0.9256
Intercept	**17.7230 (2.1442)	2.4833 (0.4653)	8.3025 (1.2958)
c_0	0.1506 (0.3879)	0.0924 (0.3155)	0.5534 (1.1040)
c_1	0.0200 (0.0575)	0.3850 (0.8747)	0.3853 (1.0447)
c_2	0.8346 (1.1418)	0.2853 (0.8057)	-0.1476 (-0.7450)
d_1	***-1.0840 (-4.1402)	0.1112 (0.6833)	-0.0279 (-0.1588)
d_2	-0.2046 (-1.0856)	0.0951 (0.8024)	-0.1299 (-0.6783)

Table 8. Hypotheses with IT Investment as Cause and Performance

Hypotheses	Data Sets		
	1990-1993	1991-1994	1992-1995
H1a	$b_1 = b_2 = 0$ No support	$b_1 = b_2 = 0$ No support	$b_1 = b_2 = 0$ No support
H2a	$b_1 = b_2 = 0$ No support	$b_1 = b_2 = 0$ No support	$b_1 = b_2 = 0$ No support
H3a	$b_1 = b_2 = 0$ No support	$b_1 < 0^*, b_2 = 0$ Negative impact	$b_1 = b_2 = 0$ No support
H4a	$b_1 > 0^{***}, b_2 = 0$ Partial support	$b_1 = b_2 = 0$ No support	$b_1 = b_2 = 0$ No support
	$b_1 > 0^*, b_2 = 0$ Partial support	$b_1 = b_2 = 0$ No support	$b_1 = b_2 = 0$ No support

Significant level: *** p<0.01, ** p<0.05, * p<0.1

Table 9. Hypotheses with Performance as Cause and IT Investment as Effect

Hypotheses	Data Sets		
	1990-1993	1991-1994	1992-1995
H1b	$c_1 = c_2 = 0$ No support	$c_1 > 0^{***}, c_2 = 0$ Negative support	$c_1 = c_2 = 0$ No support
H2b	$c_1 = c_2 = 0$ No support	$c_1 > 0^{**}, c_2 = 0$ Partial support	$c_1 = c_2 = 0$ No support
H3b	$c_1 < 0^{**}, c_2 = 0$ Partial support	$c_1 > 0^{***}, c_2 = 0$ Partial impact	$c_1 = 0, c_2 > 0^{***}$ Partial support
H4b	$c_1 = c_2 = 0$ No support	$c_1 = c_2 = 0$ No support	$c_1 = c_2 = 0$ No support
	$c_1 = c_2 = 0$ No support	$c_1 = c_2 = 0$ No support	$c_1 = c_2 = 0$ No support

formance measures, such as ROA and ROE, other alternatives have been proposed. Barua, Kriebel and Mukhopadhyay (1997) advocate the use of intermediate variables (e.g., capacity utilization and inventory turnover) to study the impact of IT since they reflect the direct impact of IT investment. From a different perspective, Brynjolfsson (1996) suggests that if the impact of IT investment fails to show up the in the statistics of producers' performance data, it should be reflected in the surplus that consumers have benefited from lower prices of the products due to the use of IT by the producers.

While both studies provided empirical evidence that support the hypotheses, one central question is: no matter how much IT has contributed to the consumer surplus or the capacity utilization rate, what is the value of IT investment to shareholders if it fails to increase the profitability of a for-profit-organization? "Business leaders, IS executives, consultants, and academics for years have debated whether it's necessary or even desirable to measure IT's return on investment. But the discussion is being cut short by CEOs and chief financial officers with their eyes on the balance sheet. Before granting funds for a major project, these execs are demanding to see the expected payback – in financial terms they understand." (Violino, 1998, p. 61).

It seems that we have raised more questions than provided answers in this study. This is perhaps a reflection of the ongoing debate about the economic value of information technology and how it should be measured properly (Violino, 1997b, 1998). It is our hope that this study will assist in moving the focus of future research on the economic value of IT from the discovery of statistical correlations to the development of new metrics and methodologies that are appropriate for evaluating the causal relationship between IT investment and firm performance.

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ENDNOTE

[1] *Computerworld* is one of the premier national publications on corporate IS related news and issues. It publishes a list of 100 public companies annually named the "Computerworld Premier 100" selected from 1000 companies based on how effectively they use IT. The criteria used to rank the companies, however, are not consistent from year to year. See Computerworld Premier for details (e.g., September 11, 1989 and October 9, 1995)

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