# ON THE STATE-OF-THE-ART: METHODS FOR EVALUATING THE PERFORMANCE EFFECTS OF INVESTMENTS IN INFORMATION TECHNOLOGY

by

**Robert J. Kauffman**
Leonard N. Stern School of Business
Information Systems Department
New York University
90 Trinity Place
New York, NY 10006

and

**Peter Weill**
Graduate School of Management
University of Melbourne
200 Leicester Street
Carlton 3053
Melbourne, Australia

**March 1989**

Center for Research on Information Systems
Information Systems Department
Leonard N. Stern School of Business
New York University

**Working Paper Series**

CRIS #203
STERN #89-40

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

# ON THE STATE-OF-THE-ART:

# METHODS FOR EVALUATING THE PERFORMANCE EFFECTS

# OF INFORMATION TECHNOLOGY

March 1989

Robert J. Kauffman
New York University

Peter Weill
University of Melbourne

---

## ABSTRACT

IT creates impacts at several levels in the firm and often indirectly contributes to firm profitability. The problem IS researchers face is identifying robust methods that give reliable results. This paper reports on state-of-the-art methods in IT value research, reviews eleven major empirical studies and suggests three fundamental classes of considerations for conducting successful IT value research. To illustrate methodological advance, new results are presented from two recently completed IT value studies in financial services and manufacturing. The paper concludes by suggesting untapped theory bases that have the most to offer IT value research.

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

## 1. Introduction

Senior managers responsible for determining the level of a corporation's resources to invest in information technology (IT) are struggling with the difficult challenge of evaluating the impact of their IT investments. In essence, the problem is a simple one: the best IT investments are those which help to maximize the value of the firm. But IT creates impacts at several levels in the organization, and some only indirectly contribute to the firm's profitability. The problem is so complex in practice that a recent Index Systems poll reported that of 240 senior information systems (IS) managers surveyed, 90% said they did not know how to measure the leverage IT was creating. Despite these concerns, still more than one-half believed that their IT investments were enhancing firm performance [11, 13]. Thus, managers are faced with investing in IT with a "gut feel" that value will ensue, without having good measures to determine the performance effects.

Two years ago in a paper which appeared in these proceedings, Bakos [1] appealed to other researchers in the IS field to develop a tradition of common technique, broadly agreed upon and tested value measures, and models which capture the direct impacts of IT, wherever they occur in the firm. It is our observation in 1989 that research efforts appear to be reaching "critical mass" in this branch of IS research. If the major questions are not yet answered, at least they appear to be on the table and under close scrutiny. For example, the *American Banker*, the daily newspaper of the U.S. banking community, published a special issue last year which attempted to evaluate how return and bottom line performance were related to technology investments [42]. *Computerworld* also recently published a special survey on the effectiveness of IT investments, including a description of the method they used to distinguish among leading edge firms and those perceived as having substandard performance [12]. Also, within the last year and a half, the International Center for Information Technology sponsored a seminar series on Measuring Business Value of Information Technologies and published a book with the same name [19]. Finally, in May of this year the Association for Computing Machinery held a "Workshop on Value and Impact of IT".

There is a tremendous amount of research and learning occurring in this branch of IS. The problem that we face as researchers in IT value analysis (and which we share with a large percentage of managers responding to the Index System's poll) is identifying robust methods that give reliable results in a variety of settings. In this paper, we report on eleven important empirical IT value analysis studies. We observe that convergence is occurring particularly in the area of appropriate methods. Our primary goal here is to focus on the question of *methodological advance*, both as a means to help managers get better results and to suggest how additional research can build on the critical mass. Having recently completed separate dissertation research projects on IT value analysis in different settings (financial services [24] and manufacturing [40]), we have experienced first hand the difficulties of getting persuasive results. In this paper we critique the state of IT value research and then present our general findings with respect to the potency of the methodologies available. Recommendations about future directions are also included and we use our own work to illustrate.

The paper is organized as follows. Section 2 briefly describes the IT value studies that we use as the basis of our critique of the state-of-the-art in methods. The eleven studies we have chosen constitute a representative body of work, and a wide range of methods, variables and models were employed. Section 3 extends our critique in terms of the appropriateness of the methods used to get results. To structure this critique we have identified three general classes of considerations important to the success of any IT value study. We proceed to analyze IT value studies in

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

the light of these general considerations, and both the strengths and weaknesses of the studies are identified. Section 4 presents results taken from our own recent work to illustrate the kinds of refinements in methodology that we believe are necessary for further progress in the area. Section 5 concludes the paper with a postscript on some untapped theory bases which we think have the most to offer IT value research.

## 2. Previous Work

Bakos [1] identified five levels at which IT value analyses can be carried out:

- the economy as a whole;
- the industry within an economy;
- the firm within an industry;
- a work group or division within a firm;
- the level of the individual or information system.

The eleven studies we consider span all of Bakos' five levels. As a basis for deciding which studies to include, we carefully examined the descriptions the authors provided about the data sets used in their studies. Quality work in this area is not feasible unless care has been taken in assembling a data set which measures relevant aspects of performance and IT investment, and is large enough to provide a reasonable level of statistical power. The studies shown in Table 1 below more than meet each of these criteria.

One important commonality among the studies is strikingly apparent: many found little persuasive evidence that IT investments created strong leverage on the value of the firm. Lucas [30], for example, found that information system usage was not a very good predictor of performance among the more than 200 California bank branches he studied. Cron and Sobol [14] identified that surgical warehousing companies making extensive use of IT were either very strong or very weak financial performers. Working at the level of the macroeconomy, Jonscher [23] found that computer investment did little to speed up white collar productivity between the 1950s and the 1980s; in fact, he observed that "information handling" work actually lagged production work in efficiency gains. Turner [39] also found little evidence to suggest that mutual savings banks which made relatively larger investments in IT compared to industry competitors performed better. More recently, Roach [35], an economist with Morgan Stanley, was unable to detect any significant baseline changes in service sector productivity, despite the large investments made since the 1960s. Banker and Kauffman [2] also found little evidence of value from investments in automated teller machine (**ATM**) network technology. Instead their empirical results showed that ATM deployment helped to protect a bank branch's deposit base rather than extend it greatly; only a very restricted set of competitive conditions were found to be conducive to the creation of this kind of business value via ATM deployment. Finally, Loveman [29] presented results which showed IT created little value in terms of manufacturing sector output productivity, despite his use of well-accepted econometric methods and a solid data set.

Next, consider the studies which presented more favorable conclusions about the role of IT investments in leveraging better performance. For example, Harris and Katz [18] found that insurance firm profitability was related to the level of IT investments. Results presented by Bender [7] suggested the "optimal" level of IT investment expense as a percentage of total expenditures within the insurance industry was between 20% to 25%. The PIMS

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

**Table 1:** Eleven Empirical Studies in the IT Value Analysis Literature

| AUTHOR | INDUSTRY | DATA SOURCE | SUMMARY OF MAJOR RESULTS |
|---|---|---|---|
| Lucas (1975) | Banking | 200+ branches in California | Usage, not investment level, the key performance indicator |
| Cron and Sobol (1983) | Wholesalers | 138 firms in Surgical Trade Assn. survey | Detected bimodal distribution of performance for firms with large IT investments |
| Jonscher (1983) | Economy as a whole | U.S. Dept. of Commerce & Bur. of Labor Stat. | Argued that IT investments will help to reverse economic slowdown in industrial nations |
| PIMS (1984) | Various sectors | Proprietary PIMS database | Strassmann's "return on mgmt," argued for IT investments as component of "mgmt capital" |
| Turner (1985) | Banking | 58 mutual savings banks | No relationship found for org. perf., and IT expense, usage |
| Bender (1986) | Insurance | 132 firms in Life Office Mgmt Assn. | Suggested 15-25% of IT expense/total expense yields best firm performance |
| Breshnahan (1986) | Financial services sector | U.S. Dept. of Commerce, 1958 and 1972 | Showed that benefits accrue to customers based on area under derived demand curve for mainframe computer services |
| Roach (1987) | Service sector | U.S. Dept. of Commerce, 1950s to 1980s | Suggested IT investments have done little to improve productivity in services |
| Banker and Kauffman (1988) | Banking | 508 bank branches in Pennsylvania | ATM network membership more important than branch ATMs to protect deposit market share |
| Harris and Katz (1988) | Insurance | 40 firms over four years | Found that firm profitability correlated with IT investments |
| Loveman (1988) | Manufacturing | 60 bus. units from 1978-84, MPIT database | Failed to show a significantly positive relationship between IT expense and productivity |

study [34] supplemented this view by identifying IT expense as a component of overall "management costs" for the many firms in a large proprietary database.[1]

Unfortunately, use of the PIMS database and the studies which reported more favorable results for the value of IT expenditures failed to explain *how* and *why* IT creates leverage on economic measures of firm and industry performance. The results presented by Bender lack context: knowing that the 20%-25% range for IT as a percentage of total expenditures is correlated with superior performance begs the more difficult question of why these levels make sense in managerial IT investment decisions for a particular organization. In fact, the results of these studies,

[1]The database is well-known among IS practitioners and researchers: a firm provides answers to a large questionnaire about its investments and performance, and receives analyses which describe its "fingerprint" relative to those of anonymous industry competitors.

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

taken as a group, raise numerous questions about a set of issues that are just coming to be recognized as key dimensions along which methodological advance in IT value research can proceed. These include:

- **Method Selection** -- Was the methodology selected well-suited to detecting the mechanisms by which IT business value is created in a department, firm, industry or economy? [1]
- **Output Validity** -- Were the IT value measures employed measuring the "right" things? [26]
- **Conversion Effevtiveness** -- Is the method selected flexible enough to identify contextual factors within the organization which make a difference in converting the IT investment into productive outputs? [41] (Conversion effectiveness thus varies from firm to firm.)
- **Robust and Refined Results** -- What alternative methods might have led to results that were more refined, leaving fewer questions open to debate? [6, 27]

Asking these methodological questions of our own research helped lay a foundation for an evaluative framework which we believe is useful to take a more careful look at each of the IT value studies. The framework is introduced in the next section.

## 3. An Evaluative Framework for IT Value Research

In order to better understand the strengths and limitations of the IT value studies presented above, we introduce a framework consisting of three classes of considerations important for conducting IT value research.

- **Motivation for methods selected,** in terms of purpose, methodological approach and theory base;
- **Focus of analysis,** in terms of unit of analysis, locus or timing of IT value, and the role of information system performance;
- **Caveats for measurement,** in terms of reliability of specific performance measures, mode of data analysis and importance of organization context.

In the paragraphs which follow, we develop these classes of considerations in some detail, by applying them to each of the eleven IT value studies as shown in Table 2 below.

### 3.1. Motivation for the Methods Chosen

The questions of *methodological approach*, *purpose* and *theory base* all attempt to get at the basic **motivation** for each of the IT value studies we have reviewed. Understanding the motivation behind them is helpful when interpreting the results and determining the, often unstated, paradigm implicit in each study. The motivation and research questions identified within each study also provide insight into the state of IT value research at the time it was conducted, and how research in this area has progressed since.

#### 3.1.1. Purpose

*Purpose* (P) identifies the research question(s) addressed in the study. What was the expressed purpose of the study? Is management interested in securing a baseline of performance for an IT investment that has already been made? Or is additional investment being considered that is meant to further leverage existing investment? As the table indicates, the early studies tended to address the question of computer use [30] and the relationship between

**Table 2:** Motivation, Focus and Caveats for Eleven IT Value Studies

| AUTHOR | MOTIVATION | FOCUS | CAVEATS |
|---|---|---|---|
| LEGEND | P: Purpose<br>A: Approach<br>T: Theory base | U: Unit of analysis<br>L: Locus of value<br>S: System perf | M: Measures<br>D: Data analysis<br>C: Org. Context |
| Lucas<br>(1975)<br>Bank | P: Effects of on performance<br>A: Causal model<br>T: Org Theory | U: Bank branch<br>L: Branch/individual<br>S: Not considered | M: 7 measures incl % target, perceptual<br>D: Cross-section<br>C: 8 situational vars |
| Cron & Sobol<br>(1983)<br>Warehousers | P: Computerization impacts<br>A: Exploratory<br>T: No theory | U: Firm<br>L: Firm performance<br>S: Not considered | M: Four measures, including ROA & ROI<br>D: Cross-sectional<br>C: No context |
| Jonscher<br>(1983)<br>U.S. Economy | P: IT investment impact on econ<br>A: Exploratory<br>T: Microeconomics | U: Economy<br>L: Macroeconomics<br>S: Not applicable | M: Info & production worker efficiency<br>D: Longitudinal, 30 yr<br>C: No context |
| PIMS<br>(1984)<br>General | P: IT inv. impact on mgmt prod.<br>A: Exploratory<br>T: Mgmt accounting | U: SBU<br>L: SBU, firm performace<br>S: Not considered | M: "Return on mgmt", as IT leverage<br>D: Cross-sectional<br>C: Mgmt structure |
| Turner<br>(1985)<br>Banks | P: IT investment impact on performance<br>A: Exploratory<br>T: Innovation theory | U: Bank<br>L: Bank performance<br>S: Not considered | M: Oper inc/tot assets Pearson correlation<br>D: Cross-sectional,<br>C: No context, but descriptive (size) |
| Bender<br>(1986)<br>Insurance | P: IT investment to max perf.<br>A: Exploratory<br>T: No theory | U: Firm<br>L: Firm performance<br>S: Not considered | M: Expense/ premium income<br>D: Cross-sectional<br>C: No context |
| Breshnahan<br>(1986)<br>Financial Services | P: IT inv. impact on soc. welfare<br>A: Extends theory<br>T: Welfare econ., innovation theory | U: Financial service sector<br>L: Consumers<br>S: Not considered | M: "Implied welfare" and "spillover"<br>D: Two periods only<br>C: No context |
| Roach<br>(1987)<br>Services | P: IT impact on econ. prod.<br>A: Exploratory<br>T: Macroeconomics | U: Service sector<br>L: Sector productivity<br>S: Not applicable | M: One measure, but not well defined<br>D: Longitudinal<br>C: No context |
| Banker and Kauffman<br>(1988)<br>Banks | P: Extent of ATM leverage<br>A: Mkt share model<br>T: Microeconomics, marketing science | U: Bank branch<br>L: Branch competitive deposit taking<br>N: Not considered | M: Mrgnl impact on $ deposit share<br>D: Cross-sectional<br>C: Territory demographics |
| Harris & Katz<br>(1988)<br>Insurance | P: IT impact on performance<br>A: Exploratory<br>T: No theory | U: Firm<br>L: Firm performance<br>S: Not considered | M: Expense/premium inc<br>D: Longitudinal, 4 yr<br>C: No context, but descriptive |
| Loveman<br>(1988)<br>Manufacturing | P: IT investment impact on prod<br>A: Five models<br>T: Microeconomics | U: Firm<br>L: Firm performance only<br>S: Not considered | M: Impact on product, leverage on labor<br>D: Longitudinal<br>C: None |

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

performance and computerization intensity [14]. These studies used surrogates for IT investment which the later studies measured directly. The studies by PIMS [34] and Bender [7] measured the proportion of expenses dedicated to IT in firms, while Breshnahan [8] and Roach [35] measured amounts of resources dedicated to IT in a sector.

The difficulty of identifying interesting, consistent results is further compounded by the use of inconsistent definitions of key input and output variables. "IT expenditures" is a good example. Some studies adopted a narrow definition of just information system expenses; others broadened the definition to include communications, software and hardware-related employees, and also managers.[2] The result for IT value research, as Bakos has observed, is that little *sequential* building of understanding has developed. Unlike in other areas where a coherent line of incremental research can be identified, IT value research has gone through a phase where exploratory studies are driven by diverse base disciplines. Given the nature and the level of understanding of the problem, it is curious that none of the studies we cite was a theory-building case study.[3]

### 3.1.2. Methodological Approach

*Methodological approach* (A) attempts to capture the essence of the research approach. Was the study testing solid hypotheses coming from a strong theoretical base or was it an exploratory, loosely directed data analysis? The majority (seven of eleven) of the studies was classified as exploratory as they were loosely directed data analyses. Exploratory data analysis is useful because it can suggest the kinds of hypotheses to test for IT value, but this normally requires follow-up research with the same or a supplemented data set.

Four exceptions were identified. Lucas [30] conducted a test of a causal model driven by a contingency theory approach. Breshnahan [8], basing his arguments and modeling approach on welfare economics and the theory of innovation, used the notion that the area under the "derived demand curve" for IT (as an intermediate input in financial services) could also be interpreted as a measure of social welfare. Banker and Kauffman [2] tested to determine how ATMs indirectly affected bank branch deposit competition via a competitive interaction model of market share. The model they used has been widely validated in the marketing science literature. Loveman [29], relying on relevant theory from production and labor economics, tested five separate models to determine IT impacts on sectoral production and labor productivity. He was careful to distinguish among models in which output can be tied directly or indirectly to an IT. When IT can be tied directly to the output, a simplified production function of the form OUTPUT = f(INPUTS) is an appropriate test. But, when the IT only indirectly affects the production of an output, as in the link between airline computer reservation system investment and airline market share, it may be necessary to introduce an intermediate production process. A two-stage model incorporating the previous production function, e.g., OUTPUT = g(f(INPUTS)), may be more appropriate.

[2]Weill [40] contains a review of the range of definitions of IT adopted in these and other references in the IT value literature.

[3]For an example of a theory-building case study in this area, see Weill and Olson [41].

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

### 3.1.3. Theory Base

A third key aspect of the motivation for the methods used in the studies can be found in their underlying *theory base* (T). Is there a theory base to suggest hypotheses to test? Can the analyst rely on strong results from a large body of literature related to the theory base? Each theory base brings with it diferent methodologies, assumptions and value systems. The most commonly represented theory base was economics. The studies by Jonscher [23], Breshnahan [8], Banker and Kauffman [2], and Loveman [29] all used microeconomic theory to frame their IT value models. Microeconomic theory offers a strong and insightful theory base, which enables the creation of flexible analytic and testable empirical models. The breadth of potential coverage for IT value models based on economic concepts is broad, but models leading to powerful tests in one environment, or for one level of analysis, may not be easily transferred to other environments or levels of analysis.

Most of the studies inspired by economics generally have not included organization context, rather concentrating on broader firm, industry and economy trends. The studies by Jonscher [23] and Roach [35] were exploratory in nature. On the other hand, several had no identifiable theory base and were pure data exploration [14, 18, 7]. The remainder relied on organization theory [30], management accounting [34], and innovation theory [39], respectively.

## 3.2. Focus of Analysis

The *unit of analysis*, *locus of value* and the *role of information system performance* all describe the **focus** of IT value study. The focus includes what aspect of performance is of greatest interest to the researcher, what unit of the business under investigation and whether the systems information systems are directly considered.

### 3.2.1. Unit of Analysis

The *unit of analysis* (U) of the study indicates the level at which various techniques are applied to the relevant data to identify IT value (e.g., the five levels discussed by Bakos). The unit of analysis is often suggested by the theory base used in the study. For each unit of analysis adopted an implicit assumption is made: that a relationship is present between the IT investment and value created at that level. In order to find a relationship between IT investment and performance the link between investment and performance must be bounded by the unit of analysis. In addition, the higher the level of aggregation, the greater the chances are of diluting the evidence that a link does exist.

Five of the studies used the firm as the unit of analysis [14, 18, 39, 7, 29]. This unit of analysis suffers from potential dilution when a firm has several radically different business units. This highlights the idea that intermediate production is occurring which cannot be adequately expressed in a model which captures secondary impacts of IT at the firm level. Three of the studies addressed this problem and used a firm subunit as the unit of analysis, e.g., the strategic business unit (**SBU**) or bank branch [30, 34, 2]. The remaining studies looked at the sectoral and social value of IT, using the financial services sector, and the economy as a whole as the separate units of analysis [23, 8, 35]. This unit of analysis maximizes the likelihood of dilution and allows the effects of many unidentified mediating and moderating variables to go unnoticed. Failure to recognize the importance of the potential dilution can easily invalidate the results of an IT value analysis.

### 3.2.2. Locus and Timing of IT Value

Identification of the *timing of IT value* (L) is crucial. Investments in IT will take time to add value to a firm and show up in performance measures. This time lag is often omitted from models and not considered in most cross-sectional studies. Organizations absorb technology at different rates and omission of the time lag variable is a potentially serious shortcoming of an IT value study.

In addition, most attempts to accurately measure when value accrues after an IT investment has been made have not been well-grounded in theory. For example, Loveman [29] tested models for IT value with and without lagged independent variables. Although the forms of the models he tested make intuitive sense, they are subject to the criticism that no adequate theory was employed to determine which variables should have been lagged and what the lags were. Lucas [30] summed up another problem associated with using lagged variables: "Because of the time lags among the variables, a priori reasoning on the direction of causality is often difficult." Weill's [40] recent results on valve manufacturers' IT investments supported Lucas' view. An important goal of Weill's study was to identify whether levels of IT investment in previous periods correlated with improved firm performance, but he also found that good performance in previous periods correlated with IT investments in later periods. This clouds the distinction between performance, which has traditionally been viewed as a dependent variable, and IT investment as an independent variable: their relationship may be circular.

The *locus of IT value* (L) addresses the kinds of IT value measured. IT could potentially create value at many levels and in each study the researchers have defined a target locus of value. At first glance, it may seem as though the unit of analysis is functionally defined by the locus of value. For example, if the locus of value is firm performance then one might expect the unit of analysis to be the firm. Yet in several studies there was more than one locus, e.g., both bank branch and individual [30], and SBU and firm [34]. In the remaining studies, the locus of value was broader, e.g., sector productivity [23, 8].

The locus of value need not explicitly determine the unit of analysis, however. The studies by Breshnahan [8], and Banker and Kauffman [2] are useful illustrations of this idea. Breshnahan's locus of value was aggregate consumer welfare. But he did not measure IT value at this locus directly; data simply were not available. Instead, he made concessions to the difficulties of data collection, and devised a means to avoid the problem altogether, by shifting the unit of analysis to firm demand for mainframe computer services. In another study Banker and Kauffman recognized that most previous work on ATM value looked at aggregate impacts on firm performance, and dilution has resulted in weak and uncertain results. But, by shifting the unit of analysis to bank branch deposit collection competition, the authors were able to show how ATMs leveraged a well-defined component of bottom line performance.[4]

[4]Another study is in progress which recognizes this distinction. Barua, Kriebel and Mukhopadhayay plan to look at relative performance among firms in the MPIT database by employing "path analysis" to explain firm level performance through intermediate production activities, such as inventory management. An overview of the research they are carrying out is found in [6].

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

### 3.2.3. The Role of Information System Performance

Much of the early research on information systems impact on organizations includes consideration of the role of the *performance of the specific information system(s) or technology* (S) under study. Some studies imputed information system performance using measures of user satisfaction [21], system success [31], system effectiveness [36] or system quality [17]. None of our eleven studies considered information system performance explicitly. Instead, the implicit assumption was made that IT investment (or use) influences organizational (or sector) performance. The intervening variable of information system performance was ignored, even though it is certain that given similar investments in different firms or divisions, there will be variability in information system performance and use. This variability is bound to affect the potential business value to be gained from IT investment. However, based on what we have learned from the recent studies on ATMs and treasury management workstations [24], it is clear that system performance *in isolation* is rarely a good way to measure business value [25]. In methodological terms, system performance is a mediating, not criterion, variable.

## 3.3. Other Caveats for Measurement

The final dimension of our evaluative framework for conducting studies to assess IT value is **other caveats for measurement**. These include the *reliability of performance measures*, *mode of data analysis*, and *importance of organization context*.

### 3.3.1. Reliability of Specific Performance Measures

Once a theory base and methodology have been chosen, and the unit of analysis has been decided upon to measure IT value at its locus of value, the next logical step in the progression is to select a set of performance measures. Kauffman and Kriebel [26] have argued that it is rare that isolated measures will suffice; instead, measurement of IT business value is best thought of as a process of triangulating to identify the presence and magnitude of the value created. In some cases, it is sufficient to construct very rough measures which act as "ballpark" estimators for value; this depends on the kinds of questions management wishes to have answered. In other cases it is crucial to construct very sensitive measures to provide evidence that a hypothesized impact is actually occurring.

Banker and Kauffman [3] have argued that measures (and models to identify the "business value linkage") should be constructed with the locus of value in mind. For example, if an airline IS executive believes that computer reservation systems helped to gain market share, then this assertion would have to be tested in the context of a model for airline market share. If ATMs are thought to lead to cost reductions in the bank branch, then models should be constructed which estimate both the direct and indirect impacts on branch teller labor and funding costs [4]. Finally, Banker, Kauffman and Morey [5] have suggested that IT business value measures must represent the probabilistic nature of IT value creation. In fast food operations, for example, IT is often deployed to reduce resource waste and improve coordination, but there may be other factors in the environment (e.g., management control procedures, peak demand characteristics and varying levels of trained staff) that would either increase or decrease the likelihood that IT will have the intended value.

The eleven studies under review evidenced little agreement among the authors on the "right" measures of IT business value. At the firm and industry levels of analysis, ROA and ROI were natural choices -- they are

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

monitored by senior management and were readily available. But these are aggregate measures in which the value of IT is likely to be diluted, if it is present at all. The studies by Breshnahan [8] and Banker and Kauffman [2] (and Loveman [29] to a lesser extent) incorporated the kinds of measures that are most likely to lead to methodological progress. Each study derived measures directly related to the theory bases used (derived demand for mainframe services as a measure of consumer welfare, marginal branch deposit market share, and manufacturing firm output quantity).

### 3.3.2. Mode of Data Analysis

The *mode of data analysis* (**D**) refers to whether the research uses cross-sectional or longitudinal data to establish value estimates for IT investments. The choice of using cross-sectional or longitudinal data for an IT evaluation is crucial, and each of the studies which chose the sector or economy locus of value used longitudinal data [23, 8, 35, 29]. Most used time-series involving many periods. Since Breshnahan was focusing on the cumulative change in consumer welfare between the 1950s and the 1970s, he only required data for two representative years. Time-series data is very difficult to obtain at levels other than the economy. Moreover, the analyst must take special care to ensure the data obtained are actually measuring the same things at different points in time. As an example, consider the value of computer reservation systems in terms of commercial airlines' financial performance. It would be very difficult to measure at the firm level using longitudinal data; the industry has undergone significant consolidation due to changes in its regulatory environment. Testing for reservation system value would pose difficult problems for the best econometrician.

Six of the eleven studies used cross-sectional analysis. Cross-sectional analysis is often more attractive due to data availability. Some of the standard sources area include government organizations, industry and trade associations, and firms which specialize in analyzing certain industries. For example, Turner [39] obtained data from the National Association of Mutual Savings Banks, while both Bender [7] and Harris and Katz [18] obtained data from the Life Office Management Association. Banker and Kauffman [2] used a combination of the three strategies, obtaining U.S. census data from a market research firm, data on deposit market share from a compilation of regulatory reports from individual banks, and ATM location data from the publications of a shared ATM network.

Cross-sectional data alone can provide interesting insights into relative investment and performance. In addition, when longitudinal data are difficult to collect, it is possible to use cross-sectional data to simulate a time-series. This is done by ensuring that there are firms in the data set that have or have not invested in a specific IT, and then testing whether a specific impact occurs in both cases. (See, for example, Banker, Kauffman and Morey [5].) A time-series of cross-sections would be the ideal data set. At this time, however, we know of no studies in the IT value literature which have utilized panel data and the powerful techniques available to analyze them.

### 3.3.3. Importance of Organization Context

*Organization context* (**C**) is an important concern that the IT value literature as a whole has almost entirely failed to address. Organization context refers to the characteristics of the organization that will influence the relationship between IT investment and firm performance. This context is specific to each organization and adds a richness of data to the analysis. Contextual factors can be any characteristic of an organization that theory indicates will moderate the relationship between IT investment and performance. Bakos [1] asserted that answering questions of

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

IT value places a premium on identifying "methodologies [that] allow us to control or compensate for contextual variables when it is feasible."

Weill identified four organization context variables that made up conversion effectiveness:

1. Top management commitment to the IT;
2. Organization experience with the IT
3. Satisfaction with the IT;
4. Political turbulence.

He found that conversion effectiveness did moderate the relationship between IT investment and firm performance in the manufacturing sector [40].

Among the studies we cited, Lucas [30] most fully deals with the problem of organization context. He incorporated eight variables to describe bank branch operating environments, including such concerns as the potential business levels of a location, the stability of its customer base, whether it was a hub office, and the intensity of competition nearby. Suggesting the measurement difficulties involved, Lucas found "little apparent consistency in the nature of the relationship[s]" among his performance measures and these situational variables. A second set of contextual factors included in his study involved the decision styles and other personal descriptors for managers which were believed to have an effect on system usage and managerial action. Lucas' analysis is useful because it points out the variety of contextual factors that can potentially influence conversion effectiveness. The study by Banker and Kauffman [2] also included a consideration of context. Based on the results of their field study, they distinguished between the contexts of savings and demand deposit market share competition. Finally, since the leverage that ATM deployment creates on branch market shares was estimated for bank branches in separate competitive territories, a description of the intensity of competition was implicit in the competitive interaction model used.

Recognition of the organization context suggests that extreme care must be taken to incorporate into the analysis information that managers have about a given IT value problem. This makes the analysis more relevant from a manager's perspective: the more information the value measure takes into account, the more likely they are to explain individual firm variance.

Barua, Kriebel and Mukhopadhayay [6] pointed out another way this problem can be addressed: by partitioning the data sets employed in the value analysis. Partitioning a data set is analogous to using categorical variables which describe the partitions, and then running a value analysis on pooled data. The authors pointed out that "bimodality" -- when high IT expenditures are observed to lead to *both* high and low firm revenues or return on investment in different firms -- is symptomatic that the wrong unit of analysis was chosen, or that other contextual factors need to be better represented. Among the studies we reviewed, the results of Cron and Sobol [14], Harris and Katz [18], Bender [7] and Loveman [29] are subject to this criticism. Banker and Kauffman [2], however, employed data set partitioning, to control for deposit competition taking place in territories where different ATM networks dominated. They found that this lead to more refined estimates of ATM business value.

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

## 4. An Illustration of State-of-the-Art Methods

We now turn to a discussion of methods, models and results from two studies on IT value that we have recently completed in financial services and manufacturing settings. By describing the methods used, and their advantages and disadvantages, we hope to suggest how these new IT value research efforts are helping to redefine the state-of-the-art.[5] This section concludes with a brief consideration of how the studies measure up to the studies we reviewed in Sections 2 and 3.

### 4.1. The Relationship Between Investment in ATM Technology and Branch Performance in Banking

Banker and Kauffman [2] used a competitive interaction model to estimate the value of ATMs in retail banking. The marginal impact on deposit market share was captured using a model representing the set of features which distinguishes a branch from its competitors branch in territories where they interact. (For details of the model, please refer to the paper.) Data were collected for 508 bank branches in southeastern Pennsylvania. The branches were located in 54 separate local areas termed "branch operating territories" (**BOTs**). The BOTs were further aggregated to form retail service clusters (**RSCs**) matching the sponsoring bank's management responsibility areas in its retail banking operations. The BOT level represented local competition, while the RSC level represented regional markets. Membership in the regionally larger network (**MAC**) generally was found to be a positive influence in defending deposit market share.[6] Branches belonging to the regionally dominant network exhibited larger deposit market share gains when the regionally smaller network (**Cashstream**) was over-represented locally.

These results were developed by testing four data partitions: the entire data set, the Philadelphia area only, and then the BOTs dominated by MAC and the BOTs dominated by CashStream. Review of the major results of the Banker and Kauffman study by bank managers suggested it would be worthwhile to further investigate the data to determine if other aspects of the BOT environments were acting to enhance or suppress ATM business value. They wanted to know answers to questions such as: Were the ATM business value estimates robust to different competitive conditions? Could they be used to estimate ATM business value where no data had been collected? How much variation occurred in the business value estimates? The basic question was whether *spatial variation* was present ATM business value estimates, implying that a more carefully crafted ATM location strategy could lead to increases in average ATM business value.

#### 4.1.1. General Design

To examine these questions more closely, Kauffman, Ghosh and Bansal [27] employed a method from statistics known as the "jackknife" technique. This technique helps to determine the extent of spatial variation of the parameter estimate for the MAC ATM network membership variable across the BOTs.[7] The jackknife technique is

---

[5]For full details of the studies, the interested reader should refer to the authors' doctoral dissertations [24, 40].

[6]Clemons [9] presents an excellent overview of the issues related to ATM network competition in Pennsylvania in his case study of the MAC network.

[7]The jackknife technique is presented in Tukey [38], and Mostellar and Tukey [32], and applied by Ghosh [16].

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

iterative. In order to determine whether the ATM network membership value estimate was stable, Banker and Kauffman's deposit market share model was recalibrated, each time dropping a subset of branches forming a BOT.

Here we will report on results extending those presented in Kauffman, Ghosh and Bansal [27] and examine how ATM network membership varies at three different levels of analysis of interest to management:

- Regional responsibility level (RSCs)
- Branch responsibility level (all BOTs)
- Electronic banking responsibility level (not MAC-dominated BOTs only)

These three units of analysis were chosen to provide answers to questions posed by different participants in the study within the sponsoring bank. A reading on differential ATM business value was of interest at the regional retail banking responsibility level (RSC) to identify if ATMs were underperforming in major segments of the bank's business. Identification of variations in ATM business value at the branch (BOT) level was useful to pinpoint BOTs that were "special situations." Finally, electronic banking management found the last analysis -- BOTs in which MAC did not have a majority of the ATM locations -- to be of greatest interest. These BOTs were targets for the bank's new ATM placements at the time the study was carried out, and so information on potential variation in ATM business value could provide a useful input to management's location decisions.

#### 4.1.2. Method of Analysis

*Jackknife pseudovalues* for iterative subsamples of the data set were calculated as follows:

$$J(\beta)_i = N\,\beta_{all} - (N-1)\beta_{-i}$$

where

$J(\beta)_i$ = *jackknife pseudovalue for the MAC network membership parameter,* $\beta$, *when subsample i is omitted;*

$N$ = *the number of observations in the data set;*

$\beta_{all}$ = *global MAC network membership parameter estimate;*

$\beta_{-i}$ = *revised parameter estimate, subsample i excluded from data set.*

Excluding subsets of the data partition provides a direct way to identify whether the omitted BOTs, i, are drawn from different populations. Significant variation in the set of jackknife pseudovalues, $J(\beta)_i$, indicates potential *spatial non-stationarity* in the parameters of the original model.[8]

[8]For additional details on the application of the jackknife technique to this data set, see Kauffman, Ghosh and Bansal [27].

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

### 4.1.3. Results

Table 3 below presents the results of the iterative jackknife procedure (with replacement) for the savings deposit market share model, focusing on just one coefficient, $\beta_{all}$, which represents the contribution of membership in the MAC ATM network to branch market share for all observations in the data partitions examined by Banker and Kauffman [2]. The jackknife pseudovalues are summarized in terms of their means (E(J)), standard deviations (σ(J)), and maximum (MAX(J)) and minimum (MIN(J)) values.

**Table 3:** Jackknife Pseodovalues (J) for Saving Deposit Market Share

| DATA | β | E(J) | σ(J) | MAX(J) | MIN(J) |
|---|---|---|---|---|---|
| RSCs (19) | .27 | .24 | .44 | 1.18 | -0.84 |
| BOTs (50) | .27 | .25 | .76 | 2.76 | -2.74 |
| NON-MAC (33) | .35 | .47 | .76 | 3.27 | -0.77 |

*LEGEND:*

| | |
|---|---|
| *DATA* | *Partitions for mgmt responsibility levels* |
| *β* | *Previously estimated MAC network coefficient* |
| *E(J)* | *Mean of jackknife pseudovalues* |
| *σ(J)* | *Standard deviation of jackknife pseudovalues* |
| *MAX(J)* | *Maximum jackknife pseudovalue* |
| *MIN(J)* | *Minimum jackknife pseudovalue* |
| *RSCs* | *Retail service clusters* |
| *BOTs* | *Branch operating territories* |
| *NON-MAC* | *BOTs not dominated by MAC network* |

A word on the interpretation of the results is in order. If a jackknife pseudovalue, $J(\beta)_i$, is greater than $\beta_{all}$, this indicates that the observations in subset i (which was dropped) enhanced the overall estimate of ATM business value. When a set of observations associated with a BOT or an RSC is dropped in iterative estimation of the competitive interaction model, finding values where $J(\beta)_i > \beta_{all}$ prompts us to inspect the managerial, competitive and demographic conditions under which greater than average business value appears to have been created. Similar reasoning applies when $J(\beta)_i < \beta_{all}$; the observations which comprise subset i suppress overall business value. The key management concern is how to explain the differential conversion effectiveness.

At the highest level of aggregation (RSCs), the jackknife pseudovalues exhibited substantial variation around the original estimated MAC network membership coefficient, $\beta_{all}$. This variation suggests that the 19 RSCs may be drawn from more than one distribution, in terms of ATM conversion effectiveness. At the BOT level, there is

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

significantly greater variation. The standard deviation of the jackknife statistics is nearly twice as large, and the maximum and minimum values are quite far apart. The NON-MAC partition, in which Banker and Kauffman [2] found that MAC ATM network membership offered an important strategic contribution, exhibits a similar degree of variation, though it contained far fewer branches (261 in NON-MAC vs. 508 in the all BOT partition).

This kind of analysis focuses management's attention on identifying the contextual factors that lead to higher business value. In order to provide evidence that the jackknife pseudovalues we have analyzed are systematically explained by contextual factors, the next step in the analysis is to correlate aspects of the environment specific to each BOT (or RSC) with the jackknife pseudovalue when that BOT (or RSC) was dropped. Preliminary analysis suggested that demographic factors such as age of the population and average household income may be moderating variables at the individual BOT level. At the RSC level, management identified recent merger and acquisition activities as a potential suppressor of ATM business value; as banks changed ownership, the service levels associated with their ATM operations often changed, too. A set of panel data would be useful to sort out this and other issues.

## 4.2. The Relationship Between Investment in IT and Firm Performance in Manufacturing

In this section we describe the methodology used in a study of 33 valve manufacturing firms. Readers interested in the findings or other aspects of the study are referred to the original work [40]. The focus here will be the research design and statistical methodology.

### 4.2.1. General Design

The general design of the study was generated to test the a contingency theory model [37] (modified to include the effects of power and politics). The model argues that the relationship between investment in IT and firm performance is moderated by the conversion effectiveness of the firm. Firms vary significantly in their conversion effectiveness. This construct, as we noted above, consists of four contextual measures: top management commitment to IT, the political turbulence of the firm, the firm's IT experience and the satisfaction of the users with the IT. The study was restricted to the valve manufacturing industry in the U.S. in an attempt to remove large industry effects.

The variables collected can be classified into *quantitative facts* and *perceptual measures*. The quantitative variables were measures of some facet of the firm, such as size or total sales, in 1986. To avoid the difficulties of interpretation faced by many of the previous cross-sectional studies in this area, historical data were collected for all quantitative fact variables. For example, IT investment was collected for the current year and five previous years. Data on perceptual measures were collected from three sources within the firm: the CEO, the controller and the production manager. This strategy was adopted to gather firm-wide data and validate these measures. In all cases, previously used perceptual measures were chosen and inter-rater reliabilities were calculated [22].

The design can be summarized as a study of 33 single-SBU organizations in one narrowly defined manufacturing industry with six years of historical data using three independent sources in each firm. A broad definition of IT [33] was adopted which included all centralized and decentralized computing, communications, personnel and other resources dedicated to the management and use of IT. This broad definition is needed to capture all IT investment in

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

an organization, particularly in the rapidly growing area of communications, e.g., facsimile transmission, electronic mail, etc. Different IT investments are made with different management objectives. To reflect this variance three types of IT investment were included in this study:

- **Strategic IT** -- This "changes a firm's product or the way a firm competes in the industry" [20], relative to the firm's competitors. Strategic IT was defined as IT investment intended to generate sales growth and thus increase market share.
- **Informational IT** -- This creates the information infrastructure of the firm and assists management to communicate, account, report, analyze and plan.
- **Transactional IT** -- These investments are generally made with the goals of reducing the costs of doing business by substituting capital for labor, reducing resource waste and so on. For the study it was operationally defined as IT investment made to cut costs.

The IT investment of the firm was measured by the ratio of IT expenditure over total sales per annum. The chief executive officer and controller of each firm responding to the survey classified their IT expenditures into the three types of IT investment. Data on performance measures related to each type of IT investment were also gathered. The measures included sales growth, market share, return on assets and non-production labor per million dollars of sales.

#### 4.2.2. Method of Analysis

The collection of six years of data allowed much flexibility in the analysis. Time lagged analyses were performed with both IT investment and firm performance as dependent variables in an attempt to get at the circularity of the relationship. The main statistical technique used was *hierarchical regression* with sets of variables [10]. One of the difficulties of this type of work is isolating the effects of the particular variables one is studying. To deal with this problem the effect of the previous average performance of the firm was statistically removed from the most recent year's (1987) performance measure that was used as the dependent variable. This procedure, known as *partialling*, has two advantages:

1. The total explained variance for the equation is usually high (often over 50%), providing increased statistical power and adding to our confidence in the model.
2. Previous years' performance measures also carried variance explained by previous years' IT investment levels. The removal of this variance leaves just the direct effect of IT investment on the 1987 performance. The example below will help clarify this point.

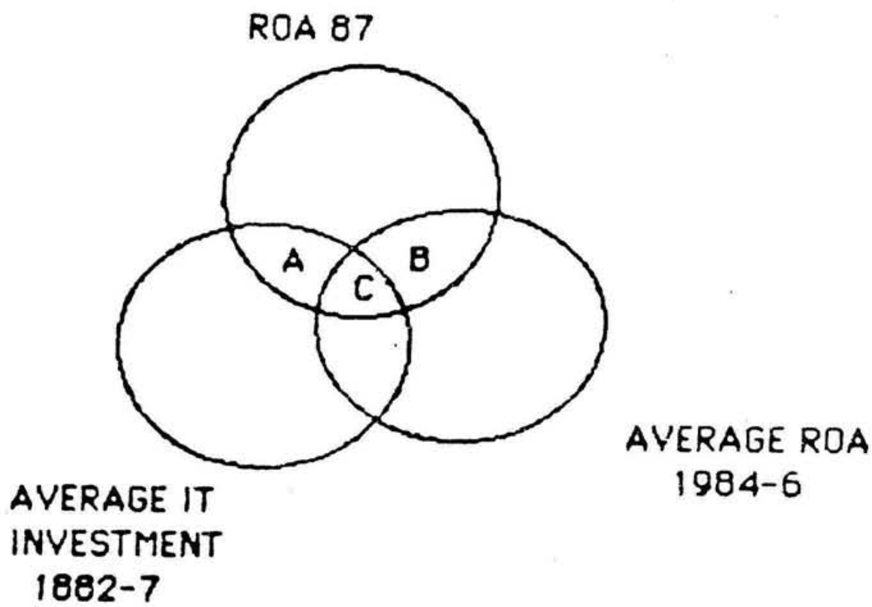
The application of hierarchical regression and the nomenclature used generally follows Cohen's approach [10]. A useful property of hierarchical regression is that the independent variables in the system are entered cumulatively in a prespecified sequence according to the model being tested. The total cumulative explained variance ($R^2$) and the *semi-partial coefficient* are calculated as each variable is entered. The semi-partial is an estimate of the unique variance associated with the newly entered variable. This variance is termed the *incremental variance* for each variable and we identify it by the symbol I.

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

### 4.2.3. Results

In order to determine if firms exhibited an *association*[9] between average IT investment (1982-87) and ROA in 1987 a hierarchical regression was used. The two stages of the analysis can be illustrated using the Venn diagram pictured in Figure 1. Related results are shown in Table 4 which follows later in the text.

**Figure 1:** Venn Diagram of Example




Each of the circles represents the standardized unit variance of the associated variable. Intersections between circles represent shared variance. The dependent variable (**DV**) was ROA adjusted for sales in 1987 (ROA87). The first independent variable (**IV**) entered in the equation was the three previous years' average of adjusted non-production labor (ROA84-86). The previous years' ROA explained 47% of variance in ROA (i.e., Cum $R^2$=0.47 represented by areas B plus C on the Venn diagram) and has a significant F-test of p=0.00. The next variable entered was the average IT investment from 1982 to 1987 (IT82-87). This variable uniquely explained very little variance (I=0.00002) in the DV and was not significant ($\Delta$sig F=0.98 represented by area A on the Venn diagram). Therefore there was no significant association between ROA in 1987 and the average IT investment from 1982 to 1987, after the effects of previous performance were partialled out.

The advantage of this approach is that the shared variance between previous years performance and 1987 perfor-

[9]Technically, the terms *correlation* and *association* have the same, or very similar, meanings. However, in behavioral science the latter is often used when there is no causal implication. Given that the tests Weill [40] carried out investigated the possibility of a circular relationship between IT investment and performance, we use the term association throughout this section.

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

**Table 4:** Results of Hierarchical Regression Example

| DV - Return on Assets 1987 | | | | | |
|---|---|---|---|---|---|
| IV | Final Eqn B | Cum $R^2$ | I | ΔsigF | Final Eqn t |
| ROA 84-86 | .64 | .47 | .47 | .00** | .00** |
| IT 82-87 | .01 | .47 | .00002 | .98 | .98 |

*LEGEND:*

| | |
|---|---|
| *IV* | *Independent Variable* |
| *B, t* | *Coefficient and t-test of variable in final equation* |
| *Cum* $R^2$ | *Cumulative Multiple R Square* |
| *I* | *Incremental variance explained uniquely by the variable* |
| *ΔsigF* | *Change in Significant F-test for set* |
| *Significance* | ***=<0.01* |
| *ROA84-86* | *Average return on assets 1984 to 1986* |
| *IT82-87* | *Average total IT investment 1982 to 1987* |

mance was removed before IT investment was entered into the regression. This is represented by areas B plus C. In removing this variance, the area C, the shared variance between IT investment (IT82-87) and previous years performance (ROA84-86), was also removed. Thus the test of association between ROA in 1987 and IT investment is a measure of the *unique* contribution of IT investment with the unwanted influence of previous years performance removed. Fortunately, the average of the previous years' performance does not explain all the variance in 1987 performance, leaving ample variance to be explained by other factors such as IT investment.

This technique can be readily extended to allow sets of independent variables to be entered at each stage in the hierarchy. The procedure we describe is known as *set correlation*. A *set* is defined "as a group of variables classified as belonging together [for] reasons of substantiative content or logic of the research" [10]. Thus the set of the three types of IT investment can be entered individually in place of IT. The set of variables is tested for significance using the change in the significant F-statistic while the coefficients of the individual variables (the β's) are tested in the final equation using a t-statistic. In this way both the effects of the set of the three types of IT investment (from their interaction) and each type of IT investment (in isolation) can be tested for significance. To protect against "experiment-wise" Type I error, we advocate performing a protected Fisher F-test [10]. The F-test for the overall set of variables is performed first. If the set is significant then the individual variables can be tested next. This is particularly relevant when the set of variables is large, since "experiment-wise" Type I error quickly mounts.

The corollary to this approach is that when a set is significant it only makes sense to interpret the coefficients (for direction of the effect) of those variables with a significant t-score. Interpretation of non-significant coefficients is an attempt at interpreting error variance. In the use of sets, both the significance of the set and the significance of the individual variables are interesting. The variance explained by the set (and its significance) gives an indication of

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

the effect of all three types of IT working together. The tests of significance of the individual variables report which variables are significant alone and the directions of their effects.

Results of the technique using sets are illustrated in Table 5. They focus on the relationship between ROA in 1987 (DV) and the set of the three types of IT investment in 1986 (IV Sets). The upper table presents the cumulative $R^2$ and incremental variance (I) for each set as it was entered into the equation. The lower table contains the coefficients and t-tests for the final equation to interpret the direction of any effect.

**Table 5:** Results of Hierarchical Regression for Sets

| DV - Return On Assets 1987 | | | |
|---|---|---|---|
| IV Sets | Cum $R^2$ | I | Δsig F |
| ROA82-84 | 0.47 | 0.47 | 0.00** |
| Set of: Strategic IT 86 Informational IT 86 Transactional IT 86 | 0.60 | 0.13 | 0.048** |

| Final Equation ROA87 | | |
|---|---|---|
| IVs | B | t |
| ROA 84-86 | 0.70 | 0.00** |
| Strategic IT 86 | -3.1 | 0.15 |
| Informational IT 86 | -0.40 | 0.34 |
| Transactional IT 86 | 5.25 | 0.007** |

*LEGEND:*

| | |
|---|---|
| *ROA87* | *Return on Assets in 1987* |
| *Significance:* | ***=<0.01* |
| *B, t* | *Coefficient and t-test of variable in final equation* |
| *CumR²* | *Cumulative Multiple R Square* |
| *I* | *Incremental variance explained uniquely by the variable* |
| *ΔsigF* | *Change in Significant F-test for set* |
| *Note:* | *The upper table contains the results for the hierarchical regression of two stages of sets of variables. The lower table contains the coefficients and t-test for the individual variables in the final equation.* |

The first variable entered is the average of the previous three years ROA, explaining 47% ($R^2$=0.47) of the

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

variance (see top half, Table 5.). The set of the three types of IT investment in 1986 was then entered and found to uniquely explain 13% of variance (I=0.13). Since the set was significant (Δsig F=0.048) the variables contained in the set were tested individually. Transactional investment (t=0.007) was significant (see lower half, Table 5) and positively ($\beta = 5.25$) associated with ROA87. Thus, high transactional IT investment in 1986 was associated with superior ROA in 1987. No attempt should be made to interpret the coefficients of the informational or strategic IT; these were not significant and the direction of the effect could be due to error variance.

### 4.3. Summary of Illustrative Studies

Table 6 puts the contribution of these studies to the IT value research literature in perspective. Kauffman, Ghosh and Bansal [27] offered methodological advance in several dimensions. First, they suggested a means to *refine* IT business value estimates using jackknife statistics to analyze if spatial non-stationarity is present. Second, using the same unit of analysis throughout (the bank branch), careful data partitioning in conjunction with the jackknife technique enabled the evaluation to focus on the key management issues, at three responsibility levels. Third, the analysis opens up the possibility of testing to determine whether the jackknife pseudovalues systematically vary with aspects of the demographic not explicitly included in the IT value model.

Weill [40] first introduced the use of hierarchical regression and set correlation in IT value research. This enabled unexplained year-to-year variation in a time-series of performance measures to be identified and associated with IT expenditure levels. Such explanation of "residual association" constitutes an important advance in our understanding of how to work with longitudinal data and immediately casts the results of the studies by PIMS [34], Bender [7], and Harris and Katz [18] in a new light. Another important aspect of this work is the way in which it sought to provide refined results for different kinds of IT investments (strategic, informational and transactional). Finally, Weill's use of contextual variables provides a new perspective on how to incorporate information about conversion effectiveness in IT value analysis models.

## 5. Concluding Thoughts

### 5.1. Summary

Summarizing the results of the eleven studies and the new research results we have presented leads us to an important conclusion: recent research on IT value appears to be ending a long adolescence. Since the use of strong theory bases are likely to improve the likelihood of achieving meaningful IT impact analysis results, future IS research should tap an even broader range of applicable theories and methods. For example, Kriebel [28] argued that management science methods could be used to focus on IT's role to promote "frontier efficiency" and improve managerial decisions; Bakos [1] suggested industrial economics and organizational theory; Crowston and Treacy [15] recommended transaction cost theory and marketing channels, among others; and Kauffman, Ghosh and Bansal [27] recently pointed out that marketing science offers a rich body of methods for IT value research. Moreover, it appears that many new areas should be explored -- behavioral decision theory from psychology, project management and scheduling theory from operations management, location theory from operations research, agency theory from accounting and finance, game theory from microeconomics, and modern macroeconomic theory -- just

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

**Table 6:** Motivation, Focus and Caveats for Illustrations

| AUTHOR | MOTIVATION | FOCUS | CAVEATS |
| --- | --- | --- | --- |
| LEGEND | P: Purpose<br>A: Approach<br>T: Theory base | U: Unit of analysis<br>L: Locus of value<br>S: System perf. | M: Measures<br>D: Data analysis<br>C: Org. Context |
| Kauffman, Ghosh and Bansal (1989)<br><br>Branch banks | P: Identify spatial variation in ATM business value<br>A: Jackknife stats. on validated model<br>T: Marketing science, statistics | U: Bank branch, with refined evaluation for 3 mgmt responsib. levels<br>L: Bank branch competition<br>S: Not considered | M: Mrgnl impact on $ deposit share<br>D: Iterative, cross-sectional<br>C: Territory demographics, ATM deployment density |
| Weill (1988) | P: Effects of IT investment on firm performance<br>A: Hierarchical regression, set correlation<br>T: Contingency theory modified | U: SBU<br>L: SBU<br>S: System treated as a moderating variable | M: 6 financial meas.<br>D: Cross-sectional with lags<br>C: Context variables, including political turbulence, user satisfaction, experience w/IT |

to name a few. All these areas offer IT value researchers rich new means by which methodological progress can be achieved.

To take advantage of these other approaches we believe that consistency of definition of key terms and variables will reduce the number of conflicting findings in the future. We present our framework for viewing IT value analysis research as it helped us critically evaluate our own work and the research tradition which has shaped it. Concepts such as organization context, locus of value, unit of analysis and theory base, among others, are general to any IT value approach.

This paper has been the result of the synthesis of two quite different approaches to IT value analysis: economics and behavioral science. The framework we presented suggests the common ground we have found, and the potential we see for continued advances in the field of IT value research.

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

## References


[1] Bakos, J. Y.
Dependent Variables for the Study of Firm and Industry-Level Impacts of Information Technology.
In *Proceedings of the Eighth International Conference on Information Systems.* Pittsburgh, Penssylvania, December, 1987.

[2] Banker, R. D., and R. J. Kauffman.
Strategic Contributions of Information Technology: An Empirical Study of ATM Networks.
In *Proceedings of the Ninth International Conference on Information Systems.* Minneapolis, Minnesota, December, 1988.

[3] Banker, R. D., and R. J. Kauffman.
A Scientific Approach to the Measurement of IT Business Value -- Part I: A Manager's Guide to 'Business Value Linkage' Impact Analysis.
September, 1988.
Working Paper #194, Center for Research on Information Systems, Stern School of Business, New York University.

[4] Banker, R. D., and R. J. Kauffman.
A Scientific Approach to the Measurement of IT Business Value -- Part II: A Case Study of Electronic Banking Operations at Meridian Bancorp.
September, 1988.
Working Paper #195, Center for Research on Information Systems, Stern School of Business, New York University.

[5] Banker, R. D., R. J. Kauffman and R. C. Morey.
Measuring Input Productivity Gains from Information Technology.
In *Proceedings of the ACM Workshop on IT Impact and Value.* Minneapolis, MN, May, 1989.
Forthcoming.

[6] Barua, A., C. H. Kriebel, and T. Mukhophadhayay.
A New Approach to Measuring the Business Value of Information Technologies.
In *Proceedings of the ACM Workshop on IT Impact and Value.* Minneapolis, MN, May, 1989.
Forthcoming.

[7] Bender, D. H.,
Financial Impact of Information Processing.
*Journal of Management Information Systems* 3(2), Fall, 1986.

[8] Breshnahan, T. F.
Measuring the Spillovers from Technical Advance: Mainframe Computers in Financial Services.
*American Economic Review* 76(4):742-755, September, 1986.

[9] Clemons, E. K.
MAC -- Philadelphia National Bank's Strategic Venture in Shared ATM Networks.
December, 1988.
Working Paper, Decision Sciences, Wharton School, University of Pennsylvania.

[10] Cohen, J., and Cohen, R.
*Applied Multiple Regression/Correlation Analysis for Behavioral Sciences, Second Edition.*
Erlbaum, 1983.

[11] Editor.
Editorial -- The Perception.
*Computerworld* , December 5, 1988.

[12] Computerworld.
The Premier 100 -- The Companies Investing Most Effectively in Information Systems.
*A Supplement to Computerworld* , June 20, 1988.


Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

[13] Connolly, J.
Study: Spending Up; Stress on Strategy.
*Computerworld* , November 28, 1988.

[14] Cron, W., and M. Sobol.
The Relationship between Computerization and Performance: A Strategy for Maximizing Economic Benefits of Computerization.
*Information And Management* 6:171-181, 1983.

[15] Crowston, K., and M. E. Treacy.
Assessing the Impact of Information Technology on Enterprise Level Performance.
In *Proceedings of the Seventh International Conference on Information System*, pages 299-310. San Diego, CA, December, 1986.

[16] Ghosh, A.
Parameter Non-Stationarity in Retail Choice Models.
*Journal of Business Research* 12:425-436, 1984.

[17] Ginzberg M.A.
A Study of the Implementation Process.
*TIMS Studies in Management Science* 13:85-102, 1979.

[18] Harris, S. E. and J. L. Katz.
Profitability and Information Technology Capital Intensity in the Insurance Industry.
In *Proceedings of the Twenty-First Annual Hawaii International Conference on System Sciences*, pages 124-130. January, 1988.

[19] ICIT Research Study Team #2.
*Measuring Business Value of Information Technologies.*
ICIT Press, Washington, D.C., 1988.

[20] Ives, B., and G. P. Learmonth.
The Information System as a Competitive Weapon.
*Communications of the ACM* 27(12):1193-1201, December, 1984.

[21] Ives B., M. H. Olson and J. J. Baroudi.
An Empirical Study of the Impact of User Involvement on System Usage and Information Systems.
*Communications of the ACM* 29(3):232-238, March, 1983.

[22] James, L. R., R. G. Demaree and G. Wolf.
Estimating Within Group Inter-rater Reliabilities With and Without Response Bias.
*Journal of Applied Psychology* 69(1):85-98, 1984.

[23] Jonscher, C.
Information Resources and Economic Productivity.
*Information Economics and Policy* 1: 13-35, 1983.

[24] Kauffman, R. J.
*Assessing the Performance of Information Technologies Which Deliver Financial Services.*
PhD thesis, Graduate School of Industrial Administration, Carnegie Mellon University, 1988.

[25] Kauffman, R. J., and C. H. Kriebel.
Modeling and Measuring the Business Value of Information Technology.
*Measuring the Business Value of Information Technologies.*
ICIT Press, Washington, D.C., 1988.
Edited by ICIT Research Study Team #2.

[26] Kauffman, R. J., and C. H. Kriebel.
Identifying Business Value Linkages for Production Processes Involving Information Technology.
In *Advances in Working Capital Management*. JAI Press, New Haven, CT, 1989.
Forthcoming.

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

[27] Kauffman, R. J., A. Ghosh and A. Bansal.
Parameter Non-Stationarity in a Model Which Estimates the Business Value of Information Technology.
In *Proceedings of the ACM Workshop on IT Impact and Value*. Minneapolis, MN, May, 1989.
Forthcoming.

[28] Kriebel, C. H.
Understanding the Strategic Investment in Information Technology.
In Laudon, K. C., and J. Turner (editor), *Information Technology and Management Strategy*, pages 106-118.
Prentice-Hall, Englewood Cliffs, NJ, 1989.

[29] Loveman, G.
An Assessment of the Productivity Impact of Information Technologies.
1988.
Working paper, Management in the 1990s, Sloan School, MIT.

[30] Lucas, H. C., Jr.
The Use of an Accounting Information System, Action and Organizational Performance.
*The Accounting Review* :735-746, October, 1975.

[31] Martin, E. W.
Critical Success Factors of Chief MIS/DP Executives.
*MIS Quarterly* 6(2):1-9, June, 1982.

[32] Mosteller, F. and J. W. Tukey.
*Data Analysis and Regression.*
Addison-Wesley, Reading, MA, 1977.

[33] Panko, R.
Spending on Office Systems: A Provisional Estimate.
*Office, Technology and People* 1:177-194, 1982.

[34] The PIMS Program.
*Management Productivity and Information Technology.*
The Strategic Planning Institute, Cambridge, MA., 1984.

[35] Roach, S. S.
Technology and the Service Sector: America's Hidden Competitive Challenge.
*Economic Perspectives -- Morgan Stanley* , August, 1987.

[36] Srinivasan, A.
Alternative Measures of System Effectiveness: Associations and Implications.
*MIS Quarterly* 9(3):243-253, September, 1985.

[37] Szilagi, A., Jr., and M. Wallace.
*Organizational Behavior and Performance.*
Goodyear, Santa Monica, CA, 1980.

[38] Tukey, J. W.
Bias and Confidence in Not Quite Large Samples.
*Annals of Mathematical Studies* 29:614, 1958.

[39] Turner, J.
Organizational Performance, Size and The Use of Data Processing Resources.
1985.
Working Paper #58, Center for Research in Information Systems, New York University.

[40] Weill, P.
*The Relationship Between Investment in Information Technology and Firm Performance in the Manufacturing Sector.*
PhD thesis, Stern School of Business, New York University, 1988.

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40

[41] Weill, P., and M. H. Olson.
Managing Investment in Information Technology: Mini-Case Examples and Implications.
*MIS Quarterly* , March, 1989.
Forthcoming.

[42] Zimmerman, W., ed.
*American Banker 1988 Managing Technology Survey: The Impact on the Bottom Line.*
International Thompson Publishing Corp., New York, NY, 1988.

Center for Digital Economy Research
Stern School of Business
Working Paper IS-89-40