IDENTIFYING BUSINESS VALUE LINKAGES FOR INFORMATION TECHNOLOGY: AN EXPLORATORY APPLICATION TO TREASURY WORKSTATIONS[1]

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Abstract

Pervasive and costly automation of information handling activities continues to put pressure on senior managers to quantify the contributions of information technology **IT** to the strategic goals of the firm. This paper proposes the use of "business value linkage **BVL**" correlation tests to provide evidence that investments in IT create the desired higher order, economic impacts. We argue that managers should carry out econometric tests which are specialized to capturing *primal*, revenue-enhancing impacts, as opposed to *dual*, cost-reducing impacts. As an illustration, a sample BVL correlation test is constructed to quantify the impact of a "treasury workstation" system on a large commercial bank's ability to increase demand balances from corporate customers. We conclude with some thoughts about where BVL correlation will provide the bt results for managers.

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1. Introduction

Pervasive and costly automation of information handling and other activities in the office, the factory, the marketplace and the executive suite continues to put pressure on senior managers to assess the extent to which information technology **IT** contributes to their strategic goals. In a recent survey of 26 firms, for example, Nolan, Norton and Company [25] found that IT expenditures had increased fourfold. Such investment levels reveal the revolutionary developments in the information technologies that corporations are rushing to incorporate into their operations. At the same time they also suggest the extraordinary expectations the investors have about the potential returns that IT investments should be producing. Reliance on the popular literature suggests that IT is a strong tool by which firms can gain increased market share, a broader customer base, and overall competitive advantage. Consider the Merrill Lynch/Banc One Ohio Cash Management Account, large regional commercial banks' use of automated teller network **ATM** participation, and the airlines' use of proprietary reservation systems.[1] Because the beneficial impacts may seem obvious, it is unlikely that managers would think that any of these ITs present very difficult performance assessment problems.

It is likely that a number of other similar investments in IT have been less favorably rewarded. How are these cases to be evaluated confidently by management? What claims can be made for the extent to which an IT with less obvious, higher order impacts in a corporation can be attributed 'business value'? What kinds of methodologies are suited to handling the difficulties of enterprise level IT performance assessment? Though managers might wish it were otherwise, it is not easy to make strong assertions about the extent to which IT investments actually have the desired impact in practice.

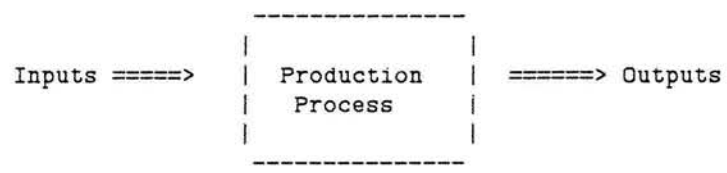
We will argue that microeconomics affords a useful vantage point from which to develop stronger methods for IT performance assessment. Traditional planning tools for IT including budgets, project screening, and return on investment **ROI** models take a relatively "micro" view of the investment, and application of these tools may not always be appropriate in view of the range of technological developments in the last two decades. In this era of expanding opportunity for innovative, 'big hit' IT investments, managers require performance assessment tools that capture and translate IT's impact on the achievement of enterprise level business goals into meaningful and convincing managerial information. This necessarily entails a "macro" view of

[1] See [4] and [20] for a discussion of some other IT success stories of the late 70s and early 80s.

the possibilities of IT and the firm itself, consistent with the methods of microeconomics as the "theory of the firm."

A microeconomic analysis of IT performance involves modeling the production process which transforms input resources into direct and indirect output commodities, as depicted in Figure 1 below.

Figure 1: Input-Output Production Process Model



In a recent paper, Crowston and Treacy [11] commented on the challenges posed by methods which draw on microeconomics as the referent discipline for performance evaluation:

> *Since we know nothing specific about the process, we find ourselves in the same position as before when we come to choose variables. Literally anything could be an input or output of the process, and we have no theory to guide our choice... Filling the process box with a theory that links inputs to outputs has some obvious advantages that recommend it as an approach for future research. First, the process theory should classify which inputs and outputs of the firm are important and may even contribute methodologies to measure them. Second, by explicitly including the processes within the firm, we can look at the impacts of IT in much more detail. Instead of standing outside and attempting to pick out small variations in, for example, return on investment, we can look at where IT directly impacts the firm and make a more precise estimate of this impact. Finally, and most importantly, we can discover the contingencies that allow systems to affect firm performance and prescribe the features of systems that will be useful to particular firms.* [11]

In this paper we present a method to provide evidence for the linkage between specific information technology investments and "strategic" outputs which occur at higher levels of an organization. This method represents our response to the challenge of "filling the process box" embodied in the remarks of Crowston and Treacy. Advances in performance assessment for IT will result when indirect inputs and outputs are *validated* as contributors to and results of a production process. Our approach to determining which inputs and outputs are relevant develops a

methodology which we term "business value linkage **BVL** correlation." We argue that the question of which higher level IT impacts to include in a performance evaluation can be reduced to a set of hypotheses which a manager should attempt to test.

We believe that use of BVL correlation will enable a broader range of IT investments to be adequately evaluated so that management need not succumb to the temptation to make IT investments on "faith in the future." The method we propose puts the spotlight on the investigation of production processes involving IT. It does not presuppose selection of a particular methodology by which to evaluate IT process boxes once the inputs and outputs have been defined and measured. Instead it provides management with a means to ensure that it is evaluating the "right" outputs, regardless of how subsequent evaluation is carried out.

1.1. Organization of the Paper

In the section which immediately follows we lay out formal definitions for some of the terms that we will use to describe the methodology. We further review other approaches which have appeared in the IT assessment literature to determine the extent to which higher order output validation has been addressed. In Section 3 we present our BVL correlation approach, ways in which to focus the analytic process leading to the creation of testable BVL models and some caveats for the potential user. We argue that the business value linkages of IT can be tested by providing evidence for links to proposed higher order outputs. Then, in Section 4 this procedure is applied to a generalized treasury management information system **TMIS**. Our example suggests the potential of BVL correlation as a means to improve upon current approaches where management's intuition and faith play the dominant role in the identification of outputs submitted to cost-benefit analyses for ITs. The paper concludes with a discussion of where we think the method will provide the best results.

2. Basic Definitions and Review of Approaches for IT Performance Assessment

In order to break ground for the exposition of our new approach to IT performance assessment, it is worthwhile at the outset to clearly define a basic set of terms that will be used throughout this paper. This will also enable us to contrast our own views more sharply with those of other authors that have proposed various approaches to IT performance assessment.

2.1. Defining Terms: 'Business Value' and the 'Business Value Linkage'

Our approach to assessing the impact of ITs in the financial services and other industries involves identifying its role in the value maximization of the firm. Where the availability of data and appropriate methodology allow we seek to quantify the focused and diffuse impacts of IT. Our referent discipline for the analysis of the 'business value' of IT is the theory of the firm. Managers possess the goals of maximizing the value of the firm, its profitability and revenue flows, subject to the constraints of limited budgets. Managers also attempt to make well-informed decisions about the purchase and mobilization of a variety of input resources which can be organized to produce outputs that possess economic value in a market. IT possesses 'business value' when its application contributes to management's goal of profit maximization. The organizational level of the impact determines whether the impacts are strategic or operational, diffuse or focused. At both levels, managers should have tools and mechanisms at their disposal to enable them to gauge the impact of their resource allocation decisions.

Business value can be measured in a number of ways. For example, the "net economic contribution" of an input resource to an output product or service is measured by the unit profit sales price less cost of the output, multiplied by the marginal product of the input. This method presumes that the marginal revenue product can be readily identified, not very often the case for IT investments. In other situations where management feels it is difficult to discern the relevant underlying costs, net economic contribution may be replaced by "marginal value product." However, this still requires management to identify a market price for the output or otherwise attribute some value to the output within the firm.

We further term the process which links IT inputs to firm level economic outputs as the "business value linkage" for IT. Management's ability to measure the business value of an IT requires that that the business value linkage from IT investment to higher order, economic impacts be defined. Some of the impacts of IT will be first order, and relatively easier to measure. However, some investments yield much higher order impacts which will be very difficult to measure. Consider the difficulty that business value assessment for firm-wide electronic mail would present. Unfortunately, this is precisely the sort of problem that every manager doing performance assessment for IT can expect to face.

"IT business value measures", simply stated, are measures of the economic impact of an IT within the business value linkage defined by management. Business value measures should originate in the basic business goals of a firm which in turn acquire coherence as they relate to

senior management's vision of the firm's corporate strategy. Since ITs are likely to have multiple impacts on a firm with varied levels of focus, it follows that a number of business value measures, rather than a single measure, should be developed to best inform management about the aspects of IT performance most relevant to the success of its strategy. Though unitary measures will continue to be attractive and simple for managers to understand -- the net present value **NPV** of an IT investment is a good example -- it is unlikely that they will provide the robustness, validity, responsiveness, informativeness and transferability necessary to support powerful management insights into the effectiveness of IT investments.

2.2. Critique of Approaches

Overall, we believe there will be substantial payoffs to management from methodological progress in the IT assessment area. We should state at the outset that we do not expect that any one approach will capture and/or validate the range of diffuse impacts provided by IT. We also expect that some impacts will either never be captured or not be worthwhile for management to consider. But to achieve success in evaluating a broad range of ITs, work on this issue should proceed in a step-wise, scientific manner to initially gain experience with easier to quantify impacts, and then progress to IT impacts which are increasingly more difficult to quantify and validate.

At this point, our discussion turns to recent approaches to the IT assessment problem.[2] Some approaches have already won support and acceptance among managements; others, the results of more recent research efforts, are less well-tested, but appear to hold out significant promise. In our critique, we will consider the tools already available to managers in light of whether they can be adapted or naturally extended to support IT output validation, rather than as performance methods in isolation. Figure 2, shown below, presents an executive summary of the methods we will discuss further below.

[2]The interested reader should refer to McNurlin [23] for an excellent summary of the issues involved in measuring the effectiveness, or strategic impact, of an IT versus the efficiency of the operations it influences.

Figure 2: A Representative Overview of IT Assessment Approaches

Authors	Theory Base	Level of Analysis	Performance Measures	Comments
Cost-Benefit Analysis				
Emery, 1971	Finance Mgmt acct	System	NPV/DCF of tangible items	Estimated values of intangibles
Strassman, 1976 & 1982	Mgmt acct	System	Mkt value-added divided by labor overhead cost	Assumes market price for output
Nolan, 1987	Finance, Micro-economics	SBU, firm	ROI via IS investment; cost & revenue per employee	Emphasizes link between IS and org impact
Value-added Chain				
Clemons, 1986; Cash & Konsynski, 1985	Corporate strategy literature	System w/ links to firm	No specific measures	Requires theory for strategic impact of IT
Management Productivity				
Strassman, 1985; & van Nievelt, 1984	Mgmt acct	SBU, firm	Mgmt value-added divided by mgmt; "return on mgmt"	Non-operations IT assumed as mgmt capital cost
Parametric Production Functions				
Jonscher, 1983 & 1986	Micro economics	Economy	Marginal IT impact on economic growth	Uses translog prod function
Non-Parametric Frontiers				
Stabell, 1983 & 1985	Micro-economics	System	IT costs/sales; "admin intensity"	
Chismar & Kriebel, 1985	Micro-economics, DEA	SBU, firm	Efficiency; subst of K, L & IT inputs; mkt share, ROI, revenue output	No output validation
Kauffman & Kriebel, 1988	Micro-economics, DEA	System, SBU or firm	IT input costs/ business value outputs	Suggests validation for outputs

2.2.1. Cost - Benefit Analysis Methods

There is already a well-developed tradition among managements to treat IT investment analysis in much the same way as investments in property, plant and equipment. Typically, one computes the NPV of two sets of offsetting cash flows, one representing revenues and the other representing costs. The problem in evaluating cash flows, of course, is that costs are normally quite tangible, while the benefits of an IT investment besides operational cost savings are more difficult to assess. Chismar [8] commented that one potential outcome of IT assessment via NPV or discounted cash flow **DCF** methods is that they will lead to under-investment in IT, as acceptable projects are turned down due to the relative non-quantifiability of higher order impacts.

Recognizing this problem, Emery [13] recommended extending NPV/DCF-based cost benefit analyses for IT by considering intangible benefits in terms of the costs management is willing to bear to support them. He stopped short of suggesting that intangibles be assigned monetary values by management. Strassman [31] argued that a logical approach to the improvement of firm-level productivity via IT was to make the information systems executive more accountable for the management of non-computer costs, e.g., office machines and personnel, related to information handling activities. As an outgrowth of his earlier work, Strassman [32] later recommended a market-based value added measure for the worth of a system. Also based on the well-accepted methods of accounting and finance, his measure involved a ratio of system-generated market value less input resource costs to the overhead cost of labor.

NPV/DCF assessment is particularly well-suited to the inclusion of a validation procedure for the relatively intangible outputs that are considered apart from tangible costs and benefits. Provided the output validation test can be crafted by managers in a straightforward way and its results are readily interpreted, the addition of such a procedure would strengthen the results managers might gain from NPV assessments of IT performance. Strassman's approach suffers, in our view, from the assumption that the system-generated outputs are evident, measurable and that they can be subsequently assigned some market value. Again, some validation process is appropriate for the outputs to increase the internal validity of the measure. Both methods discussed here also lack sensitivity to the strategic role which IT can play in the firm. More generally, Myers [24] has commented that DCF methods suffer in their ability to capture the essence of value in strategic plans.

Recently, Nolan [25] suggested developing a "new economics of computing" which stresses the need "to reflect the strategic linkage between the IT investment and the business strategies of the

organization"[3] He identified the human resource as the primary target of an IS investment and recommended measures of productivity and leverage which gauge IT's longer-term impacts on corporate financial structures. His key measures involved long-term return on the IT investment via reduced expenses per employee and increased revenues. Nolan also proposed testing for "strategic interlock," the extent to which the predicted impact of an IT investment has enabled a firm to adjust its budget or achieve some other business goal, by establishing a well-defined relationship between the IT investment and the primary measures of ROI. The mechanics of performing such tests are not entirely evident from Nolan's exposition. Work on these issues which emphasizes the relationship between IT investments and corporate goals is also underway at IBM; see, for example, [15] and [5].

2.2.2. Value-added Chain and Management Productivity Methods

A second set of approaches seeks to characterize the set of elements which enable a corporation to formulate and carry out effective business strategy. Wiseman [39, 40, 41], for example, has identified five categories of strategic impact for IT: differentiation, cost, innovation, growth and alliance. Another well-known approach involves analysis of the "value-added chain" for the firm; see, for example, [27, 28]. This begins with the procurement and conversion of raw material resources into intermediate products and later to the goods and services that represent economic value to firm. Along these lines, Cash and Konsynski [6], and Clemons and Kimbrough [9] have suggested the need for frameworks which explicitly suggest where firms might apply IT to create sustainable competitive advantage. Some obvious applications involve changes in channels of supply, development of barriers to entry and switching costs, IT-driven cost leadership via low cost operations, and reduction in transactions costs to effect sales. Recently, banks have begun to investigate the viability of "electronic data interchange" by placing their order-entry systems on the factory floor. This is meant to just-in-time inventory management and link the buyer to its suppliers. It also simultaneously handles the necessary billing and payment details via computer-delivered advices and electronic funds transfers. In this context, McFarlan [22] recognized that the potential of IT lies in the extent to which it influences the structure of competition in the marketplace and changes the way a firm can compete.

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[3] The urgency of these issues in executive suites is also suggested by Parker and Benson, in a recent lead article in *Datamation* [26]. Their call is for new methods for IT assessment motivated by economics, what they term "information economics." We prefer the terms "economics of computing" and "economics of information systems" to distinguish IT assessment from *information economics* as it is known in the economics literature. The focus of the latter is on information, rather than technology.

While the "marginal analysis" of the value-added chain approach does much to focus management attention on strategic opportunities for IT, it does relatively less to provide management with business value measures for the strategic gains a firm makes by investing in IT. Value-added approaches offer a natural point of departure for business value linkage descriptions and make sense in the framework of the theory of the firm. Moreover, they may suggest higher order impact validation tests. But, since value-added chain approaches do not actually constitute a theory for the workings of production processes creating strategic IT impacts, we suggest the need to look elsewhere for descriptive measures of performance in a value-added chain setting.

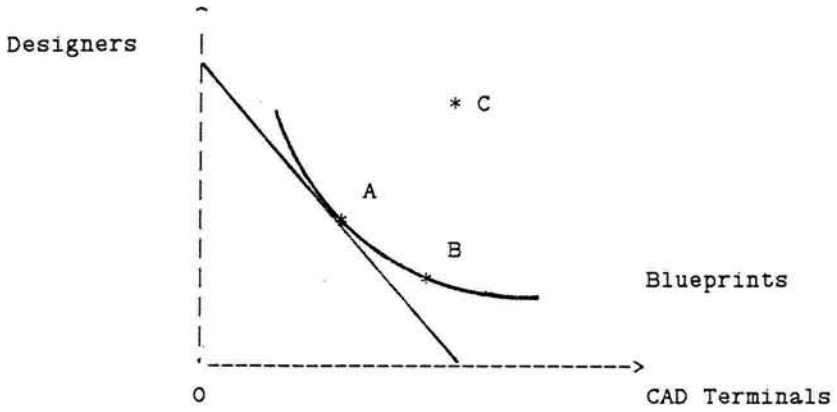
Strassman [33] and van Nievelt [34] are also often-quoted proponents of a related "value-added" assessment approach. These authors split the firm into two realms: one involving direct production operations, and another involving the overhead of the firm management, computing, etc.. Their approach seeks first to identify the impact of management on firm performance. They recommend use of measures called "return on management" **ROM** and "management productivity". ROM is defined as gross profit before tax profit divided by the costs of employed and purchased management services and management capital. This ratio is roughly "management value added" divided by "management cost." IT investments initially are lumped into the non-operating side and subsequently backed out in order to explain inter-division and inter-firm performance variations. Their treatment of business value linkages for IT are only implicit in the cost accounting arithmetic they perform; i.e., the business value outputs for IT, along with the intervening processes which give rise to them for IT, are not explicitly considered.

2.2.3. Microeconomic Assessment Methods

Approaches with a strongly contrasting theory base rely on parametric and non-parametric production function assessment methods. These methods are based on the theory of the firm. An economist defines "productive efficiency" in terms the amount of physical inputs required to produce physical outputs. Consider Figure 3, an oversimplified diagram of the key relationships in a microeconomic production process present at an architectural design firm.

The graph contains a production frontier representing tradeoffs between inputs, "designers" and "CAD-terminals", in the production of a fixed amount of output, "blueprints," the product which the firm sells to its clients. All input combinations represented as points above and to the right of the production frontier are inefficient: they utilize greater amounts of one or both inputs in order to achieve the same amount of output.

Figure 3: A Graph Depicting Allocative Inefficiency in Production Economics



- Point A is allocatively efficient: an optimal mix of inputs is used.
- Point B is allocatively inefficient: although it uses the fewest inputs in its region of the production frontier, the wrong input mix is used;
- Point C is both technically and allocatively inefficient.

Using the production frontier approach, managers can reach conclusions about "economic" or "allocative" efficiency by determining the mix of inputs which enables the production of some level of output for a minimum cost. This is shown in Figure 3 by the point B, the point on the frontier where the isocost line, which represents the relative prices of the inputs, is tangent to the production surface. Thus, the economist's perspective on productive and economic efficiency measurement is congruent with the goal of value maximization of the firm.

2.2.4. Parametric Production Frontiers

Parametric production frontiers are representations of average performance for a population of firms or for one firm over a time series of periods. They involve full mathematical specification of the relationships between inputs and output. While strong econometric methods exist to estimate parameters for production functions, economists recognize that the model specification or choice of functional form for example, Cobb-Douglas, translog or min-flex Laurent can influence parameter estimates. Varian [35] has argued that the state-of-the-art in parametric production function estimation does not yet provide for the validation of the functional form to be tested.

Recent work utilizing these methods has been done by Jonscher [16, 17] and Loveman [21] whose objective was to isolate the economic value of information resources in the American economy. Jonscher presented a microeconomic model which specifies a functional relation between output efficiency and information inputs. In a subsequent paper he utilized translog production frontier estimation to explore the effect of falling IT costs on total economic output over the last twenty years.

2.2.5. Non-parametric Production Frontiers

Non-parametric frontiers capture "best observed" or "state-of-the-art" production technologies, and so are likely to lie southwest of the empirically derived mean-value performance that parametric frontiers represent.[4] Non-parametric frontiers are also known as "data envelopment" methods, since the frontier will create an envelope which contains all other input-output combinations of lesser efficiency. The measurement of best observed practice provides management with a set of exemplars for less efficient units in a firm. Moreover, the approach does not require a pre-specified functional form for the IT process box or require management to make assumptions that might have little basis in theory or practice.[5] This is appropriate in view of how little management really knows about the workings of IT in the firm's creation of business value outputs.

Other authors have used non-parametric frontier analysis to relate IT investment to the efficient production of firm level business value outputs. Stabell and Forsund [30] attempted to explain efficiency for a large data set of Norwegian firms by investigating a set of surrogate

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[4] Because parametric production functions are estimated, their parameters are not the *true* parameters.

[5] Translog and Cobb--Douglas technologies, for example, require explicit assumptions about input substitution elasticities.

measures for levels of IT investment. One aspect of DEA's attractiveness for IT performance assessment is that it can handle multi-input and multi-output production technologies. Chismar and Kriebel [7] employed "data envelopment analysis" **DEA** to gauge the impact of IT expenditures on business value outputs such as sales revenue and return on investment. The authors provided examples of how managers can use DEA to identify rates of substitution among labor, capital and information technology to support profit maximization. Elam, Henderson and Thomas [12] also used DEA to study the performance of a set of data centers within one firm. More recently, Kauffman and Kriebel [18] proposed the explicit development of a business value linkage which ties lower order direct outputs of an IT to higher order economic impacts They argued that the more diffuse, higher order impacts of IT, submitted as outputs to appropriate DEA models for performance evaluation, require validation to ensure that the "right" outputs are being evaluated.

3. Identifying 'Business Value Linkages' for IT Investments Using BVL Correlation

3.1. Requirements for Developing a Business Value Linkage

A basic requirement to the development of a business value linkage for an IT is that management spend the time to carefully develop a conceptual understanding of what kinds of impacts the IT has in the firm, and at what organizational levels they are felt. The direct, tangible outputs of an IT will almost never capture the full range of impacts. Instead, management needs to begin by identifying the direct outputs that arise from an IT, and from there continue to make a conceptual tracing of the links between the direct outputs and higher order impacts in the firm.

ATM networks provide a nice illustrative example.[6] Even a casual observer might note that transactions processed at an ATM alone do not tell the whole story of its business value to a bank. Yet transactions processed are a readily quantifiable direct output which is tangible at the local ATM level. If we continue to trace the impacts of the ATM to the branch level, we could argue that transactions processed provide an indirect means to gauge the additional service value that customers enjoy, which does not require the bank to invest in more branch labor. In some situations, labor costs may even be displaced directly through a reduction in teller staff. An ATM network manager's business value assessment problem would be to test whether this latter impact can be substantiated.

[6] For a fuller discussion of ATMs as an IT performance assessment problem, see Banker and Kauffman [3].

Just as the purpose or function to be served by productivity measures will influence which measures are relevant, so will management's purpose in conducting an IT business value assessment influence the kind of business value linkage it seeks to define. If the firm is in a cost-cutting mode, management may wish to justify investment in an IT based on the costs it will enable the firm to save. This would require a different business value linkage than if management wished to demonstrate that the IT will lead to increased market share in a product area.

Stating that management must spend considerable time up front in the definition of a business value linkage does not imply that we believe, once management has defined the business value linkage, that it is immutable. Indeed, the business value linkage could be defined differently for an initial IT investment than for a later performance review. This is consistent with Ginzburg's view:

> *It is only once we understand how the new information will be used that its value can be estimated. Thus, efforts to quantify benefits should focus on the changes in organizational process which will result from changes to information systems.* [14]

It makes sense to reconsider the business value linkage defined at the time an IT investment was initially evaluated, because it is very likely that unintended uses and benefits may have arisen which promote cost reduction or revenue enhancement. This is a contingency approach similar to Nolan's suggestion to track the "strategic interlock" of IT investments.

3.2. Indirect Output Validation: A 'Business Value Linkage' Procedure

The philosophy behind the approach which we will describe below is that it is possible to attribute business value to information technology investments, provided there is evidence of a business value linkage. In this section we discuss a means to provide such evidence using tests of correlation for IT as input variables into, or design variables affecting, an economic production process, and that results in higher order firm outputs. If it can be shown that the model tested has explanatory power and the IT variables are significant, then this provides evidence to suggest a business value attribution to the IT is warranted. Assuming a regression model were used, for instance, an estimate for the actual amount of business value is given by the sum of the values of the coefficients of the IT design variables in the regression model multiplied by the value of the higher order output, provided the model has reasonable explanatory power and the IT variables are significant.

The basic procedure for creating testable BVL correlation models can be described as follows:

STEP 1: Based on prior study, management should propose a set of indirect outputs, $Y_1, \ldots, Y_I$, which it believes are linked to a particular IT investment.

STEP 2: Characterize hypothetical production processes, $P_1, \ldots, P_J$, for the indirect outputs.

STEP 3: Characterize a limited set of models, $M_1, \ldots, M_K$, to test for BVL correlation in which the relevant variables (design features, including IT, for example) are included.

STEP 4: Gather data to estimate the models.

STEP 5: Perform statistical tests to determine if the model(s) has (have) explanatory power for the production of the indirect output(s) and whether the IT variable(s) is (are) "significant."

STEP 6: If the BVL correlation test shows that the IT variable(s) provide(s) explanatory power for the higher order output levels, then determine approximately what portion of the output varies with the IT investment.

The term "significance" deserves comment here; we distinguish between its management policy-related and technical meanings. In the technical sense, a variable may be significant in a regression model, for example, without being particularly relevant to managerial policy adjustments. This can occur when an environmental variable which management cannot control, for instance, provides explanatory power for a business value output. Management's choice is about whether or not to operate in the environment, and not about a means to change it. Of greater interest to management are controllable variables, such as investments in IT, and staffing and operating cost levels, which may be related to output and profitability. The controllable predictors of business value outputs, once identified, can be adjusted through revised management policies to enable more efficient production of business value outputs. If it turns out that the IT variables is are not correlated with the output, while the remainder of the model has explanatory power for the creation of the output, this still constitutes a "positive result." It provides evidence to management that it need not include this higher order output in a cost-benefit analysis of the IT. This can serve to reduce the uncertainty decision makers experience when they consider the key dimensions of a managerial decision.

3.3. Indirect Output Validation: Primal and Dual Approaches

One basis by which to improve the power of the BVL correlation procedure suggested above is to specialize the tests of IT-influenced outputs to the unique requirements posed by the production process. A related basis is to consider the role that IT performance evaluation will play in senior management decision making. The analog that we suggest follows along the lines of the primal-dual analysis from theory of the firm. The acid test is whether the indirect output which management wants to link to an IT investment primarily leads to enhancement of value or cost reduction. This suggests the use of correlation tests which are specialized to gauging IT's impact on the consumption of other inputs or the creation of outputs which affect the bottom line.

Crowston and Treacy [11] suggest a similar, somewhat less general approach that is tied to specific theories about the underlying mechanism inside the process box and that we believe supports our view.

> *Many different theories about organizations could be used to fill the process box. One obvious source for such theories is the field of strategy. In a rough sense, strategic performance is concerned with long-term profits, which can be achieved through superior revenues or superior cost performance. The utility of partitioning strategic performance into these two components is that a body of literature within industrial economics and corporate strategy relates to each, namely monopolization theory and Williamson's theory of transaction cost economics.*[7] *These two fields are obvious places to look for foundation theory for studying the impact of information systems on enterprise performance and they provide methodologies which could serve us well in these studies.*

Reliance on monopolization theory or Williamson's theory of transaction cost economics represent particular primal and dual approaches, which appear to be quite useful to us. However, future research and practitioner experience with these and other theories will determine their range of applicability and fit in gauging IT performance. The thrust of our more general approach is embodied in Figure 4 below, adapted from a publication of the American Productivity Center [1, 2]. We will draw on it in our subsequent discussion of primal and dual side impact validation.

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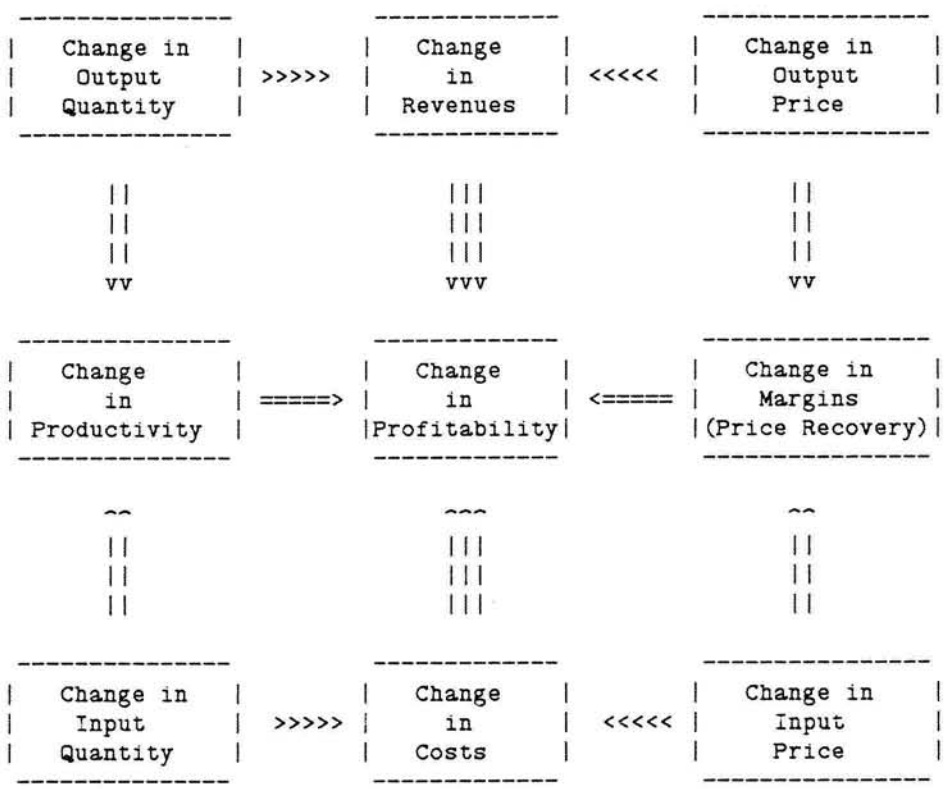
[7] See, for example, [37, 38].

Figure 4: Components of Change in Profits



3.3.1. Primal Approach: Validating Revenue Enhancing Impacts

Suppose an ATM manager believes that one of the benefits to a bank of operating an ATM network is that depositors tend to leave more money with banks on average as a result. Thus, an evaluation of an ATM network or individual ATMs should be extended to include the marginal revenue product of ATM-generated deposits, provided the higher order impact can be strongly linked to ATM deployment. The manager's belief that retail payment IT produces business value for the bank can be reduced to a hypothesis testable via our BVL regression approach. Such a test involves identifying the role that various independent variables might have in the creation of demand deposit or savings deposit dollars, the dependent variable in this case. The independent variables used to predict area deposits might include local demographic factors and branch design characteristics, including the presence of ATM, the network the banks participates in, the number of ATMs in the competing network, its relevant rates of interest, and so on.

The purpose of this brief example is to illustrate the primal approach to IT output validation: providing evidence that ATMs create a revenue-enhancing impact. Since a market rate for demand and savings deposits can readily be determined, it is not hard to assess the relative impact of ATMs via the coefficient of our regression model. This enables us to reduce the following assertion by Clemons to a testable hypothesis:

> *ATMs offer considerable convenience to retail banking customers -- 24 hour access to information about their accounts and to their money. This has no doubt been useful and attractive, but it is not nearly as attractive as offering triple their interest* ... [10]

It is possible that the coefficients of the ATM-related independent variables may not be significantly positive; if they are though, higher order business value for ATMs has then been quantified.

The validation of revenue-enhancing impacts can be assisted by creating tests which identify top-row impacts in Figure 4, i.e., changes in output quantity or changes in price. Together, these lead to changes in firm revenues, which in the absence of other changes affect profitability. The output validation test in the ATM example above is representative of an application of the left upper most box in the figure. We could incrementally extend our analysis to the right upper most box, for example, by investigating hypotheses which suggest that 24 hour access to their money makes customers more willing to accept a lower interest rate for their savings. Such tests would represent different views on the part of management about the content of the BVL for ATMs and the justification of ATM deployment.

3.3.2. Dual Approach: Validating Cost Reducing Impacts

A similar set of arguments can be made for ATM impacts on the dual, or cost reduction, side. Basically, the argument is that ATMs promote the production of higher customer service levels without requiring the added costs. This suggests testing to gauge those expenses a bank avoids, which can be linked to the use of IT, while maintaining or increasing customer service levels.

Figure 4 on the changes in the components of profits is again instructive. Dual side cost gains flow from reductions in input quantities, such as labor, and in input prices, leading to changes in the underlying overall cost of production. This is depicted in the bottom row. IT investments, to the extent that they can enable new channels of supply to be developed, can potentially change the effective price the firm pays for its inputs. When IT is used to improve inventory tracking or

promote better selection of materials to use in a productive process, management can assert better control over input resources.

The synthesis of primal and dual side IT impacts in a production process develops from measures of performance which capture the efficiency of resource use and the goodness of management's resource allocation decisions. In Figure 4, changes in technical efficiency, the standard productivity effects, are captured by the set of boxes on the left side. Management's ability to respond to changes in the exogenous environment of input and output prices with new resource allocation policies is assessed via the set of boxes on the right side of the diagram. Taken together, these analyses ensure that managers will be using performance measures which can support profit maximization.

3.3.3. Theoretical Derivation of a Firm's Production Technology

To complete our contacts with the primal and dual analysis of microeconomics we turn to a brief discussion of the theoretical derivation of a firm's production technology from its cost function. A basic result in microeconomics is that all the information necessary to reconstruct a firm's production function is present in a well-behaved cost function. More precisely, given a cost function $c(\mathbf{w},y)$ for a vector of input prices w and output y, we can solve for the conditional factor demand for an input, $x(\mathbf{w},y)$, via Shephard's lemma the derivative property, provided the cost function is twice differentiable and input resource prices are strictly greater than zero.[8] Subsequent manipulation of the conditional factor demand will yield $f(x)$, a function corresponding to the production technology of the firm.

If it were possible to derive one in practice, a production function of this sort would be the ideal statement of the business value linkage for IT. But, we are typically prevented from doing so because it is hard to write a representative cost function linking the higher order impacts of IT and the investment itself. An additional difficulty is that there is no guarantee that the production technology of a firm actually meets the strict requirements needed to derive a unique production technology. A third concern is that such a production technology would need to capture all the relevant aspects simultaneously. This means that we would require a flawless method for separating out various kinds of costs related to production.

Lest we leave the impression that the results of microeconomics are swamped by the com-

[8] As a basic reference in this area, see Varian [36].

plexities of the real world, we remind the reader that these basic results still can yield useful managerial information. Restrictions on the cost function, for example, can be interpreted in terms of the structure of production. And, basing productivity assessment measures on the assumption of cost minimizing behavior enables management to encourage behavior which leads to profit maximization. Where managers can clearly identify "separable" sub-production processes, i.e., aspects of production in a firm which do not exhibit interdependence with other aspects of production say, in a division or department, and higher order IT-related outputs can be identified via BVL correlation, this theoretical approach is more useful. The remaining difficulty for a manager is to be assured that the necessary structure on the production technology can be reasonably assumed.

3.4. Tests of BVL Correlation: Caveats When Regression is Used

Implementing our BVL regression procedure requires considerable time on the part of management to thoroughly understand how IT fits into the firm's production. Since we do not advocate defining or testing a large number of models, management will need to do a substantial amount of reflecting up front about the role of the IT they wish to assess and the outlines of the business value linkage. Management should attempt to characterize the best possible model based on its *a priori* beliefs about the "possible" impacts of IT and other variables affecting the output. If these expectations are later found to be unrealistic, modifications can be made to the original model. These models should be developed with the support of and intermittent feedback from senior management, who will make decisions based on the business value measures for IT. Without the commitment of senior management, the developers of models which test for the business value linkage are likely to meet with little success or acceptance of their work.

Data availability and collection pose another serious problem which can hinder the use of BVL correlation. For some kinds of ITs it may not be feasible to collect data that management believes are relevant. The effort necessary to develop the data base of information to carry out a BVL correlation may be unattractive given the magnitude of the IT investment. Where management is making an investment in an entirely new IT, data may just not be available. To gauge its usefulness in a variety of circumstances, management should familiarize itself with BVL correlation by evaluating previous investments to support *ex post* cost-benefit analyses. This will also provide a baseline of performance against which to evaluate the impacts of future changes to strategic information systems.

We close our discussion of the caveats of using BVL regression for IT-influenced production processes by again recommending that the reader keep in mind the technical interpretation of 'significant variables' in regression models. The presence of a significant explanatory variable related to IT with a positive sign on its coefficient provides evidence that it is worthwhile for management to attribute some business value from a higher order output of the firm to the IT. It improves on arbitrary decisions about which outputs to include and which to exclude in cost benefit analysis, but users of BVL regression should recognize that regression rarely provides "conclusive" evidence. Thus, although an IT variable may be significant in a BVL regression model with a high multiple correlation coefficient and a low standard error of regression, it is still possible that a business value attribution can be made in error.

4. An Application of BVL Correlation

In this section we present an example involving treasury workstations to illustrate how our BVL correlation procedure can be used to provide evidence for the indirect outputs of IT. Many IT applications in the financial services industry present very similar assessment difficulties; their direct outputs may not possess any "economic" or "business value" content while their higher order, indirect outputs may be difficult to definitively link to the IT and measure. Direct outputs constitute focused impacts while indirect outputs result from more diffuse impacts. An added feature of the IT we discuss is it has revenue and cost impacts. This enables the explicit consideration of primal and dual side output validation.

4.1. An Application of BVL Correlation to Treasury Workstation Assessment

Treasury management is the management of a firm's cash and debt positions. Good treasury management reduces financing costs by mobilizing funds within the firm and improves profitability by leaving no idle balances uninvested. Increasingly unstable economic conditions, rising interest rates, and the shift to floating currency exchange rates in international markets in the early to mid-1970s has made more careful treasury management a necessity. About the same time, however, advances in data processing and time-sharing computer-based services by banks have made improved management of day-to-day treasury operations possible. In today's environment, treasury management has become even more complex, calling for on-line, up-to-the-moment balance positions, and the ability to move money around the globe to where it is needed most in an instant.

4.2. The IT Assessment Problem in the Corporate Treasury

To meet some of these requirements, banks and other third party software vendors have designed treasury management information systems with various types of application software designed to support the treasury function of a company. Treasury workstations generally deliver a packaged set of capabilities, which in some cases can be customized to the specific treasury requirements of large volume clients. Saturnia, Houlihan and Coluccio [29] suggest some examples of what a treasury workstation can do for a corporate treasurer:

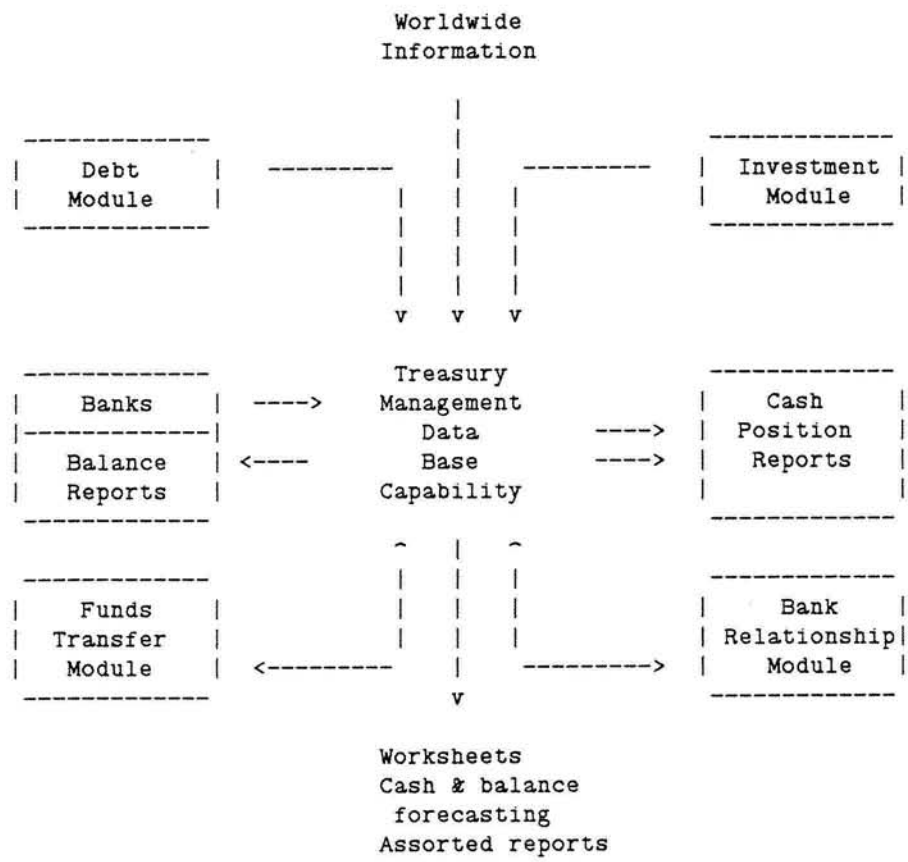
- Communication: Facilitates the electronic transmission of data from the bank to the treasurer's workstation and pre-formatted funds transfer requests from the treasurer to the bank.
- Balance Reporting: Arranges and presents historical bank account information in report format, allowing the user to review bank balances, transaction details and float information.
- Intraday Transactions: Allows the user to obtain bank balances and detailed debit and credit information on a same-day basis.
- Target Balance: Provides the ability to track and target required bank balances as well as to perform sensitivity analysis for cash flow planning.
- Investment/Debt: Tracks the maturities of securities in a portfolio and permits the user to initiate investment transactions and to receive confirmation of purchases and sales of securities.

The data flows within a typical corporate or bank treasury workstation system is pictured in Figure 5 below. Many aspects of a bank's transaction processing systems are linked to a treasury management information system, and this is likely to increase its value to users.

The development of these systems by a commercial bank requires a significant investment in hardware and software. Since a bank is a monopolist with respect to its own customers' transaction information, it can benefit by developing a TMIS that ties its customers ever closer. As a corporate treasury manager begins to depend on a particular bank's TMIS, this will lead to the creation of switching costs, should the customer wish to begin conducting a larger portion of his transaction processing business elsewhere.

In this context, it is only natural for senior managers investing in TMIS development to inquire whether these systems are actually producing the level of business value initially envisioned. In a recent paper, Krcmar and Lucas [19] provided some concrete evidence about how a NYC money

Figure 5: A Treasury Management Information System



Note: This figure is adapted from [29].

center bank marketed a TMIS product called "MicroStation" in the early 1980s to provide competitive advantage. The authors presented data, shown in Table 1 below, to estimate the bank's business volume increase for its corporate relationships during 1985, broken into categories which highlight the impacts of treasury workstations.

The authors concluded that "the use of any microstation except one offered by another bank is associated with an increase in business with the bank." They further note that the major competitive problem is the existence or development of TMISs "offered by or tied to other banks." This creates a barrier to entry into a meaningful account relationship if the bank has not been the first to sell a treasury workstation to a corporation.

Table 1: Business Increases Associated with "MicroStation" TMIS

Overall increase on average	11.0%
Firms with no cash micros	9.8%
Firms with bank's micro	13.6%
Firms with other vendor's micro	19.9%
Firms with another bank's micro	3.9%

How should business value for a TMIS be measured? Besides account relationship business increases, what other higher order impacts accrue to the bank providing the service? How can these higher order outputs be linked to the TMIS, i.e., validated as its outputs? Assuming a set of higher order impacts can be validated by a TMIS manager, is this IT actually providing the desired level of return on the investment commercial bankers have made?

4.3. BVL Correlation for the Economic Impacts of TMIS

Next we turn to the development of a simplified business value linkage for a TMIS, using Krcmar and Lucas' [19] results as our point of departure. In particular, we need to construct a BVL correlation test which would provide stronger evidence to suggest that TMISs have such favorable impacts in commercial banking. Our initial investigation of bank production processes involving a TMIS would begin by attempting to identify a set of direct and potential indirect, business value outputs. From a bank's perspective, some of the outputs which provide expense reductions include:

- automated funds transfers which require no bank intervention;
- automated balance inquiries which require no bank staff;
- fewer funds transfer errors, due to pre-formatted input screens;
- growth in balances due to banking relationship concentration.

The first two are direct outputs and could be evaluated in a straightforward manner: a first order approximation by the bank of the business value of these would be given by the costs of having bank employees perform these activities, in the absence of the TMIS. The third could also be approached from this perspective, but there may be a more diffuse benefit as well.

One possible approach to evaluating the third is to construct a statistical test to determine whether there is evidence that supports the assertion that TMIS use delivers cost savings via lower funds transfer error rates. Since most banks capture information about funds transfer errors, it would be sufficient for the test to evaluate whether there are significant differences between customer error rates in pre-TMIS and post-TMIS implementation settings. Once the bank has built up a significant TMIS customer base, error statistics would be tested in the pre/post TMIS conditions. Assuming the bank can identify explicit costs for its funds transfer errors, this cost can then be applied as a surrogate for the value of the incremental reduction in transfer errors made by the corporate treasurer's staff. If there is no significant difference in the pre-TMIS and post-TMIS groups, then management would not include error reduction as a quantifiable TMIS benefit. The focus on *ex post* evaluation is justified by management's need to develop a baseline for the technology's contributions. It can also guide future value assessments as management decides to add new capabilities.

From results of Lucas and Kremar, management may believe that the presence of TMIS encourages its clients to concentrate their banking business with a bank which offers this capability. Based on the costs involved with conducting multiple banking relationships, customers of a given class say, in terms of total deposits with banks or funds transfer dollar volume often attempt to leave balances with the smallest number of banks possible. We propose the following sample BVL correlation test for this higher order business value output in three account groups:

- Treatment Group #1: Using bank's TMIS product as of January 1, 198x;
- Treatment Group #2: Using another bank's TMIS product as of January 1, 198x;
- Treatment Group #3: Using no bank's TMIS product as of January 1, 198x.

Next, we would collect two time series, for example, 48 months of monthly average balances for the accounts in each group. Further suppose that the product introduction occurred across a broad account base during month 24. We split each time-series into pre-TMIS and post-TMIS introduction series. Our null hypothesis for months 25 to 48 is that the account balances of TMIS users would not exhibit significantly different growth or change patterns from those of the

control group, given that all other group-specific influences are held constant.[9] If the TMIS product introduction has had a higher order impact on account balance positions, then we would expect to find that the three time series exhibit different trends.

Finally, assume that based on previous examination of growth or decline in balances for the bank's corporate accounts, management is confident that the following simple logarithmic autoregressive trend model provides a reasonable forecasting tool:

$$\ln Y_{c,t} = d_0 + d_1 \ln Y_{1,t-1}$$

where

$Y_{c,t}$ = the value of the average balances of corporation c in month t, t =1, ... 24

d_1 = the trend parameter

The actual values of Y_{24} for each of the three treatment groups should be checked; if the null hypothesis held for the pre-treatment condition then each group should be starting at roughly the same aggregate balance level. In order to force an intercept of zero for the second 24 months, we adjust subsequent Y by denoting a new variable:

$$Z_t = Y_t - Y_{24} \quad \text{for } t > 24$$

To perform the BVL correlation test, we can estimate the model for panel data involving multiple accounts over the time periods:

Group #1	Group #2	Group #3
$\ln Z_{1,t} = Y_{24} + \alpha_1 \ln Z_{1,t-1}$	$\ln Z_{1,t} = Y_{24} + \delta_1 \ln Z_{1,t-1}$	$\ln Z_{1,t} = Y_{24} + \lambda_1 \ln Z_{1,t-1}$
⋮	⋮	⋮
$\ln Z_{c,t} = Y_{24} + \alpha_1 \ln Z_{ct-1}$	$\ln Z_{c,t} = Y_{24} + \delta_1 \ln Z_{c,t-1}$	$\ln Z_{c,t} = Y_{24} + \lambda_1 \ln Z_{c,t-1}$

[9] Since we would have no way to identify the members of each of the treatment groups prior to the product introduction, we would expect that the null hypothesis would hold during months 1 to 24.

where

$Z_{c,t}$ = incremental value of average balances of corporation c in month t, for t = 25, ... 48

α, δ, λ = trend parameters to be estimated for treatment groups

Y_{24} = a constant representing the three groups' balance position in month 24.

If panel data analysis yields results suggesting that the treatment group coefficients of the previous period's account balance, α, δ, and λ, are significant predictors of current balance levels, we next must determine if the coefficients of the groups are significantly different from one another. If management's beliefs about the impact of TMIS on business concentration are justified, they would expect $\lambda = \delta < \alpha$. This information might then be used to attribute business value to the bank's TMIS in proportion to the differences in the coefficients of the regressor. At the minimum, it could be used to point senior management's attention to a higher order economic impact of TMIS for which significant evidence is available. A similar approach could be used to evaluate monthly changes in the dollar value of the bank's fee-based business increases.

5. Conclusion

Developing and testing a business value linkage for an IT should be a useful thought process for senior management. In a sense, "positive" results will be guaranteed: management can obtain guidance to include or exclude outputs which might justify their investments in IT. Knowing what to exclude is often just as important as ascertaining that all the appropriate impacts have been recognized. This can also boost senior management's confidence about making decisions based on the results of previous IT performance assessments. In addition, our approach provides a solid basis on which to begin to build new cost-benefit models for information systems. For example, performance evaluation for decision support systems, executive information systems, and expert systems is just becoming an issue with management, as firms begin to gain experience with their development and use.

A related use of business value assessment is to enable management to operationalize the quality gains which IT can provide. Our example involving the deployment of a treasury management system provides an appropriate context in which to test for quality gains in the payments process. BVL correlation tests could be run on alternate configurations of the same basic system at beta-test sites, as product managers finalize the design of a treasury product involving information

technology. Since quality in funds transfer operations involves minimizing the occurrence and speeding the repair of errors, business value assessment can be used to identify opportunities to boost "back-office profit."

Business value linkage assessment may also provide a means to test whether 'user satisfaction' is a useful surrogate for system value in specific corporate contexts. Currently, there is a controversy in the IS literature over whether user satisfaction with an information system is a relevant dimension in tagging its value. While our purpose in this article is not to make a judgment about the viability of measures of user satisfaction, the method we propose might be used to identify circumstances where user satisfaction is associated with hard, economic gains for the firm, and thus, is an appropriate surrogate.

We believe the biggest benefits from BVL correlation are likely to accrue in situations where careful retrospective study of IT investments is required to assist the evaluation of proposed IT investments. BVL assessment methods are strengthened when substantial data from ongoing operations are available. And, their results are more likely to influence senior managers if they provide enhanced insights beyond those of the trusted methods of managerial finance. Their primary usefulness will be in providing the chief executive officer and the chief financial officer with scientifically developed evidence about the impact of new information technologies at any level of the firm deemed to be relevant. Management decision, as ever, involves triangulating with multiple methods to an acceptable outcome; so much the better that the tools supporting this process provide sharp insights along the way.

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