Systems Design, Process Performance, and Economic Outcomes in International Banking

PRABU DAVAMANIRAJAN, ROBERT J. KAUFFMAN, CHARLES H. KRIEBEL, AND TRIDAS MUKHOPADHYAY

PRABU DAVAMANIRAJAN received his Ph.D. in Industrial Administration (major in Information Systems) from the Tepper School of Business, Carnegie Mellon University in 1996. His research focuses on the economics of information systems. His research has been published in the *Journal of Organizational Computing and Electronic Commerce,* and International Conference on Information Systems and Hawaii International Conference on System Sciences proceedings.

ROBERT J. KAUFFMAN is the Director of the MIS Research Center, and Professor and Chair in the Information and Decision Sciences Department at the Carlson School of Management, University of Minnesota. He previously worked in international banking, and served on the faculty of New York University and the University of Rochester. His graduate degrees are from Cornell University and Carnegie Mellon University. His research focuses on senior management issues in IS strategy and business value, IT infrastructure investments, technology adoption, e-commerce and e-markets, and supply-chain management. His research has been published in *Organization Science, Journal of Management Information Systems, Communications of the ACM, Management Science, MIS Quarterly, Information Systems Research, Decision Sciences,* and other leading journals and conferences. He recently won best research paper awards at the INFORMS Conference on Information Systems and Technology (CIST) in 2003, 2004, and 2005; Hawaii International Conference on System Sciences in 2004; International Conference on Electronic Commerce in 2006; and the Eighth Information Management Conference in Taiwan in 2006. He is also a 2006 recipient of the IEEE Society for Engineering Management's "Best Research Prize."

CHARLES H. KRIEBEL is a Professor of Industrial Administration (Information Systems) Emeritus at the Tepper School of Business, Carnegie Mellon University. He received his Ph.D. from Massachusetts Institute of Technology in 1964. His research interests include computer and information systems, information economics, telecommunications, management science, operations management, robotics, applied economics, productivity, manufacturing systems, and information resource management. His recent papers have examined the business value of information technologies, software productivity and quality, strategic IT investments, and software maintenance. He previously served as a vice president of Metropolitan Life Insurance Company in New York City, and contributed many years of his time as the area editor for Information Systems at the journal *Management Science.*

TRIDAS MUKHOPADHYAY is Deloitte Consulting Professor of E-Business at the Tepper School of Business, Carnegie Mellon University. He received his Ph.D. in Computer

Journal of Management Information Systems / Fall 2006, Vol. 23, No. 2, pp. 65–90.
© 2006 M.E. Sharpe, Inc.
0742–1222 / 2006 $9.50 + 0.00.
DOI 10.2753/MIS0742-1222230204

and Information Systems from the University of Michigan in 1987. His research interests include business value of information technology, e-business, and software development productivity. His recent papers on e-business examine competition between Internet search engines, adoption of Web procurement, and models of electronic intermediation. His other research projects study the productivity and quality of software products and offshore software contracts. His papers have appeared in *Information Systems Research, Journal of Management Information Systems, Communications of the ACM, Journal of Manufacturing and Operations Management, Journal of Marketing Research, MIS Quarterly, Omega, IEEE Transactions on Software Engineering, Electronic Commerce Research and Applications, Journal of Operations Management, Accounting Review, Management Science, Information Systems Frontiers, Information, Technology & Management, Decision Support Systems, Journal of Experimental and Theoretical Artificial Intelligence, Journal of Organizational Computing, International Journal of Electronic Commerce, Journal of Money, Credit, and Banking, American Psychologist,* and other publications.

ABSTRACT: Information technology (IT) value remains a serious concern of management today, especially how it should be measured and how it is created. Although we have made significant progress at the firm and aggregate levels of analysis, process-level analysis is still in its infancy, and there is a need for a systematic basis for identifying IT effects. We provide such an approach by developing two models: a *process performance model* of how system characteristics enhance process output and quality and an *economic performance model* linking process performance to the economic performance of the firm. We apply these models to global trade services in international banking. We obtained estimates for key variables in both models and general support for the approach. We interpret our results and discuss the merits of the process-level approach for the assessment of IT-reliant work systems.

KEY WORDS AND PHRASES: business process, business value, economic performance, financial services, international banking, IT value, process performance, technology management, trade services.

THE BUSINESS VALUE OF INFORMATION TECHNOLOGY (IT) is a matter of concern for management. Although IT investment has grown rapidly over the years, our understanding of its effects on firm performance remains unclear. Even though recent studies have reported positive findings (e.g., [13, 19, 26]), we still do not have a clear understanding of how IT creates business value. The earlier work on IT value was plagued by a lack of generalizable theory and quality data at an appropriate level of analysis, and weak methodology [20, 48]. However, significant advances have occurred in the past several years, with the result that we now have much greater confidence in asserting the circumstances under which investment decisions are made and how IT pays off. They include the *business process level* (e.g., [3, 40, 41, 55, 58, 68, 70]), the *firm level* (e.g., [12, 13, 26, 28, 51]), the *industry and market level* (e.g., [32, 35, 37, 56]), and the *aggregate level of the economy* [16, 27, 30, 44, 45, 46]. We will shortly provide more detail about the nature of the advances as we review the literature—especially at the business process level—but, nevertheless, much more work still needs to be done to improve the effectiveness, usability, and insights that the methods have to offer.

Davenport [23] provides early motivation for the evaluation of IT investments and organizational performance at the business process level. He states that business activities should be broken down into processes that can be designed for maximum effectiveness and that business processes should be considered in terms of the capabilities IT can provide. Alter has argued that a focal point of information systems (IS) research should be *IT-reliant work processes,* or "work systems whose efficient and/or effective operation depends on IT" [2, p. 367]. He further posits that assessment and performance measurement should occur at the process level. Subramanian and Shaw [72] have also argued that IT value assessment at the business process level affords a range of benefits, especially in the e-commerce context. First, unlike assessing IT effects using the organization as the unit of analysis, process-level analysis does not involve aggregation across multiple processes where IT investment may result in different levels of effectiveness [48]. Second, it allows us to gauge IT usage [57] and trace the effect of IT on specific processes and tasks [58]. Third, IT evaluation at the process level is important because investment decisions are made at this level. Curtin et al. [21] make a similar point with respect to radio frequency identification (RFID), which has the potential to create additional business intelligence leverage at the business process level through its introduction into inventory, procurement, and logistics services; hospital and corporate equipment, property, and asset management; and a range of other processes where mobility is a key factor in organizational systems and technologies.

Despite the advantages, process-level IT value research is still in its infancy. Nevertheless, we need a systematic basis for identifying IT impact at this level. We develop such an approach for assessing the IT impact at the business process level that considers both productivity and quality [74, 75]. First, we study how IT can improve process performance by assessing the effect of system characteristics. Second, we examine if improved process performance translates into higher profitability for the firm. We control for the influence of relevant process environmental factors. This generalizes to other business process settings where different drivers are responsible for IT value outcomes.

We illustrate our approach for letter of credit (LC) initiation and trade services in international banking [22]. Trade services facilitate the financing of import and export transactions. Using primary data collected from international banks, we analyze how systems characteristics drive process performance and profitability in this line of business. We find that productivity and quality of the business process are rewarded. We also find that a higher level of business process quality and productivity is possible through judicious IT investments.

Proposed Approach

THE PRIMARY FOCUS OF RESEARCH ON IT VALUE has been measuring IT impact. We take this research process on one step forward by attempting to understand how IT creates value. This research question dictates that we focus on a process rather than the organization as our unit of analysis. By examining a specific process, we are able to link system design with economic performance. If we consider all the processes in an organization, we must study multiple systems together, which would make our model too complex. As a first step, then, we examine the link between system design and value for a single process.

Relevant Literature in the IT Value Area

Much of the earlier work on IT impact has used the firm as the unit of analysis [17]. At the same time, some researchers have argued that IT effects can be identified through intermediate-level contributions [47]. Consequently, quite a few studies have taken a process orientation to measure IT business value. Banker et al. [3] examined the impact of new cash register and order coordination technology in fast food restaurants. Barua et al. [6] used a two-stage model to measure IT contribution in different functional areas (production, marketing, and innovation). Tallon et al. [73] adopted executives' perceptions of performance at the process-level to measure IT impact. Ray et al. [66] found that measuring effectiveness of business processes enhanced by IT resources may be more appropriate than adopting overall firm performance measures.

We also note the recent findings from other studies on the business value of IT. Bharadwaj et al. [13] showed that IT investments are positively associated with Tobin's q-value, which gets at the capability of the firm to produce equity value in the stock market. Devaraj and Kohli [26] examined the use of IT coupled with business process reengineering for enhanced performance in health care. Kohli and Devaraj [51] also used a process-oriented approach for the longitudinal study of IT payoffs. Additional process-centric work has been done by researchers associated with the Center for Research on Electronic Commerce at the University of Texas, who have studied the process transformation in the production of goods and services that can be transacted on the Internet (e.g., [7, 8, 9, 10]). Their emphasis has been on technology-enabled value for the firm and the market, measurement of the effects of the Internet and e-commerce capabilities on organizational performance, and the concomitant impacts on industries and the economy.

There are a few studies that attempt to explain how system characteristics create value. Venkatraman and Zaheer [77] found that electronic integration between an insurance underwriter and its independent agents aided in supporting new business. Mukhopadhyay et al. [61] examined the impact of electronic data interchange (EDI) on Chrysler assembly centers, and Mukhopadhyay et al. [63] examined the mail processing operations at the U.S. Postal Service. Mukhopadhyay and Gadh [59] and Mukhopadhyay et al. [62] examined how a new IT design changed the toll collection process of the Pennsylvania Turnpike. Mukhopadhyay and Kekre [60] examined strategic and operational benefits of electronic integration for business-to-business (B2B) procurement processes.

On the basis of this foregoing literature, we argue that providing a systematic basis for identifying the impact of systems characteristics at the process level is a first step toward normative implications for management practice.

Process Orientation

A *process* is a structured, measured set of activities designed to produce a specified output for a particular customer or market [24]. A process may encompass multiple functional areas of an organization and may be broken down into its component subprocesses. Davenport shows that organizations such as IBM, Xerox, and British Telecom may have 14 to 18 key processes. We consider an *end-to-end process* with a customer request triggering the process and the fulfillment of customer needs bringing closure to the process. Consider the foreign exchange trading process in banking. The steps involved include customer requests for a trade, pretrade analysis, trade execution and clearance, and settlement in the market.[1]

Improvement of a process necessitates a clear understanding of its current and desired states. To describe the current state, appropriate process performance measures should be developed. Process performance can be measured in terms of *productivity* and *quality.* Some of the performance measures for a foreign exchange trading process, for example, include the number of transactions per labor hour (productivity) and the percentage of error-free transactions processed (quality). Another aspect of quality is the extent to which transactions are carried out under the appropriate risk controls. Describing the state of a foreign exchange process might require us to identify things related to the IT investment, such as the number of digital market data feeds, the extent to which customized market analytics are available to traders, how risk management trading limits are implemented, and so on. System design features may lead to somewhat different outcomes.

Thus, in gauging outcomes of IT investment at the business process level, productivity and quality must be recognized as building blocks for process assessment. As an enabler of continuous process improvement and process innovation, IT needs to be evaluated by process managers who make the design choices that influence firm performance. Moreover, because there has been a dramatic increase in the number of firms redesigning end-to-end processes in the guise of business process reengineering, providing tools for assessment that stress end-to-end process assessment is also worthwhile.

An important step in conducting an in-depth analysis of IT impact is the development of a *business process performance analysis model* for the process that is being evaluated. Such a model assesses the overall performance of a business process in the presence of variables related to IT, human factors, managerially controllable aspects, and the business environment. IT impact analysis is a by-product of the operationalization of this model. It puts the analysis of the technology-related variables in perspective within the appropriate context. This "control" component adds to senior management's understanding of how IT value develops, and creates an opportunity for the findings to be portable to other business process environments in which similar controls are required. Such an approach to analysis also effectively addresses the methodological issue of ineffective control variables.

Process Models

We develop two models to quantify IT impact and to understand the mechanism that delivers it. For IT to affect profitability, it must improve the level of process performance. So in the *process performance model* (PPM), we examine how *system characteristics* enhance the process output and/or quality. In the *economic performance model* (EPM), we assess how improved *process performance* affects the firm's *economic performance.* However, overall *firm characteristics* and prevailing *market conditions* may also affect economic performance, and should be accounted for. The PPM and EPM are shown in Figures 1 and 2.

The PPM inputs are controllable by process management. Among the EPM inputs, managers can influence only the PPM outputs through judicious selection of process inputs. Environmental factors that constitute the rest of the EPM inputs are not controllable. These two models, PPM and EPM, are consistent with the *organizational process framework* proposed by Parsons [65] and Thompson [76], and later adopted in the IT context by Malone and Crowston [53], as well as with Alter's [2] IT-reliant work system view. According to Parsons, organizational processes are subject to three levels of responsibility and control: *technical* (production system), *managerial* (resource allocation), and *institutional* (environmental interface). While PPM examines the technical level, EPM is concerned with the institutional level of control. The locus of managerial responsibility is limited to the process management in PPM, and it extends to the senior management in PPM. Thinking about the business process end-to-end in this manner emphasizes that the *locus of control* needs to occur close to the *locus of value* of the IT investment [48] to create the right incentives.

Identification of Variables

Operationalizing the PPM and EPM models using the relevant factors necessitates an understanding of the information and workflows among the relevant entities in trade services. These include customers, shared networks, and the firm. In-depth knowledge of the value chain also helps to identify the relevant variables.

In the EPM model, the economic performance measures include *profit margin, market share, consumer surplus,* and *shareholder value.* We also need to identify the firm and market characteristics. To further illustrate, a *firm's capital strength,* its *international presence* (firm characteristics), and the *strength of the economy* (market characteristic) are critical for the foreign exchange trading process. Process performance variables are typically measures of productivity and quality that may affect economic performance. For example, *labor productivity* and *percentage of error-free trades* are possible performance measures for the foreign exchange trading process.

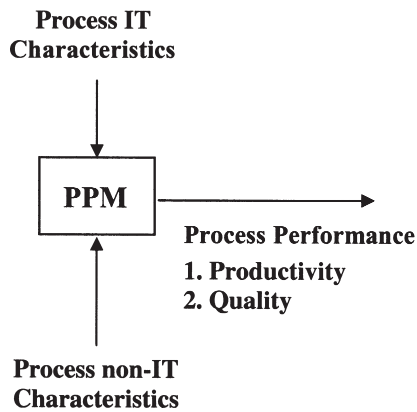

Figure 1. A Process Performance Model (PPM)

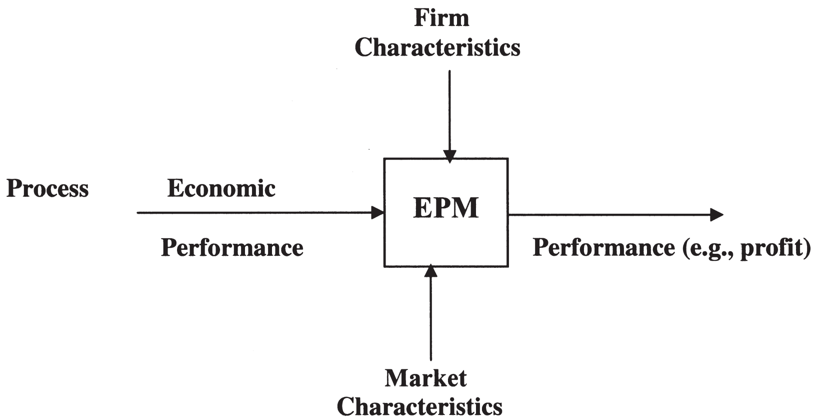

Figure 2. An Economic Performance Model (EPM)

With respect to the PPM model, we first identify the non-IT process characteristics that are expected to affect process performance. *Labor quality* is a factor that plays a role in several business processes. The most challenging task in operationalizing our model is the identification of the relevant system characteristics. To identify system characteristics, we draw on Barua et al. [5]. They propose a mathematically consistent attribute set shared by the signals generated by an information system: signal timing, reporting frequency, monitoring time, signal resolution, and accuracy. This attribute set can be used to identify systems characteristics.

First, we identify the *"payoff-relevant" information attributes* [54] expected to influence process performance. *Time to process a trade* (information attribute) can influence labor productivity (process performance measure) in foreign exchange trading. Second, we identify *system characteristics* that generate the payoff-relevant information attributes identified above. *Fully automated straight-through (FAST) processing* *capability* (system characteristic) can significantly reduce time to process a trade by facilitating trade processing with minimal human intervention.

Application

WE SELECTED THE TRADE SERVICES BUSINESS PROCESS to illustrate our model. Why? First, trade services have become a strategic business process for many large banks due to the dramatic increase in global trade, as reflected by the signing and implementation of trade agreements, including the North America Free Trade Agreement (NAFTA) and the General Agreement on Tariffs and Trade (GATT), as well as increasing participation by countries in the World Trade Organization (WTO). Senior executives have made large IT investments to support trade services. Second, decisions involved in trade services require quality IT support, an important driver of process performance. Third, the trade services business process is an end-to-end process that is not directly dependent on any other major process.

Trade Services Business Process

The trade services business process provides banking services that facilitate global trade. Its main product offering is the *letter of credit,* a key trade financing document. An LC is a payment assurance to the seller for delivered goods or services, when all the criteria specified are met. The criteria specified include a list of documents to be presented and stipulations regarding quality levels, packaging specifications, delivery dates, prices, and payment terms.[2]

LC issuance is initiated when the buyer submits a formal application to the issuing bank. The bank evaluates the credit standing of the buyer and issues an LC and forwards it to the beneficiary through the advising bank (beneficiary's bank). The role of IT in the trade services business process is to enable buyers and beneficiaries to electronically initiate and track their requests. It makes possible the integration of the trade services system with funds transfer and general ledger systems, leading to the automated initiation of trade services–related payments. It also enables financial controls to be effected to manage risk, and it creates the link that supports automating accounting and financial performance evaluation.

Modern LC systems support electronic submission and amendments to LCs. They offer a standard set of database definitions for trade finance–related data items, and the capability to have the system interface with other typical international banking systems. These include customer relationship management, intraday funds control and financial risk management, and Society for Worldwide Interbank Financial Telecommunication (SWIFT) funds transfer and messaging capabilities, and so on.[3]

Model Outline

Variables corresponding to the trade services business process model are listed in Table 1.

Table 1. Trade Services Process Model Variables

Variables	Description
IT characteristics	
• *ELECIN*	• Percent requests initiated electronically
• *FTINT*	• 1 for integration with funds transfer (*FT*) system, 0 otherwise
• *GLINT*	• 1 for integration with general ledger (*GL*) system, 0 otherwise
Non-IT characteristics	
• *EMPCOMP*	• Average employee compensation of the process group in thousands of dollars: adjusted for cost-of-living differences using the American Chamber of Commerce Research Association (ACCRA) cost-of-living index
Process performance	
• *TIME*	• Average time interval from customer request to issuance: hours, 1 day = 8 hours
• *PROD*	• Labor productivity: transactions per employee
Firm characteristics	
• *ASSET*	• ln(asset size in millions of dollars)
Market characteristics	
• *TRADE*	• Volume of trade: U.S. exports/imports in billions of dollars from the *International Financial Statistics Yearbook*
Process economic performance	
• *MARGIN*	• Profit margin: (revenue – cost)/revenue

Process Performance Model

We capture productivity and quality for trade services delivery. We use *transactions per employee* to measure labor productivity (*PROD*) and *average time from customer request to issuance* of the LC or cycle time (*TIME*) as the process quality measure. It is widely held that lower cycle times are indicative of higher-quality operations [64].

Labor Productivity

From our discussion above, it follows that the trade services process is essentially composed of information-processing tasks. Based on our PPM, we hypothesize that labor productivity (*PROD*) in this context is primarily determined by *labor quality* and *systems characteristics.* Prior research has shown that wages typically reflect employee skills, qualifications, and experience. Differences in wages reflect differences in skill levels [14]. Based on this evidence, we use average employee compensation (*EMPCOMP*) as a proxy for labor quality. We expect labor quality to positively influence productivity.

One reason IT is being applied increasingly to the trade services area is that IT-enabled capabilities can reduce effort. Strecker [71] identifies electronic interfaces with customers and integration with electronic funds transfer as two key IT capabilities in the trade services area. We hypothesize that both electronic initiation of LCs (*ELECIN*) and the integration with the funds transfer system (*FTINT*) will increase labor productivity. For example, if an LC request is generated manually (e.g., fax or telephone request), the bank has to rekey the information for further processing, including credit checking and transfer of funds [57]. Similar to just-in-time manufacturing, where system integration plays an important role, system integration is also expected to be a key driver of labor productivity in trade services. In particular, integration with the funds transfer system enables automated initiation of trade services–related payments without the rekeying of data available in the trade services files. This is expected to improve labor productivity (*PROD*):

$$PROD = f\left(ELECIN, EMPCOMP, FTINT\right). \tag{1}$$

Cycle Time

As before, we hypothesize that the average time between LC initiation and issuance (*TIME*) is primarily determined by system characteristics and labor quality or average employee compensation (*EMPCOMP*). The minimal cycle time can be achieved if the customer sends the application electronically and the bank fully automates the issuance process described earlier. Two system characteristics, the percentage of electronic requests (*ELECIN*) and the integration with the general ledger system (*GLINT*), can bring a bank close to this ideal, and largely reduce the cycle time [49]. The electronic initiation capability not only reduces effort but it also allows bank employees to use computers to check the application on line for accuracy and completeness without waiting for the data to be first input into the system [71]. Integration with the general ledger system also facilitates the quick retrieval of a customer's past transactions and yields more complete control of the risk exposure to a specific customer. Hence, the absence of such integration may introduce delays in issuing LCs. In sum, integration with the general ledger can reduce delays but has minimal effect on labor productivity. Note that responding to an LC request does not involve any funds transfer, and therefore *FTINT* does not appear in this model. Because the percentage of electronic initiations and integration with the general ledger system are two important system characteristics of the front-office portion of the service delivery value chain, we include an interaction term in the cycle time equation.

$$TIME = f\left(ELECIN, EMPCOMP, GLINT, ELECIN * GLINT\right). \tag{2}$$

Economic Performance Model

Profit margin (net profit/revenues) is a common measure of the economic performance of a process. An alternative measure is the *risk-adjusted return on capital,* which is equivalent to return on equity at the business process level (e.g., [36]). It is constructed by imputing a capital/asset ratio to a business process on a risk-adjusted basis. However, it is a relatively new concept, and few banks have computed this measure for their trade services business processes in the past. Instead, it is better suited for implementation in the financial market trading arena, where intraday and overnight exposures can significantly fluctuate. Therefore, we use profit margin as the economic performance measure.

Profit Margin

Most studies on bank profitability have been conducted only at the bank or industry level. Studies analyzing the profitability of specific activities or business processes are scarce because of the lack of publicly available data. In the banking literature, three broad categories of factors that may influence profitability have been identified [25]. They are structural characteristics of the banking industry, economic and business factors, and banking regulations.

In the trade services business process we expect *profit margin* (*MARGIN*) to be driven by the two process performance measures, *labor productivity* (*PROD*) and *cycle time* (*TIME*). Based on existing trade services literature [52], we also expect that the bank-specific characteristic, asset size (*ASSET*), may influence a bank's standing in the marketplace and hence affect the profit margin. Finally, the volume of foreign trade (*TRADE*) is a relevant market characteristic included in our analysis. Since there were no significant changes in either market concentration (a structural characteristic) or relevant banking laws and regulations during the period of our study, they are not included here.

$$MARGIN = f\left(PROD, TIME, ASSET, TRADE\right). \tag{3}$$

Data Collection

The United States Council on International Banking previously endorsed our study, which covers the years 1991 to 1995. The primary data collection effort began with detailed discussions with bankers. First, we conducted field interviews to develop a perspective on global wholesale banking and to assess the feasibility of examining IT value. We operationalized our theoretical model for the trade services area. Based on the process model and discussions with banking executives, we designed a data collection instrument.

The questionnaire was pilot tested and mailed to 18 trade services groups in the United States that agreed to participate in our study. There are two main factors that constrain our sample size. First, the off–balance sheet market is very concentrated with the top 20 U.S. banks dominating the market [49]. Second, some banks do not track data at the business process level. We asked for data from banks for multiple years. Thus we have a panel data set consisting of 70 data points representing 11 banks in the trade services area. We supplement the primary data with secondary

Table 2. Summary Statistics

Variable	Definition	Average	Standard deviation
ELECIN	Percent electronic LC requests	21	16
FTINT	Integration with funds transfer system	0.44	0.50
GLINT	Integration with general ledger system	0.61	0.50
EMPCOMP	Mean employee compensation, thousands of dollars	NR	NR
TIME	Cycle time in hours	10.9	3.8
PROD	Transactions per employee	944	240
ASSET	ln(assets in millions of dollars)	10.6	0.8
TRADE	Foreign trade in billions of dollars	1,002	166
MARGIN	Profit margin	NR	NR

Notes: NR = not reported. Employee compensation (*EMPCOMP*) and profit margin (*MARGIN*) data are sensitive data in the financial services industry. Although we had access to this information for our study, we agreed to withhold it from publication based on requests from participating banks. We believe that the specific facts here are immaterial to the reader's understanding of the issues and results that we discuss in this paper.

data on bank and global business characteristics. Summary statistics are given in Table 2.

Trade services processes vary greatly across banks. For example, the electronic initiation of LC requests ranged from 0 percent to 48 percent in our sample. Similarly, process performance measures, labor productivity (*PROD*) and cycle time (*TIME*), also show a wide range of values. It is no surprise, then, that the profit margin in the trade services area across these banks fluctuates substantially.

Estimation Results

WE FIRST ESTIMATE THE EPM TO GAUGE the impact of process performance characteristics on economic performance. Then we estimate the PPM to analyze the impact of systems characteristics on process performance. We adopt the linear form for both models for the sake of simplicity. We first tested the three equations for normality. The skewness and kurtosis, and the test statistic are provided in Table 3. The Bera–Jarque test of normality [50, p. 266] does not reject the hypothesis of normality for any equations at the 5 percent level.

We believe our annual data are not subject to severe autocorrelation because random shocks in trade flows typically last for a few months. We are unable to use the Durbin–Watson test because our time series is short. However, for comparison's sake, we will estimate each equation before and after correcting for autocorrelation.

Economic Performance Measurement

The Breusch–Pagan test [50, p. 294] does not reject the assumption of homoskedasticity ($\chi^2 = 8.2$, degrees of freedom [df] = 4; $p < 0.05$). We estimate this model in two ways.

Table 3. Skewness and Kurtosis Values

Equation	Skewness	Kurtosis	Test statistic (χ^2, 2 df)
MARGIN	0.31	3.58	4.60
PROD	0.27	3.20	3.27
TIME	0.22	3.72	4.08

Table 4. Economic Performance Measurement

Variable	Profit margin
CONSTANT	0.1331***
PROD	0.0003***
TIME	–0.0092***
ASSET	0.0396***
TRADE	–0.0003

Notes: Model $R^2 = 0.76$, $n = 70$; *** $p < 0.01$.

First, we assume no autocorrelation, and obtain ordinary least squares (OLS) estimates. Second, we assume first-order autocorrelation, and use the Prais–Winsten method [50, p. 318], which does not sacrifice degrees of freedom. In both cases, four parameters are significant at 0.01 level while the fifth parameter is not significant at the conventional level. In addition, the coefficient estimates are identical in signs and very similar in magnitudes across the different estimation methods. We report OLS estimates in Table 4.

Our results indicate that the model fit is reasonably good as measured by the R^2 statistic. The signs of the significant parameter estimates are also consistent with our expectations. It is clear that the process performance measures, labor productivity (*PROD*) and cycle time (*TIME*), have a significant impact on profit margin. Labor productivity has a positive influence on profit margin. This result is in agreement with prior work on the impact of labor productivity on profitability [78]. If the number of transactions per employee increases by 1 percent from its average value of 944, profitability in this sample jumps by 0.28 percent. Lower cycle time also greatly increases the profit margin. For example, a reduction of cycle time by one hour can improve profitability by 0.92 percent, on average. The impact of process performance on economic performance indicates that banks reap benefits of effective business process management.

We also find that asset size (*ASSET*) is positively related to profit margin. Banks with a large asset base are noted for their financial stability, which is an important trait in the trade services business. One drawback of the earlier work on IT value has been the lack of appropriate control variables, and this result indicates the importance of controlling for firm characteristics. The market characteristic, volume of foreign trade (*TRADE*), did not turn out to be a significant determinant of profitability. This could be due to the lack of sufficient variation in the volume of foreign trade during the period of our study.

Process Performance Measurement

The Breusch–Pagan test again does not reject homoskedasticity for *PROD* ($\chi^2 = 6.3$, df = 3; $p < 0.05$) or *TIME* ($\chi^2 = 8.7$, df = 4; $p < 0.05$). We estimate these two equations as a seemingly unrelated regression (SUR) model in which the equations are linked only by their disturbances because both performance variables result from processes that ensue together in a firm. We again estimate these two equations in two ways. First, we estimate the two equations using SUR with autoregressive disturbances [50, p. 646]; this method does not sacrifice any degrees of freedom. Second, we assume no autocorrelation, and estimate the two equations using regular SUR [50, p. 643]. The second method produces marginally lower *t*-statistics, and provides a little more conservative results. We report these results in Table 5. Both models seem to fit the data reasonably well given the respective R^2 statistics. Overall, the PPM analysis results show that the system characteristics have a significant impact on process performance measures.

We also examine the relationship between productivity and quality. Productivity is a fairly standard notion, but quality is context-dependent. In this case, we decided to test to see if labor productivity and cycle time affect each other. For this, we model a system of simultaneous equations with *TIME* as an explanatory variable in the *PROD* equation, and *PROD* as an explanatory variable in the *TIME* equation. We use the two-stage least squares method to estimate the model parameters. We also apply the Spencer and Berk specification test [69] to test the null hypothesis of exogeneity for the variable *TIME* in the *PROD* equation, and vice versa. This test did not reject this null hypothesis at the 0.05 level. Hence, our data do not support the assumption of simultaneity here.

Labor Productivity

As the percentage of electronic initiations (*ELECIN*) increases, labor productivity (*PROD*) increases. For example, if the percentage of electronic initiation of LC requests increases by 1 percent, the number of transactions per employee may increase by 9.6, on average. LC requests sent manually warrant more work on the bank's side and decrease the productivity of labor. Banks that have a trade services system integrated with the funds transfer system (*FTINT*) attain higher labor productivity than banks where the integration of the systems is absent. Integration with the funds transfer system enables banks to automatically trigger the payments associated with trade services, improving labor productivity. We found that the non-IT characteristic, labor quality, or average employee compensation (*EMPCOMP*), is also positively related to productivity.

Cycle Time

Cycle time (*TIME*) decreases as the percentage of electronic initiations (*ELECIN*) increases. Increasing electronic integration by 1 percent can reduce cycle time by

Table 5. Process Performance Measurement

Variable	Labor productivity (*PROD*)	Cycle time (*TIME*)
CONSTANT	198.7***	17.4**
ELECIN	9.6***	–0.29**
EMPCOMP	13.7***	0.07
FTINT	348***	
GLINT		–9.8***
*ELECIN * GLINT*		0.18

Notes: PROD model $R^2 = 0.74$, $n = 70$; *TIME* model $R^2 = 0.59$, $n = 70$; ** $p < 0.05$, *** $p < 0.01$.

0.29 hour, on average. Manually initiated LC requests require the bank to do additional work, and hence increase the time to turn around LCs. Cycle time is almost ten hours less for the banks that have their trade services system integrated with the general ledger system (*GLINT*) compared to the banks whose trade services and general ledger systems are not integrated. Integration with the general system automates accounting and also enables the bank to get a more complete picture of the exposure to a specific party. This enables the bank to make faster LC issuance decisions. Labor quality (*EMPCOMP*) does not seem to significantly influence cycle time. Therefore, cycle time seems to be primarily driven by IT capabilities.

Discussion

We developed and tested a model to enhance our understanding of how IT creates value.

Key Features of Our Analysis Approach

Our approach has several salient features. First, we conduct the analysis at the *business process level,* where many investment decisions are made. Second, we examine how *system design characteristics* drive value. Third, we assess the impact of IT by building a *performance analysis model of the business process.* Fourth, we supplement a process performance analysis model with a model that gauges *economic contribution.* Fifth, we attempt to *implement controls* for the extent to which external factors might cap system value flows.

Our analysis of the trade services business process showed that it was appropriate to work with separate, but linked, models for process and economic performance. In our first model, system design characteristics were found to significantly affect process performance variables. For example, the percentage of electronically initiated LC requests and the integration with the general ledger system appears to reduce response time. This result reinforces our expectation about the impact of system design characteristics on process quality in the trade services area. Similarly, both IT characteristics and labor quality are found to affect labor productivity. In our second model, we found that both labor productivity and response time had significant effects on profitability. Therefore, our measures of process performance—in terms of both productivity and quality—affect firm performance in the marketplace. In addition, when we controlled for bank characteristics, we also learned that asset size may constrain profitability.

We can analyze the value of specific system characteristics from our results. Consider a bank whose trade services area is not integrated with its general ledger system ($GL = 0$). From our parameter estimates of the PPM model, we find that in our sample an increase of electronic initiation of LC by 1 percent can increase labor productivity by 9.6 transactions per employee per year and reduce cycle time by 0.29 hour (on average). From the EPM, these improvements, in turn, enhance profitability by 0.0003 * 9.6 + 0.0092 * 0.29 = 0.0055 or 0.55 percent. Management can examine the value of this benefit against the cost of increasing electronic initiation of LCs by 1 percent.

Breadth of Applicability of the Process Approach

A key consideration in analyzing IT value in the business process context is the extent to which one process exhibits *interdependence* with other processes [76]. With uncoupled processes, there is no interdependence among processes. Hence, it is easier to trace the impact of IT on the individual processes. For example, the corporate finance and equities trading processes in a bank are relatively uncoupled due to regulatory requirements. Thus IT value in these processes can be analyzed independently using our approach.

The level of interdependence among processes increases from pooled to sequential to reciprocal interdependence. End-to-end processes exhibiting *pooled interdependence* are not directly linked but have a pool of shared activities. Consider bank lending and foreign exchange trading processes. They are not directly related to one another in any fashion except that they compete for scarce capital from the same source within the firm, and cover the business of the same set of bank customers. Performance analysis for these business processes can be conducted separately using our approach.

Sequentially interdependent processes are those in which the output of one process serves as an input for the other. Trade execution and settlement processes are sequentially interdependent. Such processes can be isolated and analyzed using our model, provided a market exists for the output of each process. If there is no market for output of the first process, the PPM analysis may be used. Such an analysis enables managerial fine-tuning at the “individual” process level. However, because process interdependencies often are not taken into consideration by managers, individual process level analysis could lead to overall suboptimization. Developing a model for the overall process would overcome this problem.

Reciprocally interdependent processes are characterized by intricate interdependencies. One way to apply our process model is to analyze all reciprocally related processes together. For example, the credit verification and the lending processes are reciprocally interdependent. While credit verification provides an input to the lending process, defaults are used to revise the credit verification process. It may be difficult to analyze these processes in isolation. However, the combined "credit services" process can be analyzed rigorously using our model.

Stepping Back: Evaluating the Strengths of the Proposed Process Approach

We use a number of criteria in comparing our approach with others that are available to indicate its strengths.

Level of Analysis

Our approach focuses on providing evidence about the value of IT in *end-to-end* business processes. Thus, we avoid aggregation across multiple processes where IT investment may be meant to do different things, resulting in different levels of effectiveness. Because many investment decisions are made at this level, it is important to gauge business value for an IT investment that is "in synch" with the relevant *locus of control,* and the *locus of value* for the firm.

The reader should contrast our process level of analysis with the levels of analysis used in other prior work on IT value. For example, Brynjolfsson and Hitt [18] conducted their analysis at the *firm level.* The strength of their work is the use of rich data to derive conclusions about IT investment that are broadly relevant to the U.S. economy. This level of analysis, however, does not guide day-to-day investment decision making for IT. A second example is the work of Barua et al. [6], whose research emphasizes the *business function level.* However, business processes often cut across functions. So it may be hard to measure IT value in this manner. Thus, our selected level of analysis is more "micro" by design: it matches the loci of control and value. It also helps us to capture useful managerial information about an IT-reliant work system that is readily identified within international banking organizations.

Analytical Structure

Our approach involves two models to describe the business process and the creation of economic value from IT investment for the firm. The primary benefit of a model of process performance is that it enables us to relate system design choices to performance in the context of a *chain of activities* leading to an IT impact. This will have important implications for better system design. And, it has the added benefit of being sufficiently general so that many physical and service environments involving IT can be mapped onto it.

Our second model captures economic outcomes, in isolation from the operational aspects of the business process. This is realistic: not all IT-related processes lead to measurable value based on the direct outputs (e.g., transactions in automated teller machine network processing or in credit card processing), and for many systems investments, the true locus of value occurs at some "distance" in business process terms from where the system's outputs are observed. Barua et al. [6] relate IT investment dollars to functional area–level performance such as capacity utilization. Our models relate system design characteristics to the performance of an end-to-end process, and hence have implications for system design. We would be unable to accomplish this had we chosen to rely on production function modeling alone, however, as in Brynjolfsson and Hitt [18]. Applied in the traditional way, the production function approach relates IT investment to firm economic performance directly.

Identification of Variables

Success in identifying the right variables for analysis (and measuring them well) is a matter of interest in terms of theory and practice. The extensive research on production economics makes the identification of the input and output variables for a production function model a relatively structured task. However, "IT capital" is known to be a challenge to measure well [37]. The functional level analysis of Barua et al. [6] also lends itself to the proper identification of variables. However, their method relies to a greater extent on the analyst as to how IT is applied in support of different business functions.

Our approach also puts additional burden on the analyst to identify the relevant variables for analysis. At a minimum, a thorough knowledge of the business process is necessary to enable the specification of a useful process model. Our argument is that focusing on the business process end-to-end will help to remedy this; if value flows from IT are not measurable in the end-to-end process, then there is good reason to ask whether organizational structure will impede good decision making relative to IT.

Model Specification and Estimation

Specification of the relationship among the variables in our models poses an additional challenge, yet it is one that we observe elsewhere in the literature on IT value. For example, when researchers estimate production function models, there are a number of tactical choices that must be made relative to model specification and functional form. The research literature offers a variety of theoretically established functional forms that may be appropriate under differing circumstances of production, and many robust estimation techniques are available. The simplest functional form is the linear model, and it imposes the structure of linear and separable impacts on production. We use this parsimonious functional form but emphasize that the analyst must decide if it is adequate.

Data Requirements

The production approach requires less detailed data than our process model. Although production modeling for IT impacts can be conducted entirely on the basis of secondary data sources, our approach cannot. It requires primary data and access to the business process. This means that some access to the firm's operations must be obtained. We also illustrated the need for secondary data that provides the analyst with a reading on the relevant controls for process and economic performance (e.g., data on market competitiveness, or the economic backdrop of production).

Management Implications

Brynjolfsson and Hitt's [18] analysis generated results that are broadly relevant to the U.S. economy. Barua et al.'s [6] approach highlighted the importance of measuring the IT impact at the business function level. Complementing the above studies, our process modeling approach helps identify systems characteristics that are best suited to supporting a business process. It also yields managerial information that can be applied to refine the systems support and achieve more effective use and higher value.

Conclusion

IT PRODUCTIVITY RESEARCH GOES BEYOND the IS literature to the economics literature. Whereas some researchers have examined the IT impact at the economy and sector levels (e.g., [44, 45, 46, 67]), others have focused on industry- or firm-level analysis (e.g., [15, 28]). While the results from the broader literature are mixed, in the past decade, studies have shown a positive impact of IT (e.g., [39]). As the level of analysis changes from firm to industry or economy level, researchers face increasing measurement problems. Poor output measures become an albatross in any productivity research study [34]. In particular, IT productivity research has to deal with IT benefits such as improved quality, greater variety, and faster service, which are hard to quantify [74, 75].

While researchers have made significant progress with firm-level analysis, process-level analysis is still in its infancy. We attempt to fill this gap in IT value research level. There is a great need for a systematic basis for identifying IT impact at the process level. We develop such a model. We exploit the notion of "payoff-relevant" information attributes from information economics to realize the possibility of assessing the effects of alternative system designs on process performance. But we also link process performance measures with firm performance. So we control for non-IT characteristics in the PPM, and firm and market characteristics in the EPM. Our objective is to draw attention to IT-reliant work systems, develop a model, apply it in a real-world context using primary data, and discuss its merits and limitations.

Our research also relates to the broader literature. It provides fresh evidence that IT creates positive economic benefits to banks in trade services. The performance of international trade activities is increasingly affected by a variety of ITs, and so it is an interesting platform for showcasing our approach. Our results are based on primary data, after controlling for firm and market characteristics, and labor quality employed in the process. We quantify the impact of IT on labor productivity and cycle time for LC generation, which, in turn, determines bank profitability. Our models can be combined to determine direct effects of IT characteristics on profits.

We illustrated the use of a new method for IT investment valuation that emphasizes the analytical importance and managerial relevance of separating business process performance and economic performance as an aid in discovering the source of IT value. Our approach structures the assessment of complete, or "end-to-end," business processes that reflect management responsibility areas within the firm. The process performance analysis helps us to understand how system characteristics influence specific process performance measures, such as productivity and quality. Understanding how IT drives business value enables management to choose system design characteristics that will maximize payoffs for the organization. This approach also facilitates analysis of bottom-line impacts of process performance, whose magnitude may be influenced by factors (such as firm and market characteristics) that are exogenous to business process production. We characterize these through modeling controls that work in other contexts.

Our approach represents a starting point in understanding the link between system design and business value. Typically, systems take longer to build than projects do, but projects are typically the building blocks of systems. We should point out that it makes greater sense to control and measure projects in terms of costs, but, consistent with the approach we have taken in this research, applications and systems should be evaluated in terms of their business value for the firm.

Limitations

The current work has limitations that are worthwhile to point out to the reader. First, we will consider the limitations from a general methodological perspective. For an analyst to be effective in using the modeling and analysis approaches that we have discussed, the person needs to have thorough knowledge of the business process. This will permit the identification of the appropriate variables for the two models in the IT investment evaluation and performance measurement context. The measurement of IT characteristics also is a challenging task, and the implementation of our process model requires detailed data. Primary data collected from a firm or from multiple firms, supplemented by secondary data from other sources, will be necessary. We also should point out that certain kinds of business processes may be especially difficult to analyze using our approach, and additional exploration and testing will be required before we can confidently suggest that the appropriate measurement outcomes will be obtained. An example is the evaluation of IT investments in business settings that involve reciprocally interdependent processes. Although we have specified conceptual models and performance econometric analyses that implement the conceptualized assessments, to effectively measure reciprocally interdependent processes, we will need to do some additional theoretical and methodological work to establish how to implement similar kinds of evaluations.

A second aspect of the limitations of the present research is more specific to the selected research context of trade services, LC initiation and systems integration, and the environment of international banking. The data set that we used for testing our modeling approach is modest in size because of the high level of market concentration in wholesale banking and the scarcity of data tracking that most banking firms were doing at the business process level when we collected our data. This is quite common for the international banking and investment banking industries, based on our experience [4, 29, 31, 36]. In addition, it would have been beneficial if we had been able to acquire more distinguishing information about the banks that adopted the electronic LC initiation technology, similar to Jallath-Coria et al. [42, 43], all the way down to the individual transaction level. Additional information would have enabled us to tease out underlying relationships in the data that might have done more to help us understand differential performances, and explanations for deviation from mean performance or the lack of achieving high performance in process performance and economic performance terms.

In the prior section, we also mentioned that studies on IT value that seek to establish business process–level evaluations inevitably will run into issues and difficulties related to model specification and estimation. This certainly was true in this study, and it is appropriate for us to report several additional issues that may be of interest to future researchers who take up IT value assessments in similar kinds of international financial services settings (e.g., customer relationship management, foreign exchange trading, financial risk management, credit scoring and lending, and credit card systems and technologies). For example, one aspect is the possibility of endogenous choice on the part of a banking customer of the firms that invested in LC initiation automation and trade services systems. Endogeneity could arise in this case when the customer—probably a correspondent bank that acts as an LC application intermediary—consciously chooses to implement its own LC automation in order to work productively with specific counterparties or trade services providers. Because current capabilities with electronic LC initiation systems are now Web-based and increasingly permit direct interaction between buyers and sellers in B2B e-commerce (for example, see the *Fast*LC demo at www.ec-finance.com), endogenous choice to adopt and use electronic initiation may be a logical by-product of banking customers' experience with the operating capabilities of their banks and their counterparties in trade.

Another potential limitation of the modeling approach that we demonstrated is its failure to properly account for the stochastic qualities of the operating and the economic environment of the firm, as well as the internal changes that occur within an organization as it rolls out new technology at the business process level. There have been many industry-level studies that deal with check processing, payment systems, and automated clearing house performance in bank-to-bank settlement [1, 11, 33, 38]. The work of Jallath-Coria et al. [42, 43] is especially interesting and relevant to the limitations of our research. The authors explore what happened in the adoption of an electronic interbank payment and online balance inquiry system by 19 commercial banks in Mexico, with an emphasis on the stochastic aspects of the environment that affected the value of IT investments. They demonstrate the role for volatility-focused econometric estimation models, including the autoregressive conditional heteroskedasticity (ARCH) and generalized autoregressive conditional heteroskedasticity (GARCH) models. These models have the capability to capture the underlying operational volatility in payments processing for interbank settlement efficiency, while considering the extent of paper-based versus electronic-based payments. Although our data lacked the day-to-day details of demand for trade services, we nevertheless recognize that both the operational productivity and the economic performance of the deploying trade services banks in our data set would have had to be sensitive to the volatility of trade flows and changing expectations about interest rates and foreign exchange rates in determining when it was appropriate to initiate LCs and defray the risks of international trade financing. Considering our prior comments about firm technology and services choices in the import–export services context, the reader may recognize, as we do, that investment choices, selected partners, and the density of LC initiations could be equally influenced by endogenous and exogenous forces.

Acknowledgments: The authors thank the United States Council for International Banking for help with supplying data that made this study possible. An earlier version of this paper was presented and appeared in the proceedings of the Hawaii International Conference on System Sciences (HICSS) in January 2006. They appreciate the comments from two anonymous reviewers for the HICSS in summer 2005, as well as from Hugh Watson, chair of HICSS's Organizational Systems and Technologies Track, and three anonymous *JMIS* reviewers. The authors also benefited from useful comments offered by the cochairs of the Competitive Strategy, Economics, and Information Systems Mini-Track, Eric Clemons, and Rajiv Dewan. Rob Kauffman also thanks the MIS Research Center at the University of Minnesota for partial support. All errors of fact or interpretation are the sole responsibility of the authors.

Notes

1. Foreign exchange trading systems are complex secure systems. Their functionality includes automating and making amendments to customer trade requests, linking to customer relationship management and financial risk management systems, and providing customer-side analysis and modeling tools that promote transaction development and control risk positions. They normally accommodate *fully automated straight-through (FAST) trade processing,* as well as connectivity for clearing trades and making funds transfers to settle transactions. A final capability is information reporting for the purposes of effective managerial control and performance assessment.

2. LCs are an off–balance sheet activity. In the past, they provided a means for banks to increase their earnings without having to reflect the transactions as income-producing assets on their balance sheet. In this context, the financial intermediation activities will be reflected as contingent liabilities that must be disclosed in footnotes to audited financial statements for the firm. The contingency arises because the bank may be left "holding the bag" if the importer fails to pay, when all other aspects of the transaction are in order for the exporter.

3. LC systems typically include capabilities that are designed with security considerations in mind also. See www.sterlingbancorp.com/intl/sterlinks.cfm, which describes a current-day Web-based LC system for Sterling National Bancorp. For additional information on current LC systems capabilities on the Internet, the interested reader should also see ec-Finance.com (www.ec-finance.com).

References

1. Ackerberg, D.A., and Gowrisankaran, G. Quantifying equilibrium network externalities in the ACH banking industry. *Rand Journal of Economics* (2006), forthcoming.

2. Alter, S. 18 reasons why IT-reliant work systems should replace the IT artifact as the core subject matter of the IS field. *Communications of the AIS, 12,* 23 (2003), 365–394.

3. Banker, R.D.; Kauffman, R.J.; and Morey, R.C. Measuring gains from operational efficiency from IT. *Journal of Management Information Systems, 7,* 2 (Fall 1990), 29–54.

4. Bansal, A.; Kauffman, R.J.; Mark, R.; and Peters, E. Financial risk and financial risk management technologies: Issues and advances. *Information and Management, 24,* 3 (1993), 267–281.

5. Barua, A.; Kriebel, C.H.; and Mukhopadhyay, T. MIS and information economics: Augmenting rich descriptions with analytical rigor in IS. In J.I. DeGross, M. Alavi, and H. Oppeland (eds.), *Proceedings of the Tenth International Conference on Information Systems.* New York: ACM Press, 1989, pp. 327–339.

6. Barua, A.; Kriebel, C.H.; and Mukhopadhyay, T. IT and business value: An analytical and empirical investigation. *Information Systems Research, 6,* 1 (1995), 3–23.

7. Barua, A.; Whinston, A.B.; and Yin, F. Value and productivity in the Internet economy. *IEEE Computer, 33,* 5 (2000), 102–105.

8. Barua, A.; Konana, P.; Whinston, A.B.; and Yin, F. Driving e-business excellence. *Sloan Management Review, 34,* 1 (2001), 36–44.

9. Barua, A.; Konana, P.; Whinston, A.B.; and Yin, F. Measures for e-business value assessment. *IEEE IT Professional, 3,* 1 (2001), 47–51.

10. Barua, A.; Konana, P.; Whinston, A.B.; and Yin, F. An empirical investigation of net-enabled business value. *MIS Quarterly, 28,* 4 (2004), 585–620.

11. Bauer, P.W., and Ferrier, G.D. Scale economies, cost efficiencies, and technical change in Federal Reserve payment processing. *Journal of Money Credit and Banking, 28,* 4 (November 1996), 1004–1039.

12. Bharadwaj, A. A resource-based perspective on information technology capability and firm performance: An empirical investigation. *MIS Quarterly, 24,* 1 (2000), 169–196.

13. Bharadwaj, A.; Bharadwaj, S.; and Konsynski, B. IT effects on firm performance as measured by Tobin's *q*. *Management Science, 45,* 6, (1999), 1008–1024.

14. Bound, J., and Johnson, G. Changes in the structure of wages in the 1980s. *American Economic Review, 82,* 3 (1992), 371–392.

15. Breshnahan, T.F. Measuring spillovers from technical advance: Mainframe computers in financial services. *American Economic Review, 76,* 4 (1986), 742–755.

16. Breshnahan, T.F.; Brynjolfsson, E.; and Hitt, L.M. Information technology, workplace organization, and the demand for skilled labor: Firm-level evidence. *Quarterly Journal of Economics, 117,* 1 (2001), 339–376.

17. Brynjolfsson, E. The productivity paradox of IT: Review and assessment. *Communications of the ACM, 36,* 12 (1993), 66–77.

18. Brynjolfsson, E., and Hitt, L.M. Paradox lost? Firm-level evidence on the returns to IS spending. *Management Science, 42,* 4 (1996), 541–558.

19. Brynjolfsson, E., and Hitt, L.M. Beyond the productivity paradox. *Communications of the ACM, 41,* 8 (1998), 49–55.

20. Brynjolfsson, E., and Yang, S.K. IT and productivity: A review of the literature. *Advances in Computing, 43,* 1996, 179–214.

21. Curtin, J.; Kauffman, R.J.; and Riggins, F.R. Making the "MOST" out of RFID technology: A research agenda for the study of the adoption, use and impacts of RFID. *Information Technology and Management* (2006), forthcoming.

22. Davamanirajan, P.; Mukhopadhyay, T.; and Kriebel, C.H. Assessing the business value of IT in global wholesale banking: The case of trade services. *Journal of Organizational Computing and Electronic Commerce, 12,* 1 (2002), 5–16.

23. Davenport, T. The new industrial engineering: IT and business process redesign. *Sloan Management Review, 31,* 4 (Summer 1990), 11–27.

24. Davenport, T. *Process Innovation: Reengineering Work Through IT.* Boston: Harvard Business School Press, 1993.

25. Davis, R.G. *Recent Trends in Commercial Bank Profitability: A Staff Study.* New York: Federal Reserve Bank of New York, 1986.

26. Devaraj, S., and Kohli, R. IT payoff in the health-care industry: A longitudinal study. *Journal of Management Information Systems, 16,* 4 (Spring 2000), 41–67.

27. Dewan, S., and Kraemer, K.L. International dimensions of the productivity paradox. *Communications of the ACM, 41,* 8 (1998), 56–62.

28. Dewan, S., and Min, C.K. Substitution of IT for other factors of production: A firm-level analysis. *Management Science, 43,* 12 (1997), 1660–1675.
29. Dhar, V.; Duliba, K.A.; and Kauffman, R.J. Re-engineering trading and treasury operations in international financial services. In C. Deans and K. Karwan (eds.), *Global Information Systems and Technology.* Middletown, PA: Idea Group, 1994, pp. 186–211.
30. DiNardo, J.E., and Pischke, J.S. The returns to computer use revisited: Have pencils changed the wage structure too? *Quarterly Journal of Economics, 112,* 1 (1997), 291–303.
31. Duliba, K.A., and Kauffman, R.J. Information technology investments and price recovery effects in international banking. Working Paper 96–8, Center for Digital Economy Research, Stern School of Business, New York University, 1996.
32. Duliba, K.A.; Kauffman, R.J.; and Lucas, H.C., Jr. Appropriation of value from airline computer reservation systems. *Organization Science, 12,* 6 (2001), 702–768.
33. Gowrisankaran, G., and Stavins, J. Network externalities and technology adoption: Lessons from electronic payments. *Rand Journal of Economics, 35,* 2 (2004), 260–276.
34. Griliches, Z. Productivity, R&D and the data constraint. *American Economic Review, 84,* 2 (1994), 1–23.
35. Gurbaxani, V., and Whang, S. The impact of information systems on organizations and markets. *Communications of the ACM, 34,* 1 (1991), 59–73.
36. Han, K.; Kauffman, R.J.; and Nault, B.R. Information exploitation and IS ownership. *Journal of Management Information Systems, 21,* 2 (Fall 2004), 109–135.
37. Han, K.; Kauffman, R.J.; and Nault, B.R. Does IT outsourcing pay off? Evidence from industry-level data. Paper presented at the 2005 Workshop on Information Systems and Economics, University of California, Irvine, December 2005.
38. Hancock, D.; Humphrey, D.B.; and Wilcox, J.A. Cost reduction in electronic payments: The roles of consolidation, economies of scale, and technical change. *Journal of Banking and Finance, 23,* 2–4 (1999), 391–421.
39. Hitt, L., and Brynjolfsson, E. Beyond computation: IT, organizational transformation and business performance. *Journal of Economic Perspectives, 14,* 4 (2000), 23–48.
40. Hitt, L.; Frei, F.X.; and Harker, P.T. How financial firms decide on technology. In R.E. Litan and A.M. Santomero (eds.), *Brookings–Wharton Papers on Financial Services.* Washington, DC: Brookings Institution Press, 1999, pp. 93–146.
41. IBM Global Services. The IT value model: Winning the business "battle" with the right "nails." Armonk, NY, 2006 (available at www-1.ibm.com/services/ondemand/business/it_value_model.html).
42. Jallath-Coria, E.S.; Mukhopadhyay, T.; and Yaron, A. Optimal bank reserves under deposit uncertainty. *Journal of Money, Credit, and Banking, 37,* 4 (2005), 623–643.
43. Jallath-Coria, E.S.; Mukhopadhyay, T.; Slaughter, S.; and Yaron, A. The economic value of network externalities in an electronic inter-bank payment network: An empirical evaluation. Working Paper, Tepper School of Business, Carnegie Mellon University, Pittsburgh, 2002.
44. Jorgenson, D.W. Information technology and the U.S. economy. *American Economic Review, 91,* 1 (2001), 1–32.
45. Jorgenson, D.W., and Stiroh, K. Computers and growth. *Economics of Innovation and New Technology, 3,* 3–4 (1995), 295–316.
46. Jorgenson, D.W., and Stiroh, K.J. Information technology and growth. *American Economic Review, 89,* 2 (1999), 109–115.
47. Kauffman, R.J., and Kriebel, C.H. Modeling and measuring the business value of IT. In P. Strassmann, P. Berger, B. Swanson, C.H. Kriebel, and R.J. Kauffman (eds.), *Measuring the Business Value of Information Technology.* Washington, DC: ICIT Press, 1988, pp. 97–119.
48. Kauffman, R.J., and Weill, P. An evaluative framework for research on the performance effects of IT investment. In J.I. DeGross, J.C. Henderson, and B.R. Konsynski (eds.), *Proceedings of the Tenth International Conference on Information Systems.* New York: ACM Press, 1989, pp. 377–388.
49. Khambata, D. Off-balance sheet activities of U.S. banks. *Columbia Journal of World Business, 24,* 2 (1989), 3–13.
50. Kmenta, J. *Elements of Econometrics.* New York: Macmillan, 1986.
51. Kohli, R., and Devaraj, S. Measuring IT payoff: A meta-analysis of structural variables in firm-level empirical research. *Information Systems Research, 14,* 2 (2003), 127–145.

52. Koppenhaver, G.D., and Stover, R.D. Standby letters of credit and large bank capital: An empirical analysis. *Journal of Banking and Finance, 15,* 2 (1991), 315–327.

53. Malone, T., and Crowston, K. The interdisciplinary study of coordination. *ACM Computing Surveys, 26,* 1 (1994), 87–119.

54. Marschak, J. The payoff relevant description of states and acts. *Econometrica, 31,* 4 (1963), 719–725.

55. Melville, N., and Ramirez, R. Assessing IT value within inter-firm business processes. In D. Gallett and J. Ross (eds.), *Proceedings of the Americas Conference on Information Systems.* Atlanta: Association for Information Systems, August 2003, 1469–1474.

56. Menon, N.M.; Lee, B.; and Eldenburg, L. Productivity of information systems in the healthcare industry. *Information Systems Research, 11,* 1 (2000), 83–92.

57. Mookerjee, A.S., and Cash, J.I. *Global Electronic Wholesale Banking*. London: Graham and Trotman, 1990.

58. Mooney, J.G.; Gurbaxani, V.; and Kraemer, K.L. A process-oriented framework for assessing the business value of IT. In G. Ariav and J. DeGross (eds.), *Proceedings of the Sixteenth International Conference on Information Systems.* Atlanta: Association for Information Systems, 1995, pp. 17–28.

59. Mukhopadhyay, T., and Gadh, V. Direct and indirect impacts of IT applications on productivity. *International Journal of Electronic Commerce, 1,* 3 (Spring 1997), 85–100.

60. Mukhopadhyay, T., and Kekre, S. Strategic and operational benefits of electronic integration in B2B procurement processes. *Management Science, 48,* 10 (2002), 1301–1313.

61. Mukhopadhyay, T.; Kekre, S.; and Kalathur, S. Business value of information technology: A study of electronic data interchange. *MIS Quarterly, 19,* 2 (1995), 137–156.

62. Mukhopadhyay, T.; Lerch, J.; and Mangal, V. Assessing the impact of IT on labor productivity. *Decision Support Systems, 19,* 2 (1997), 109–122.

63. Mukhopadhyay, T.; Rajiv, S.; and Srinivasan, K. Information technology impact on process output and quality. *Management Science, 43,* 12 (1997), 1645–1659.

64. Osburn, W. Managing letters of credit effectively. *Journal of Cash Management, 13,* 2 (1993), 44–51.

65. Parsons, T. *Structure and Process in Modern Societies.* New York: Free Press of Glencoe, 1960.

66. Ray, G.; Barney, J.; and Muhanna, W.A. Capabilities, business processes, and competitive advantage: Choosing the dependent variable in empirical tests of the resource-based view. *Strategic Management Journal, 25,* 1 (2004), 23–37.

67. Roach, S.S. Services under siege: The restructuring imperative. *Harvard Business Review, 39,* 2 (1991), 89–92.

68. Soh, C., and Marcus, L. How IT creates business value: A process theory synthesis. In G. Ariav and J. Degross (eds.), *Proceedings of the Sixteenth International Conference on Information Systems.* Atlanta: Association for Information Systems, 1995, pp. 29–41.

69. Spencer, D.E., and Berk, K.N. A limited information specification test. *Econometrica, 49,* 4 (1981), 1079–1085.

70. Srinivasan, K.; Kekre, S.; and Mukhopadhyay, T. Impact of electronic data interchange technology on JIT shipments. *Management Science, 40,* 10 (1994), 1291–1304.

71. Strecker, R. Automation is still an advantage in global banking services. *Information Strategy* (Fall 1990), 5–8.

72. Subramanian, C., and Shaw, M.J. The effects of process characteristics on the value of B2B e-procurement. *Information Technology Management, 5,* 1–2 (2004), 161–180.

73. Tallon, P.; Kraemer, K.; and Gurbaxani, V. Executives' perceptions of the business value of information technology: A process-oriented approach. *Journal of Management Information Systems, 16,* 4 (Spring 2000), 145–173.

74. Thatcher, M., and Pingry, D. An economic model of product quality and IT value. *Information Systems Research, 15,* 3 (2004), 268–286.

75. Thatcher, M., and Pingry, D. Understanding the business value of IT investment: Evidence from alternative market and cost structures. *Journal of Management Information Systems, 21,* 2 (Fall 2004), 61–85.

76. Thompson, J.D. *Organizations in Action: Social Science Bases of Administrative Theory.* New York: McGraw-Hill, 1997.

77. Venkatraman, N., and Zaheer, A. Electronic integration and strategic advantage: A quasi-experimental study in the insurance industry. *Information Systems Research, 1,* 4 (1990), 377–393.

78. Wizarat, S. On profitability and industrial concentration in Pakistan. *Journal of Economic Behavior and Organization, 17,* 3 (1992), 363–375.

Copyright of Journal of Management Information Systems is the property of M.E. Sharpe Inc. and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.