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*Executive Overview*

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## **Key Issues in Information Systems Management: 1994-1995 SIM Delphi Results**

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This article reports on the fifth of a series of studies undertaken jointly by SIM, International and the MIS Research Center (MISRC) at the University of Minnesota to determine the most critical issues in IS management. For this study, 108 SIM institutional members participated in three rounds of a Delphi process, and seven SIM officers and/or board members were interviewed after having read a draft of the Delphi results.

The findings indicate a continuation of the rising importance of technological infrastructure (e.g., responsive infrastructure, distributed systems, information architecture, and communication networks) issues. Many of the business relationship issues (e.g., IS organizational alignment, strategic planning, IS role and contribution, and competitive advantage) have accordingly declined in their rankings. Thus, for the first time in its 15-year history, the SIM/MISRC key issues ranking has taken on a technical flavor. The authors do not believe that this suggests IS executives are reverting back to their technical roots, as was reflected in the 1960s and 1970s. Instead, business requirements for speed, flexibility, and responsiveness are driving the importance of infrastructure issues. Clearly, this heightened concern with infrastructure has important implications for organization structure, human resource development, investment justification, application integration, and the future of electronic commerce.





# Productivity, Business Profitability, and Consumer Surplus: Three Different Measures of Information Technology Value<sup>1,2</sup>

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## Abstract

*The business value of information technology (IT) has been debated for a number of years. While some authors have attributed large productivity improvements and substantial consumer benefits to IT, others report that IT has not had any bottom line impact on business profitability. This paper focuses on the fact that while productivity, consumer value, and business profitability are related, they are ultimate-*

<sup>1</sup> Allen Lee was the accepting senior editor for this paper.

<sup>2</sup> An earlier version of this paper appears in the *Proceedings of the Fifteenth International Conference on Information Systems* under the title: "The Three Faces of IT Value: Theory and Evidence," where it won the awards for "Best Paper Overall" and "Best Paper on the Conference Theme."

*ly separate questions. Accordingly, the empirical results on IT value depend heavily on which question is being addressed and what data are being used. Applying methods based on economic theory, we are able to define and examine the relevant hypotheses for each of these three questions, using recent firm-level data on IT spending by 370 large firms. Our findings indicate that IT has increased productivity and created substantial value for consumers. However, we do not find evidence that these benefits have resulted in supranormal business profitability. We conclude that while modeling techniques need to be improved, these results are collectively consistent with economic theory. Thus, there is no inherent contradiction between increased productivity, increased consumer value, and unchanged business profitability.*

**Keywords:** IT productivity, business profitability, IS investment, economic theory, consumer surplus, computers

**ISRL Categories:** AM, EF07, EI0205.04, GA01

## Introduction

Questions about the business value of Information Technology (IT) have perplexed managers and researchers for a number of years. Businesses continue to invest enormous sums of money in computers and related technologies, presumably expecting a substantial payoff. Yet a variety of studies present contradictory evidence as to whether these expected benefits have materialized (Brynjolfsson, 1993; Wilson, 1993). The debate over IT value is muddled by confusion over what question is being asked and what the appropriate null hypothesis should be. In some cases, seemingly contradictory results are not contradictory at all because different questions are being addressed. Research has been further hampered by the lack of current and comprehensive firm-level data on IT spending.

This paper attempts to pinpoint the right questions regarding IT value and explicitly define

the appropriate theoretically grounded hypotheses. Now that detailed survey data on IT spending by several hundred large firms have been made available by the International Data Group (IDG), each of these hypotheses can be empirically examined using the same data set. Thus, our goals are: (1) to explain the theoretical relationships among the principal measures of IT's economic contribution, and (2) to apply the diverse models previously used to address these different measures to the same data set. In the process, some of the previous research findings in this area are highlighted and some implications for managers and researchers are derived.

In interpreting past findings, it is useful to understand that the issue of IT value is not a single question, but is composed of several related but quite distinct issues:

1. Have investments in IT increased productivity?
2. Have investments in IT improved business profitability?
3. Have investments in IT created value for consumers?

The first question asks whether IT has enabled the production of more "output" for a given quantity of "inputs." The second considers whether firms are able to use IT to gain competitive advantage and earn higher profits than they would have earned otherwise. The final issue is concerned with the magnitude of the benefits that have been passed on to consumers, or perhaps reclaimed from them.

We argue that these three questions are logically distinct, each having different implications for how managers, researchers, and policy makers should view IT investment. Because different researchers have used not only different methods, but also different data, it has been difficult to determine the cause of seemingly contradictory results.<sup>3</sup> We demonstrate that for the same

data, IT appears to have increased productivity and provided substantial benefits to consumers, but there is no clear empirical connection between these benefits and higher business profits or stock prices. This indicates that at least some of the apparent discrepancies among earlier conclusions about IT value were not due to differences in data. Nonetheless, we show that there is no inherent contradiction in these results; they are all simultaneously consistent with economic theory. However, our findings do highlight the fact that the answers one gets will depend on the questions one asks and how one addresses them, even when the same data are used. Models matter.

The remainder of this paper is organized as follows: The next section reviews the existing literature and relevant theory, the following section presents an empirical analysis of the three approaches, the section after that discusses the results, and the final section includes a summary and discusses the implications.

## Theoretical Perspectives and Previous Research

Microeconomic theory and business strategy can provide useful foundations for assessing the benefits of IT. This section examines the relevant theory applied in many of the previous studies of IT value and provides a guide to interpreting the various findings. In particular, three frameworks map consistently to the three questions raised in the introduction:

Issue	Framework
Productivity	Theory of Production
Business Profitability	Theories of Competitive Strategy
Consumer Value	Theory of the Consumer

### *Theory of production*

For over 60 years, the theory of production approach has been used extensively to evalu-

<sup>3</sup> This problem is by no means unique to the IT value debate. Gurbaxani and Mendelson (1991) ascribe it to the entire IS field.

ate the productivity of various firm inputs such as capital, labor, and R&D expenditures (Berndt, 1991). More recently, it has been used to assess IT investments. The theory posits that firms possess a method for transforming various inputs into output, represented by a *production function*. Different combinations of inputs can be used to produce any specific level of output, but the production function is assumed to adhere to certain mathematical assumptions.<sup>4</sup>

By assuming a particular form of the production function, it is possible to econometrically estimate the contribution of each input to total output in terms of the *gross marginal product*. This represents the additional output provided by the last dollar invested and is distinct from the overall contribution, which is the average for all dollars invested.<sup>5</sup> Since firms will seek to invest in the highest value uses of an input first, theory predicts that rationally managed firms will keep investing in an input until the last unit of that input creates no more value than it costs. Thus, in equilibrium, the *net* marginal product for any input will be zero. However, because costs are positive, the *gross* marginal product should also be positive.

Therefore, in equilibrium, the theory of production implies the following hypotheses:

**H1a: IT spending has a positive gross marginal product (i.e., it contributes a positive amount to output, at the margin),**

and

**H1b: IT spending has zero net marginal product, after all costs have been subtracted.**

These hypotheses are empirically testable, and deviations from them will require elabora-

<sup>4</sup> Specifically, the production function is assumed to be quasi-concave and monotonic (Varian, 1992). Furthermore, specific functional forms, such as the Cobb-Douglas production function, entail additional restrictions.

<sup>5</sup> It bears pointing out that *total* benefits of IT spending can still be large even if *marginal* benefits are zero or negative. In fact, a high marginal product may be a sign of underinvestment.

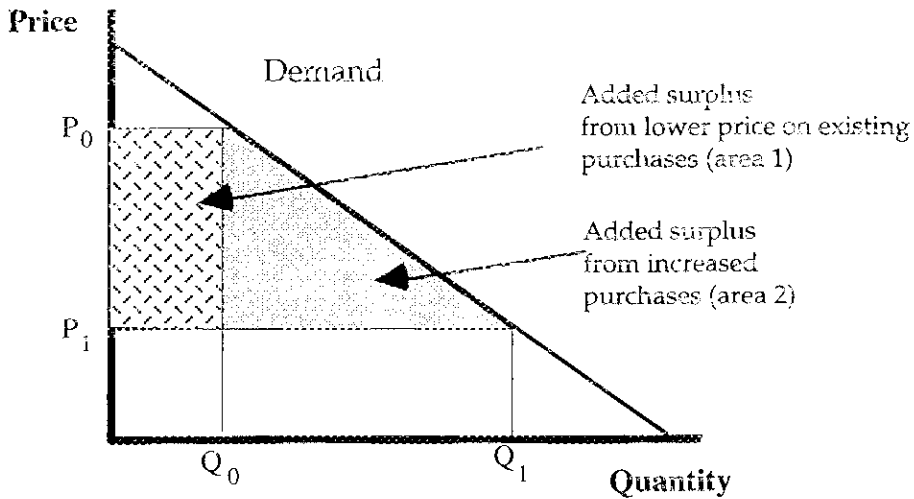
tion or modification of the basic theory and/or the underlying assumptions.

Several studies have employed methods based on the theory of production to evaluate IT productivity for firm- and industry-level data. Loveman (1994) found that gross marginal benefits did not deviate significantly from zero for a sample of 60 manufacturing divisions (1978-84 time period). Using more recent firm-level data for *Fortune* 500 manufacturing and service firms (1988-1992 period), Brynjolfsson and Hitt (1993; 1996) and Lichtenberg (1995) found gross marginal benefits of over 60 percent. As a practical matter, the marginal costs of IT will depend on factors such as the depreciation rate, which can be difficult to determine. Brynjolfsson and Hitt (1993; 1996) and Lichtenberg (1995) calculated net benefits using various assumptions about depreciation rates and found that net returns to IT were likely to be positive. In contrast, Morrison and Berndt (1990) explicitly estimated a cost function for 20 manufacturing industries from 1968-1986 and found that net marginal benefits were -20 percent. Because these studies examine different time periods and different data as well as different specifications, it is not obvious how to reconcile the results.

### *Theories of competitive strategy*

While the theory of production predicts that lower prices for IT will create benefits in the form of lower production costs for a given level of output, it is silent on the question of whether firms will gain competitive advantage and therefore higher profits or stock values. For that, we must turn to the business strategy field and the literature on *barriers to entry*.

As Porter (1980) has emphasized, in a competitive market with free entry, firms cannot earn sustainable *supranormal* profits because that would encourage other firms to enter and drive down prices. Although there is the possibility of exploiting an unusually profitable opportunity in the short run, long run accounting profits will be just enough to pay for the



As the price drops from  $P_0$  to  $P_1$ , the following things occur: there is an increase in the quantity demanded from  $Q_0$  to  $Q_1$ , there is added surplus due to the lower price on existing purchases (shaded area 1), and there is added surplus from the increase in purchases (shaded area 2).

**Figure 2. Components of Added Surplus — Increased Value on Existing Units and Added Value From Increased Purchases**

### *Comparing and integrating the alternative approaches*

As noted in the discussion above, the three methods measure several different things. The production theory approach measures the marginal benefit of IT. Examining business profitability indicates whether the benefits created by IT can be appropriated by firms to create competitive advantage. The consumer surplus approach focuses on whether the benefits are passed on to consumers.

In order to understand the relationship between the three measures of IT value it is useful to consider how the concept of value is treated in economics. There are only two ways to obtain value: value can be created, and value can be redistributed from others. While the processes of value creation and value redistribution are often linked, they can also be considered separately.

Productivity is most closely associated with the process of value creation. If IT investments are productive, then more output is realized for a

given quantity of input, leading to increased value that can be distributed among IT investors, suppliers, customers, or other economic agents. Business profitability and consumer surplus are also affected by value redistribution. If a firm is able to use IT to create and retain value, then IT investment can lead to increased business profitability. Alternatively, a firm can increase profitability with IT by redistributing value from customers or suppliers (i.e., using information to improve price discrimination between different types of consumers, foreclosing competition, or driving down prices paid to suppliers) without increasing the size of the total value "pie."<sup>8</sup> In this sense, business profitability is distinct from productivity — productive IT can facilitate higher business profitability but is neither necessary nor sufficient. Consumer surplus represents the other side of business value. To the extent that value is being created by IT without being captured by firms, consumers will be

<sup>8</sup> The pursuit of value need not be zero sum. Some types of competitive tactics, such as raising rivals' costs (Salop and Scheffman, 1983), actually lead to a loss of total value, even though these activities may be privately beneficial.

receiving the benefits. By the same token, if firms use IT for value redistribution, consumer surplus may decrease as business profitability is increased.

The net effect of IT on these three factors thus represents a complex interplay between the types of IT investment, the ease with which these investments are copied by competitors, the nature of competition within an industry, and other industry-specific factors such as consumer demand. Under normal competitive conditions where managers are making good or optimal investments in productive technologies, consumer surplus and productivity will generally increase together. The same is not true for business profitability because short-term profit increases from new technology will typically be eliminated by the increased competition that the new technology facilitates.

## Empirical Analysis

In order to investigate the effects of IT investment, each of the approaches described in the previous section is applied to the same data set. It is then possible to examine how the three approaches are interrelated without the potential confusion created by comparing different studies with different data. By the same token, for each approach, we attempt to apply the same model used in the previous literature for that approach. Our results can thus be more easily compared with prior work.<sup>9</sup> This strategy should help highlight which differences are due to data and which are due to models.

### Data

The data used for this analysis comprised an unbalanced panel of 370 firms over the period

<sup>9</sup> In fact, to facilitate a cumulative research tradition, the complete data set is available from the authors on request, along with a data appendix describing the variables in more detail.

1988-1992, with 1109 data points overall,<sup>10</sup> out of a possible 1850 data points (5x370) if the panel were complete. Computer spending data were obtained from IDG's annual surveys of IT spending by large firms (top half of the *Fortune* 500 manufacturing and service listings) from 1988-1992. These data were matched to Standard & Poor's Compustat II database to obtain values for the output, capital, labor, industry classification, and other financial data. These data were augmented with price indices from a variety of sources to remove the effects of inflation and allow interyear comparisons on the same basis. The precise variable definitions and sources are shown in Table 1, and sample statistics for the key variables are given in Table 2.

Ideally, we wanted to incorporate all components that are considered IT into our measure. A broad definition could have included hardware expenses (computers, telecommunications, peripherals), software expenses (in-house or purchased), support costs, and also complementary organizational investments such as training or the costs of designing and implementing IT-enabled business processes. Unfortunately, detailed data on the totality of IT expenses is generally not available.

Our measure of information technology, called "IT Stock," is comprised of two components. The first component is Computer Capital, which represents the total dollar value of central processors (mainframes, minicomputers, and supercomputers) as well as the value of all PCs currently owned by the firm. The second component is IS Labor, which is the labor portion of the central IS budget (total budgets cannot be used because capital expenditure on IT would be counted both in the budget and in Computer Capital). To create a single measure of "IT" two assumptions were made: (1) IS Labor represents a type of capital expenditure that produces an asset that lasts, on average, three

<sup>10</sup> This sample size refers to a complete set of productivity and profitability measures for which there is more than one observation over the five years in a 2-digit SIC industry. The sample may decrease further for analyses that require additional variables, but the base case analyses for productivity and profitability were conducted on exactly the same data points.

Table 1. Variable Definitions

Variable	Computation	Source
Output	Gross Sales deflated by Output Price (see below).	Compustat
Value Added	Output minus non-labor expense. Non-labor expense is calculated as total firm expenses (excluding interest, taxes, and depreciation) divided by Output Price less Labor (see below).	Compustat
IT Stock	Calculated as Computer Capital plus three times IS Labor (see below).	Calculation
Computer Capital	Market value of central processors plus value of PCs and terminals. Deflated by Computer Price (see below). Average value of PC determined as weighted average of PC price from Berndt and Griliches (1990) and value of PC from IBM. Resulting estimate is \$2.84 K in 1990 dollars.	IDG Survey
Non-Computer Capital	Deflated book value of Capital less Computer Capital as calculated above (for deflator see below).	Compustat
IS Labor	Labor portion of IS budget. Deflated by Labor Price (see below).	IDG Survey
Labor	Labor expense (when available) or estimate based on sector average labor costs times number of employees minus IS Labor. Deflated by Labor Price (see below).	Compustat
Industry	Primary industry at the 2-digit SIC level.	Compustat
Total Shareholder Return	Price change plus accumulated dividends divided by initial price.	Compustat
Return on Equity	Pretax income divided by total shareholders equity.	Compustat
Return on Assets	Pretax income divided by total assets.	Compustat
Computer Price	Gordon's deflator for computer systems—extrapolated to current period at same rate of price decline (-19.7%/yr.).	(Gordon, 1993)
Output Price	Output deflator based on 2-digit industry from BEA estimates of industry price deflators. If not available, sector level deflator for intermediate materials, supplies, and components.	(Bureau of Economic Analysis, 1993)
Labor price	Price index for total compensation.	(Council of Economic Advisors, 1992)
Capital Price	GDP deflator for fixed investment. Applied at a calculated average age based on total depreciation divided by current depreciation.	(Council of Economic Advisors, 1992)
Sales Growth	One-year change in sales.	Compustat
Capital Investment	Capital investment as percentage of total assets.	Compustat
Market Share	Total sales divided by industry total sales at the 2-digit SIC level. Industry total sales were computed by adding up all firms in Compustat that report a particular 2-digit primary SIC.	Compustat
Debt to Equity	Book value of total debt divided by book value of total equity.	Compustat
Research and Development Stock	An accumulation of annual R&D expense calculated by a procedure used by Hall (1990). Represents capitalized value of R&D conducted over 20 years.	Compustat



**Table 2. Sample Statistics — Average Over All Five years in Constant 1990 Dollars**

Variables	Mean	Std. Deviation
Value Added	\$3.27 Bn	\$4.98 Bn
IT Stock	\$304 mm	\$626 mm
Non-Computer Capital	\$8.84 Bn	\$13.9 Bn
Labor Expense	\$1.78 Bn	\$2.85 Bn
Return on Assets	7.55%	7.37%
Return on Equity	19.5%	19.5%
Shareholder Rtn.	12.1%	27.6%
ITRATE (IT Stock/Employees	\$6.84 K/employee	\$6.52 K/employee
Capital Investment (Cap. Inv./Assets)	7.38%	7.02%
Sales Growth	5.29%	10.8%
Market Share	6.3%	9.3%
Debt (Debt/Equity Ratio)	96.7%	93.1%
R&D Stock	\$1.94 Bn	\$3.81 Bn

years (e.g., software, templates, training); and (2) current IS spending is a good approximation of IS spending in the last three years. This allowed us to convert the annual flow of IS labor to a "stock" of IS labor, comparable to Computer Capital, which is an accumulation of spending over time. The actual computation is:

$$\text{IT Stock} = \text{Computer Capital} + 3 * \text{IS Labor}$$

where the factor of three represents the assumed service life of the asset created by IS Labor. This measure was used in earlier work to study the relative contributions of IT in various subsectors of the economy (Brynjolfsson and Hitt, 1995).

To the extent that IT Stock fails to capture the full range of IT expense, our results can only be interpreted as applying to the components we were able to measure. However, if the unmeasured components were to be correlated with the parts of IT we incorporated in our analysis, then our estimates would partially reflect this broader definition. This is likely to be true for other types of hardware or software expenditures, although it may be less true for investments in less tangible components such as "organizational technology." An extensive dis-

cussion of the impact of omitted IT spending can be found in Brynjolfsson and Hitt (1996) in the context of productivity analysis.

There are a number of other limitations of this data set. First, the IDG data were self-reported, which could lead to errors in reporting and sample selection bias. However, the large size of our sample helped mitigate the impact of data errors. The high response rate (68 percent) suggested that the sample would likely be reasonably representative of the target population, and we found that the included firms did not appear to differ substantially from the target population in terms of size or profitability measures (return on equity, return on assets, total shareholder return). In addition, the total annual values were generally consistent with a survey done by CSC/Index (Quinn, et al., 1993) and aggregate computer investment data by the Bureau of Economic Analysis.

Second, estimation procedures were used for some items, particularly the value of PCs and terminals and labor expenses (see Table 1). However, a range of alternative estimates were tested for these values, and the overall results were found to be essentially unchanged. Finally, the three-year average life

assumption for the IT capital created by IS labor was only an approximation. It was chosen to be between the life of Computer Capital assumed by the Bureau of Economic Analysis (seven years), and the life of IS labor if it were only an annual expense (one year) (Bureau of Economic Analysis, 1993). This assumption appeared reasonable because the components of IS labor spanned a range of activities such as software development, software maintenance and enhancement, user support, and hardware installation that ranged in useful life from less than a year to the life of a system.<sup>11</sup> In general, the coefficient estimates in the productivity analysis did not vary much as this assumption was changed over the range of one to seven years, although the implied rates of return to IT investment did change somewhat. In other analyses, the coefficients do change somewhat because the mean of IT stock changes, but overall, the basic conclusions remain the same.

### Production function approach

The production function approach was applied to this data set using the same methods employed by previous researchers (Brynjolfsson and Hitt, 1993; Lichtenberg, 1995; Loveman, 1994). Using the Cobb-Douglas production function, three inputs were related, measured in constant 1990 dollars: Total IT Stock (C), Non-Computer Capital (K), and Labor (L) to firm Value Added (V).<sup>12</sup> Dummy variables were also used to control for the year the observation was made ( $D_t$ ), and the industry (2-digit SIC level) or sector of the economy in which a firm operates ( $D_j$ ):

$$V = \exp \left( \sum_t D_t + \sum_{j=1}^J D_j \right) C^{\beta_1} K^{\beta_2} L^{\beta_3}$$

<sup>11</sup> Interestingly, the average life age of 642 systems reported in Swanson and Beath (1988) is 6.6 years, which is quite close to our seven-year upper bound.

<sup>12</sup> While this approach is not the only method used for conducting productivity analyses, it is by far the most common in the context of calculating the elasticities and marginal products of inputs. The Cobb-Douglas equation has the virtues of simplicity and empirical validity. Variations of this

After taking logarithms and adding an error term, we had the following estimating equation:

$$\log V = \sum_t D_t + \sum_{j=1}^J D_j + \beta_1 \log C + \beta_2 \log K + \beta_3 \log L + \epsilon$$

In this specification,  $\beta_1$  represents the output elasticity of IT Stock, which indicates the percentage increase in output provided by a one-percent increase in IT Stock. Dividing the elasticity by the ratio of IT Stock in Value Added provides an estimate of the gross marginal product of IT (which can be interpreted as a rate of return *before* costs of investment are subtracted).

Unbiased estimates of the parameters can be obtained by Ordinary Least Squares (OLS) provided the error term is uncorrelated with the regressors. However, following Brynjolfsson and Hitt (1993) we also employed Iterated Seemingly Unrelated Regression (ISUR) to enhance estimation efficiency by incorporating the fact that the productivity of particular firms is likely to be correlated across time. Furthermore, we tested the assumption that the error term is uncorrelated with the regressors by computing Two Stage Least Squares estimates (2SLS) with lagged values of the independent variables as instruments.<sup>13</sup>

The results of this analysis are presented in Table 3. When all industries and years were estimated simultaneously, we found that the output elasticity of IT Stock was .0863, implying a gross marginal product of approximately 94.9 percent.<sup>14</sup> The elasticity was similar for the ISUR analysis (using sector dummy vari-

approach include the use of more complex function forms such as the translog or using different estimation methods such as stochastic production frontiers or data envelopment analysis. These alternatives can be employed to address other issues related to the productivity question such as substitution between inputs or relative efficiencies of various firms (see e.g., Banker and Majumdar, 1988; Caves and Barton, 1990; Lee and Barua, 1994).

<sup>13</sup> For example, the instruments for the 1992 data points would be the 1991 values of IT Capital, Non-IT Capital, and Labor Expenses, along with the sector and time dummy variables. These are far from perfect instruments.

<sup>14</sup> The marginal product is equal to the elasticity divided by the percentage of IT in Value-Added, which is .0930. Therefore, the gross marginal benefit is: .0863/.0930 = 94.9 percent.

Table 3. Production Function Analysis

	OLS Estimates	ISUR Estimates	OLS on 2SLS Sample	2SLS
IT Stock	.0883* (.0118)	.0897* (.00920)	.0696* (.00940)	.0479* (.0219)
Non-Computer Capital	.212* (.0125)	.225* (.00864)	.181* (.0159)	.128* (.0269)
Labor	.663* (.0231)	.630* (.0112)	.725* (.0216)	.812* (.0415)
Dummy Variables	Industry & Year	Sector & Year	Industry & Year	Industry & Year
N	1109	1109	765	765
R <sup>2</sup>	97.2%	94.2-95.1%	97.0%	97.0%

\*-p<.05.

**Notes:** Heteroskedasticity-consistant standard errors used for OLS and 2SLS. Multiple R<sup>2</sup> measures are presented for ISUR because a sparate R<sup>2</sup> is computed for each year.

ables) although the standard errors decreased somewhat, indicating a gain in estimation efficiency. The gross marginal product for other capital and labor were 7.8 percent and 1.22 respectively, which is approximately what would be expected for inflation-adjusted estimates of these figures,<sup>15</sup> and was not inconsistent with estimates of production functions performed by other researchers on a comparable set of firms (e.g., Hall, 1993a). Considering the standard error for our estimate of the gross marginal product of IT Stock, we found strong support for the hypothesis that IT has contributed positively to total output (p<.001). This is consistent with hypothesis H1a. To calculate the net returns, it was necessary to subtract an estimate of the annual cost of capital.

<sup>15</sup> Note that because labor expense is an annual cost, a zero net return would require a gross return of 1.0. That is why the returns to labor appear much different than the returns to capital, which represent an accumulation of spending over time and have an inflation adjusted cost on the order of five-10 percent.

<sup>16</sup> This appeared to be substantially higher than a "reasonable" estimate of the capital cost based on the Jorgensonian cost of capital (Christensen and Jorgenson, 1969). The Jorgensonian cost is a function of the risk-free rate, a risk premium, depreciation charges, and capital gains or losses. Following Hall (1993b) we used six percent as the risk-free rate and assigned a risk premium of

Strikingly, even when we assumed that capital costs were as high as 69 percent per year,<sup>16</sup> we rejected the hypothesis that the net return to IT Stock was zero (p<.05), contradicting hypothesis H1b.

It is possible that the high rates of return were a result of a misspecification of the productivity equation. Rather than IT causing increased output, unexpectedly large output could motivate increased investment in IT. If this were the case, our estimates would show positive productivity benefits of IT even if the actual contribution were zero. This type of bias was

three percent. The Bureau of Economic Analysis (1993) assumes computers depreciate over a period of seven years, while IS Labor stock depreciates over three years. Weighting the two over the sample average composition gives an average life of 4.5 years or a depreciation rate of 22 percent per year. Finally, holders of IT Stock face capital losses of approximately four percent per year because the quality-adjusted costs of new computers (and therefore the value of old computers) declines at 19 percent per year (Gordon, 1987), and the costs of IS Labor increase by four percent per year. Accounting for the above factors yields a total cost of capital of 35 percent per year. However, it should be noted that other factors, such as taxes, the benefits of learning, the options value of investments, and unmeasured costs and benefits can substantially affect the true costs of capital, although they are difficult to quantify.

addressed by estimating the equation by Two Stage Least Squares, although this resulted in a loss of about one third of the sample because observations were needed for the same firm in adjacent years. While our 2SLS estimates appear somewhat lower than our base OLS and ISUR estimates, about half the difference is accounted for by sample differences (see Table 3). After accounting for these changes we were unable to reject the null hypothesis that our estimates of the elasticity of IT Stock were unbiased using the Hausman specification test (Hausman, 1978), although the coefficient on Non-Computer Capital did change significantly. Overall, this set of estimates suggests that our basic results regarding the high marginal product of IT were not due to simultaneity issues.

These results are consistent with similar analyses by Brynjolfsson and Hitt (1993, 1995; 1996) and Lichtenberg (1995), which also provide further methodological discussion and robustness checks. In addition, this analysis provides an exact baseline that was used as a comparison against the business profitability results presented below to highlight the differences caused by modeling changes as opposed to data differences.

### Business profitability analysis

Our business profitability model follows in the tradition of the existing IT literature on business value (Ahituv and Giladi, 1993; Alpar and Kim, 1990; Harris and Katz, 1989; Strassmann, 1990; Weill, 1992). While there is not a single standard form for the estimating relationship, we began by estimating a simple correlation, essentially replicating Strassmann's (1990) widely cited model on our data and then extending his model to include additional control variables. Following the established convention in the literature of using ratios of IT to various size measures, we

assumed firm profitability is a function of the ratio of IT Stock to firm employees.<sup>17</sup> Thus:

$$\text{Profitability Ratio} = \alpha_0 + \alpha_1 * (\text{ITRATE}) + \text{control variables} + \epsilon$$

The three measures of profitability (see Table 1 for precise definitions) considered in this study have been employed in past research: (1) Return on Assets (ROA) (Barua, et al., 1995; Cron and Sobol, 1983; Strassmann, 1990; Weill, 1992), which measures how effectively a firm has utilized its existing physical capital to earn income; (2) Return on Equity (Alpar and Kim, 1990), which provides an alternative measure of how effectively a firm has utilized its financial capital and is algebraically related to "Economic Value Added," a measure attracting increasing interest in the managerial community (Tully, 1993); and (3) Total shareholder return (Dos Santos, et al. 1993; Strassmann, 1990), which theoretically furnishes the discounted value of future profits.

For our base case analysis the results of Strassmann (1990) were replicated by computing the correlation of IT and profitability for each year of our sample (Table 4a). Overall, this simple analysis was generally inconclusive, although, if anything, it suggests the possibility of a negative relationship. In year-by-year regressions, only four of the 15 coefficients were statistically significant, but the majority were negative. Because multiple years were available, we also calculated the analysis pooling all the years and including control variables for the year (Table 4b). The pooled analysis shows significant negative effects for two measures (ROA, Total Return). However, the low R<sup>2</sup> in all three regressions indicates that these analyses explain a relatively small portion of the profitability measure variance. Furthermore, the relatively high R<sup>2</sup> in the total return regression is primarily a result of the year dummy variables, which explain 21 percent of the variance of this measure. The

<sup>17</sup> The actual choice of denominator for the IT measure does not affect the results substantially. However, there is a possible negative bias when sales is used as the denominator: irrespective of the contribution of IT, an unexpectedly good sales figure will increase profits but

lower the IT ratio, inducing a negative coefficient. The use of other inputs such as employees or capital avoids this bias. We chose employees to most closely replicate Strassmann's (1990) analyses, which do not use sales as the denominator.

**Table 4a. Sign and Significance Levels of IT Stock Coefficient in Single-Year Profitability Regressions**

	Return on Assets (1 Year)	Return on Equity (1 Year)	Total Return (1 Year)
1988	.*	-	+
1989	.*	-	-
1990	.*	-	.*
1991	-	-	-
1992	-	+	-

\* $p < .05$ .**Table 4b. Business Profitability Analysis**

	Return on Assets (1 Year)	Return on Equity (1 Year)	Total Return (1 Year)
IT Stock per Employee	-.00130* (.000306)	-.000668 (.000700)	-.00256* (.00122)
Dummy Variables	Industry & Year	Industry & Year	Industry & Year
N	1109	1109	1109
R <sup>2</sup>	3.3%	2.5%	21.8%
<b>Profit Measure</b>			
Mean	7.6%	19.5%	12.1%
Std. Deviation	7.4%	19.5%	27.6%

\* $p < .05$ ; Heteroskedasticity-consistent standard errors in parenthesis.

magnitudes of the coefficients on IT suggest that even large changes in IT have small effects on profitability. For instance, a 10 percent change in the IT Stock to employees measure implied only a 0.09 percent change in ROA. One interpretation of these results is that firms are using approximately the correct amount of IT: by the envelope theorem, no first order improvements can be made by raising or lowering spending on an input that is at its optimal level.

Because these estimates did not control for barriers to entry or other factors that may affect returns independent of the use of IT, they present the possibility of a spurious correlation. Two different approaches have been employed for extending these models. Weill (1992) and Barua, et al. (1995) extend this

basic model by incorporating firm specific variables that are unique to a particular theory or group of firms under study. Because these variables are not publicly available, we were unable to replicate this approach. An alternative, found in the broader literature on business profitability, was to identify generic variables that are likely to affect profitability and incorporate these variables in the model. Capon, et al. (1990) survey this literature and summarize the key predictors of business profitability.

We thus incorporated all the variables identified by Capon, et al. (1990) as having a significant impact on firm profitability that were available for the firms in our data set. A number of these related to characteristics of particular industries, such as concentration and barriers

to entry or size. Assuming these factors change relatively slowly, the effects of these industry-level variables were incorporated by including dummy variables for each industry. Other variables identified characteristics of particular firms. From these, we included growth, market share, capital investment, and debt for almost all the firms in our sample, as well as research and development expenditures (R&D) for about half of the firms (further description of these variables is included in Table 1, and summary statistics appear in Table 2). Several other potentially informative variables were either completely unavailable from public sources (e.g., relative price, quality) or available for very few firms in our sample (e.g., advertising).

The results of this extended analysis are presented in Table 5 (without R&D). As in the earlier analysis with industry controls, none of the IT coefficients were significantly different than zero, although we found significant effects of many of the control variables. Sales growth had a positive contribution, while debt (as measured by Debt to Equity Ratio) had a negative effect, both of which are consistent with prior research. The signs were mixed for mar-

ket share and capital investment and were not always significant. Compared with the previous analysis, while the overall fit was improved, the t-statistics on the IT coefficient appeared to drop (for example, in the total return regression the t-statistics dropped from 2 to .4). This suggests that many of the significant effects found in the earlier models may have been partially caused by a failure to adequately control for firm differences. When R&D was included in the regression (reducing the usable sample to 465), we found that R&D had a consistently positive effect (significant in the ROA and ROE regressions), but that there was no change in the signs or significance of other coefficients. We also found similar results for a related specification in which a dummy variable was included for each firm (rather than industry), which controlled for all slow-changing firm characteristics.

Taken in totality, the results showed little evidence of an impact of IT on supranormal profitability, which is consistent with our hypothesis H2 and much of the prior literature. However, it is interesting to note that the majority of our analyses showed negative but insignificant effects, suggesting the possibility of an overall

**Table 5. Profitability Regressions With Extended Firm-Specific Control Variables**

	Return on Assets (1 Year)	Return on Equity (1 Year)	Total Return (1 Year)
IT Stock per Employee	-.000402 (.000360)	.000158 (.000845)	-.000536 (.00119)
Capital Intensity	.204* (.0536)	.469* (.166)	-.256 (.0279)
Debt/Equity Ratio	-.0235* (.00230)	-.0194* (.000112)	-.0358* (.0106)
Market Share	-.000257 (.0336)	.00313 (.103)	-.0318 (.158)
Sales Growth	.139* (.0180)	.359* (.0614)	-.467* (.0861)
Dummy Variables	Industry & Year	Industry & Year	Industry & Year
N	1045	1045	1045
R <sup>2</sup>	46.2%	35.2%	30.3%

\*-p<.05; Heteroskedasticity-consistent standard errors in parenthesis.

negative effect of IT on profitability. It should be stressed that these models (both here and in the broader literature) are based on less rigorous theory than are the production function models, and, therefore, the failure to find a strong result may simply reflect inadequate modeling. Two alternative perspectives for interpreting these results are presented in the Discussion section below.

### Consumer surplus

In order to estimate consumer surplus for our sample, we used the index number method proposed by Caves, et al. (1982) and applied by Bresnahan (1986). For a general utility function (the translog), the increase in consumer surplus between two periods ( $t$ ,  $t+1$ ) was a function of the ratio of IT Stock to Value Added ( $s$ ), the Price of IT Stock ( $p$ ), and Value Added ( $V$ ) in the reference year, as follows:

$$Surplus_{t+1} = \frac{1}{2}(s_{t+1} + s_t) * \log\left(\frac{p_t}{p_{t+1}}\right) * V$$

The intuition behind this equation was that it represents the area under the demand curve between two price points. To apply this equation, we further assumed that the quantity of IT could be adjusted between years by purchasing more or less depending on prices. The primary difficulty with this analysis was that it required two important assumptions: (1) that

the increased purchases of IT are caused only by a decrease in prices and not by an exogenous shift in the entire demand schedule, and (2) that benefits received by upstream producers from their IT purchases are "competed away" and ultimately received by end consumers in the final product markets. The implications of these assumptions is discussed further in the conclusion. But overall, minor changes in these assumptions are unlikely to alter the general conclusions of this section.

Since IT Stock was a composite measure of two types of spending with different price changes over our sample period, it is important to understand the relative impact of each. The price of computers was dropping dramatically over this period – about 20 percent per year. However, the price of IS labor (as well as the quantity purchased) was flat or increasing in real terms over this same period. The net impact of these two changes was that despite the rapid decrease in the cost of computers, the overall cost of IT was declining at a much slower rate, averaging only 4 percent per year.

Annual surplus for the firms in our sample was computed as shown in Table 6. Overall, we found that IT Stock created significant value for consumers. Over our sample period, the price change in IT created \$14.5 billion (\$3.6 billion per year) in value above the cost of IT investment for the firms in the sample. This is consistent with hypothesis H3 and is propor-

**Table 6. Consumer Surplus Analysis  
(Constant 1990 dollars)**

Year	IT Stock	Value Added	IT as a Share of Value Added	Price of IT* (1990=1)	Surplus Using 1992 Output
1988	\$48.3 Bn	\$677.0 Bn	7.14%	1.064	na
1989	\$52.9 Bn	\$639.0 Bn	8.27%	1.031	\$2.09 Bn
1990	\$74.5 Bn	\$861.9 Bn	8.64%	1.000	\$2.18 Bn
1991	\$88.6 Bn	\$844.2 Bn	10.5%	.959	\$3.37 Bn
1992	\$98.1 Bn	\$848.5 Bn	10.6%	.892	\$6.85 Bn

\* IT price is a current period dollar weighted average of the price of Computer Capital and the price of IS Labor.

tional to the consumer surplus calculation for the economy as a whole that was performed by Brynjolfsson (1996). It should be noted that the above surplus calculation assumes that the net marginal benefit of the input (IT) is zero. Our findings of excess return to IT in the productivity analysis suggest that consumer surplus is substantially larger.

## Discussion -- Reconciling the Results

To summarize the empirical results, we found evidence that IT investment had a significant impact on firm output. Our production function estimates of the productivity of IT Stock suggested a gross marginal product of nearly 95 percent, implying positive net returns for most estimates of the cost of capital. These results are consistent with recent studies on IT and productivity by Brynjolfsson and Hitt (1993; 1995; 1996) and Lichtenberg (1995). When examining profitability as the dependent variable, we found no evidence that IT use led to supranormal profits, but found some evidence of a small negative impact on profitability. This is similar to previous research that typically found no relationship between IT and business profitability (Ahituv and Giladi, 1993; Barua, et al., 1995; Strassmann, 1990). Finally, using the consumer surplus approach, we estimated the total benefit to consumers to be substantial. The increase in surplus (above costs) was between \$2 billion and \$7 billion per year. This is consistent with previous approaches to that used industry- or economy-level data (Bresnahan, 1986; Brynjolfsson, 1996).

It is important to recognize that these results apply to the "average" firm. While IT appears to have been productive for the average firm, many firms undoubtedly made unproductive investments in IT. Similarly, while there was no discernible contribution to supranormal profits for the average firm, the high standard errors of the estimates suggest that some firms were obtaining significant competitive advantage while others were not. While the data were not sufficiently detailed to reliably

distinguish characteristics of "winners" and "losers," this variation is of significant interest for future research.

The most striking aspect of the empirical results is that IT Stock appears to be correlated with substantial increases in net output and consumer surplus, but unrelated to supranormal business profitability. These findings were based on data from the same firms, over the same time period, using the same measures of IT, so the conventional explanation of incomparable data sets does not apply. Below, two possible explanations are offered for this finding, one that takes the empirical results at face value and is based on an elaboration of the theory, and one that stresses the need for new econometric models and data.

### *Productivity without profit?*

The theoretical discussion in the second section asserts that profits, productivity, and consumer value are not equivalent. Information technology is commonly characterized as reducing the coordination costs involved in locating appropriate, low-cost products and services, and switching production to new suppliers (Malone, 1987). Such an increase in efficiency (and therefore productivity) can be shown to intensify competition by lowering barriers to entry and eliminating the market inefficiencies that enable firms to maintain a degree of monopoly over their customers (Bakos, 1991). One effect of this increased competition is to reduce prices paid for firm output. A second effect is that firms will work to squeeze out "fat" by reducing their consumption of other inputs such as ordinary capital and labor (Caves and Krepps, 1993). Because productivity calculations are performed after removing the effects of price changes, the reduction in input utilization and any direct contributions of IT to output will appear as productivity increases regardless of changes in output prices. However, the lower price paid for output will directly reduce profitability, possibly more than any cost savings achieved through rationalization.<sup>16</sup> Thus, under this theoretical sce-

<sup>16</sup> In our empirical analysis the actual distinction is somewhat more complex because neither prices nor industry boundaries were measured exactly. If industry definitions



nario, the result can be higher productivity and consumer value, but lower profits.

There is some evidence that this theoretical story is consistent with business practice. In an in-depth study of the banking industry, Steiner and Teixeira (1991) found that while IT seemed to be creating enormous value, it was simultaneously intensifying competition and destroying profitable businesses by enabling entry and radically lowering prices. This reduction in prices coincided with massive layoffs in the financial services sector. Clemons and Weber (1990) discovered a similar outcome in their analysis of the "big bang," which introduced a computerized system for matching buyers and sellers in London's stock market. It is important to note that the fundamental technologies involved (e.g., ATMs and automated stock trading) were ultimately available to all competitors in an industry, so investing firms were unable to appropriate the full value they were creating.<sup>19</sup> Jensen (1993) makes a related argument about how technology-based productivity improvements in the tire industry created massive overcapacity, consolidation, and exit from the industry for a number of firms. However, in each of these cases, large benefits were created for consumers. Thus, there is some theoretical and anecdotal support for our econometric finding that IT can create value (in terms of productivity and consumer surplus gains) without improving profits, although a

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were exact, the dummy variables included in our performance regression would control for differences in the rate of price change across industries and eliminate empirically the negative effect on profitability. However, because in practice the effective competitors of the firms in our sample did not map perfectly on to the 2-digit SIC code definitions we used and the industry dummy variables did not account for differences in price changes within industries over time, some of the residual price changes were still reflected in our estimates.

<sup>19</sup>In principle, the dummy variables we included for each industry in the basic profitability regressions should have partially controlled for the effect of industry-wide IT spending on profits. As mentioned in an earlier footnote, imperfections in the match between true competitors and 2-digit SIC codes and the fact that the dummy variables are invariant over time lead to less control for spurious industry effects. As a result, to the extent that a firm's IT budget is correlated with its competitors' spending, the coefficient on IT will in part reflect the indirect effects of higher overall industry spending on IT.

definitive finding is dependent on specific competitive conditions that cannot be fully examined in this study.

### *Measurement and modeling problems*

The issues of measurement and modeling shortcomings are probably the most frequently cited problems with empirical research. By considering over 1100 observations and triangulating on IT value using three modeling approaches, the measurement problem may be mitigated somewhat. However, we still believe modeling weaknesses cannot be ruled out as explanations for the results of each of our models.

First, a key assumption of the production function approach is that inputs "cause" output. Yet, it may also be true that output "causes" increased investment in inputs, since capital budgets are often based on expectations of what output can be sold. If this is the case, we may have overstated the contribution of IT, although without a detailed model of the reverse causality, we cannot estimate the magnitude of this bias. While no direct evidence of such simultaneity was found in our Hausman tests, this may simply reflect the inadequacy of our instrument list.

Second, while the gross returns to IT appear to be very high, the net returns would be much more difficult to calculate, especially given that significant maintenance "liabilities" may be created whenever computer projects are undertaken (Kemerer and Sosa, 1991). While we rejected the hypothesis that the net return to IT Stock is zero, additional unmeasured expenses (such as IS spending outside the central department or costs of IT related organizational change) could reduce the net return to close to zero. This would be consistent with economic equilibrium as well as the lack of correlation between IT and supranormal business profits. This suggests that future research should seek to identify "hidden" costs (which may be organizational) not currently considered part of the costs of IT. On the other hand, other factors

such as options value might lower the economic cost of IT capital, and unmeasured benefits from IT such as greater product quality may not have been fully reflected in our estimates of IT's gross marginal product. In addition, the cost of IT may be partially driven by our assumption of the average life of IS Labor, although earlier studies have found similar results for only the Computer Capital portion of IT Stock. The bottom line is that the precise net return cannot be determined with certainty.

Third, the consumer surplus approach assumes that the demand curve is stable over time, so that increases in the quantity purchased can be directly attributed to declines in price. In reality, it is likely that diffusion of the computer "innovation" would have led to some increase in quantity even if prices had not declined, although Gurbaxani and Mendelson (1990) found that by the 1980s, the vast majority of the increase in the quantity of computers purchased could be attributed to price declines, not diffusion. In any event, as shown by Brynjolfsson (1996), our consumer surplus estimates are likely underestimates to the extent that they do not account for diffusion, and, therefore, our finding of significant value would only be strengthened if diffusion were explicitly modeled.

We are most concerned by the fourth modeling weakness: the possibility that the insignificant results in the profitability regressions may simply be due to the fact that these models are comparatively blunt instruments. Past models on smaller data sets have usually been unable to explain more than about 10-20 percent in the variance of profitability measures, as measured by  $R^2$ . This also holds true for our base analysis, although we were able to obtain some improvement by adding additional control variables.<sup>20</sup> As noted by Ahituv and Giladi (1993), IT is just one item in a multitude of factors that affect firm returns, and many of these other factors are not controlled for in the model. This means that the profitability regressions will tend to have low statistical power

<sup>20</sup>By contrast, an  $R^2$  of 95 percent or more has been achieved for both production function analyses and consumer surplus analyses (e.g., Brynjolfsson, 1996; Brynjolfsson and Hitt, 1993; 1995; 1996).

and will not necessarily be able to detect effects even when they are present.

Furthermore, as we improved the fit of the models of profitability by adding commonly used control variables, the IT effects only became more insignificant. This suggests that there may be omitted variables in this analysis that are correlated with the use of IT. Failure to identify these variables can lead to biased estimates. In addition, many of the controls commonly used in the literature, such as sales growth and market share, are likely to be partially endogenous in the sense that they are not chosen by firms independently but are a product of other decisions. As with omitted variables, treating endogenous variables as independent variables in a regression leads to biased estimates. In summary, without a more complete and theoretically grounded model of the relationship between firm inputs and profitability it is more difficult to draw conclusions about the "true" relationship between IT and business profitability than it is to make inferences about the relationship between IT and output or IT and consumer surplus.

## Conclusion

The question of IT value is far from settled. Indeed, one advantage to the comparative approach taken in this study is that the existing gaps in knowledge become more apparent. For instance, our analysis underscored the relatively low power of the commonly used models of IT's effect on business profitability, and we presented some possible steps that can be taken to improve this situation.

Of equal importance, we separated the issue of IT value into three dimensions: the effect of IT on productivity, the effect of IT on business profitability, and the effect of IT on consumer surplus. Our empirical examination confirmed that, like any multidimensional object, IT's value can look different depending on the vantage point chosen. While we found evidence that IT may be increasing productivity and consumer surplus but not necessarily leading to supranormal business profits, we also showed that there is

no inherent contradiction in the idea that IT can create value but destroy profits.

From a managerial perspective, it is important to understand how investment in IT affects the bottom line. Our theoretical discussion suggests that it is possible for firms to realize productivity benefits from effective management of IT, without seeing these benefits translate into higher profitability. This theoretical prediction is also borne out by our empirical analysis. Taking the theory literally, our profitability results suggest that, on average, firms are making the IT investments necessary to maintain competitive parity but are not able to gain competitive advantage.

This analysis suggests two potential insights for managers. First, when cost is the central strategic issue in an industry, our productivity results suggest that IT investment may be one way to pursue a cost leadership strategy, provided that the cost reductions cannot be emulated by other firms. However, for industries where cost is not the central strategic issue or where there are few barriers to adoption of IT, firms are unlikely to create lasting competitive advantage simply by spending more on IT. This raises the second issue: managers seeking higher profits should look beyond productivity to focus on how IT can address other strategic levers such as product position, quality, or customer service. While IT can potentially lower the cost of providing these services, attaining competitive advantage may involve using IT to radically change the way products or services are produced and delivered in a way that cannot be duplicated by competitors. This may be possible by leveraging existing advantages with IT or using technology to target other segments of the industry where competition is less intense. The key to improving business profitability may lie less in achieving productivity gains, and more in pairing the benefits of IT with an available market opportunity. Again, our results on business profitability suggest that, on average, IT spending alone is not determinative of success.

From a research perspective, by clarifying the issues and results in the existing literature on IT value, we hope to provide a mechanism for

extending this literature substantially in the future. Because the value of IT was unknown, most of the previous literature focused on estimating the overall contribution of IT. Little is known about the distribution of benefits across individual firms, what characteristics of firms and industries determine which types of IT investment are productive, and which firms are effective or ineffective users of IT. Future research should go beyond estimating the "average" effects of IT and focus on differentiating successful and unsuccessful strategies. By identifying "best practices," either in terms of specific characteristics or as overall strategies of specific firms, managers can be provided with the information they need to fully exploit the value of IT.

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