

**Creating Value and Destroying Profits?  
Three Measures of  
Information Technology's Contributions**

**by  
Lorin Hitt  
Erik Brynjolfsson**

**CCS WP #183, Sloan WP #3796-95  
December 1994**

**Creating Value and Destroying Profits?  
Three Measures of Information Technology's Contributions**

Lorin Hitt

MIT Sloan School, E53-334  
Cambridge, MA 02139  
617-253-6614  
617-258-7579 (fax)  
lhitt@mit.edu

Erik Brynjolfsson

MIT Sloan School, E53-313  
Cambridge, MA 02139  
617-253-4319  
617-258-7579 (fax)  
ebrynjo@mit.edu

December, 1994

*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".*

# Creating Value and Destroying Profits? Three Measures of Information Technology's Contributions

## Abstract

The business value of information technology (IT) has been debated for a number of years. Some authors have found large productivity improvements attributable to computers, as well as evidence that IT has generated substantial benefits for consumers. However, others continue to question whether computers have had any bottom line impact on business performance. In this paper, we focus on the fact that productivity, consumer value and business performance are separate questions and that 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 examine the relevant hypotheses for each of these three questions, using recent firm-level data on IT spending by 367 large firms. Our findings indicate that computers have led to higher productivity and created substantial value for consumers, but that these benefits have not resulted in measurable improvements in business performance. We conclude that while modeling techniques need to be improved, these results are consistent with economic theory, and thus there is no inherent contradiction between increased productivity, increased consumer value and unchanged business performance.

**Keywords:** IT Productivity, Business Performance, IS Investment, Economic Theory, Consumer Surplus

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

## Acknowledgements

This research has been generously supported by the MIT Center for Coordination Science, the MIT Industrial Performance Center, and the MIT International Financial Services Research Center. We would like to thank Chris Kemerer, Albert Wenger, and the conference referees for ICIS 94 for helpful comments on earlier drafts of this paper. We are also grateful to International Data Group for providing essential data.

## Biographical Information

Lorin M. Hitt is a doctoral student in information technology at the MIT Sloan School of Management. He received his Sc.B. and Sc.M. degrees in electrical engineering from Brown University. His research interests include assessing the productivity effects of information technology investments and using information economics and econometrics to understand the effects of IT on organizations and markets.

Erik Brynjolfsson is Assistant Professor of Information Technology at the MIT Sloan School of Management. His research analyzes how information technology can transform the structures of markets and firms and assesses the productivity of information technology investments. He has written numerous articles in academic journals and served as the editor of special issues of *Management Science* and *Journal of Organizational Computing*. He was co-chairman of the 1993 Workshop on Information Systems and Economics. Professor Brynjolfsson holds degrees in Applied Mathematics, Decision Science, and Managerial Economics from Harvard and MIT. Before joining the MIT faculty, he directed a software development and consulting firm.

# **Creating Value and Destroying Profits? Three Measures of Information Technology's Contributions**

## **I. Introduction**

Doubts about the business value of computers have perplexed managers and researchers for a number of years. Businesses continue to invest enormous sums of money in computer technology, presumably expecting a substantial payoff, yet a variety of studies present contradictory evidence as to whether the expected benefits of computers have materialized (Attewell 1993; Brynjolfsson 1993a; Wilson 1993). The debate over information technology (IT) value is muddled by confusion as to 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.

In this paper, we attempt to clarify what the right questions are regarding IT value and explicitly define the appropriate theoretically-grounded hypotheses. Now that detailed survey data on computer spending by several hundred large firms have been made available by the International Data Group (IDG), we can empirically examine each of these hypotheses using the same data set.

In interpreting the past findings regarding IT value, 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 computers increased productivity?
- 2) Have investments in computers improved business performance?
- 3) Have investments in computers created value for consumers?

The first issue concentrates on whether computers have enabled the production of more "output" while using fewer "inputs". The second is related to whether firms are able to use computers to gain competitive advantage and earn higher returns 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, and have different implications for how managers, researchers and policy makers should view computer investment. Because different researchers have used not only different methods, but also different data, it has been difficult to know the cause of the seemingly contradictory results.<sup>1</sup> In this paper, we demonstrate that for this same data on the same group of firms, computers appear to have 1) increased productivity and, 2) provided substantial benefits to consumers, but that 3) there is no clear empirical connection between these benefits and higher business profits or stock prices. We show that there is no inherent contradiction in these results; they are all simultaneously consistent with economic theory. However, our findings do highlight that the answers one gets will depend on the questions one asks. Methods matter.

The remainder of this paper is organized as follows: in Section II we review the existing literature and relevant theory, Section III presents an empirical analysis of the three approaches, Section IV discusses the results, and Section V concludes with a summary and implications.

## **II. 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 that was applied in many of the previous studies of the value of IT, and provides a guide on how to interpret the various findings. In particular, three frameworks map consistently to three questions we raised in the introduction:

<b>Issue</b>	<b>Framework</b>
Productivity	Theory of Production
Business Performance	Theories of Competitive Strategy
Consumer Value	Theory of the Consumer

### **Theory of Production**

---

<sup>1</sup> This problem is by no means unique to the IT value debate. Gurbaxani & Mendelson (1991) ascribe it to the entire IS field.

The theory of production approach has been extensively applied to study the productivity of various firm inputs such as capital, labor and R&D expenditures for over 60 years (Berndt 1991), and more recently has been used to assess IT investments. The theory posits that firms possess a method for transforming various inputs into output that can be 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>2</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* benefit. This represents the rate of return on the last dollar invested, and is distinct from the overall rate of return, which is the average return for all dollars invested.<sup>3</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 returns (gross returns less costs) for any input will be zero. However, because costs are positive, the gross marginal returns must also be positive.

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

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

and

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

These hypotheses are empirically-testable and deviations from them will require elaboration or modification of the basic theory and/or the underlying assumptions.

Methods based on the theory of production have been employed to study IT productivity for firm- and industry-level data. Loveman (1994) found that gross marginal benefits were not significantly different 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

---

<sup>2</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>3</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 rate of return may be a sign of underinvestment.

firms (1988-1992 period), Brynjolfsson & Hitt (1993; 1994) and Lichtenberg (1993) found gross marginal benefits of over 60%. 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; Brynjolfsson and Hitt 1994) and Lichtenberg (1993) calculated net benefits using various assumptions about depreciation rates and found that net returns to IT were likely to be positive. In contrast, Morrison & Berndt (1990) explicitly estimated a cost function for 20 manufacturing industries over 1968-1986, found that net marginal benefits were -20%. Because these studies examined different time periods and different data as well as slightly 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 costs of production and greater 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 supranormal profits because that would encourage other firms to enter and drive down prices. Normal accounting profits will be just enough to pay for the cost of capital and compensate the owners for any *unique* inputs to production (e.g. management expertise) that they provide. Accordingly, if a firm has unique access to IT, then that firm may be in a position to earn higher profits from that access. On the other hand, IT will not confer supranormal profits to any firm in an industry if it is freely available to all participants. In this case, there is no reason to expect, a priori, that a firm that spends more (or less) on an IT than its competitors will have higher profits. Instead, all firms will use the amount of IT they consider optimal in equilibrium, but none will gain a competitive advantage from it. This is consistent with the argument of Clemons (1991) that IT has become a strategic necessity, but not a source of competitive advantage.

The only way IT (or any input) can lead to supranormal profits is if the industry has barriers to entry. Bain (1956) has broadly defined a "barrier to entry" as anything that allows firms to earn supranormal profits, such as patents, economies of scale, search costs, product differentiation or preferential access to scarce resources. There are two possible

ways in which IT value is related to barriers to entry. The first is that in industries with existing barriers to entry, it may be possible for firms in a particular industry to increase profits through the innovative use of IT, provided the barriers to entry remain intact. Second, the use of IT may raise or lower existing barriers or create new ones, thus changing the profitability of individual firms and industries.

The impact of IT on barriers to entry is ambiguous. On one hand, it may reduce economies of scale and search costs (Bakos 1993), thereby leading to lower industry profits. On the other hand, it may also enable increased product differentiation (Brooke 1992), supporting higher profits. If there are particular investments in IT that cannot be replicated by other firms, then firms can increase their own profits while industry profits can be increased or decreased. However, there are relatively few IT investments which provide sustainable advantage of this sort (Clemons 1991; Kemerer and Sosa 1991). On balance, any or all of the above conditions may hold for a given industry, so competitive strategy theory does not clearly predict either a positive or negative relationship between IT and profits or market value (which, after all, represent the expected discounted value of future profits). This implies the following null hypothesis:

*H2: IT spending is uncorrelated with firm profits or stock market value.*

Much of the previous research in this area has examined correlations between measures of IT spending and measures of business performance (Ahituv and Giladi 1993; Dos Santos *et al.* 1993; Markus and Soh 1993; Strassmann 1985; 1990). Some studies have attempted to examine direct correlations between IT spending and performance ratios (Ahituv and Giladi 1993) while others examine how IT influences intermediate variables which in turn drive performance (Barua *et al.* 1991; Ragowsky *et al.* 1994). In general, these studies find little overall correlation between IT spending and increased business performance, although the models are plagued with relatively low predictive power overall and have generally not controlled for many industry specific or firm specific factors other than IT spending.

### Theory of the Consumer

A third approach, also grounded in microeconomic theory, can be used to estimate the total benefit accruing to consumers from a given purchase. The demand curve for a product represents how much consumers would be willing to pay (i.e., the benefit they gain) for

each successive unit of that product. However, they need only pay the market price, so consumers with valuations higher than the market price retain the surplus. By adding up the successive benefits of each additional unit of the good, the total benefit can be calculated as the area between the two curves. Schmalensee (1976) further showed that in a competitive industry, the surplus from an input to production will be passed along to consumers, so the area under the demand curve for an input such as computers will also be an accurate estimate of consumer surplus.<sup>4</sup>

The major difficulty with this approach is determining the locus of the demand curve.<sup>5</sup> Fortunately, in the case of IT, a natural experiment has occurred in which the cost of computer power has dropped by several orders of magnitude. By examining how the actual quantity of computers purchased has changed over time, we can trace out the demand curve and calculate the total consumer surplus.

As the price of IT declines, benefits are created in two ways: 1) a lower price for investments that would have been made even at the old price, and 2) new investments in IT that create additional surplus. In competitive equilibrium, a decline in the price of an input will lead to an increase in spending on that input and an increase in consumer surplus. If firms are making optimal investments, the additional consumer surplus should be no less than the cost of these investments, suggesting the following simple hypothesis:

*H3: The consumer surplus created by IT is positive and growing over time.*

The literature on the consumer surplus from IT is somewhat more sparse than the others. In addition to Bresnahan (1986), who studied the effects of IT spending on the financial services industry and found substantial benefits, this method has been applied to data on the entire U.S. economy by Brynjolfsson (1993b), who estimated that computers generated approximately \$50 billion in consumer surplus in 1987.

### Comparing and Integrating the Alternative Approaches

---

<sup>4</sup> When an industry is not perfectly competitive, the area under the derived demand curve will generally underestimate welfare.

<sup>5</sup> In particular, see Berndt (1991) for an excellent discussion of simultaneity in supply-demand systems and Gurbaxani and Mendelson (1990) on the role of technology diffusion.

As noted in the discussion above, the three methods measure several different things. The production theory approach measures the marginal benefit of IT investment. The performance ratio approach shows 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 together, 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 can be produced with less input, leading to increased value that can be distributed among producers, suppliers, customers or other economic agents. Business performance and consumer surplus refer to value redistribution. If a firm is able to create value through IT and retain some of the value that it creates, then IT investment can lead to increased business performance. Alternatively, a firm can increase performance 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>6</sup> In this sense, business performance is decoupled from productivity -- productive IT can facilitate higher business performance 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 and that value is not being captured by firms, consumers will be receiving the benefits. By the same token, if firms use IT for value redistribution, consumer surplus may decrease as business performance is increased.

The net effect of IT on these three factors thus represents a complex interplay between the types of IT investment, how easily 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

---

<sup>6</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 behaviors may be privately beneficial.

generally increase together. The same is not true for business performance, where profit increases from new technology will be eliminated by increased competition that the new technology facilitates.

### **III: Empirical Analysis**

In order to investigate the effects of computer investment, we apply each of the approaches described in Section II to the same data set. It is then possible to examine how the three approaches are interrelated without the potential confusion created by the comparison of 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. This strategy should help highlight which differences are due to data, and which are due to models.

#### Data

The data used for this analysis comprise an unbalanced panel of 367 firms over the period 1988-1992 with 1248 data points overall,<sup>7</sup> out of a possible 1835 data points (5x367) if the panel were complete. We obtained computer spending from an annual survey conducted by International Data Group (IDG) of computer spending by large firms (top half of the Fortune 500 manufacturing and service listings) over the period 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. We augmented these data with price indices from a variety of sources to remove the effects of inflation and allow inter-year 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.

There are a number of limitations of this data set. First, the IDG data are self-reported, which could lead to error in reporting and sample selection bias. However, the large size of our sample should help mitigate the impact of data errors. The high response rate (68%) suggests that the sample is likely to be reasonably representative of the target population and we find that the included firms do not appear to differ substantially from the target population in terms of size or performance measures (return on equity, return on assets,

---

<sup>7</sup>This sample size refers to a complete set of productivity variables. The sample size may increase or decrease for some analyses that use different subsets of the variables.

total shareholder return). In addition, Lichtenberg (1993) compared this data with an alternative source (Information Week) and found high correlations for specific firms, and the total annual values are 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, the survey records a relatively narrow definition of IT, namely Computer Capital, including only PCs, terminals, minicomputers, mainframes and supercomputers, but not the related peripherals, telecommunications equipment or software, and thus the results need to be interpreted as applying only to the subset of IT variables that we are able to measure. Finally, we use estimation procedures for some items; particularly the value of PCs and terminals and labor expenses. However, we tested a range of alternative estimates for these values and found that the overall results were essentially unchanged.

### Production Function Approach

We apply the production function approach to this data set using the same methods employed by previous researchers (Brynjolfsson and Hitt 1993a, Lichtenberg 1993; Loveman 1994). We relate three inputs, measured in constant 1990 dollars, Total Computer Capital (C), Non-computer Capital (K) and Labor (L) to firm Value Added (V) by a Cobb-Douglas production function.<sup>8</sup> We also use dummy variables to control for the year the observation was made ( $D_t$ ), and the sector of the economy in which a firm operates ( $D_j$ ):

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

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

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

In this specification,  $\beta_1$  represents the output elasticity of Computer Capital, which is the percentage increase in output provided by a small increase in Computer Capital. Dividing the elasticity by the percentage share of Computer Capital in Value Added, provides an estimate of the (gross) marginal return on computer investment.

---

<sup>8</sup>The Cobb-Douglas form is by far the most commonly assumed type of production function. It has the virtues of simplicity and empirical validity, and can be considered a first-order approximation to any other type of production function.

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 & Hitt (1993) we also employ Iterated Seemingly Unrelated Regression (ISUR) to potentially enhance estimation efficiency.<sup>9</sup> Furthermore, we test 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>10</sup>

The results of this analysis are presented in Table 3. When all industries and years are estimated simultaneously, we find that the output elasticity of computer capital is .0307, implying a gross marginal return of approximately 86.5%.<sup>11</sup> The gross marginal return for other capital and labor are 8.5% and 1.21 respectively, which is approximately what would be expected for inflation-adjusted estimates of these figures, and is not inconsistent with estimates of production functions performed by other researchers (e.g. (Hall 1993a)). Considering the standard error for our estimate of the gross rate of return to computer capital, we find strong support for the hypothesis that computers have contributed positively to total output ( $p < .001$ ). This is consistent with hypothesis H1a. To calculate the net returns, it is necessary to subtract an estimate of the annual cost of capital. Strikingly, even if we assume that capital costs are as high as 42% per year,<sup>12</sup> we can reject the hypothesis that the net return to computer investment is zero, contradicting hypothesis H1b.

Our 2SLS estimates are close to the OLS estimates, suggesting that the equation is properly specified, and this result is confirmed by a Hausman specification test (Hausman 1978).

<sup>9</sup> Since this data set is a panel of repeated observations on the same set of firms, it is likely that the error terms for a single firm will be correlated over time. One way to accommodate this feature is to employ ISUR to estimate separate equations for each year and allow the error terms for the same firm in different years to be correlated. Our use of ISUR is confirmed by the estimated correlation structure from the ISUR procedure: adjacent year correlations range from .46 to .76, suggesting a substantial amount of within-firm autocorrelation.

<sup>10</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.

<sup>11</sup> The rate of return is equal to the elasticity divided by the percentage of IT in Value-Added which is .0355. Therefore, the gross marginal benefit is:  $.0307/.0355 = 86.5\%$ .

<sup>12</sup> This estimate is derived from the Jorgensonian cost of capital (Christensen and Jorgenson 1969). The cost is a function of the risk free rate, a risk premium, depreciation charges, and capital gains or losses. Following Hall (1993b) we use 6% as the risk free rate and assign a risk premium of 3%. The Bureau of Economic Analysis (1993) assumes computers depreciate over a period of 7 years, or 14% per year. Finally, holders of computer capital face capital gains of approximately 19% per year because the quality-adjusted costs of new computers (and therefore the value of old computers), declines at this rate (Gordon 1987). Accounting for the above factors yields a total cost of capital of 42% per year. However, it should be noted that other factors, such as taxes, the costs of learning, the options value of investments and unmeasured costs and benefits can also affect the costs of capital, although they are difficult to quantify.

All of these results are consistent with the more detailed analyses of the same data by Brynjolfsson and Hitt (Brynjolfsson and Hitt 1994) and by Lichtenberg (1993). In section IV below, we discuss the implications of these findings.

### Business Performance Analysis

Our business performance 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 posit a simple but flexible form which accommodates the features of previous research and uses dependent variables employed by other authors. Firm performance is assumed to be a function of the Computer Capital ( $C$ ), the industry (at the 2-digit SIC level) in which a firm operates ( $j$ ), the time period considered ( $t$ ), and the size ( $S$ ) of the firm as measured by total capital. The industry variable will help control for different barriers to entry and differences in performance among industries. However, because the firms in our sample were large, and often diversified firms, the industry dummy variable will be an imperfect proxy for the true competitive environment facing the firm. We include size to avoid confounding any performance benefits that are received (or lost) by large firms with computer spending.<sup>13</sup> We take logarithms of Computer Capital and Size to approximate a normal distribution for the regressors. Thus we can write:

$$\text{Performance Ratio} = A(j, t) + \alpha_1 \log C + \alpha_2 \log S + \varepsilon$$

Three measures of performance (see Table 1 for precise definitions) that are considered here have been employed in past research: 1) Profitability as measured by Return on Assets (ROA) (Barua *et al.* 1991; Cron and Sobol 1983; Strassmann 1990; Weill 1992) measures how effectively a firm has utilized its existing physical capital to earn income; 2) Profitability as measured by Return on Equity (Alpar and Kim 1990) 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) is used to measure how much value a firm has created for shareholders.

---

<sup>13</sup>Also, by including size, this specification can be compared to the IT investment ratio approach. If  $\alpha_1 = -\alpha_2$ , this formula is essentially a correlation between the logarithm of (IT investment/size) and performance.

The analysis of each of the measures was performed using OLS, as well as ISUR although the results were almost identical. The OLS results are in Table 4a. The measures of ROA and ROE are consistent with competitive strategy theory and previous research: we cannot reject hypothesis H2, that Computer Capital has no effect on ROA or ROE. However, we do find that Computer Capital has a small negative correlation with total shareholder return. The regression for total return indicates that firms with 1% higher Computer Capital spending is associated with a reduction of about 0.03% in shareholder return. However, when the analysis is repeated on a year by year basis (Table 4b), a significant effect is only found for total return in 1990 and for ROA in 1988 and 1990, and the signs of the effect for each of the measures varies over time. We also recomputed the regression results using a 3-year and 5-year average for each of the dependent variables and obtained similar results. Therefore, while there is little evidence that IT is correlated with changes in firm performance as predicted by H2, the evidence we do find suggests that, if anything, there is a negative effect. This possibility is further explored in section IV below.

As shown in the table 4a, the predictive ability of these specifications is relatively low, with  $R^2$  ranging from 17% to 24%. Therefore, it is possible that there are important control variables that we have not included, and that the overall effect of IT is simply lost in the statistical noise. To rule out the possibility that the equivocal results on business value are caused by omitting some obvious control variable, we also examined the broader literature on business value measurement and analyzed simple extensions of our basic model.

Capon, Farley and Hoenig (1990) performed a meta-analysis of the business performance literature and identified over 100 additional variables that have been used in 320 studies of the relationship between firm characteristics and performance measures conducted between 1921 and 1987. While their analysis shows that there is no general form of the estimating equation, a number of variables tend to recur in a substantial number of studies. Many of the variables used in previous work address industry wide factors such as entry barriers, minimum efficient scale or concentration. Because we have already included a dummy variable for each industry, our analysis captures these effects, at least to the extent that they have not substantially changed over our 5 year sample frame.

However, a number of commonly used variables describe characteristics of specific firms. We incorporated these additional variables by estimating two extensions of the basic performance regression. The first, most general approach, assumes (as we do with

industry effects) that performance is a function of time-invariant characteristics of individual firms. We can then include separate dummy variables for each firm to capture the aggregate of all these firm-specific factors, although this approach leads to a substantial reduction in degrees of freedom and an increased imprecision of the estimates. The firm-dummies may "explain" much of the variance and leave relatively little for the other variables. The second method is to explicitly include four of the most common firm-specific factors, which focus on risk (Miller and Bromily 1990) and market position: 1) Systematic risk as measured by stock market beta, which captures the volatility of the value of a firm; 2) Leverage as measured by debt to equity ratio which is a measure of bankruptcy risk that a firm faces; 3) Market share, with the market defined as other firms in Compustat in the same 2-digit SIC industry; and 4) Sales growth over a 1-year period.

The summary of these additional regression analyses appears in table 5a for the firm effects analysis and table 5b for the added control variables. Both the firm-effects model and the model with both risk and market position measures improve the  $R^2$  substantially (for example, in the return on assets regression  $R^2$  increases from about 22% to 37% for the risk/market position analysis and 76% for firm effects), although the overall fit, except for firm effects, is still somewhat low. As shown in table 5, the effect of IT on performance is consistently negative for total return, mixed for ROA, and positive for ROE. However, the effect is not statistically significant in any of the new regressions. The signs of the added variables firm-specific factors generally correspond with expectation and are often significant: performance is negatively affected by leverage and positively affected by sales growth. The sign is mixed for systematic risk (beta), although the coefficient in the total return regression is 3.5% which is a reasonable value for the market risk premium. However, there is a surprising negative effect of market share. Taken in totality, these extended results provide some added confirmation of the possibility of a negative effect of IT, although none of the analyses are conclusive. However, it should be stressed that these models (both here and in the broader literature) are based less on rigorous theory than the production function models, and, therefore, the failure to find a strong result may simply reflect inadequate modeling.

### Consumer Surplus

In order to estimate consumer surplus for our sample, we use 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 ( $t, t+1$ ) is a

function of the ratio of Computer Capital to Value Added ( $s$ ), the Price of Computer Capital ( $p$ ) 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 is that it represents the area under the demand curve between two price points. To apply this equation, we further assume that the quantity of computer capital can be adjusted between years, by purchasing more or less depending on prices. We compute annual surplus for the firms in our sample as shown in Table 6.

Overall, we find that Computer Capital has created significant value for consumers. Between 1988 and 1990, the price change in computers created \$4.1 billion in value above the cost of IT investment for the firms in our sample. This is consistent with hypothesis H3 and is proportional to the consumer surplus calculation for the economy as a whole performed by Brynjolfsson (1993b).<sup>14</sup>

#### **IV Discussion - Reconciling the Results**

To summarize the empirical results, we find that computer investment has had a significant impact on firm output. Our production function estimates of the productivity of Computer Capital suggest a gross rate of return of nearly 87%, which imply positive net returns for most plausible estimates of the cost of capital. These results are consistent with recent studies on IT and productivity by Brynjolfsson and Hitt (1994) and Lichtenberg (1993). When examining business performance as the dependent variable, we find no evidence of a positive impact, and even some evidence of a small negative impact on performance. This is similar to previous research which typically found no relationship between IT and business performance (Strassmann 1990; Barua, Kriebel and Mukhopadhyay, 1991; Ahituv and Giladi 1993). Finally, using the consumer surplus approach, we estimate the total benefit to computers to be substantial. The increase in surplus (above costs) is at least \$4.1 billion per year. This is consistent with previous approaches to this issue that used different data (Bresnahan 1986; Brynjolfsson 1993b).

---

<sup>14</sup> The above surplus calculation follows the convention of assuming that the net marginal benefit of the input (IT) is zero. However, if we use our production function estimate that IT created an excess return of 44.5% on each additional unit purchased, this amount has to be added in to get total consumer surplus. For 1990, this amounts to an additional \$1.7 billion of consumer benefit, bringing the total surplus to \$5.8 billion in 1990.

The most striking aspect of the empirical results is that Computer Capital appears to be correlated with substantial increases in net output and consumer surplus, but uncorrelated with business performance. These findings are based on data from the same firms, over the same time period, using the same measures of computers, so the conventional explanation of incomparable data sets does not apply. Below, we put forth two possible explanations for this finding, one based on elaboration of the theory, and one which stresses the need for new econometric models.

### Creating Value and Destroying Profits.

The theoretical discussion in section II highlights that profits, productivity, and consumer value are not equivalent. Information technology is commonly characterized as reducing the coordination costs involved in finding appropriate, low cost products and services to buy 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 inefficiencies in the market which enable firms to maintain a degree of monopoly over their customers (Bakos 1991). The result is 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 lower prices. 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>15</sup> However, in each of these cases, large benefits have been created for consumers. Thus, there is some

---

<sup>15</sup> In principle, the dummy variables we included for each industry in the basic performance regressions should have partially controlled for the effect of industry-wide IT spending on profits. However, in practice the effective competitors of the firms in our sample do not map perfectly on to the 2-digit SIC code definitions we used. Furthermore, IT spending changed over time in each industry, while the industry dummy was invariant over time. 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.

theoretical and anecdotal support for our econometric finding that computers can create value and yet destroy profits.<sup>16</sup>

### Measurement and Modeling Problems

The issues of measurement and modeling shortcomings are probably the most cited problems with empirical research. By considering over 1200 observations and triangulating on IT value using three modeling approaches, we may be able to mitigate the measurement problem 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 overstate the contribution of computers, although without a detailed model of the reverse causality, we cannot estimate the magnitude of this bias. While we did not find direct evidence of such simultaneity in our Hausman tests, this may simply reflect the inadequacy of our instrument list.

Second, while the gross returns to computers appear to be very high, the net returns are much more difficult to calculate, especially in light of the fact that significant maintenance "liabilities" may be created whenever computer projects are undertaken (Kemerer and Sosa 1991). When we calculate a cost of computer capital using commonly accepted methods, we are just able to reject the hypothesis that the net returns to computers are zero, and therefore, any costs that we have not accounted for could reduce the net returns to zero. However, at the same time, there are other factors such as options value that might lower the cost of capital, and thus the precise net return cannot be determined with certainty.

Third, an implicit assumption of the consumer surplus approach is 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. Gurbaxani & Mendelson (1990) found that by the 1980s, the vast majority of the increase in the quantity

---

<sup>16</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.

of computers purchased could be attributed to price declines, not diffusion. In any event, as shown by Brynjolfsson (1993b), our consumer surplus estimates are likely to be underestimates to the extent 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 performance ratio 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% in the variance in performance measures, as measured by  $R^2$ , and this also holds true for our base analysis, although we are able to obtain some improvement by adding additional control variables.<sup>17</sup> As noted by Ahituv and Giladi (1993), IT is just one item in a multitude of factors that affect firm returns, and most of these other factors are not controlled for in the model. A simple calculation highlights the importance of statistical power in finding the relationship between IT and business value. If our production function regression is correct, then computers should be increasing firm return on assets by approximately 0.7% each year. While this is a significant contribution in dollar terms, it would be less than one standard error in the performance regression, evaluated at the sample mean (1.19%), and would therefore be undetectable by such models.<sup>18</sup> Our extended performance analysis suggests that even when the base model that has generally been applied in IT is extended, we are still unable to find conclusive results on the business value of IT. Altogether, this suggests we will have to substantially augment our modeling toolkit in order to fully resolve the question of the business value of IT.

## **V. Conclusion**

The question of IT value is far from settled. Indeed, one advantage to the comparative approach we have taken 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 performance (and the general inconsistency in the broader

---

<sup>17</sup> By contrast, an  $R^2$  of 95% or more has been achieved for both production function analyses and consumer surplus analyses (e.g. (Brynjolfsson 1993b; Brynjolfsson and Hitt 1993)).

<sup>18</sup> The hypothetical increase in firm return is based on the following rough calculation: increase in value added each year by IT as a fraction of total assets = {IT capital stock (\$110 million) \* net marginal benefit of IT (54%)} / total capital (\$8,420 million) = .7%. The standard error calculation is as follows: standard error on IT coefficient for model with both risk and market position controls (.00253)\* log of average computer capital measured in millions of dollars (log(110) = 1.19%

literature on business performance), and we presented some possible steps that can be taken to improve this situation.

Of equal importance, we clarified the point that there are three related, but distinct dimensions to the question: the effect of computers on productivity, the effect of computers on business performance, and the effect of computers 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 business profits, we also showed that there is no inherent contradiction if computers create value but destroy profits.

From a managerial perspective, it is important to understand how investment in computers affects the bottom line. Our theoretical discussion suggests that it is possible for firms to realize productivity benefits from effective management of IT, but not to see these benefits translate into performance improvements. This theoretical prediction is also borne out by our empirical analysis. Taking the theory literally, our performance results suggest that firms are making the necessary IT investments to maintain competitive parity but are not able to gain competitive advantage.

There are two potential insights for managers resulting from this analysis. 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 competitive advantage simply by spending more on IT (but can stand to substantially lose if they fail to invest). Our results on business performance suggests that the latter scenario potentially dominates the former, although the fact that we do not see firms that have invested less doing worse suggests that managers are making the necessary investments to maintain competitive parity. This raises the second issue: managers 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 performance 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 performance 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 foundation to extend this literature substantially in the future. Because the question of IT value was in doubt, most of the effort in the existing literature is focused on establishing the overall contribution of IT. Little is known about the distribution of benefits across individual firms, what characteristics of firms and industries determine the types of IT investment that 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, we can provide managers with the information they need to fully exploit the value of IT.

Table 1: Variable Definitions

<b>Variable</b>	<b>Computation</b>	<b>Source</b>
Output	Gross Sales deflated by Output Price (see below).	Compustat
Value Added	Output minus non-Labor expense(see below).	Compustat
Computer Capital	Market value of central processors plus value of PCs and terminals. Deflated by Computer price (see below).	IDG Survey
Non-Computer Capital	Deflated Book Value of Capital less Computer Capital as calculated above (for deflator see below).	Compustat
Labor	Labor expense (when available) or estimate based on sector average labor costs times number of employees. Deflated by Labor Price (see below).	Compustat
Industry	Primary industry at the 2-digit SIC level.	Compustat
Sector	Grouped in eight economic sectors based on primary SIC code (mining, durable manufacturing, non-durable manufacturing, transport & utilities, trade, finance, other service).	Compustat
Total Shareholder Return	Price change plus accumulated dividends divided by initial price. Only values between +/- 100% per year considered valid.	Compustat
Return on Equity	Pretax income divided by total shareholders equity. Only values between +/- 100% per year considered valid.	Compustat
Return on Assets	Pretax income divided by total assets. Only values between +/- 50% per year considered valid.	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. Only values between +/- 50% considered valid.	Compustat
Beta	Computed as the ratio of the variance of monthly stock returns computed over the past five years to the equivalent variance measure for the S&P 500 average. Only values between +/-3 considered valid.	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. Only values up to 10:1 considered valid.	Compustat

Table 2: Sample Statistics - Average over all five years in constant 1990 dollars

	<b>Average Firm</b>	<b>All Firms</b>
Output	\$8.42 Bn	\$2,104 Bn
Value Added	\$3.10 Bn	\$774 Bn
Computer Capital	\$110 mm	\$27.5 Bn
Non-Computer Capital	\$8.24 Bn	\$2,057 Bn
Labor Expense	\$1.76 Bn	\$439.3 Bn

Table 3: Production Function Analysis

	<b>ISUR Estimates</b>	<b>OLS Estimates</b>	<b>2SLS Estimates</b>
Computer Capital	.0307*** (.00688)	.0427*** (.00740)	.0530*** (.0151)
Non-Computer Capital	.228*** (.00792)	.221*** (.00837)	.197*** (.00999)
Labor	.686*** (.0107)	.698*** (.0131)	.724*** (.0173)
Dummy Variables	Sector & Year	Sector & Year	Sector & Year
N	1248	1248	763
R <sup>2</sup>	95.1%	95.3%	94.9%
<u>Gross Marginal Products</u>			
Computer Capital	86.5%	120%	131%
Non-Computer Capital	8.6%	8.3%	7.2%

\*\*\* -  $p < .001$ , \*\* -  $p < .01$ , \* -  $p < .05$

Heteroskedasticity-consistent standard errors used for OLS

Table 4a: Business Performance Analysis

	<b>Return on Assets (1 Year)</b>	<b>Return on Equity (1 Year)</b>	<b>Total Return (1 Year)</b>
Computer Capital	-.00401 (.00264)	-.00485 (.00706)	-.0287* (.00915)
Size	.00429 (.00270)	.000206 (.00727)	.0290* (.00931)
Dummy Variables	Industry & Year	Industry & Year	Industry & Year
N	1263	1228	1232
R <sup>2</sup>	21.5%	16.7%	24.3%
<u>Perf. Measure</u>			
Mean	6.9%	18.8%	11.3%
Std. Deviation	8.1%	20.6%	28.5%

\* - p&lt;.05

Table 4b. Sign and Significance Levels of Computer Capital Coefficient in Single Year Performance Regressions

	<b>Return on Assets (1 Year)</b>	<b>Return on Equity (1 Year)</b>	<b>Total Return (1 Year)</b>
1988	-*	-	+
1989	+	+	-
1990	-*	-	-*
1991	+	+	-
1992	+	+	-

\* - p&lt;.05

Table 5a. Performance Regressions with Firm-Effects

	<b>Return on Assets (1 Year)</b>	<b>Return on Equity (1 Year)</b>	<b>Total Return (1 Year)</b>
Computer Capital	.00132 (.00314)	.00606 (.0111)	-.0144 (.0172)
Size	.00499 (.0119)	-.0319 (.0431)	-.127 (.0667)
Dummy Variables	Firm & Year	Firm & Year	Firm & Year
N	1199	1161	1150
R <sup>2</sup>	75.8%	58.6%	46.2%

\* - p&lt;.05

Table 5b. Performance Regressions with Extended Firm-Specific Control Variables

	<b>Return on Assets (1 Year)</b>	<b>Return on Equity (1 Year)</b>	<b>Total Return (1 Year)</b>
Computer Capital	-.000488 (.00253)	.00215 (.00687)	-.0121 (.00942)
Size	.00391 (.00262)	.0104 (.00728)	-.0193 (.00998)
Debt/Equity Ratio	-.0181* (.00178)	-.0160* (.00568)	-.0253* (.00727)
Beta	-.00848 (.0066)	-.0395* (.0179)	.0351 (.0251)
Market Share	-.137* (.0372)	-.421* (.102)	-.186 (.144)
Sales Growth	.151* (.0185)	.410* (.0503)	.486* (.0697)
Dummy Variables	Industry & Year	Industry & Year	Industry & Year
N	1133	1114	1100
R <sup>2</sup>	36.8%	28.8%	30.5%

\* - p&lt;.05

Table 6: Consumer Surplus Analysis  
(Constant 1990 dollars)

<b>Year</b>	<b>Computer Capital Stock</b>	<b>Value Added</b>	<b>Computers as a share of Value Added</b>	<b>Price of Computers (1990=1)</b>	<b>Surplus using 1992 Output</b>
1988	\$13.1 Bn	\$677.0 Bn	1.94%	1.43	na
1989	\$15.8 Bn	\$639.0 Bn	2.47%	1.19	\$3.36 Bn
1990	\$25.1 Bn	\$861.9 Bn	2.91%	1.00	\$4.11 Bn
1991	\$34.8 Bn	\$844.2 Bn	4.12%	.83	\$5.37 Bn
1992	\$48.6 Bn	\$848.5 Bn	5.73%	.70	\$7.52 Bn

Increase in surplus calculated under the assumption that the net return to computer spending is zero on the margin.

## References

- Ahituv, N. and R. Giladi, "Business Success and Information Technology: Are They Really Related", *Proceedings of the 7th Annual Conference of Management IS*, Tel Aviv University, 1993.
- Alpar, P. and M. Kim, "A Comparison of Approaches to the Measurement of IT Value", *Proceedings of the Twenty-Second Hawaii International Conference on System Science*, Honolulu, HI, 1990.
- Attewell, P., "Information Technology and the Productivity Paradox", CUNY mimeo (1993).
- Bain, J., *Barriers to New Competition*, Harvard University Press, Cambridge, MA, (1956).
- Bakos, J. Y., "A Strategic Analysis of Electronic Marketplaces", *MIS Quarterly*, 15 (3): (1991).
- Bakos, Y., "Reducing Market Search Costs: Implications for Electronic Marketplaces", University of California, Irvine Working Papers in Information Systems (Revised, January 1993).
- Barua, A., C. Kriebel and T. Mukhopadhyay, "Information Technology and Business Value: An Analytic and Empirical Investigation", University of Texas at Austin Working Paper (May 1991).
- Berndt, E., *The Practice of Econometrics: Classic and Contemporary*, Addison-Wesley, Reading, MA, (1991).
- Bresnahan, T. F., "Measuring the Spillovers from Technical Advance: Mainframe Computers in Financial Services", *The American Economic Review*, 76 ( 4): 742-755, (1986).
- Brooke, G. M., "The Economics of Information Technology: Explaining the Productivity Paradox", MIT Sloan School of Management CISR Working Paper 238, (April 1992).
- Brynjolfsson, E., "The Productivity Paradox of Information Technology", *Communications of the ACM*, 35 (December): 66-77, (1993a).
- Brynjolfsson, E., "Some Estimates of the Contribution of Information Technology to Consumer Welfare", MIT Sloan School of Management Working paper (September 1993b).
- Brynjolfsson, E. and L. Hitt, "Is Information Systems Spending Productive? New Evidence and New Results", *Proceedings of the 14th International Conference on Information Systems*, Orlando, FL, 1993.
- Brynjolfsson, E. and L. Hitt, "Paradox Lost? Firm-level Evidence of the Returns to Information Systems Spending", *Management Science*, (forthcoming): (1994).

- Bureau of Economic Analysis, U. S. D. o. C., *Fixed Reproducible Tangible Wealth in the United States, 1925-85*, U.S. Government Printing Office, Washington, D.C., (1993).
- Capon, N., J. U. Farley and S. Hoenig, "Determinants of Financial Performance, A Meta-Analysis", *Management Science*, 36 (10): 1143-1159, (1990).
- Caves, D. W., L. R. Christensen and W. E. Diewert, "The Economic Theory of Index Numbers and the Measurement of Input, Output and Productivity", *Econometrica*, 50 (6): 1393-14114, (1982).
- Christensen, L. R. and D. W. Jorgenson, "The Measurement of U.S. Real Capital Input, 1929-1967", *Review of Income and Wealth*, 15 (4): 293-320, (1969).
- Clemons, E. and B. Weber, "London's Big Bang: A Case Study of Information Technology , Competitive Impact and Organizational Change", *Journal of Management Information Systems*, 6 (4): 41-60, (1990).
- Clemons, E. K., "Evaluation of Strategic Investments in Information Technology", *Communications of the ACM*, 34 (1): 22-36, (1991).
- Council of Economic Advisors (ed.), *Economic Report of the President*, United States Government Printing Office, Washington, (1992).
- Cron, W. L. and M. G. Sobol, "The Relationship Between Computerization and Performance: A Strategy for Maximizing the Economic Benefits of Computerization", *Journal of Information and Management*, (6): 171-181, (1983).
- Dos Santos, B. L., K. G. Peffers and D. C. Mauer, "The Impact of Information Technology Investment Announcements on the Market Value of the Firm", *Information Systems Research*, 4 (1 ): 1-23, (1993).
- Gordon, R. J., "The Postwar Evolution of Computer Prices", National Bureau of Economic Research, Cambridge, MA Working Paper 2227, (1987).
- Gordon, R. J., *The Measurement of Durable Goods Prices*, University of Chicago Press (for NBER), Chicago, (1993).
- Gurbaxani, V. and H. Mendelson, "An Integrative Model of Information Systems Spending Growth", *Information Systems Research*, 1 (1 ): 23-46, (1990).
- Gurbaxani, V. and H. Mendelson, "The Use of Secondary Analysis in MIS Research", in *The Information Systems Research Challenge: Survey Research Methods*, Harvard Business School Press, Boston, (1991).
- Hall, B. H., "New Evidence on the Impacts of Research and Development", *Micro-BPEA Conference*, Washington, DC, 1993a.
- Hall, B. H., "The Stock Market's Valuation of R&D Investment During the 1980's", *American Economic Review*, 83 (2 (May)): 259-264, (1993b).
- Harris, S. E. and J. L. Katz, "Predicting Organizational Performance Using Information Technology Managerial Control Ratios", In *Proceedings of the Twenty-Second Hawaii International Conference on System Science*, Honolulu, HI, 1989.

- Hausman, J. A., "Specification Tests in Econometrics", *Econometrica*, 46 (November): 1251-1271, (1978).
- Jensen, M. C., "The Modern Industrial Revolution, Exit, and the Failure of Internal Control Systems", *Journal of Finance*, XLVIII (3 ): 831-881, (1993).
- Kemerer, C. F. and G. L. Sosa, "Systems Development Risks in Strategic Information Systems", *Information and Software Technology*, 33 (3 ): 212-223, (1991).
- Lichtenberg, F., "The Output Contributions of Computer Equipment and Personnel: A Firm Level Analysis", Columbia Business School Working Paper (October 1993).
- Loveman, G. W., "An Assessment of the Productivity Impact on Information Technologies", pp. 84-110 in *Information Technology and the Corporation of the 1990s: Research Studies*, Allen, T. J. and M. S. Scott Morton (ed.), MIT Press, Cambridge, MA, (1994).
- Malone, T. W., "Modelling Coordination in Organizations and Markets", *Management Science*, 33 1317-1332, (1987).
- Markus, L. and C. Soh, "Banking on Information Technology: Converting IT Spending into Firm Performance", pp. 375-404 in *Strategic Information Technology Management: Perspectives on Organizational Growth and Competitive Advantage*, Banker, R., R. Kaufmann and M. Mahmood (ed.), Idea Group Publishing, (1993).
- Miller, K. D. and P. Bromily, "Strategic Risk and Corporate Performance: An Analysis of Alternative Risk Measures", *Academy of Management Journal*, 33 (4): 756-777, (1990).
- Morrison, C. J. and E. R. Berndt, "Assessing the Productivity of Information Technology Equipment in the U.S. Manufacturing Industries", National Bureau of Economic Research Working Paper 3582, (January 1990).
- Porter, M., *Competitive Strategy*, Free Press, New York, (1980).
- Quinn, M. A., M. A. Craumer, A. Weaver, R. S. Buday and T. J. Waite, "Critical Issues of Information Systems Management for 1993", CSC Index, Cambridge, MA The Sixth Annual Survey of Information Systems Management Issues (1993).
- Ragowsky, A., S. Neumann and N. Ahituv, "Documenting the Benefit an Organization May Gain by Using Information Systems", Tel Aviv University mimeo (February 1994).
- Salop, S. C. and D. T. Scheffman, "Raising Rivals' Costs", *American Economic Review*, 73 (2): 267-271, (1983).
- Schmalensee, R., "Another Look at Social Valuation of Input Price Changes", *American Economic Review*, 66 (1): 239-243, (1976).
- Steiner, T. D. and D. B. Teixeira, *Technology and Business: Creating Value and Destroying Profits*, Dow Jones Irwin, Homewood, IL, (1991).

- Strassmann, P. A., *Information Payoff, The Transformation of Work in the Electronic Age*, The Free Press, New York, (1985).
- Strassmann, P. A., *The Business Value of Computers*, Information Economics Press, New Canaan, Connecticut, (1990).
- Tully, S., "The Real Key to Creating Wealth", *Fortune*, 30-50, (September 20, 1993).
- Varian, H., *Microeconomic Analysis*, Third edition ed., W. W. Norton & Company, Inc., New York, (1992).
- Weill, P., "The Relationship Between Investment in Information Technology and Firm Performance: A Study of the Valve Manufacturing Sector", *Information Systems Research*, 3 (4 (December)): (1992).
- Wilson, D., "Assessing the Impact of Information Technology on Organizational Performance", in *Strategic Information Technology Management*, Banker, R., R. Kauffman and M. A. Mahmood (ed.), Idea Group, Harrisburg, PA, (1993).