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Examining the Contribution of Information Technology Toward Productivity and Profitability in U.S. Retail Banking

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Examining the Contribution of Information Technology Toward Productivity and Profitability in U.S. Retail Banking [1]

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Abstract: There has been much debate on whether or not the investment in Information Technology (IT) provides improvements in productivity and business efficiency. Several studies both at the industry-level and at the firm-level have contributed differing understandings of this phenomenon. Of late, however, firm-level studies, primarily in the manufacturing sector, have shown that there are significant positive contributions from IT investments toward productivity. This study examines the effect of IT investment on both productivity and profitability in the retail banking sector. Using data collected through a major study of retail banking institutions in the United States, this paper concludes that additional investment in IT capital may have no real benefits and may be more of a strategic necessity to stay even with the competition. However, the results indicate that there are substantially high returns to increase in investment in IT labor, and that retail banks need to shift their emphasis in IT investment from capital to labor.

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Introduction

It has been a matter of much debate whether or not investment in Information Technology (IT) provides improvements in productivity and business efficiency. For several years, scholars and policy makers lacked conclusive evidence that the high levels of spending on IT by businesses improved their productivity, leading to the coining of the term "IT Productivity Paradox". Morrison and Berndt (1990) concluded that additional IT investments contributed negatively to productivity, arguing that "estimated marginal benefits of investment [in IT] are less than the estimated marginal costs". Others, such as Loveman (1994) and Barua *et al.* (1991), posit that there is no conclusive evidence to refute the hypothesis that IT investment in inconsequential to productivity. Of late, researchers working with firm-level data have found significant contributions from IT toward productivity (Lichtenberg 1995, and Brynjolfsson and Hitt 1996, for example). Most of these firm-level studies have been restricted to the manufacturing sector, in large part owing to lack of firm-level data from the service sector.

This paper considers the effects of IT on productivity in the retail-banking industry in the United States. For this study, data on IT spending in the retail banking industry was collected through fieldwork conducted as part of a major study of financial service organizations. Recognizing that issues relating to productivity and profitability pose different questions (Hitt and Brynjolfsson 1996), the contribution of IT toward both productivity and profitability of US retail banking is analyzed herein. This analysis, which is carried out with two measures of productivity and two for profitability, indicates that increased investment in IT capital may have no real benefits and may be more of a strategic necessity to stay even with the competition. The results, however, indicate that there are substantial returns to additional investment in IT labor.

1. Previous Research on IT and Productivity

Several studies over the years have been conducted at both the industry and firm-level to examine the impact of IT on productivity. Brynjolfsson (1993) and Wilson (1993) provide reviews of this literature on the business value of IT. Some studies have drawn on statistical correlation between IT spending and performance measures such as profitability or stock value for their analyses (Dos Santos *et al*. 1993, Strassman 1990), and have concluded that there is insignificant correlation between IT spending and profitability measures, implying thereby that IT spending is unproductive. Brynjolfsson and Hitt (1996), however, caution that these findings do not account for the economic theory of equilibrium which implies that increased IT spending does not imply increased profitability.

In this paper, attention is restricted to research that has drawn upon the economic theory of production. Such studies use a technology or production function which relates the output of a firm to its inputs. It is this line of research that has contributed significantly to the establishment of the "IT Paradox" with the industry-level studies of the mid- and late 1980s; this "paradox" indicated a negative correlation between IT investments and productivity.

More recent firm-level studies, however, paint a more positive picture of IT contributions to productivity. These findings raise several questions about mis-measurement of output by not accounting for improved variety and quality, and about whether IT benefits are seen at the firm-level or at the industry-level. Such issues have been discussed in Brynjolfsson (1993), and to a lesser extent in Brynjolfsson and Hitt (1996). One illustration of the industry-level studies is that of Morrison and Berndt (1991), which found that in the manufacturing industry, "estimated marginal benefits of investment in [IT] are less than marginal costs, implying over investment". More specifically, they determined that for each additional dollar spent on IT, the marginal increase in measured output was only 80 cents.

Of late, the increased availability of firm-level data has led to several other studies which report results different from those found in industry-level studies. Loveman (1994), for example, using data from the Management Productivity and Information Technology (MPIT) Database in a Cobb-Douglas production function framework, concludes that for the manufacturing firms included in his study, there is no significant contribution to output from IT expenditure. Lichtenberg (1995), on the other hand, concludes that there is significant benefit from investment in IT. For his analysis, he draws data from annual surveys conducted between 1988 and 1991 by *Information Week* and *ComputerWorld* magazines. Using a Cobb-Douglas production function, he estimates that there are "substantial excess returns to investment in computer capital" and further, that one Information Systems (IS) employee is equivalent to six non-IS employees in terms of marginal productivity.

The latest in this trend of research is Brynjolfsson and Hitt (1996) and Hitt and Brynjolfsson (1996). Brynjolfsson and Hitt (1996) use data from two sources: the dataset compiled by the International Data Group (IDG), and Standard and Poor's Compustat II database. The IDG data includes self-reported firm-level details of IT expenditure collected annually, while the Compustat database provides various measures of output and non-IT expenses. Using this data in a Cobb-Douglas production function, Brynjolfsson and Hitt conclude that "computers contribute significantly to firm-level output." In fact, they find that computer capital contributes an 81% marginal increase in output, whereas non-IT capital contributes 6%. Similarly, they show that IS-labor is more than twice as productive as non-IS labor.

Most of such studies relating to the contribution of IT toward firm-level productivity have been restricted to the manufacturing industry, possibly owing both to a lack of data at the firm-level in the service industry and perhaps, more significantly, the difficulty of unambiguously identifying the "output" of a service industry. The latter problem is particularly persistent in the banking industry, which is the focus of this study. This problem is discussed more fully in Section 4. As Parsons, Gotlieb, and Denny (1993) argue in the banking industry, "the growth of output, and the measurement of productivity, is very sensitive to the choice of output." Parsons, Gotlieb, and Denny (1993), in fact, is one of the very few studies that deal with the impact of IT on banking productivity per se. They conclude from their estimation of data from five Canadian banks using a translog production function that, while there is a 17-23% increase in productivity with the use of computers, the returns are very modest compared to the levels of investment in IT.

2. The Production Function Model

The production function framework has been the most widely used methodology in the study of returns to IT investment (Parsons *et al.* 1993, Loveman 1994, Lichtenberg 1995, Brynjolfsson and Hitt 1996). In the absence of measures of actual benefits associated with IT, it is not possible to perform cost-benefit analyses of IT investment and thus, production functions which relate IT spending to overall productivity or output measures are seen as the best alternative (Parsons *et al.* 1993). Production function techniques have been shown to be valid and quite successful through hundreds of empirical studies (for example, see Berndt 1991).

The choice of the form of the production function is constrained by economic theory which requires that conditions such as monotonicity and quasi-concavity be satisfied. One of the simplest production functions that satisfies such conditions and has been used for about a hundred years is the Cobb-Douglas function (Berndt 1991). Most of the studies on IT-based productivity have used this model (Loveman 1994, Lichtenberg 1995, Brynjolfsson and Hitt

1996, for example), and our study also models banks as operating according to the Cobb-Douglas production function.

Previous studies have further separated the IT-components of capital and labor expenses from the non-IT components, and used all four parameters as inputs in the Cobb-Douglas function to make relative comparisons about contributions to output, and the resulting marginal products. Thus, according to this methodology, the Cobb-Douglas function becomes (as in Brynjolfsson and Hitt 1996):

$$Q = e^{b_0} C^{b_1} K^{b_2} S^{b_3} L^{b_4} \quad (1)$$

where Q = output of the firm

C = IT Capital

K= Non-IT Capital

S = IS Labor Expenses

L = Non-IS Labor Expenses

and β_1, β_2, β_3, and β_4 are the associated output elasticities.

While production functions have been employed by several studies in the past, it is important to remember that different issues may be addressed with production function approaches. Thus, while Brynjolfsson and Hitt (1996) or Lichtenberg (1995) address the impact of IT on productivity, Barua *et al.* (1991) are concerned with its impact on profitability. These contribute to hypotheses that may be related but are *distinctly* different. Thus, following Hitt and Brynjolfsson (1996), the hypotheses for a productivity-oriented study are:

H1a: ***IT investment makes positive contribution to output (i.e., the gross marginal product is positive)***

H1b: ***IT investment makes positive contribution to output after deductions for***

depreciation and labor expenses (i.e., the net marginal product is positive)

Moving from the productivity perspective, where the focus is on IT as an enabler of internal efficiency, profitability studies attempt to understand whether the deployment of IT provides any competitive advantage for the firm. Therefore, profitability-oriented studies are concerned with the question of whether IT investments have contributed to firm profits or stock market value.

Several researchers in competitive strategy have pointed out that the competitive environment in which the firm operates has significant effects on the returns from IT investment. Porter (1980), for example, posits that in a free entry competitive market, firms cannot gain sustainable competitive advantages from technologies that are available to every firm. It is only when a technology creates significant barriers to entry that it becomes profitable to invest in it. From this point of view, information technology, freely available to all firms as it is, does not provide any sustainable competitive advantage to the firm and, in such an environment, IT investment becomes more of a "strategic necessity" rather than a provider of competitive advantage (Clemons 1991). Thus, the firm's investment in IT should not be associated with supra normal profits. This leads to the profitability-oriented hypothesis suggested by Hitt and Brynjolfsson (1996):

H2: ***IT investment makes zero contribution to profits or stock market value of the firm.***

3. Methodology and Data Sources

This section discusses the methodology adopted in our analysis of productivity returns of IT investments along with the sources for the three-year data set used herein.

3.1 Methodology

We employ the Cobb-Douglas production function as discussed earlier, but for estimation purposes, we linearize it by taking logarithms of equation (1) and adding an error term. Further, following Brynjolfsson and Hitt (1996), we perform the estimation using a system of three equations, one for each year:

$$Log(Q_{93}) = b_{93} + b_1 Log(C_{93}) + b_2 Log(K_{93}) + b_3 Log(S_{93}) + b_4 Log(L_{93}) + e_{93} \quad (2a)$$

$$Log(Q_{94}) = b_{94} + b_1 Log(C_{94}) + b_2 Log(K_{94}) + b_3 Log(S_{94}) + b_4 Log(L_{94}) + e_{94} \quad (2b)$$

$$Log(Q_{95}) = b_{95} + b_1 Log(C_{95}) + b_2 Log(K_{95}) + b_3 Log(S_{95}) + b_4 Log(L_{95}) + e_{95} \quad (2c)$$

where Q, C, K and L and β_1-β_4 are defined in (1) and ε_{93} - ε_{95} are the error terms.

In terms of the coefficients we derive from our estimation of the sets of equations (2a-2c), our hypotheses now become:

H1a: ***$b_1 > 0$; $b_3 > 0$ versus the null hypothesis that $b_1 = b_3 = 0$***

i.e. the marginal products of IT capital and IT labor are positive, implying that investment in IT improves productivity.

H1b: ***b_1*(Output/IT Capital) - Cost of IT Capital > 0;***

b_3*(Output/IT Labor) - Cost of IT Labor > 0.

H1b allows us to verify that IT investment is not just positive, but that it pays more than what we spend on it. This is a stronger test than H1a, which only tests for the gross benefits, since we are estimating whether there are any positive net benefits (i.e. benefits after we have subtracted the costs from the gross benefits) associated with IT.

Finally, we can also test the following hypothesis:

H1c: b_1 **- *(IT Capital Expenses / Non-IT Capital Expenses)** $b_2 > 0$; and***

b_3 **- *(IT Labor Expenses / Non-IT Labor Expenses)** $b_4 > 0$.***

This hypothesis states that the ratio of the marginal product to the investment in IT capital and labor is higher than it is for the corresponding non-IT investments; this is a much stronger hypothesis than H1a. Not only does it imply that there are positive returns to investment in IT capital and labor but also, that the returns are higher than those from non-IT capital and labor.

3.2 Data Sources

The data for this study is obtained from an ongoing four-year project at the Financial Institutions Center at the Wharton School, which has been studying efficiency drivers in the retail banking industry in the United States. This project collected extensive data relating to operations management, human resource management, and corporate strategy, which are deemed proprietary by the firms, from nearly 115 retail banks in the United States. Of these, IT spending data is available for the years 1993-95 for about 47 banks, each of which has assets exceeding $6 billion (these banks constitute the larger banks in our dataset); Appendix A provides details of the Wharton Financial Institutions Survey. The availability of this exclusive data allows us to divide IT-related and non-IT related expenses in these banking institutions with a fair amount of confidence. Further, we have corroborated non-IT expenditure data with public sources of information such as the annual financial statements of banks provided both in annual reports and in the Federal Deposits Insurance Corporation (FDIC) database.

3.3 Data Problems

As is well known, the U.S. banking industry has been undergoing major structural changes with frequent mergers and acquisitions and, consequently, banks are not able to report extensive historical expenditure data. Therefore, our data has been restricted to three years but, possibly owing to structural changes again, many banks have not been able to provide IT-expenditure for all three years. This has caused our dataset to be quite small in comparison to studies such as Brynjolfsson and Hitt (1996).[1] However, as Brynjolfsson and Hitt (1996) note, if we assume that the error terms in each year are independent and identically distributed, and coefficients are constrained to be equal across years, estimating this set of equations is equivalent to pooling the data and estimating the parameters by ordinary least-squares (OLS). While we adopt this method, we use a 2-step weighted least squares estimation to overcome effects of heteroskedacity. As the detailed estimation results in Appendix B show, the tests with fixed and random effects indicate that the 2-step OLS with common intercept that is used herein provides robust results with little correlation effects.

4. Output of Banks for a Production Function Analysis

Studies of productivity in the banking industry struggle with the issue of what constitutes the “output” of a bank. The various approaches researchers have chosen to evaluate the output of banks may be classified into three broad categories: the assets approach, the user-cost approach, and the value-added approach (Berger and Humphrey 1992). The assets approach considers banks as “financial intermediaries” between depositors (or those who provide money to the bank) and borrowers (or those who receive money from the bank). Thus, loans and other assets become bank outputs, and deposits and other liabilities which provide the finance that permits banks to “sell” finance become bank inputs. The assets approach of determining a bank’s outputs is exemplified, for example, by Mester (1987), who argues that “output is best measured by the

[2] The smallness of the dataset has consequences for the type of analysis we can carry out. In particular, owing to lack of sufficient degrees of freedom, we cannot employ statistical methods such as Seemingly Unrelated Regression (SUR) in estimating the system of equations (2a) - (2c).

dollar value of earning assets of the firm, with inputs being labor, capital, and deposits." However, a criticism that emerges against the assets approach is that such an approach groups inputs and outputs arbitrarily, with choices of what constitutes a bank's outputs by one set of researchers becoming open to debate and questioning by others. A more significant problem with such an approach is that it is reductionist in its view of a bank's function, and fails to recognize the services a bank provides to depositors in return for the finance they provide to it (Triplett 1992).

The user cost approach studies the net contribution of each of the financial products to the bank's revenue. Depending on whether the product adds or detracts from the revenues of the firm, it becomes an output or an input. If an asset's financial returns are more than its opportunity costs, it becomes an output, as does a liability whose financial costs are less than its opportunity cost. Those assets and liabilities that do not satisfy the conditions to become outputs, become inputs. Hancock (1991), for example, employed the user-cost approach to determine that loans categorically are bank's outputs, whereas deposits present an ambiguous picture: time deposits are inputs, but demand deposits are outputs. As Berger and Humphrey (1992) discuss, there are several problems with user-cost methods of determining bank outputs. Most significant of these problems is that it is difficult, if not virtually impossible, to measure and unambiguously apportion financial returns and opportunity costs among the various financial products of a bank.

The value-added approach (or the activity approach as it is sometimes called) studies all assets and liabilities as having some output characteristics without grouping them into exclusive input or output categories. Benston, Hanweck and Humphrey (1982) posit that "output should be measured in terms of what banks do that cause operating expenses to be incurred." Following this line of thought, Berger and Humphrey (1992) argue that the value-added for each financial measure of the bank should be determined on the basis of operating costs, and those that have "significant" value-added should be considered the outputs of the bank.

A final measure that is often considered representative of a bank's output, and one that is particularly relevant to our study in view of the comparison we draw to other studies such as Brynjolfsson and Hitt (1996) or Lichtenberg (1995) [2], is the total revenues of a bank. The Compustat database that Brynjolfsson and Hitt (1996) employ in their study of the impact of Information Technology defines revenues to be the output of the few banks it includes. However, econometric studies of the banking industry have been loathe to use revenues as an output measure. This unease is illustrated in Berger and Humphrey (1992) who argue that revenues are often both inputs and outputs. To illustrate, interest and fees derived from loans can be considered to be outputs but often, business borrowers are required to hold idle deposits as a condition of the loan, and these idle deposits give rise to "implicit revenues". Berger and Humphrey demonstrate that the situation with deposits is worse, with implicit revenues contributing as much as 80% of the total deposit revenues in 1988. This leads to their conclusion: "... in banking, unlike other industries, explicit revenues are an unreliable guide to determining outputs or service flows."

5. Results

In this study, we tested the three hypotheses mentioned in Section 2 using two measures of output for productivity and two for profitability. For the productivity analysis, we first use the sum of Total Loans and Total Deposits for each year as representative of output. Then, we repeat the analysis with Net Income of the bank (Revenues) as the output measure. The main results

[3] We thank Erik Brynjolfsson and Lorin Hitt for pointing this out.

obtained through a weighted 2-step least squares estimation of the system of equations (2a) - (2c) are reported in Tables 2 and 3.

5.1 Productivity Contributions of IT

As can be seen from the summary statistics in Table 1, the banks in our sample have an average of $34.5 billion in terms of loans and deposits and $596 million in terms of revenues generated. Table 1 also shows the average investment in IT and non-IT capital and labor.

Table 1. Summary Statistics

Output Measures (Dependent Variables)			
Avg. (Loans + Deposits)	Avg. Revenues	Avg. ROA	Avg. ROE
$34.5 Billion	$596 M	1.214%	15.55%

Inputs (Independent Variables)			
Avg. IT Capital	Avg. IT Labor	Avg. Non-IT Capital	Avg. Non-IT Labor
$15.6 M	$19.92 M	$147.6 M	$508.7 M

Table 2. Output = (Total Loans + Total Deposits)

Parameter	Coefficient	Std. Error	t-statistic	t-statistic: Significance	Ratio to Output	Marginal Product
IT Capital	0.00116	0.013	0.089	7%	0.000452	2.56
IT Labor	0.25989	0.031	8.34	100%	0.0006	449.75
Non IT Capital	-0.02071	0.026	-0.79	57%	0.00428	-4.84
Non IT Labor	0.53244	0. 059	8.95	100%	0.01475	36.10

R^2 = 41% (OLS); 99% (2-Step WLS)[3]

Test of Hypothesis When Output = Total Loans and Deposits

H1a: We see that the elasticities (the coefficients) associated with IT capital and labor are positive. However, the low significance associated with the IT capital coefficient implies that there is a high probability (0.93) that the elasticity of IT capital is zero. Thus, we are not able to establish evidence to support Hypothesis H1a for IT capital (i.e., that IT capital produces positive returns in productivity). It is interesting to note that the elasticity of non-IT capital is definitely negative, implying that IT capital investment is relatively better than investment in non-IT capital. However, the results show that we cannot reject H1a for IT labor, and since the marginal product of IT labor is $449.75, we can safely conclude that IT labor is associated with a high increase in the output of the bank.

[4] Results reported in this paper are obtained with 2-Step Weighted Least Squares (2SWLS).

H1b and H1c: Since we cannot verify H1a for IT capital, we will restrict our discussion of the stronger hypotheses, H1b, to the IT labor results. First, we see that the marginal product for IT labor is very high. Since IT labor is a flow variable, it means that every dollar of IT labor costs a dollar. In view of this, the excess returns from IT labor can be computed to be $(449.75 - 1), or $448.75. Thus, H1b cannot be rejected for IT labor.

For H1c, we see, using the figures from Table 1 for non-IT labor expenses and the coefficients from Table 2, that

$$\beta_3 - \text{(IT Labor Expenses / Non-IT Labor Expenses)} * \beta_4 = .2390 > 0.$$

Thus, we can verify H1c for IT labor.

As far as H1c is concerned for capital expenses, we see that the marginal product of non-IT capital is negative. Further, given the standard errors of the estimation, we can assert that IT capital is more likely to yield either slightly positive or no benefits, whereas non-IT capital will most probably have a negative effect, decreasing productivity. More formally, we have

$$\beta_1 - \text{(IT Capital Expenses / Non-IT Capital Expenses)} * \beta_2 = .00334 > 0.$$

Given the significance associated with the IT capital estimate however, we cannot definitely fail to reject H1c.

Next, consider the results when net income is used as the output; see Table 3 for these results.

Table 3. Output = Net Income of Bank

Parameter	Coefficient	Std. Error	t-statistic	t-statistic: Significance	Ratio to Output	Marginal Product
IT Capital	-0.053	0.056	-0.936	65%	0.02614	-2.009
IT Labor	0.192	0.0477	4.024	100%	0.03341	5.74
Non IT Capital	-0.09	0.038	-2.377	98%	0.24744	-0.37
Non IT Labor	0.467	0.061	7.655	100%	0.85280	0.548

R^2 = 37% (OLS); 99% (2-Step WLS)

Test of Hypothesis When Output = Net Income

H1a: We see that the elasticities (the coefficients) associated with both types of capital expenses are negative, while those associated with the labor variables are positive. This is perhaps reflective of the banking industry where the emphasis on service delivery implies that labor is a more worthwhile investment than capital. Given that the results imply negative productivity with investment in IT capital, we are forced to reject H1a, and conclude that IT capital investment impacts negatively on productivity. H1a, again, cannot be rejected for IT labor since the marginal product of IT labor exceeds $5. Thus, IT labor, when analyzed with Net Income of the bank as the output measure, is associated with increase in the output of the bank.

H1b and H1c: The rejection of hypothesis H1a for IT capital means that we can reject the stronger hypothesis H2a for IT capital (there can be no "excess benefits" given that there are no benefits with IT capital investment). For IT labor, we see that the marginal product is $5.74; i.e. with every dollar invested in IT labor, we see an increase in the output (net income) of $5.74. Again, since IT labor is a flow variable, every dollar of IT labor costs a dollar. The excess returns from IT labor, therefore, can be computed to be $(5.74 - 1), or $4.74. Thus, H1b cannot be rejected for IT labor.

For H1c, from the figures from Table 1 for IT labor and non-IT labor expenses and the coefficients from Table 3, we have

$$\beta_3 - (\text{IT Labor Expenses / Non-IT Labor Expenses})^* \beta_4 = .0563 > 0.$$

Thus, we cannot reject H1c for IT labor.

As far as H1c is concerned for capital expenses, we see that the marginal product of both IT- and non-IT capital is negative. H1c then becomes a test of the question of whether the negative influence of investing in IT capital is less than that of investing in non-IT capital. Using the figures from Table 3, we have

$$\beta_1 - (\text{IT Capital Expenses / Non-IT Capital Expenses})^* \beta_2 = -0.043 < 0.$$

Therefore, we therefore reject H1c for IT capital.

Issue of Multicollinearity

In the estimation of a Cobb-Douglas production function, it is usual to expect relatively high correlation between the independent variables. In our case, there is the likelihood of high correlation between IT capital and IT labor investments. As Kennedy (1985) notes, “The existence of multicollinearity in a data set does not necessarily mean that the coefficient estimates in which the researcher is interested have unacceptably high variances. The classic example of this is estimation of the Cobb-Douglas production function: the inputs capital and labor are highly collinear, but none the less, good estimates are obtained.” The t-statistics we obtain for IT capital imply that IT capital is not a significant variable in the regression, with its estimated coefficient tending to zero. That this result is not due to collinearity problems, but a result of the estimation, is borne out by the low correlation between IT capital and IT labor investments over the three year period of our data shown in Table 4.

Table 4. Correlation between IT Capital Investment and IT Labor Expenditure

Year	Correlation Coefficient
1993	-0.02364
1994	0.38788
1995	0.214364

5.2 Profitability Contributions of IT

In this analysis, we employ two measures that banks commonly use as indicators of profitability: Return on Assets (ROA) and Return on Equity (ROE). To use the definition provided in the annual reports of several banks, ROA is "net income as a percentage of total assets...indicating how well the bank has used its assets", while ROE is "net income as a percentage of total shareholders' equity...measuring how well a bank's equity has been employed." The key findings from the estimation are reported in Tables 5 and 6.

Table 5. Output = Return on Assets

Parameter	Coefficient	Std. Error	t-statistic	t-stat: Significance	Contribution	Marginal Product
IT Capital	-0.014	0.015	-0.953	64%	0.022	-0.656
IT Labor	0.003	0.017	0.184	15%	0.028	0.113
Non IT Capital	-0.024	0.007	-3.26	99%	0.204	-0.117
Non IT Labor	-0.082	0.013	-6.19	99%	0.702	-0.117

R^2 = 15.4% (OLS); 98% (2-Step WLS)

Table 6. Output = Return on Equity

Parameter	Coefficient	Std. Error	t-statistic	t-stat: Significance	Contribution	Marginal Product
IT Capital	-0.01	0.017	-0.623	46.40%	-0.40	-23.48
IT Labor	-0.027	0.031	-0.877	62%	-0.82	-47.43
Non IT Capital	-0.026	0.012	-2.286	97%	-0.11	-6.15
Non IT Labor	0.002	0.016	0.112	9%	0.002	0.12

R^2 = 34% (OLS); 98% (2-Step WLS)

We see that the t-statistics from the analysis of the profitability measures are very low. The easy availability of IT to all banks implies that IT investments do not provide any competitive advantage. In other words, since there is no “barrier to entry” in terms of IT in the retail banking industry, a bank investing in IT does not stand to gain additional market share as a result of its investment. In fact, by not investing in IT and by foregoing the gains provided by it, a firm may, on the other hand, lose market share (Clemons 1991). Thus, in this competitive environment of retail banking, neither IT capital nor IT labor investments should make significant impacts on the firm’s profitability. The results bear this hypothesis out: IT investment has zero or insignificant effect on bank profitability.

6. Discussion of Econometric Results

To sum up the results of our econometric analysis, we see that IT capital makes zero, and even perhaps slightly negative, contribution to output both when Total Loans + Deposits is considered as the measure of output (following the value-added approach discussed in Section 4), and when Net Income of the bank (or Revenues) is the output measure (as per previous studies such as Brynjolfsson and Hitt 1996). This result is significantly different from previous studies in the manufacturing sector (Lichtenberg 1995, Brynjolfsson and Hitt 1996), and seems to be more in conformity with those obtained in Parsons *et al.* (1993), the only formal study on IT in banking to date. While Parsons *et al.* report slightly positive contribution to IT investment, we see zero or slightly negative contributions. Moreover, it is interesting to note that when Net Income is the output measure (if, for a moment, we ignore the significance levels of the coefficients), the marginal product of IT Capital is much more negative than non-IT capital. Thus, IT has a much more significant *negative* impact on output than non-IT capital investment.

IT labor presents a very different picture. Both with Total Loans and Deposits and with Net Income as output measures, we see that IT labor contributes significantly to output. Its marginal product is at least 10 times as much as that of Non-IT labor in both cases. Rather than make the simplistic conclusion from this that a single IS person is equivalent to 10 non-IS persons, it is better perhaps to speculate that this may simply reflect the fact that there is significant difference between the types of personnel involved in IS and non-IS functions. It is more interesting to compare the marginal product of IT Capital versus IT Labor. It is striking that while IT labor contributes significantly to productivity increases, IT capital does not. Thus, these results state that while the banks in our study may have over-invested in IT capital, there is significant benefit in hiring and retaining IT labor.

These results are very reflective of the stories we heard during fieldwork, and the fact that today's high demand for IS personnel is unprecedented in U.S. labor history. Figures from the Bureau of Labor Statistics show that while the overall job growth in the U.S. economy was 1.6% between 1987 and 1994, software employment grew in these years at 9.6% every year, and "cranked up to 11.5% in 1995"; the prediction is that over the next decade, we will see further growth in software jobs at 6.4% every year (Rebello 1996). During our fieldwork, a Senior Vice President at a major New York bank lamented the fact that "The skills mix of the IT staff doesn't match the current strategy of the bank," and he said he "didn't know what to do about it." At the same bank, the Vice President in charge of IT claimed, "Our current IT training isn't working. We never spend anywhere near our training budget." IT labor is very short supply, and issues as basic as re-skilling the workforce cannot be addressed given the lack of sufficient IT labor in banking.

Other researchers have observed this dependence and under-investment in human capital in technologically-intensive environments. To quote Gunn's (1987) work in manufacturing, "Time and again, the major impediment to [technological] implementation ... is people: their lack of knowledge, their resistance to change, or simply their lack of ability to quickly absorb the vast multitude of new technologies, philosophies, ideas, and practices, that have come about in manufacturing over the last five to ten years". Another observation about the transitions firms need to make to gain from technology, again in the manufacturing context, comes from Reich (1984): "... the transition also requires a massive change in the skills of American labor, requiring investments in human capital beyond the capital of any individual firm."

Finally, it is interesting to compare the ratio of investment in labor versus capital for both IT and non-IT brackets: From Table 1, it can be seen that the IT Labor to Capital ratio is 1.28, whereas the labor to capital ratio for the non-IT bracket is 3.45. This is all the more surprising given that the prices of computers are so much lower than the costs of real-estate and other non-IT capital and, furthermore, given that, as several researchers have noted (Krueger 1991, for instance), IT labor is far more expensive than non-IT labor. This implies that banks are greatly underinvested in IT labor in comparison to non-IT labor. While we realize that the Cobb-Douglas specification does not allow us to make categorical statements about substitutability between IT capital and labor, an interesting issue emerges from this analysis. Loveman (1994) summarizes research on IT labor productivity, and points out that Baily and Chakravarthy (1988) and Osterman (1986) concluded that "... as IT Capital prices fall, production becomes increasingly information-worker intensive." Our results seem to confirm this: banks have over-invested in IT capital, and investment in IT labor has become necessary. Further, IT labor is the most profitable of all four types of investment--IT and non-IT capital and labor available to the bank.

7. Is Increased IT Labor the Answer? The Story of Three Banks

The previous results clearly show the importance of IT labor in a bank's ability to improve efficiency. However, how would a bank increase its IT labor capability? One method, of course, is to hire more IT-focused employees. However, this is not the only method available to management. In this section, we explore the characteristics of high- and low-performance banks, focusing specifically on their management practices in IT in order to answer this question.

The first place to look for an answer is in the strategic decisions banks are making with respect to IT. Through the Wharton survey, we collected data for 1993-95 on each bank's technology expenditures, broken out by category, including the ratio of maintenance and development costs (i.e., how much the bank is spending on maintaining existing/ legacy systems versus development of new IT systems). A simple correlation between the maintenance-development ratio and the performance of the firm as measured by the residuals generated from the estimation of the Cobb-Douglas production function (obtained using Total loans + Total deposits / value-added as output) gives us the following result:[4]

	Maintenance %	Development %
Residual	0.204	-0.204

Thus, firms that are doing more maintenance than development perform better than those that do more development than maintenance. This raises very interesting questions: Are those firms which are doing more maintenance farther along the learning curve and hence, are better able to benefit from IT use? Do these firms perform better because they focus more on aligning existing systems to their business processes rather than on bringing in newer systems?

Another interesting factor in terms of aligning IT with business processes is that of outsourcing. We have data on how much maintenance work is outsourced on average by the bank, and on how much development work is outsourced. Using these data and the dollar figures obtained above for the maintenance and development budgets, we ran a correlation against the same residuals:

	Overall In-House IT Expenses
Residual	0.18

If we consider the total dollars spent on in-house IT, we see that overall, it is better to do things in-house rather than outsource. More specifically, if we look at the actual dollars spent on in-house maintenance versus outsourced maintenance, we observe that while in-house maintenance

[4] One note about the low values of correlations. As we have seen, the regressions explain only 42% percent of the output and thus, apart from the four inputs in our estimation equations, there are several factors that affect firm performance. Given this, the values of the correlations with residuals (20-30%) become significant enough for us to make general statements about firm practices and performance as assessed through the residual value.

has a positive correlation of about 27% with firm performance, outsourcing of maintenance is negatively correlated, although slightly (9 %), with firm performance:

	$ Maintenance In-House	$ Maintenance Outsourced
Residual	0.27	-0.09

The case is similar with development budgets. The more the in-house development, the better the performance of the firm, and the more the outsourcing, the worse the performance. The correlation values follow the same lines as the correlation with maintenance-budgets, but the values are slightly lower. Taken together with the result about the correlation between maintenance-development ratio and firm performance, this raises the question of whether maintenance of IT systems becomes more important than development of new systems in terms of affecting the performance of the banks.

	$ Development In-House	$ Development Outsourced
Residual	0.192	-0.075

The simple correlation analyses described above are very consistent with the econometric results described earlier in terms of the importance of IT labor. In most banks, the IT labor force is much more than a group of programmers. Through their systems analysis and development practices, the IT workers act as the “Industrial Engineers” of the banks, knowing how work is accomplished, and how customers are served from one end of the organization to the other. For example, in our survey of banks, approximately 75% of the institutions could not explain how very simple operations were accomplished from beginning to end (Frei and Harker 1997). In the 25% or so that did know, is was typically an IT employee that could describe, for example, how a checking account was opened from initial customer inquiry until the checks and ATM card were in the customer's hands. Thus, this labor force is the repository of process knowledge in the institutions. By outsourcing and other management practices that reduce the effective IT labor force, this process knowledge is removed from the organization.

However, none of this analysis proves definitely that IT labor management and investment is the key link in the IT-productivity puzzle. In order to gain further insight into this issue, let us consider three banks in detail that are a part of our study. These three banks are representative of our sample and will serve as useful cases of IT management practices.

Consider the cases of three banks drawn from our sample. According to the regression results in Section 5, Bank L had a low productivity-IT figure, whereas Bank M had moderate productivity gains from IT investments, and finally, Bank H had high productivity-IT figure[5]. Their summary statistics are reported in Table 7.

Table 7. Bank Data for L, M and H Banks

	Bank L	**Bank M**	**Bank H**
Avg. Assets	\$8.8Bn	\$15.5Bn	\$19.8Bn
Avg. Total Loans	\$6.1Bn	\$9.65Bn	\$12.8Bn
Avg. Total Deposits	\$6.8Bn	\$12.6Bn	\$14.3Bn
Avg. Net Income	\$103.2M	\$1.3Bn	\$178M
Avg. ROA	1.28%	0.88%	0.85%
Avg. ROE	15.63%	12.36%	11.54%

As the figures in Table 7 show, Bank M is about twice as large as Bank L, and about three-fourths the size of Bank H. The average ROA and ROE figures, interestingly, are inversely proportional to the sizes of the banks. The expenses shown in Table 8 are in keeping with the

[5] While Bank H performed better than Bank M in terms of IT-Productivity figures, the performance was not significantly higher than Bank M. Thus, in the context of the comparisons made in this section, Banks M and H tend to be closer together, whereas the disparity between these two banks and Bank L is more striking.

earlier discussion of regression results. Bank L, which invests 5.56% of its NIE expenditure on IT capital, is the worst of the three, while Bank M, with 0.3% of NIE spending on IT capital, is second; finally, Bank H, which spends the least (0.28% of NIE) on IT capital, has highest IT-productivity. The case of Non-IT capital is similar, with L, M and H spending 26.78%, 3.25%, and 1.51% of NIE, respectively, on non-IT capital. With labor spending, however, the results are somewhat more intriguing. While as a percentage of NIE expenses, Bank L seems to be spending more than Banks M and H in terms of ratios between IT and Non-IT labor expenses, they are all more or less the same: 0.0751, 0.073, 0.0744 for L, M, and H, respectively.

The fraction of IT employees out of the total number of employees is highest for Bank L, as shown in Table 9. However, in Bank L, the average salary of IT personnel is lower than the average salary of non-IT personnel. In Bank M, the ratio of average IT salary to average non-IT salary is much higher than in Bank H. This raises the question as to whether there is a significant ratio above which returns from IT-personnel start decreasing. What is the effect of disparate pay structures on the general productivity of the firm? Is Bank H doing better because it provides roughly the same average salary to its IT and non-IT personnel?

Table 8. Non-Interest Expenses and Technology Spending

	Bank L	Bank M	Bank H
Avg. Non-Interest Expenses	$295M	$5.3Bn	$6.4Bn
Avg. Technology Budget	$28M	$36.5M	$42M
Avg. IT Capital (% of NIE)	$16.4M (5.56 %)	$15.5M (0.3 %)	$17.6M (0.28 %)
Avg. Non-IT Capital (% of NIE)	$79M (26.78 %)	$172M (3.25 %)	$95M (1.51 %)
Avg. Non-IT Salaries and Benefits (% of NIE)	$136M 46.1%	$240M 4.52%	$285M 4.84 %
Avg IT Salaries and Benefits (% of NIE)	$10.2M (3.46 %)	$17.6M (0.33 %)	$23.2M (0.36 %)

Table 9. Salaries and Benefits

	L	M	H
No. of full-time equivalent employees (#FTEs)	4700	6225	6540
#FTEs in IT (% of Total FTEs)	405 (8.6%)	330 (5.3%)	500 (7.65%)
Average salary of IT personnel	$25,185	$53,300	$46,400
Average salary of Non- IT personnel	$31,664	$40,172	$47,209

Apart from the actual investment issues, there are significant differences in the way the three banks make decisions about technology investments. Table 10 reports the details of the decision making process for IT investments. All three banks seem to place more value in a committee that approves technology investment decisions versus the policy of ad-hoc allocation of technology budgets that is prevalent in some of the firms that participated in the Wharton survey. However, the significant point that emerges is that the *constitution* of the committee is just as important. In Bank L, one person of the 11-member committee was an IT-person, whereas Bank M had two people of nine from IT, and Bank H, the high performer, had four IT people on the committee of 11 persons. Thus, is it the case that a better mixture of IT and business personnel in the IT investment decision-making helps the bank do better? Further, it does not matter so much who chairs the committee as much as who makes the final investment decision. In Bank L, the Chair has the final call, and the Chair comprises the CEO and the Executive VP, neither of whom is an IT person. Banks M and H, on the other hand, seek a majority decision and, with the larger size of the IT group, this makes the participation in decision-making more even-handed in terms of the mix between business people and IT-related personnel.

Table 10. Committee to Approve Technology Investment Decisions?

	L	**M**	**H**
Committee?	Yes	Yes	Yes
Chair	CEO and Exec VP	Sr. VP Systems	CEO
Constitution	1 IT person in 11 on Committee	2 IT persons from 9	4 IT persons from 11
Meeting Frequency	Bimonthly	Quarterly	Quarterly
Decision Making	Chair Decides	Majority Decision	Majority Decision

Another interesting question concerns the issue of outsourcing. Consistent with the prior correlation analysis, the firm that does better outsources less (Table 11). Further, it is significant that there is a difference between whether maintenance is outsourced or development is outsourced. When more development is outsourced, the banks seem to perform worse. One possible explanation for this result is thatwith outsourced development, the business process is not properly incorporated into the IT system and so, Banks M and H that outsource less development work do better with IT. On the other hand, it seems to be more beneficial to outsource some of the maintenance work; this is particularly the case when, after many years of use, the IT system has become more stabilized. Bank M and H outsource 30% and 20 % of maintenance work, respectively. Bank L differs significantly and outsources both development and maintenance in the same proportion of 75%-25% (outsource-in-house).

Table 11. IT Development Strategies

Characteristic	L	M	H
% of IT Outsourced vs. In-House Development for the Year			
1993	62-38%	30-70%	25-75%
1994	48-52%	30-70%	20-80%
1995	47-53%	30-70%	20-80%
% of IT Maintenance Outsourced vs. Done In-House	75-25%	30-70%	20-80%
% of IT Development Outsourced vs. Done In-House	75-25%	30-70%	0-100%

Finally, we see significant differences in the ways in which the banks divide their IT budgets between development and maintenance. Banks H and M spend most of their IT dollars on maintenance, as Table 11 shows. Bank L, however, spends more dollars on development than on maintenance. This raises the question as to whether better productivity with IT occurs in banks that are farther up the learning curve. However, this argument is belied by the fact that Bank L has its teller systems in place since 1979, whereas Banks M and H introduced teller systems in 1992 and 1990. The platform systems in all three banks are roughly the same age, having been introduced in 1990, 1992, and 1988, respectively. In this context, the results from the econometric analysis becomes relevant, arguing for less investment in new IT hardware or software, and suggesting instead that investment in IT labor be undertaken. Thus, firms that restrict themselves to getting more out of existing systems through better maintenance than spending dollars on the development of new applications, will do better in the time-frame that this study covered.

8. Conclusion and Future Work

This paper has shown the importance of IT labor in the overall productivity and profitability of the U.S. banking industry. Beyond the econometric analysis, the paper presents an exploratory investigation into what characteristics of a bank lead to effective use of IT labor. All of this analysis points to the need to continually invest in not only the technical skills of this work force, but their industry-specific knowledge as well. As the “process engineers” of the organization, IT labor is crucial in the design, control, and execution of service delivery in banks. Thus, a key driver of efficiency and effectiveness in the industry in the management of the IT labor force and procurement process.

This research can be extended in several directions. First, using other data collected in the survey, analysis can be conducted as to what firm-level characteristics differentiate banks that use IT better from those that do not. Are there any business process-related parameters that make IT use more productive in some cases, and not in some others? What can we say about human resource practices and work-organization, and how they affect the implementation and use of IT? Does the IT capital budgeting process influence IT contributions toward productivity and efficiency? How does the decision-making process about IT investments affect the success of IT implementation--do firms that employ “technology committees” to make IT-investment decisions see better returns from IT than those that rely on “pioneers” who promote IT use in the firm? We will seek to explore these and other related questions in our future research.

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Appendix A: Data Sources

The Alfred P. Sloan Foundation sponsored study of the financial services industry at the Wharton School included a detailed survey of technology, work practices, organizational strategy, and performance in 135 U.S. retail banks. The survey was aimed at larger banks, and the team compiled a list of the 400 largest bank holding companies (BHCs) in America at the beginning of 1994. Merger activity, and the fact that a number of BHCs had no retail banking organization (defined as an entity that provides financial services to individual consumers), reduced the possible sample to 335 BHCs. Participation in the study was confidential, but not anonymous, enabling the team to match surveys with data from publicly available sources (for this paper data supplied by banks is matched with publicly available information from the annual reports of the banks, and the Federal Deposit Insurance Corporation).

Participation in the study required substantial time and effort on the part of organizations. The research team therefore sought commitment to participation by approaching the 70 largest U.S. BHCs directly, and in the second half of 1994, requested the participation of one retail banking entity from each BHC. Forty-seven BHCs agreed to participate. Of these, seven BHCs engaged the participation of two or more retail banks within the BHC, yielding a total of 64 participating retail banks in this sample. Each organization in this sample received multiple questionnaires. In late 1994, the team mailed survey questionnaires to top executives of the next largest 265 BHCs, and followed the mailing with a telephone call requesting the participation of one of their retail banking organizations. Sixty-four of these BHCs agreed to participate in the study, and four of these engaged the participation of two or more retail banks in the BHCs so that there were a total of 71 retail banks participating in the mailed survey. The two-pronged approach, while yielding a sample that is by no means representative of the industry (which comprises some 8,000 banks), did yield substantial coverage of the industry, gaining the participation of banks holding over 75% of the total assets in the industry in as of year-end 1994.

The team designed questionnaires for the "most informed respondent" (Huber and Power, 1985) in the bank in a number of areas, including business strategy, technology, human resource management and operations, and the design of business processes. The team made a telephone help line available to respondents who were unsure of the meaning of particular questions. Here we draw on two of the questionnaires; those completed by the chief officers responsible for technology, and those completed by the controllers.

Appendix B: Details of the Econometric Results

Loans + Deposits

2-Step WLS (Common Intercept)

IT Capital	0.001157	0.013180	0.087802	0.9303
IT Labor	0.259888	0.031179	8.335476	0.0000
Non-IT Capital	-0.020711	0.026312	-0.787133	0.4343
Non-IT Labor	0.532440	0.059468	8.953355	0.0000

2-Step WLS (Fixed Effects)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IT Capital	-0.211836	0.028685	-7.384841	0.0000
IT Labor	0.160495	0.053231	3.015087	0.0033
Non-IT Capital	-0.007692	0.009638	-0.798164	0.4269
Non-IT Labor	0.039356	0.027595	1.426201	0.1572

Loans + Deposits
No weighting

Common Intercept

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IT Capital	0.000186	0.091938	0.002024	0.9984
IT Labor	0.283941	0.142570	1.991595	0.0510
Non-IT Capital	-0.010402	0.089229	-0.116574	0.9076
Non-IT Labor	0.452976	0.110134	4.112943	0.0001

R-squared	0.422123	Mean dependent var	23.80229
Adjusted R-squared	0.383598	S.D. dependent var	0.959057
S.E. of regression	0.752968	Sum squared resid	34.01765
F-statistic	10.95708	Prob(F-statistic)	0.000001

Fixed Effects

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IT Capital	-0.257239	0.319842	-0.804269	0.4233
IT Labor	0.119458	0.423664	0.281964	0.7786
Non-IT Capital	-0.019261	0.202443	-0.095145	0.9244
Non-IT Labor	0.032331	0.366140	0.088303	0.9298

R-squared	0.745674	Mean dependent var	23.80229
Adjusted R-squared	0.474941	S.D. dependent var	0.959057
S.E. of regression	0.694942	Sum squared resid	14.97128
F-statistic	30.29700	Prob(F-statistic)	0.000000

Random Effects

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IT Capital	-0.013190	0.105471	-0.125063	0.9009
IT Labor	0.292327	0.161530	1.809741	0.0753
Non-IT Capital	-0.020636	0.098070	-0.210423	0.8341
Non-IT Labor	0.433132	0.125664	3.446750	0.0010

Unweighted Statistics including Random Effects

R-squared	0.634124	Mean dependent var	23.80229
Adjusted R-squared	0.609732	S.D. dependent var	0.959057
S.E. of regression	0.599137	Sum squared resid	21.53789

References

Baily, Barua, A., C. Kriebel, and T. Mukhopadhyay, "Information Technology and Business Value: An Analytical and Empirical Investigation," University of Texas at Austin Working Paper, Austin, TX, May, 1991.

Benston, G.J., G.A. Hanweck, and D.B. Humphrey, "Scale Economies in Banking: A Restructuring and Reassessment," *Journal of Money, Credit and Banking*, 14:1 (1982), 435-450.

Berger, A.N. and D.B. Humphrey, "Measurement and Efficiency Issues in Commercial Banking," in Z. Griliches (Ed.), *Output Measurement in the Service Sectors*, University of Chicago Press, Chicago, 1992.

Berndt, E., *The Practice of Econometrics: Classic and Contemporary*, Addison-Wesley, Reading, MA 1991.

Brynjolfsson, E., "The Productivity Paradox of Information Technology," *Communications of the ACM*, 35 (1993), 66-67.

Brynjolfsson, E. and L. Hit, "Paradox Lost? Firm-Level Evidence on the Returns to Information Systems Spending," *Management Science*, 42 (1996), 541-558.

Clemons, E.K., "Evaluation of Strategic Investments in Information Technology," *Communications of the ACM*, 34:1 (1991), 22-36.

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 (1993), 1-23.

Frei, F. and P.T. Harker, "Measuring the Efficiency of Service Delivery Processes: With Application to Retail Banking," *Manufacturing and Service Operatiions Management*, forthcoming.

Gunn, T. G., *Manufacturing for Competitive Advantage*. Bollinger, Cambridge, MA, 1987.

Hancock, D., *A Theory of Production for the Financial Firm*. Kluwer Academic Press, Boston, 1991.

Hitt, L. and E. Brynjolfsson, "Productivity, Business Profitability, and Consumer Surplus: Three Different Measures of Information Technology Value," *MIS Quarterly*, June 1996, 121-142.

Huber, G. P. and D.J. Power, "Retrospective Reports of Strategic-Level Managers : Guidelines for Increasing Their Accuracy," *Strategic Management Journal*. Apr/Jun 1985, v6n2, 171-180

Kennedy, P., *A Guide to Econometrics*. MIT Press, Cambridge, MA, 1985.

Lichtenberg, F., "The Output Contributions of Computer Equipment and Personnel: A Firm Level Analysis," *Economics of Innovation and New Technology* (3:4), 1995.

Loveman, G.W., "An Assessment of the Productivity Impact of Information Technologies," in T.J. Allen and M.S. Scott Morton (Eds.), *Information Technology and the Corporation of the 1990s: Research Studies*, MIT Press, Cambridge, MA 1994.

Mester, L. "A Multiproduct Cost Study of Savings and Loans," *The Journal of Finance*, 42 (1987), 423-45.

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.

Parsons, D., C.C. Gotlieb, and M. Denny, "Productivity and Computers in Canadian Banking," in Z. Griliches and J. Mairesse (Eds.) *Productivity Issues in Services at the Micro Level*, Kluwer, Boston, 1993.

Porter, M., *Competitive Strategy*, Free Press, New York, 1980.

Rebello, K., "We Humbly Beg You to Take This Job. Please.," *Business Week* 3480 (June 1996).

Reich, R.B. *The Next American Frontier*, Penguin Books, New York, 1984.

Strassman, P.A., *The Business Value of Computers*, Information Economics Press, New Canaan, CT, 1990.

Triplett, J.E., "Comment on Measurement and Efficiency Issues in Commercial Banking," in Z. Griliches (Ed.), *Output Measurement in the Service Sectors*, University of Chicago Press, Chicago, 1992.

Wilson, D., "Assessing the Impact of Information Technology on Organizational Performance," in R. Banker, R. Kauffman, and M.A. Mahmood (Eds.), *Strategic Information Technology Management*, Idea Group, Harrisburg, 1993.