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Impact of Information Technology on Public Accounting Firm Productivity

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ABSTRACT: In recent years, information technology (IT) has played a critical role in the services provided by the public accounting industry. However, no empirical research has evaluated the impact of IT on public accounting firms. This study focuses on five offices of an international public accounting firm that recently made large IT investments, primarily in audit software and knowledge-sharing applications. Both qualitative and quantitative information from the research site are analyzed to estimate the change in productivity following the implementation of IT. The results from both regression analysis and Data Envelopment Analysis (DEA) indicate significant productivity gains following IT implementation, documenting the value impact of IT in a public accounting firm.

Keywords: public accounting; information technology (IT); IT productivity; IT adoption; data envelopment analysis.

Data Availability: The confidentiality agreement with the firm that provided the data for this study precludes revealing its identity and disseminating detailed data without its written consent.

I. INTRODUCTION

Advances in information technology (IT) have transformed many firms in professional services industries, but perhaps none as much as those in the public accounting industry. Once a slow-paced and conservative industry, public accounting underwent tremendous changes at the turn of the millennium, sparked largely by the rapid changes in its IT environment (Elliott 2000). Audit software and knowledge-sharing applications are two crucial components of these changes. Automation of audit tasks and use of specialized audit software has substituted IT for labor and changed the structure of audit teams. Equally important is the use of advanced systems to share knowledge bases across different parts of the organization that has enabled professional services firms to leverage their human resources more effectively (Gogan et al. 1995).

With rapid advances in IT, numerous articles have appeared in practitioner-oriented accounting journals that discuss how to invest in IT to keep up with the current technology (Smith 1997; Zarowin 1998). To justify an IT investment, managers need to understand the potential benefits resulting from the investment. Although there is a general perception that IT investments by public accounting firms can improve firms' productivity (Lee and Arentzoff 1991), the impact of IT on firm performance is not directly observable. Public accounting firms need to understand how the technology can transform their work and whether such transformation will ultimately lead to productivity gain. While the recent IT research literature documents a positive marginal contribution of incremental IT expenditure using cross-sectional analysis across several firms (e.g., Brynjolfsson and Hitt 1995; Lichtenberg 1995), empirical evidence at the firm level has not been reported. Longitudinal analysis before and after IT implementation is important to support a causality argument leading from IT deployment to improvement in the firm's productivity. This is especially of interest in a public accounting firm where information utilization is the core competence.

The objective of this study is to evaluate whether IT implementation has an impact on the productivity of a public accounting firm. We identified a large international public accounting firm as our research site. Our research site has recently made a large investment in IT, focusing primarily on audit software and knowledge-sharing applications. With access to the firm's senior management, we obtained both qualitative and quantitative data from five offices of the firm for our analysis. We interviewed accounting professionals at different levels to explore how these IT changes might impact the firm's audit service production. Then we analyzed quantitative data on the firm's service output and input consumption to test statistically whether there was productivity improvement following the IT changes in the firm.

Since our research site was in a relatively stable business environment and followed consistent business practices, it serves as a quasi-natural experimental (Meyer 1995) test-bed to evaluate the effects of a new IT program on productivity improvement. The firm's recent large investment in IT was an abrupt and permanent intervention in the time series of the firm's production data following the implementation of the new IT program. Our empirical results from both regression analysis and Data Envelopment Analysis (DEA) indicated significant improvement in the firm's productivity following the implementation of its new IT program, documenting the value impact of IT investment in public accounting firms.

The rest of the paper is organized as follows. In Section II, we describe the research motivation and background. In Section III, we discuss how our qualitative analysis leads to the research question for quantitative examination. In Section IV, we describe the two estimation models we use to evaluate changes in firm productivity and present our empirical results. In Section V, we conclude with a discussion of the implication of our results.

II. RESEARCH BACKGROUND

Research Motivation

To understand the nature of the IT impact on firm performance, we must consider the fit between the characteristics of the IT and the users' tasks (Goodhue and Thompson 1995). Since the primary responsibility of professionals in public accounting firms involves information-intensive activities (Auditing Concepts Committee [ACC] 1972) such as gathering, organizing, processing, evaluating, and presenting data, the use of IT is likely to improve the productivity of accounting professionals (Pinsonneault and Rivard 1998). Teamwork is critical in a public accounting firm as audit engagements are performed by teams composed of professionals at different ranks. Therefore, the use of groupware technology is also expected to improve work collaboration and communication within teams, and thus enhance their productivity (Ellis et al. 1991; Vandenbosch and Ginzberg 1996-1997).

Although previous IT research has examined the impact of IT investments on firm performance in different industries such as manufacturing (Barua et al. 1995), banking (Parsons et al. 1993), insurance (Francalanci and Galal 1998), healthcare (Menon et al. 2000), and retailing (Reardon et al. 1996), empirical research has not examined the professional services industry, such as public accounting firms, in which information and knowledge work play a prominent role. Hence, examining the impact of IT implementation on public accounting firm productivity is of considerable interest to both academic inquiry and practice.

Exploration of the productivity impact of IT implementation requires the recognition that the conversion from IT expenditure to business performance enhancement is a longitudinal process (Soh and Markus 1995). Proper IT management is essential to convert IT expenditure to IT assets. Appropriate use of IT assets generates organizational innovations and redesigned business processes, and favorable competitive dynamics enable improved organizational performance due to these organizational innovations. Davern and Kauffman (2000) extended this IT conversion process sequence to emphasize the importance of considering the impact of IT planning and selection activities on realized IT value.

A few field studies have explored the longitudinal IT conversion process to identify the factors at different points of the process that determine the success of IT adoption. Venkatesh and Davis (2000) found that at different time points before and after IT implementation, factors such as subjective norm, voluntariness, job relevance, and output quality consistently influence users' perceptions about the usefulness of the systems. Bergeron and Raymond (1997) reported that organizational support, implementation process, and control procedures impacted the initial realization of benefits from Electronic Data Interexchange (EDI) adoption, but three years later, only organizational support and control procedures remained significant.

While these studies have examined factors that may impact the IT value creation process, they did not estimate the improvement in firm performance, if any, due to IT implementation. Lucas et al. (1996) conducted a case study of the introduction of a financial imaging system at Merrill Lynch. Comparing the data flow diagrams of the old and the new business processes, they identified changes in organization structure, workflows, and operations. They reported improvement in customer service and reduction in costs. However, they did not conduct any statistical evaluation of improvement in firm performance after IT implementation.

Some cross-sectional studies of IT impact have compared the business performance of firms with IT to those without IT, and statistically estimated the impact. Using data from Hardee's fast food chain, Banker et al. (1990) compared the performance of the restaurants deploying the Positran technology (a computerized cash register point-of-sale and order-coordination technology) to those without Positran. They found that the use of the Positran technology is associated with a significantly greater productivity for stores with high diversity of sales. Analyzing data for 107 banks, Pennings (1995) found that the banks with ATM adoptions incurred significantly less nonpersonnel operating expenses than those without.

There are several IT productivity studies that evaluate the contribution of IT as an input factor in the production function. For example, Brynjolfsson and Hitt (1995) and Barua and Lee (1997) estimated the economic production function using cross-sectional data to evaluate the marginal contribution of IT on output. Wang et al. (1997) and Shafer and Byrd (2000) employed DEA to evaluate the role of IT investments in firm production. Our research differs from this stream of research in two important ways. We consider IT adoption as an event and evaluate the extent to which it shifts the production function for a firm, instead of the marginal contribution of the IT input that differs cross-sectionally. Thus, we make a longitudinal instead of cross-sectional comparison of the impact of IT implementation.

Research Site

Our research site (hereafter referred to as the FIRM) is an international public accounting firm. Auditing and taxation services are the principal sources of revenue for the FIRM. We chose it as our research site because of the recent changes in its IT environment. Starting in 1997, the FIRM had initiated several major projects to improve its IT capability. An additional reason we selected this firm was the access we had to the FIRM's senior management, which enabled us to collect both quantitative and qualitative data.

Our interviews with the FIRM's MIS staff indicate that they first considered upgrading their IT capability in mid- to late-1997, and started and completed implementing the major IT projects in 1998. A MIS manager described 1998 as a year of "hectic activity" for them because of the major transformations in IT during the year. Therefore, the periods before and after 1998 provide natural points of comparison to evaluate the impact of IT expenditure on firm performance. The IT changes in the FIRM can be summarized as follows:

(1) Computer Hardware
- Increasing the number of laptops—To facilitate audit work, the FIRM purchased a large number of laptops to replace the old desktop computers, and substantially increased the ratio of number of computers to professionals. The objective was to provide accounting professionals computer access whenever and wherever they needed it.
- Construction and expansion of network infrastructure—Network construction occurred at all offices. It included bandwidth expansion at the main office and network installation at the other offices that had no local area network (LAN) before. All offices are now set up to

link to the main office via a Virtual Private Network (VPN). The network bandwidth between the main office and the international headquarters was also upgraded.

(2) Computer Software

- New audit software—To better fit its local business operation, the FIRM started to develop its own audit software in 1997. With considerable user involvement in the systems analysis stage, the software was designed to fit the audit style of the professionals in the FIRM. The beta version of the new audit software was first released in January 1998. Based on feedback from the beta users, the first version was released in July 1998. Following the formal release of the new audit software, the FIRM required the use of this software for the preparation of work papers at all its audit engagements.
- The use of Lotus Notes—Before 1998, only the main office employed the groupware technology for audit work. In 1998, all offices began using Lotus Notes after their network infrastructure was improved. The deployment of Lotus Notes created an intranet environment among all the offices in the FIRM, with connection also to their international headquarters. This groupware and associated connectivity was expected to facilitate information and knowledge sharing.

To implement these IT changes, the FIRM held mandatory training classes for its professionals to help them adapt to the new IT environment. All accounting professionals were required to attend classes that provided an introduction to computer systems and file management, and training in the use of the proprietary audit software, Lotus Notes, and knowledge-sharing applications.

To quantify the impact of these IT changes, we collected data regarding monthly IT expenditures, including IT support staff salaries, from each of the five offices of the FIRM for the years 1997, 1998, and 1999. We also examined the pattern of IT expenditures in the FIRM over our sample period, and confirmed that 1998 was the key period when the actual IT transition took place. The 1998 IT spending, including IT support staff salaries, is significantly higher than that in 1997 and 1999. On average, the 1998 IT spending exceeded that for the other two years by more than 50 percent.

III. RESEARCH HYPOTHESIS

To understand how those IT changes affected the production process in the FIRM, we conducted several interviews with audit managers and staff at different ranks. We considered sources of value creation resulting from the IT investment at various levels within the FIRM (Davern and Kauffman 2000).

IT Impact at the Individual-User Level

For IT to positively impact a user's performance, there should be a good fit between the IT and the user's tasks (Goodhue 1995). In addition, training is a significant determinant of the IT user's effectiveness (Igbaria 1990). The FIRM has designed the new IT program to fit the requirements of its professionals, and enforced the training in the use of the software. Our field interviews suggest that the IT changes had a positive impact on the auditors' performance. Since an audit team is composed of professionals at different ranks (such as managers, seniors, and juniors) with different job responsibilities (Carmichael and Willingham 1989), IT adoption may benefit audit professionals at different ranks in different ways.

IT Impact on Junior Auditor

The primary tasks that junior auditors perform are assigned audit procedures and preparation of working papers. Most of these tasks are relatively repetitive and involve substantial calculations and referencing across different accounts. Computer applications can automate such structured tasks and substantially reduce the processing time (Abbe and King 1988). In addition, the reduction in monotone work allows individuals to concentrate on more complex tasks and enhance their individual performance (Giuliano 1982; Millman and Hartwick 1987). Our field interviews indicate that the principal benefits to a junior auditor from the IT changes are the savings in effort and the reduction in errors afforded by the electronic preparation of working papers. Incorrect computation is one of the major causes for misstatement

(Bell et al. 1998), and by reducing such errors, IT use also benefits other audit team members. A junior auditor describes his experience using the new computerized systems as follows:

> The most important benefit to me is that I can develop the working papers electronically. Without the computer, I have to write down all the numbers by hand and make difficult calculations using a calculator. Sometimes I need to repeat the same entry several times on different sheets. For example, the amount of cash may appear on the balance sheet, the working trial balance, the cash flow schedule, the bank reconciliation and so on, and all the numbers are the same or related. I have to be very careful when I write those numbers down. It is very tedious! However, using the audit software, I only need to key in the entry once and make the appropriate choice. Then, all the related numbers are generated automatically and cross-referenced, and there is no need to punch any keys on a calculator. With a computer, my working hours on an engagement can be reduced by more than half of that without the computer.

IT Impact on Senior Auditor

As the middle-level member of an audit team, a senior auditor assists in audit plan development, organization of audit activities, and supervision and review of the work of junior auditors. The FIRM's audit software organized all required audit procedures in a common list and cross-referenced them to items in the working papers. Since electronic presentation of information facilitates user's information acquisition (Jones et al. 1993), a senior auditor is likely to benefit from the convenient information gathering and organization enabled by the new software. A senior in the FIRM describes her favorite IT helper as follows:

> I like to use the audit software to edit my audit plan and programs. It helps me get organized. The software lists all the necessary planning items for me, so I don't need to worry about missing an important element. All related forms are available by clicking a button, which is really convenient. In addition, we also have a database of document templates that I can use for almost all occasions.

IT Impact on Audit Managers

As supervisors and reviewers, audit managers do not benefit directly from the audit automation process, except for the convenience of computer-based presentation of information. Analyzing survey data from 260 public managers, Kraemer et al. (1993) found that managers perceived computer-based information to be more useful. Since the FIRM's audit software organizes all audit evidence collected by juniors and seniors in an electronic format, audit managers are likely to be more effective when reviewing such data. Since the order of audit working paper documentation can impact the decision of the reviewers (Ricchiute 1992), electronic working papers that comply with a regular organization should provide more consistent audit decision quality. An audit manager expresses his support for electronic working papers as follows:

> I don't use many functions of electronic working paper software. I just review its output. However, I do enjoy the neat screen output because everything is clear. Also, every item is cross-referenced which makes it easy for me to trace them. I can easily switch around and search for the items I want to see.

In the Notes, the FIRM includes various local and international databases regarding companies, industries, and regulations. Managers can easily search for information relevant to a certain client to help them perform analytical review (Cohen et al. 2000). In addition, the information in the databases is more reliable and objective (Reimers and Fennema 1999). The FIRM has also created some exclusive case databases that can be shared by its professionals. Such knowledge-sharing applications have been found to improve the quality of decision making (Orlikowski 1993, 1997). A manager describes his experience as follows:

> Our Notes database has helped me increase my professional knowledge. We share our case experience, and business regulations using the database. It helps a lot in problem solving and keeps me updated on the current trend.

IT Impact at the Business Process Level

A current trend is to create a paperless office environment that replaces paper documents with electronic documents so that information can be accessed easily and with much less effort. In the practitioner-oriented literature, advantages of a paperless office in improving work efficiency and reducing operating costs have been reported (Hunton 1994). Together with the audit software, the FIRM created a client database to store all related audit files for each client. The documents in the database can be easily retrieved by a search function or with associated links. Consequently, auditors in the same team can share audit files and significantly reduce the coordination effort of the senior auditors (Salamasick et al. 1995). An audit senior at the FIRM also observed that database storage allows quick reference and modification from previous audit plans and reports for the client and, consequently, work hours for a client can be reduced significantly. In addition, the FIRM uses Notes as a tool to manage internal resources and documents to save time and increase effectiveness.

IT Impact at the Work Group Level

A professional service firm stands to benefit substantially from the knowledge-sharing applications (Vandenbosch and Ginzberg 1996). The Professional Development Department in the FIRM updates the Notes database everyday and communicates the update to everyone by email. To encourage audit professionals to collaborate, a Question and Answer electronic bulletin board in the Notes was set up for the discussion of all types of work-related questions. The Professional Development Department checks the board periodically and ensures responses to all the questions. Network applications that enable real-time information circulation can also facilitate communications efficiency in a public accounting firm (Zarowin 1994). Email is the most important network application for the professionals in the FIRM to communicate with each other, clients, and overseas colleagues. Some groups in the FIRM described to us their positive experience in utilizing the "net meeting" function in Notes to conduct group discussion. This is consistent with the experiments by Bamber et al. (1996) and Ho (1999) that found the use of group support system technology resulted in higher quality audit decision making. Also, a manager observed that the use of telecommunications applications had led to a decrease in operating costs such as postage and travel expenses.

Task-Technology Fit

Our qualitative analysis suggests that the FIRM's new IT program matches its audit professionals' tasks in three aspects (Goodhue and Thompson 1995). First, the new IT provides data to support audit decision making. The audit software organizes the audit evidence for audit judgments and the Notes databases provide relevant supplemental information. Second, the new IT fulfills the requirements of the FIRM's routine operations in its audit engagements. The audit software automates the preparation of working papers and the Notes applications facilitate communication between the professionals and the clients. Third, the new IT program fits the business needs. The Notes applications facilitate knowledge sharing and supply up-to-date information that supports the professional requirements of the information-intensive public accounting industry.

In the FIRM, the use of the audit software is mandatory. Our field interviews also indicated that audit professionals perceived the Lotus Notes applications to be highly useful. Davis (1989) indicates that satisfaction with IT is associated with high utilization of the technology. Goodhue and Thompson (1995) suggest that a good fit between the IT and the user's tasks is the key determinant of IT success when IT utilization is high. Therefore, we expect that the IT changes have enhanced the productivity of the FIRM. Recognizing that the IT conversion process occurred in 1998, we articulate our empirical hypothesis as follows:

H1: The FIRM's productivity in 1999 is higher than in 1997.

Between 1997 and 1999, the FIRM did not make any changes in its incentive scheme, organizational structure, and business strategy. The senior management has not changed for the past decade. In addition, the FIRM's market and competitive environment was relatively stable, and the FIRM did not have any merger activity between 1997 and 1999. The Consumer Price Index (CPI) at the office locations increased on average by only one percent annually over the sample period. Under these circumstances, the comparison of the FIRM's productivity in 1997 and 1999 can be viewed as approximating a controlled experiment. If there is any significant productivity gain from 1997 to 1999, then the IT changes in 1998 are most likely to be its principal driver.

IV. EMPIRICAL ANALYSIS

Data Description and Intervention Analysis

We collected a panel of data for 24 monthly observations from January 1997 to December 1997, and January 1999 to December 1999 from the monthly income statements for each of the five offices of the FIRM. For the production function of each office, we measured the office output as the monthly revenue (REVENUE) that is computed by allocating annual fees in the proportion of staff resources assigned each month to different audits. The primary inputs for the production in each office are professional labor costs (PROFCOST) and operating costs (OPERCOST). PROFCOST includes salaries paid to different levels of accounting professionals in each office. OPERCOST includes all other operating expenses incurred in the office such as rent, utilities, travel expenses, and administrative staff costs. Note that PROFCOST and OPERCOST exclude all IT-related expenditures, as we are interested in examining how the use of IT can transform the way the FIRM utilizes the rest of the resources for output generation. To account for inflation, we deflated all variables by the monthly CPI. The descriptive statistics of the variables are shown in Table 1.

By the end of 1998, the FIRM had completed the implementation of the new IT and started to put the new technology to use. The use of the new IT is expected to shift the time series of the FIRM's production data. We model this potential shift as an interrupted time series and evaluate it using intervention analysis specified by the following functional form (DeLurgio 1998, 491–495):

$$Y_t = N(X_t) + f(I_t)$$

where:

- t = time identifier;
- Y = FIRM's output;
- $N(X_t)$ = FIRM's production input function; and
- $f(I)$ = intervention function in which $I = 1$ when intervention occurs and $I = 0$ otherwise.

Since the new IT program is expected to have transformed the FIRM's business process, the productivity impact from such transformation is expected to not decay over time. Therefore, we model $f(I)$ as an abrupt and permanent zero-order intervention function represented by $f(I_t) = \delta_0 I_t$. The coefficient of

TABLE 1
Descriptive Statistics

	1997		1999	
Variable	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
REVENUE	$3,564,006	$4,929,315	$4,817,692	$6,613,136
PROFCOST	1,943,725	2,725,208	2,836,482	3,926,451
OPERCOST	716,306	1,114,475	935,357	1,447,254

All numbers are disguised by multiplying by a scalar.

REVENUE = monthly revenue of an office;
PROFCOST = monthly labor costs for accounting professionals in an office; and
OPERCOST = monthly operating costs, including administrative staff costs, rent, utilities, office supplies, travel, postage and telephone, advertisement, training, depreciation and amortization, but excluding all items related to accounting professional labor and IT costs in an office.

the intervention, δ_0, indicates the magnitude of the impact of the intervention. In the next subsection, we report results of regression analysis to estimate the FIRM's production function with the specified intervention. In the "Data Envelopment Analysis" subsection, we use DEA to estimate the FIRM's productivity score and then evaluate how the intervention impacts the productivity score.

Regression Analysis

We specify the production function of each office as a Cobb-Douglas function in keeping with several prior studies of IT productivity (Loveman 1994; Lichtenberg 1995; Brynjolfsson and Hitt 1996). A dummy variable, POSTITINV, is included as an intervention variable to differentiate the post-IT-investment period from the prior period. It is constructed to reflect the productivity differences between the two periods (Banker et al. 1989). Since we estimate the function using a panel of monthly data for five offices, we capture office differences via a fixed effects specification (Greene 1997, 615–618) that requires four office dummy variables. The estimation model is formulated as follows:

$$\begin{aligned} 1nREVENUE_{ti} = \beta_0 + \beta_1 1nPROFCOST_{ti} + \beta_2 1nOPERCOST_{ti} + \beta_3 POSTITINV_t \\ + \gamma_1 OFFICE1_{ti} + \gamma_2 OFFICE2_{ti} + \gamma_3 OFFICE3_{ti} + \gamma_4 OFFICE4_{ti} + \varepsilon_{ti} \end{aligned} \tag{1}$$

where:

i	=	office identifier;
t	=	time (month) identifier, t = 1, 2,…,24 (1 to 12 for January 1997 to December 1997; 13 to 24 for January 1999 to December 1999);
lnPROFCOST	=	natural logarithm of professional salaries;
lnOPERCOST	=	natural logarithm of monthly operating expenses;
OFFICEi	=	dummy variables coded 1 for observations from office i, and 0 otherwise;
POSTITINV	=	coded 1 for all months in 1999, and 0 otherwise; and
ε	=	disturbance term.

In Table 2, we present the results of estimating the ordinary least square (OLS) model specified in Equation (1). We also conducted several tests to ensure that our analysis does not violate basic econometric assumptions. The value of studentized residuals was checked to see if there were any influential outliers (Belsley et al. 1980). All observations were found to be in the acceptable range with the absolute value of studentized residuals smaller than 3. The Belsley et al. (1980) condition indices indicated that multicollinearity was not a problem. The Shapiro and Wilk (1965) test revealed that the residuals from the model violated the normality assumption. White's (1980) test also indicated that the assumption of homoskedastic residuals was violated. Therefore, we used White's heteroskedasticity-consistent covariance matrix to address the non-normality and heteroskedasticity problems. White's adjusted t-statistics are reported in Table 2.

The coefficients of all independent variables are significant at the one percent level. The coefficient for POSTITINV is 0.1634, indicating that the productivity gain from the IT changes in 1998 was about 16 percent.

Data Envelopment Analysis

Albeit widely used in the filed, the regression analysis used in the previous subsection is limited by the specification of a parametric functional form without any *a priori* knowledge to justify it. The parametric structure is an untested maintained assumption, and the empirical evaluation of the hypothesis of interest is necessarily a conditional test that holds only if the untested maintained assumption is valid. To address the robustness of our empirical results to the parametric assumptions, we also examined the same data set (two input and one output variables) using DEA. DEA imposes no parametric structure on the production function except economic regularity conditions of monotonicity and concavity (Banker 1993). Following Banker et al. (1984), we estimated the inefficiency measure $\hat{\theta}_{mi}$ for office i in month m by solving the following linear program model:

TABLE 2
Regression Results for Productivity Improvement

$$\ln REVENUE_{ti} = \beta_0 + \beta_1 \ln PROFCOST_{ti} + \beta_2 \ln OPERCOST_{ti} + \beta_3 POSTITINV_t + \gamma_1 OFFICE1_{ti} + \gamma_2 OFFICE2_{ti} + \gamma_3 OFFICE3_{ti} + \gamma_4 OFFICE4_{ti} + \varepsilon_{ti}$$

Variable	Coefficient	Estimator	White's Adjusted t-statistic
lnPROFCOST	β_1	0.2989	4.55***
lnOPERCOST	β_2	0.1267	3.31***
POSTITINV	β_3	0.1634	4.77***
OFFICE1	γ_1	–2.4663	–6.68***
OFFICE2	γ_2	–1.1192	–6.16***
OFFICE3	γ_3	–1.2765	–5.62***
OFFICE4	γ_4	–1.2420	–6.47***

Adjusted $R^2 = 0.99$

***Significant at the 1 percent level.

lnREVENUE = natural logarithm of monthly revenue;
lnPROFCOST = natural logarithm of monthly labor costs for accounting professionals;
lnOPERCOST = natural logarithm of monthly operating costs;
POSTITINV = 1 when the month is in 1999, and 0 otherwise; and
OFFICEn = dummy variables coded 1 for observations from office n, and 0 otherwise.

$$\text{Max} \quad \theta_{mi} \tag{2.1}$$

$$\text{s.t. } \theta_{mi} Y_{mi} \le \sum_{t=1}^{24} \lambda_{ti} Y_{ti} \tag{2.2}$$

$$\sum_{t=1}^{24} \lambda_{ti} X_{ti}^{n} \le X_{mi}^{n}, \ n = 1,2 \tag{2.3}$$

$$\sum_{t=1}^{24} \lambda_{ti} = 1 \tag{2.4}$$

$$\theta_{mi}, \lambda_{ti} \ge 0, \ t = 1,\ldots,24 \tag{2.5}$$

Y = REVENUE (office output measure);
X^1 = PROFCOST (office input measure); and
X^2 = OPERCOST (office input measure).

In this linear program, the production of office i in month m is compared to its own production in other months of 1997 and 1999 to derive the inefficiency score. The observations across offices are not pooled together as there are differences among offices (such as customer base, market competition), which were captured by the fixed effects specification with office dummy variables in the regression analysis.

The DEA scores, $\hat{\theta}_{mi}$, were obtained by iteratively running 120 DEA programs. They were classified into two groups by year (1997 and 1999). As shown in Panel A of Table 3, the average office DEA inefficiency score of observations in 1997 is 1.0851 and that of observations in 1999 is 1.0510. Since $\hat{\theta}_{mi}$ is a consistent estimator of $\hat{\theta}_{mi}$, various statistical tests can be conducted to evaluate whether there is a significant difference between the scores of the two groups (Banker 1993). The null hypothesis is as follows:

$$H_0 : E(\hat{\theta}_{m\in 1997}) = E(\hat{\theta}_{m\in 1999})$$

For the DEA inefficiency scores, we have the following alternate hypothesis that asserts that the offices are more productive in 1999 than in 1997:

$$H_1 : E\left(\hat{\theta}_{m\in 1997}\right) > E\left(\hat{\theta}_{m\in 1999}\right)$$

We evaluated the null hypothesis using the three tests suggested by Banker (1993). Assuming that the inefficiency scores are distributed exponentially, the following sum ratio test statistic is evaluated

$$T_{EXP} = \frac{\sum_{m\in 1997} (\hat{\theta}_m - 1)/n_{1997}}{\sum_{m\in 1999} (\hat{\theta}_m - 1)/n_{1999}}$$

TABLE 3
DEA Results for Productivity Improvement

Panel A: Estimated DEA Inefficiency

Year	Mean Inefficiency	Standard Deviation
1997 (n = 60)	1.0851	0.1152
1999 (n = 60)	1.0510	0.0618

Panel B: Banker's (1993) Tests Results

$$H_0: E(\hat{\theta}_{m\in 1997}) = E(\hat{\theta}_{m\in 1999})$$

	Banker's Sum Ratio Test	Banker's Sum of Square Ratio Test	Kolmogorov-Smirnov Test
Test Statistic	1.67***	3.20***	1.73***
p-value	0.0027	< 0.0001	0.0049

Panel C: Two-Stage DEA-Parametric Test Results

$$H_0: E(\hat{\theta}_{m\in 1997}) = E(\hat{\theta}_{m\in 1999})$$

	Student's t-Test	Welch's t-Test	Cochran's t-Test
Test Statistic	2.02**	2.02**	2.02**
p-value	0.0456	0.0463	0.0479

Panel D: Two-Stage DEA-Regression Test Results

$$\ln\hat{\theta}_{mi} = \alpha_0 + \alpha_1 \text{POSTITINV}_{mi} + \omega_{mi}$$

POSTITINV_{mi} = 1 when the month is in 1999, and 0 otherwise.

Variable	Coefficient	Estimator	t-statistic
Intercept	α_0	0.0771	5.90***
POSTITINV	α_1	–0.0289	–2.07**

, * Significant at the 5 percent and 1 percent levels, respectively.

against the half F-distribution with $(2n_{1997}, 2n_{1999})$ degrees of freedom:
where $n_{1997} = n_{1999} = 60$ is the number of observations for each group. Assuming that the inefficiency scores follow a half-normal distribution, the following sum of square ratio test statistic is evaluated

$$T_{HN} = \frac{\sum_{m \in 1997} (\hat{\theta}_m^2 - 1)^2 / n_{1997}}{\sum_{m \in 1999} (\hat{\theta}_m^2 - 1)^2 / n_{1999}}$$

against the half F-distribution with (n_{1997}, n_{1999}) degree of freedom:
If we do not impose any assumptions about the distribution of the inefficiency score, then a Kolmogorov-Smirnov type test statistic based on the maximum distance between the empirical cumulative distributions can be used to examine whether the distributions of the inefficiency scores for the two years are significantly different from each other.

The Monte Carlo study in Banker and Chang (1995) indicates that Banker's (1993) sum ratio and sum of squares ratio tests outperform conventional parametric tests. The three test statistics proposed by Banker (1993) are reported in Panel B of Table 3. All of them are significant at the one percent level. Therefore, we reject the null hypothesis that the expected values of the inefficiency scores for the two years are the same. There was a significant productivity improvement in the FIRM after the major IT changes in 1998.

We also conducted a two-stage estimation involving DEA followed by parametric analysis, as proposed by Banker and Natarajan (2001), to compare the mean inefficiency of the two groups. We performed Student's (Freund 1992, 464), Welch's (Banker and Chang 1995) and Cochran's (Cochran and Cox 1950) t-tests to compare the means. The Student's t-test assumes that the two groups have equal

$$t_{STUDENT} = \frac{\bar{\theta}_{1997} - \bar{\theta}_{1999}}{s\sqrt{\frac{1}{n_{1997}} + \frac{1}{n_{1999}}}} \quad \text{where } s = \sqrt{\frac{(n_{1997} - 1)s_{1997}^2 + (n_{1999} - 1)s_{1999}^2}{n_{1997} + n_{1999} - 2}}$$

variances. The test statistic is specified as $t_{STUDENT}$ below:
s_{1997} and s_{1999} are the sample standard deviations of the two groups and the degrees of freedom equal $n_{1997} + n_{1999} - 2$.

Welch's and Cochran's t-tests assume that the two groups have unequal variances. The t-statistic for

$$t_{WELCH} = \frac{\bar{\theta}_{1997} - \bar{\theta}_{1999}}{\sqrt{\frac{s_{1997}^2}{n_{1997}} + \frac{s_{1999}^2}{n_{1999}}}}$$

Welch's test is specified as follows:

$$\nu_{WELCH} = \frac{\left(\frac{s_{1997}^2}{n_{1997}} + \frac{s_{1999}^2}{n_{1999}}\right)^2}{\frac{s_{1997}^4}{n_{1997}^2 (n_{1997} - 1)} + \frac{s_{1999}^4}{n_{1999}^2 (n_{1999} - 1)}}$$

with the degrees of freedom approximated as:

$$t_{COCHRAN} = \frac{\bar{\theta}_{1997} - \bar{\theta}_{1999}}{\sqrt{\frac{s_{1997}^2}{n_{1997} - 1} + \frac{s_{1999}^2}{n_{1999} - 1}}}$$

The t-statistic for Cochran's t-test is specified as follows:

$$\nu_{COCHRAN} = \frac{\left(\frac{s_{1997}^2}{n_{1997}-1} + \frac{s_{1999}^2}{n_{1999}-1}\right)^2}{\frac{s_{1997}^4}{(n_{1997}+1)(n_{1997}-1)^2} + \frac{s_{1999}^4}{(n_{1999}+1)(n_{1999}-1)^2}} - 2.$$

with degrees of freedom approximated as:
As shown in Panel C of Table 3, all three t-tests reject the null hypothesis at the five percent level, supporting our hypothesis of significant productivity gains in 1999 relative to 1997.

An alternative approach is to evaluate the productivity improvement by testing whether $\alpha_1 < 0$ in the following second stage OLS model (Banker and Natarajan 2001):

$$\ln\hat{\theta}_{mi} = \alpha_0 + \alpha_1 POSTITINV_{mi} + \omega_{mi} \quad (3)$$

where:

m = month identifier;
$\ln\hat{\theta}_{mi}$ = natural logarithm of DEA inefficiency score;
POSTTINV = intervention variable, coded 1 if m is in 1999 and 0 otherwise; and
ω = disturbance term.

The coefficient of the dummy variable, α_1, indicates the difference between the mean inefficiency scores of the two groups. The estimation results are shown in Panel D of Table 3. The coefficient α_1 (=–0.0289) is significantly less than zero at the five percent level, confirming the productivity improvement in the FIRM after the IT investments in 1998.

CONCLUSION

In this paper, we have explored the impact of IT implementation on the production function of an international public accounting firm. The research site implemented new audit software and groupware for knowledge sharing in 1998. From field interviews, we observed the potential impact of IT on work efficiency at individual user, business process, and work group levels. Although IT has different impacts on professionals at different ranks, the impacts are all in the positive direction.

We confirmed the statistical significance of the IT impacts by examining quantitative data. Both parametric (regression analysis) and nonparametric (DEA) estimation methods were employed to test for differences in the FIRM's productivity before and after the IT implementation in 1998. The results from both methods indicated significant productivity improvement after the adoption of IT. The regression analysis indicated that the revenue generation of the FIRM in 1999 improved by 16 percent relative to 1997. The DEA results indicated that the efficiency in 1999 improved by about three percent relative to 1997.

The significant improvement in productivity provides support for the value of audit automation and knowledge-sharing applications in public accounting firms. Qualitative evidence suggests that audit software reduces the time for working paper preparation. The electronic presentation of information facilitates the decision-making process of audit professionals. The information obtained from knowledge-sharing databases provides critical support for audit decisions. The groupware facilitates collaboration and improves decision quality. Our research site appears to have achieved its original intention to enhance its operating performance.

To the best of our knowledge, this study represents the first investigation of IT impact on firm productivity in the public accounting industry and provides a successful example for other public accounting firms or professional services firms in evaluating other similar IT investments. The positive impact of IT is consistent with the recent IT productivity literature that has analyzed cross-sectional firm-level data. Although the single firm data limits broad generalizations to other contexts, our longitudinal design helps control for unmeasured organizational and cultural factors that may influence firm productivity. In addition, the rich qualitative information explains the underlying changes in the organization and opens the black box in the traditional quantitative approach to help us understand why productivity may have improved (Barua and Mukhopadhyay 2000).

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