Productivity Change, Technical Progress, and Relative Efficiency Change in the Public Accounting Industry

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We present evidence on components of productivity change in the public accounting industry toward the end of the 20th century. Using revenue and human resource data from 64 of the 100 largest public accounting firms in the United States for the 1995–1999 period, we analyze productivity change, technical progress, and relative efficiency change over time. The average public accounting firm experienced a productivity growth of 9.5% between 1995 and 1999. We find support for the hypothesis that technical progress rather than an improvement in relative efficiency was the reason for this productivity growth. Firms that were early movers into management advisory services (MAS) and those that emphasized growth in MAS over growth in the traditional audit and tax services enjoyed significantly higher productivity growth than their peers. These firms also contributed significantly more to the industry's technical progress.

Key words: public accounting; productivity change; technical progress; relative efficiency; management advisory services; auditing; taxation services
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1. Introduction

A dramatic and dynamic transformation characterized the public accounting industry in the last few years of the past millennium. Global competition and technological change had a significant impact on the survival and growth of certified public accounting (CPA) firms' client organizations during the 1990s. This, in turn, led to considerable growth in the demand for management advisory services (MAS). The opportunities created for firms' clients by advances in information technology (IT) also contributed to the transformation of the public accounting profession. Robert Elliot (1992), former chair of the American Institute of Certified Public Accountants, remarked that advances in IT were important for both audit services and consulting services and thus presented challenges and opportunities for the future of the public accounting profession.

Very little empirical evidence exists on how the transformation in the public accounting industry affected productivity in the industry. Prior accounting research has either examined the service output aspect of the public accounting profession (Simunic and Stein 1987, Craswell et al. 1995) or explored the association between fees for audit and nonaudit services and the association between agency costs and

demand for nonaudit services (Parkash and Venable 1993, Firth 1997). There is, however, little research linking both the output and the input sides of the public accounting industry production function to examine dynamic shifts in productivity and production technology of accounting firms. Recently, Banker et al. (2003) estimated the production function for the public accounting industry using parametric methodology to examine whether there are scale economies and whether there are any significant differences between the marginal revenue products of different categories of employees in the public accounting industry. The research also documents also a 10.2% average improvement in productivity between 1995 and 1999. Our study further addresses this void in the research literature and explains the sources of improvement in productivity of public accounting firms.

In this paper, we begin by estimating the average productivity change in the public accounting industry in the late 1990s. Our major research objective is to analyze the extent to which productivity change can be explained by a shift in the public accounting industry's production technology (i.e., technical change) and a change in the efficiency of CPA firms relative to their peers (i.e., relative efficiency change).

This decomposition helps us assess whether productivity change in the public accounting industry was due to a dramatic improvement in the performance of a select few firms or to an industrywide improvement in productive efficiency. The cross-sectional analysis that we perform focuses on the characteristics of firms that were the primary drivers of productivity change and its components in the public accounting industry. This is a unique feature of our study, whereas Banker et al. (2003) only estimate the average productivity change for the public accounting industry.

Using revenue and human resource data available for the 1995–1999 period, for a sample of 64 of the top 100 public accounting firms in the United States, we analyze both the shift in the production function and the cross-sectional distribution of firm productivity. Our results indicate that the average productivity of CPA firms improved by 9.5% from 1995 to 1999. The best practice production frontier for the public accounting industry shifted upward on average by 12% during this period, but many firms in the industry did not benefit as much from the technical progress, as indicated by a decline of 2.5% in the average relative efficiency. Productivity gains in the industry were predominantly due to a subsample of firms that placed a higher emphasis on the MAS part of the business rather than on the traditional audit and tax services.[1]

The remainder of this paper is organized as follows. In §2, we provide a brief description of our sample and discuss productivity change in the public accounting industry. In §3, we discuss the different components of productivity change. We develop our main hypotheses in §4. Section 5 describes the estimation models we employ. Section 6 contains the results of estimating productivity change and its components. We consider the impact of firms' emphasizing MAS on the industry technical progress in §7. We describe the sensitivity tests in §8 and conclude with a summary in §9.

2. Productivity Change in the Public Accounting Industry

We analyze the productivity change in the U.S. public accounting industry using data from *Accounting Today's* annual surveys of the top 100 accounting firms for the period 1995–1999, both years included.[2] There are several reasons why we focus on the second

half of the last decade. In the mid 1990s there was concern and keen awareness among the industry leaders about the transformation the public accounting industry was going through. In addition, the role of IT had changed from that of process automation during the late 1980s and early 1990s to that of redefining business processes to fundamentally alter traditional ways of doing business during the middle and late 1990s (Chatterjee et al. 2001). A survey of 300 finance executives found that there was much more rapid change in the finance and accounting function between 1995 and 1999 than between 1990 and 1995 (Siegel 1999).

We focus on the overall as well as the annual trend in productivity change between 1995 and 1999. All data reported in *Accounting Today's* annual surveys are for domestic U.S. operations and exclude foreign holdings. After excluding observations for non-CPA firms such as American Express Inc., Padgett Business Services, and H&R Block and imposing the condition that data be available for a firm for all five years between 1995 and 1999, we are left with a final sample of 64 firms.[3] Our panel consists of 320 observations (64 firms × 5 years).

We estimate the production correspondence between service revenue generated (measured in millions of dollars) and human resources employed by public accounting firms.[4] The three output variables are accounting and auditing services (A&A), tax services (TAX), and MAS. A&A includes compilations, special reports, and reviews in addition to engagements involving the attest function. TAX includes tax research, planning, and preparation work. MAS is defined as consulting, systems development, integrating and reselling computer equipment and software, and any other management assistance. The three human resource input variables considered are the

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by Strafford Publications, Inc., Atlanta, GA. There are 61 firms common to the *Accounting Today* and the *Public Accounting Report* data sets for all years. The correlation coefficients between these two data sets are greater than 0.99 for all available variables for each year. The *Public Accounting Report* did not report the total number of nonprofessional employees.

[3] We arrived at our final sample by starting off with all 100 firms in the 1995 survey. Seven of these were eliminated because they were non-CPA firms. Of the remaining 93, only 86 figured in the 1996 survey. We lost seven more due to nonavailability of data for 1997 and another 11 once 1998 was also taken into account. Finally, four firms were lost because they were not part of the 1999 survey.

[4] We focus on three types of human resources because personnel costs constitute a significant fraction of total costs for public accounting firms. Recent national surveys indicate that employee costs and partner compensation account for 74.5% of revenue, while capital costs are less than 7% for public accounting practices with revenue in excess of 1 million (Texas Society of Certified Public Accountants 1999). In §8.1, we perform sensitivity analysis by including the number of branches as a proxy for capital employed.

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[1] This result is consistent with the argument that while the growth of traditional services like audit and tax follows a flat and possibly even a declining growth path, MAS is characterized by increasing growth, because it maps more closely to IT, the nation's leading economic segment (Davis 1998).

[2] An alternative data source on the 100 largest public accounting firms in the United States is the *Public Accounting Report* published

Table 1 Descriptive Statistics on Service Revenue and Human Resources

Variables	Year	Mean	Std. dev.	25%	Median	75%
Revenue	1995	$269.66 M	$841.71 M	$12.25 M	$16.90 M	$31.80 M
	1999	$485.28 M	$1,544.76 M	$17.74 M	$25.24 M	$55.75 M
Partners	1995	173.81	458.44	18	22.5	57
	1999	226.79	612.95	21	31	61
Professionals	1995	1,504.01	4,719	91	126	241.5
	1999	2,430.46	7,856.75	114.5	175.5	363
Others	1995	533	1,667.74	27.5	39	80.5
	1999	799.56	2,572.76	38.5	54.5	115.5
Revenue per	1995	$0.095 M	$0.021 M	$0.082 M	$0.091 M	$0.109 M
employee	1999	$0.104 M	$0.025 M	$0.090 M	$0.103 M	$0.114 M
A&A (%)	1995	49.51	11.54	44	50	54.5
	1999	42.33	11.26	36.5	43	48
TAX (%)	1995	29.83	9.77	23	30	35
	1999	29.28	8.78	24	28	34
MAS (%)	1995	20.65	11.67	13	18	28
	1999	28.39	13.16	20	25.5	35

Notes. N = number of public accounting firms in the sample; REVENUE = total revenue expressed in million (M) dollars deflated to 1995; PARTNERS = number of partners; PROFESSIONALS = number of professionals; OTHERS = number of other employees; A&A% = proportion of A&A revenue; TAX% = proportion of TAX revenue; MAS% = proportion of MAS revenue.

number of partners (PARTNERS), the number of other professionals (PROFESSIONALS), and the number of other employees (OTHERS). The designation PARTNERS includes all owners and shareholders. PROFESSIONALS includes professionally qualified staff who perform the accounting and other services offered by the firm. These include staff accountants, senior accountants, and managers. OTHERS are clerical and support personnel, usually involved in administration, printing of reports, record keeping, and the like.

Table 1 provides descriptive statistics for total revenue, the three human resource variables, total revenue per employee, and the mix of service revenue for 1995 and 1999. To facilitate comparison, all monetary values are inflation adjusted to 1995 dollars. High standard deviations observed for all size-related variables suggest that the sample firms vary substantially in size and composition. Median values for all size-related variables are much smaller than the means, indicating large differences between the smallest and largest firms in the sample. The mean (median) deflated total revenue grew by 80% (49%) during the period 1995–1999, while the mean (median) total employees grew by 56.4% (18%). The mean deflated revenue per employee increased from $95,000 in 1995 to $104,000 in 1999, an improvement of 9.5% over the sample period. The increase in productivity appears to be across the board, because deflated revenue per employee is greater in 1999 than in 1995 at all three quartiles of the distribution. The mix of service revenue reveals a continuing decline in the share of revenue generated by A&A, with a corresponding increase in the share of revenue generated by MAS.

3. Components of Productivity Change

Measuring productivity change simply as change in revenue per employee is not appropriate in the public accounting industry because three different types of human resource inputs are used to generate three different services, and there may be considerable variation in the output and input mix across firms and over time. Measuring growth simply in terms of the revenue per employee also imposes the restriction that the returns to scale are constant. To accommodate multiple outputs and inputs, we use a modified version of the Malmquist (1953) index to measure productivity change.

Consider a base period (denoted by 0) and a subsequent period (denoted by t). The technology set for period i is defined by the production possibility set $P^i = \{(\mathbf{y}, \mathbf{x}) \mid \mathbf{y} \text{ can be produced from } \mathbf{x} \text{ at time } i\}$, $i = 0, t$, where $\mathbf{y}$ and $\mathbf{x}$ correspond to strictly positive output and input vectors. The production set P^i, $i = 0, t$, is assumed to be monotone increasing and convex. The inefficiency measure for an output-input combination $(\mathbf{y}_j^\tau, \mathbf{x}_j^\tau)$ for observation j at time τ, relative to technology P^i from period i, measured radially by the reciprocal of Shephard's (1970) output distance function, is given by $\theta_{j\tau}^i = \theta^i(\mathbf{y}_j^\tau, \mathbf{x}_j^\tau) = \sup\{\theta^i \mid (\theta^i \mathbf{y}_j^\tau, \mathbf{x}_j^\tau) \in P^i\}$. The Malmquist productivity index to compare the base period 0 with the subsequent period t for decision-making unit (DMU) j is

$$M_j(0, t) \equiv \theta_{j0}^0 / \theta_{jt}^0. \tag{1}$$

Here, a value of the Malmquist index greater than 1 indicates an improvement in productivity relative to

the base period. For econometric purposes, productivity change is measured using a logarithmic transformation of the index in (1). This transformed measure has the natural interpretation of a percentage change in productivity. Specifically,

$$\text{productivity change for firm } j \equiv \ln(\theta_{j0}^0) - \ln(\theta_{jt}^0). \quad (2)$$

To facilitate our analysis of the factors behind the productivity change in the public accounting industry, we first describe how productivity change is decomposed into two components. Productivity change for a firm j can be analyzed into two components by adding and subtracting $\ln(\theta_{jt}^t)$ in (2) and rearranging terms to yield

productivity change

$$\equiv \ln(\theta_{jt}^t/\theta_{jt}^0) + \ln(\theta_{j0}^0/\theta_{jt}^t)$$

$$\equiv \text{technical change} + \text{relative efficiency change}. \quad (3)$$

If the firm is efficient in both periods, productivity change is the same as technical change (Solow 1957). When inefficiencies are present, productivity change is driven by both technical change and relative efficiency change (Nishimizu and Page 1982).

The relationship in (3) is illustrated in Figure 1, where we assume that a single output $\mathbf{y}$ is produced from a single input $\mathbf{x}$ and analyze the change between a base period, denoted by superscript 0, and a subsequent period, denoted by superscript t. The monotone increasing concave production frontiers characterizing the boundaries of the production possibility sets P^0 and P^t, respectively, are represented as $\mathbf{y} = \phi^0(\mathbf{x})$ and $\mathbf{y} = \phi^t(\mathbf{x})$. To simplify exposition, we assume that the input level is the same for both periods. Consider

a firm that operated at point A_0 in the base period and moved to point A_t in period t. The maximal output level for the firm relative to base period and period t technologies, respectively, is represented by the points B_0 and B_t.

For this case, θ_{j0}^0 is XB_0/XA_0 and θ_{jt}^0 is XB_0/XA_t and productivity change is $\ln(XA_t/XA_0)$, the percentage change in the actual output from the base period to period t. Technical change is $\ln(XB_t/XB_0)$, the percentage change in the maximal output. Relative efficiency measured as the ratio of actual output to frontier output is XA_0/XB_0 in the base period and XA_t/XB_t in period t. Therefore, percentage relative efficiency change is $\ln((XA_t/XB_t)/(XA_0/XB_0))$. For small values of x, $\ln(1 + x)$ is approximated by x. Therefore, productivity change $\ln(XA_t/XA_0) = \ln(1 + (A_0A_t/XA_0)) \approx A_0A_t/XA_0$, technical change $\ln(XB_t/XB_0) \approx (A_0B_t - A_0B_0)/XA_0 = B_0B_t/XA_0$, and relative efficiency change $\ln((XA_t/XB_t)/(XA_0/XB_0)) \approx \{A_0B_0 - (A_0B_t - A_0A_t)\}/XA_0 = (A_0B_0 - A_tB_t)/XA_0$. The decomposition of productivity change into technical change and relative efficiency change described in (3) is seen to correspond to the relationship $A_0A_t = B_0B_t + (A_0B_0 - A_tB_t)$ between the line segments A_0A_t, B_0B_t, A_0B_0 and A_tB_t in Figure 1.

This decomposition of productivity change into technical change and relative efficiency change is valid under more general conditions, when multiple inputs change from the base period to the subsequent period (Fare et al. 1994). For a formal development of the statistical properties of the components of productivity change, and the derivation of the statistical tests based on these estimators, see Banker et al. (2002).

Figure 1   Productivity Change and Its Components
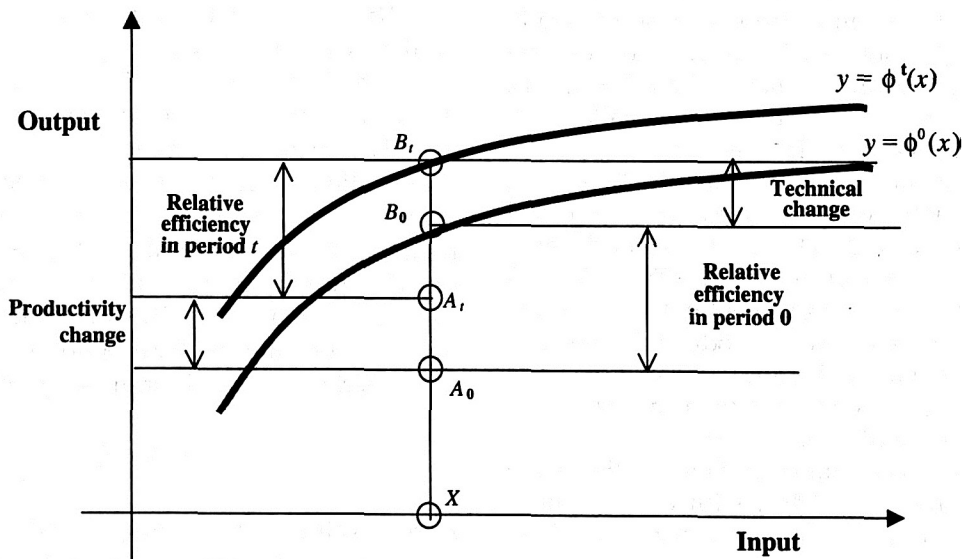
4. Research Hypotheses

U.S. labor productivity improved at an average annual rate of 2.4% from 1995 to 2000, compared to a rate of growth of 1.4% between 1973 and 1995 (Steindel and Stiroh 2001). Eight of the ten major sectors of the economy, with the exception of agriculture and mining, experienced accelerating productivity growth after 1995 (Stiroh 2001). While the service sector has had significantly lower productivity growth than the manufacturing sector, its productivity growth accelerated from annual growth of 0.5% during 1987–1995 to an annual growth of 1% during 1995–1999. Thus, the evidence at the macro level suggests that the public accounting industry, a part of the services sector, is likely to have experienced significant productivity growth during our sample period.

Stiroh (2001) finds that the industries experiencing the largest productivity growth in the late 1990s were the producers and most intensive users of IT. Investments in IT by clients spurred much innovation in the public accounting industry. Accounting firms assisted their clients in the computerization of their information systems. This also enabled the automation of many routine auditing tasks, and the accounting firms redeployed the freed human resources into high value-added consulting engagements. Competitive pressure motivated accounting firms in the industry to become leaner, more specialized, and more quality and customer oriented than before and to generate more revenue with their input resources.

A favorable environment for technical progress existed during the 1990s, when many accounting firms had the opportunity to develop unique and profitable new products and services and improve client service through total quality management and related programs (Mingle 1994). Many firms invested in IT training for their staff to meet the changing patterns in the demand for their services, offer better service, and increase efficiency (Melancon 1998). There was a great deal of consolidation in the industry to address the "one-stop shopping" needs of the consumers of professional accounting services. A recent survey suggests that CPA firms in the late 1990s reduced their reliance on traditional accounting, auditing, and tax services and moved into the practice of new assurance services and consulting services, as encouraged by the AICPA vision process (Rankin and Sharp 2000).

This favorable environment for technical progress in the industry could have either facilitated a dramatic improvement in the performance of a select few firms or led to an industrywide improvement in productive efficiency. Rogers (1985) estimates that for any given innovation, the innovators and the early adopters represent only about 16% of the total population. Rogers' model suggests that a small number of firms in the public accounting industry may have

exploited market opportunities and succeeded in substantially widening the gap between them and other firms in the industry. If a significant majority of firms in the industry fails to catch up with the relatively few firms that push out the production frontier when technical progress takes place in the industry, then the relative efficiency of the industry, as a whole, relative to the advancing best practice firms, goes down. This leads to our first set of research hypotheses pertaining to our expectations about the average changes in productivity and its components.

HYPOTHESIS 1A. *Significant improvement in productivity was experienced, on average, by firms in the public accounting industry between 1995 and 1999.*

HYPOTHESIS 1B. *Significant technical progress took place, on average, in the public accounting industry between 1995 and 1999.*

HYPOTHESIS 1C. *Significant decline in relative efficiency was experienced, on average, by firms in the public accounting industry between 1995 and 1999.*

What characterizes the first movers in the public accounting industry? Rogers (1985) identifies innovators and early adopters as those who have control of substantial financial resources, the ability to understand and apply complex technical knowledge, and the ability to cope with a high degree of uncertainty. Lieberman and Montgomery (1988) suggest that first-mover advantages in industries arise from three primary sources: technological leadership, preemption of assets, and buyer switching costs. Applying economic theories of product differentiation (Klein and Leffler 1981, Shapiro 1983) to the public accounting industry, Craswell et al. (1995) hypothesize and find positive returns to specialization. Markets with technological change are inherently imperfectly competitive (Schumpeter 1942), and potential competition in these markets does not ensure economic efficiency or lead to zero profits (Stiglitz 1987). Specialization leads to increasing returns and knowledge builds on itself (Romer 1987).

The above theoretical discussion suggests that the innovators and early adopters in the public accounting industry in the 1990s were likely to be those firms that expanded their consulting services, created one-stop shopping, developed value-based relationships, and started shifting their human resources from the traditional, low-margin revenue product areas of A&A and TAX into the relatively new, high-margin revenue product area of MAS. Lieberman and Montgomery (1988) suggest that the appropriate criterion for first-movership is market entry. We therefore use early emphasis in MAS characterized by a high percentage of revenues derived from MAS in 1995 as a measure of first-movership in the public accounting industry.

Given the differentiated, less-competitive market for MAS engagements, it is likely that firms that specialized in MAS were able to generate more revenue from their human resources than other firms that continued to focus on the more labor-intensive audit and assurance engagements. Jerris and Pearson (1996) provide some preliminary evidence that top-performing CPA firms, classified using simple ratios such as revenue per partner and revenue per professional, had a significantly higher share of revenue from MAS and a significantly lower share of revenue from tax services. The consulting side of the public accounting firms continued to be the cash cow for the industry during the late 1990s (*Wall Street Journal* 1997). As a consequence, accounting firms that moved into MAS earlier than others were able to raise the bar and push the production frontier forward more than firms that emphasized traditional services. This suggests that accounting firms that were leaders in providing MAS in the early and mid 1990s enjoyed significantly more productivity growth, contributed more to the technical progress, and were relatively more efficient than other firms in the public accounting industry. We summarize the above discussion in the form of our second set of hypotheses pertaining to differential patterns of changes in productivity and its components that are expected for firms emphasizing MAS.[5]

HYPOTHESIS 2A. *Firms that were leaders in MAS in 1995 experienced significantly higher productivity improvements over the next five years than other firms in the industry.*

HYPOTHESIS 2B. *Technical progress in the public accounting industry between 1995 and 1999 was predominantly due to firms that emphasized MAS in 1995.*

HYPOTHESIS 2C. *Relative efficiency change in the public accounting industry between 1995 and 1999 was higher for firms that emphasized MAS in 1995.*

The theory of innovation diffusion (Rogers 1985) categorizes those that immediately follow the early adopters as the early majority, who deliberate before adopting a new idea and interact frequently with peers. Lieberman and Montgomery (1988) list a set of first-mover disadvantages that are, in effect, advantages enjoyed by the early majority firms. They argue that immediate followers may benefit from the ability to free ride, the resolution of uncertainty, and the inability of first-movers to adapt to environmental change. The rapid advances in IT and structural

changes in the global economy during the 1990s contributed to highly volatile demands by the client organizations on CPA firms. The firms constituting the early majority may have benefited from the resolution of the uncertainty, understood more clearly the demands of the client organizations, and invested in IT training at a lower cost compared to the first-mover firms. Thus, there may have been some unique advantages for those firms that immediately followed first-movers into MAS, as well. Consistent with our operationalization of first-movers as those that emphasized MAS in 1995, we identify the early majority as those that experienced a significant increase in the percentage of revenues derived from MAS between 1995 and 1999. We make the following hypotheses.

HYPOTHESIS 3A. *Firms that generated significant growth in percentage revenue derived from MAS between 1995 and 1999 experienced significantly higher productivity improvements than those that had low or no growth in MAS.*

HYPOTHESIS 3B. *Firms that experienced significant growth in percentage revenue derived from MAS between 1995 and 1999 contributed to technical progress in the public accounting industry.*

HYPOTHESIS 3C. *Firms that generated significant growth in percentage revenue derived from MAS between 1995 and 1999 experienced significantly higher relative efficiency change than those that had low or no growth in MAS.*

Thus, we expect that the performance of the early majority was better than that of those that did not immediately follow the first-movers, and we expect that even among the first-movers, those that continued to enhance their MAS emphasis performed better than those that did not.

5. Estimation Models
We estimate the production correspondence for each year $t = 1995, \ldots, 1999$ using data on human resource inputs and different components of service revenue for accounting firms for the period 1995–1999. Prior studies in production economics have used both parametric and nonparametric methodologies to measure productivity change in various industries, such as railroads, banking, and pharmaceuticals (Caves et al. 1981, Fare et al. 1994, Wheelock and Wilson 1999). Parametric methods accommodate well-specified statistical tests of productivity change but require explicit assumptions on the structure of the production correspondence. Most nonparametric methods measure productivity change under very general assumptions about the structure of the production correspondence,

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[5] The tests of hypotheses presented in 2a, 2b, and 2c are joint tests of the assumption that the differentiators in the public accounting firms were those that emphasized MAS earlier than others and that the differentiators experienced greater performance improvement than others in the industry.

but their usefulness is limited by the fact that they lack a statistical foundation.

We use the nonparametric estimation procedures based on data envelopment analysis (DEA) to estimate technical change, relative efficiency change, and productivity change. The original DEA models focused primarily on the estimation of the production frontier and relative efficiency. They did not explicitly consider the statistical properties of the DEA estimators. Subsequently, Banker (1993) showed that while the DEA estimator of the frontier value is biased for finite samples, the bias vanishes for large samples. Thus, the DEA estimator exhibits the desirable asymptotic property of consistency. More recently, Banker et al. (2002) have shown that the sample mean and median of the firm-specific estimators of technical change, relative efficiency change, and productivity change derived from the DEA estimators of the production frontier values in a base period and a subsequent period are consistent estimators of the population mean and median of these change variables. They also prove that the asymptotic distributions of test statistics derived from the DEA estimators to evaluate hypotheses on population mean and median are the corresponding distributions of test statistics based on the true frontier outputs and true efficiencies if they were known. Here, we present the first empirical application of these new methods.

We denote the base year and a subsequent year that is compared with the base year by the subscripts 0 and t, respectively. Let $(\mathbf{x}_{j\tau}, \mathbf{y}_{j\tau})$, $\tau = 0, t$; $j = 1, \dots, N$ be the observed sample of N pairs of input-output vectors. Following Banker et al. (2002), we first estimate θ_{j0}^0 and θ_{jt}^t, the inefficiency values for the jth firm corresponding to base period and period t input-output vectors, respectively. Then, we estimate θ_{jt}^0, the inefficiency of firm j's period t input-output vector relative to the base period production possibility set. We denote these estimators as $\hat{\theta}_{j0}^0$, $\hat{\theta}_{jt}^t$, and $\hat{\theta}_{jt}^0$, respectively. Firm-specific estimators $\hat{g}_j$, $\hat{b}_j$, and $\hat{r}_j$, productivity change, technical change, and relative efficiency change, respectively, are then determined as functions of the various inefficiency estimators as follows:

$$\hat{g}_j = \ln \frac{\hat{\theta}_{j0}^0}{\hat{\theta}_{jt}^0}, \quad \hat{b}_j = \ln \frac{\hat{\theta}_{jt}^t}{\hat{\theta}_{jt}^0}, \quad \hat{r}_j = \ln \frac{\hat{\theta}_{j0}^0}{\hat{\theta}_{jt}^t}. \quad (4)$$

We briefly describe below the DEA programs used to estimate the inefficiency values. The estimation of θ_{j0}^0 and θ_{jt}^t is done using the Banker, Charnes, and Cooper (BCC) (1984) model as illustrated below by the linear program for estimating θ_{j0}^0:

$$\hat{\theta}_{j0}^0 = \arg\max\left\{\hat{\theta} \,\middle|\, \sum_{k=1}^{N} \lambda_{k0}^0 \mathbf{y}_{k0} \geq \hat{\theta}\mathbf{y}_{j0}; \sum_{k=1}^{N} \lambda_{k0}^0 \mathbf{x}_{k0} \leq \mathbf{x}_{j0}; \right.$$
$$\left. \sum_{k=1}^{N} \lambda_{k0}^0 = 1, \lambda_{k0}^0 \geq 0 \;\forall k = 1, \dots, N \right\}. \quad (5)$$

A similar program is used to estimate θ_{jt}^t from the input and output sample data for year t.

The estimation of θ_{jt}^0, the inefficiency of firm j's period t input-output vector relative to the base period production possibility set, is based on the following linear program:

$$\hat{\theta}_{jt}^0 = \arg\max\left\{\hat{\theta} \,\middle|\, \sum_{k=1}^{N} \lambda_{k0}^0 \mathbf{y}_{k0} \geq \hat{\theta}\mathbf{y}_{jt}; \sum_{k=1}^{N} \lambda_{k0}^0 \mathbf{x}_{k0} \leq \mathbf{x}_{jt}; \right.$$
$$\left. \sum_{k=1}^{N} \lambda_{k0}^0 = 1, \lambda_{k0}^0 \geq 0 \;\forall k = 1, \dots, N \right\}. \quad (6)$$

Note that the difference between the above model and the traditional BCC model in (5) is that the observation under evaluation is not included in the reference set of year 0 observations for the constraints in (6). The idea is to compare the maximal output achievable with period t input and base period 0 production technology with the actual output achieved in period t. This is similar to the superefficiency model (Banker et al. 1989), so the DEA inefficiency estimator $\hat{\theta}_{jt}^0$ may take a value less than 1, unlike the DEA estimator $\hat{\theta}_{j0}^0$, which is always greater than or equal to 1. Also, if the input-output vector for the observation under evaluation is outside the range of the input-output vectors contained in the referent set, it is not feasible to solve the program in (6), and the value of $\hat{\theta}_{jt}^0$ is set equal to 1.

6. Estimation Results

We first use the DEA program in (5) to estimate $\hat{\theta}_{jt}^t$, the firm-specific inefficiencies for each year in the time period 1995–1999, respectively, using contemporaneous observed data on input-output vectors. These inefficiency estimators are then combined with the actual service revenues to calculate maximal deflated total revenue, given the service mix. Table 2 presents descriptive statistics for the maximal deflated total revenue both on an absolute basis and on a per employee basis for 1995 and 1999. For comparison purposes, the cross-sectional distributions of actual total deflated revenue and actual deflated revenue per employee are also reproduced from Table 1. The estimators for relative efficiency for 1995 and 1999 are calculated as the reciprocals of the inefficiency estimators $\hat{\theta}_{jt}^t$, $t = 1995$ and 1999, respectively.

There is some preliminary evidence that the public accounting industry production possibility set shifted outward between 1995 and 1999. The average maximal deflated revenue per employee based on the 1995 technology is $109,000, and the corresponding value based on 1999 technology is $121,000. The maximal revenue per employee is also higher in 1999 than in 1995 at all quartile points. Ignoring changes in the mix

Table 2   Descriptive Statistics on DEA Estimators of Maximal Revenue and Relative Efficiency for 1995 and 1999

Variables	Year	Mean	Std. dev.	25%	Median	75%
Revenue	1995	$269.66 M	$841.71 M	$12.25 M	$16.90 M	$31.80 M
	1999	$485.28 M	$1,544.76 M	$17.74 M	$25.24 M	$55.75 M
Revenue per employee	1995	$0.095 M	$0.021 M	$0.082 M	$0.091 M	$0.109 M
	1999	$0.104 M	$0.025 M	$0.090 M	$0.103 M	$0.114 M
Maximal revenue	1995	$275.6 M	$842.9 M	$14.63 M	$20.37 M	$43.59 M
	1999	$495.6 M	$1,542.5 M	$20.45 M	$28.67 M	$69.78 M
Maximal revenue per employee	1995	$0.109 M	$0.019 M	$0.097 M	$0.110 M	$0.119 M
	1999	$0.121 M	$0.022 M	$0.107 M	$0.121 M	$0.135 M
Relative efficiency	1995	0.884	0.138	0.771	0.933	1
	1999	0.864	0.143	0.753	0.894	1

of human resources, the maximal deflated revenue increased between 1995 and 1999, suggesting technical progress in the public accounting industry. The 11% increase in mean maximal deflated revenue per employee is higher than the 9.5% increase in mean actual deflated revenue per employee, suggesting that technical progress may have been greater than productivity improvement; the difference is explained by the decline in average relative efficiency from 88.4% in 1995 to 86.4% in 1999.

The highly skewed revenue distribution suggests that it is important to understand the influence of Big 5 firms on the cross-sectional distributions of the revenue and efficiency variables. Table 3 provides a comparison of input and output characteristics, DEA estimators of maximal revenue, and relative efficiency for 1995 and 1999 between Big 5 and non-Big 5 firms. The Big 5 firms had significantly higher maximal revenue per employee (mean value of $133,000 when compared to mean value of $106,000) and significantly higher efficiency (mean value of 0.995 when compared to mean value of 0.875) than the non-Big 5 firms in 1995. They also enjoyed significantly higher maximal revenue per employee and efficiency than the non-Big 5 firms in 1999. Interestingly, the changes in both maximal revenue and relative efficiency for the Big 5 firms were not different from their counterparts for the non-Big 5 firms. Overall, the statistics in Table 3 suggest that the systematic differences between Big 5 and non-Big 5 firms are more of a concern in "levels" studies than in a study like ours that focuses on "changes."

Table 4 presents the results of nonparametric and parametric tests of Hypotheses 1a, 1b, and 1c. The estimation of productivity change and technical change requires the estimation of firm-specific inefficiency for year t input-output vectors based on year 0 or base period technology. This estimation of firm-specific inefficiency based on the base period technology corresponding to the actual input-output vector in a subsequent period is performed using the DEA program in (6).

Using the definition of productivity change in (4), we estimate the average productivity change for the public accounting industry between 1995 and 1999 to be 9.5%. This result compares well with the estimate of 10.2% for the same period documented by Banker et al. (2003) using parametric methodology. Our nonparametric procedure provides consistent estimators of productivity change under the maintained assumption of a monotone and convex production technology (Banker et al. 2002). The average as well as median productivity changes are significantly different from zero at the 1% level.[6] The productivity growth for the public accounting industry is comparable to the growth for the retail trade sector (12.5%) and the commercial banking sector (7.5%) during the same period (Bureau of Labor Statistics 2002).[7] We also find systematic and sequential improvement in productivity and technical progress throughout the sample period, as seen in Table 4. The decline in relative efficiency of 2.5% during the sample period 1995–1999 was entirely due to a decline of 2.9% during the period 1997–1998.

We explained in §3 the problems associated with using a simple metric such as growth in revenue per employee as a measure of productivity change for public accounting firms. Observed correlations

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[6] Our DEA estimations are based on the BCC model (Banker et al. 1984), which allows variable returns to scale. As a consequence, our measure of productivity change consists only of pure technical change and pure relative efficiency change components. We also estimated productivity change using the Charnes, Cooper, and Rhodes (CCR) model (Charnes et al. 1978) that imposes constant returns to scale. In this case, the components of productivity change are technical change, relative efficiency change, and scale efficiency change. The mean change in scale efficiency is −2.1%, and it is significantly different from zero in parametric tests but not in nonparametric tests. The Pearson and Spearman correlations between the BCC-based measure of productivity change and the CCR-based measure of productivity change are 0.95 and 0.94, respectively.

[7] Our choice of industries for comparative purposes is limited to the retail sector and commercial banks because the Bureau of Labor Statistics provides productivity data at the three-digit SIC level for very few service industries. Comparisons with multifactor productivity measures are relevant because nonlabor inputs comprise a negligible proportion of the total costs.

Table 3   Big 5 and Non-Big 5 Comparison of Service Revenue, Human Resource, and DEA Estimators of Maximal Revenue and Relative Efficiency for 1995 and 1999

Variables	Year	Big 5		Non-Big 5	
		Mean	Median	Mean	Median
Revenue	1995	$3,073.64 M***	$2,974.01 M***	$32.04 M	$15.20 M
	1999	$5,654.04 M***	$5,831.50 M***	$47.26 M	$23.78 M
A&A (%)	1995	41.3*	43**	50.21	51
	1999	30.4**	35**	43.35	43
TAX (%)	1995	19.8**	20**	30.68	30
	1999	18.4***	20**	30.20	28
MAS (%)	1995	38.9***	36**	19.11	18
	1999	51.2***	45**	26.45	25
Partners	1995	1,696.2***	1,529***	44.80	22
	1999	2,262.8***	2,117***	54.25	30
Professionals	1995	16,599.8***	14,195***	224.71	121
	1999	27,402.2***	21,800***	314.22	154
Others	1995	5,857.8***	5,631***	81.75	38
	1999	8,958.8***	8,935***	108.10	52
Revenue per employee	1995	$0.133 M**	$0.137 M**	$0.092 M	$0.090 M
	1999	$0.154 M**	$0.164 M**	$0.100 M	$0.100 M
Maximal revenue	1995	$3,085.45 M***	$2,974.01 M***	$37.43 M	$19.15 M
	1999	$5,654.04 M***	$5,831.50 M***	$58.44 M	$25.80 M
Maximal revenue quad per employee	1995	$0.133 M**	$0.137 M**	$0.106 M	$0.109 M
	1999	$0.154 M**	$0.164 M**	$0.118 M	$0.120 M
Relative efficiency	1995	0.995***	1.000**	0.875	0.920
	1999	1.000***	1.000**	0.852	0.879

* For the variable under consideration, indicates significant difference between the means (medians) of the two groups at the 10% level; ** significant at the 5% level; *** significant at the 1% level for two-sided hypothesis tests.

between the growth in revenue and the three performance measures provide additional evidence on its limitations as a growth measure. The correlations between the growth in revenue per employee and productivity change and relative efficiency change are only 0.23 and 0.26, respectively. The correlation between technical progress and growth in revenue per employee is zero. It appears that the observed equality of the mean growth in revenue per employee and the average productivity change is only a coincidence.

The two components of productivity change, technical change and relative efficiency change, appear to have impacted productivity change in opposite ways. We find that mean (median) technical change in the public accounting industry is 12% (6.9%), significantly

Table 4   Tests of Productivity Change, Technical Change, and Relative Efficiency Change in the Public Accounting Industry Between 1995 and 1999

Variable and predicted sign	Period from–to	Mean	P-value for T-test for mean = 0[a]	Median	P-value for sign test for median = 0[a]	P-value for sign rank test for median = 0[a]
Productivity change (+)	1995–1996	0.035***	0.01	0.034***	0.01	0.00
	1996–1997	0.052***	0.00	0.038***	0.00	0.01
	1997–1998	0.029*	0.09	0.032**	0.05	0.04
	1998–1999	0.032***	0.01	0.036***	0.00	0.00
	1995–1999	0.095***	0.00	0.076	0.02	0.00
Technical change (+)	1995–1996	0.027***	0.00	0.006**	0.05	0.01
	1996–1997	0.060***	0.00	0.039***	0.00	0.00
	1997–1998	0.058***	0.00	0.035***	0.00	0.00
	1998–1999	0.027***	0.00	0.011***	0.00	0.00
	1995–1999	0.120***	0.00	0.069***	0.00	0.00
Change in relative efficiency (−)	1995–1996	0.008	0.74	0	0.96	0.89
	1996–1997	−0.008	0.28	0	0.22	0.19
	1997–1998	−0.029**	0.05	0	0.16	0.06
	1998–1999	0.004	0.63	0	0.62	0.72
	1995–1999	−0.025*	0.10	0	0.38	0.17

[a] The *p* values are for testing whether productivity or technical change is significantly greater than zero and whether relative efficiency change is significantly less than zero. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level for one-sided hypothesis tests.

greater than zero based on both nonparametric and parametric tests. There is strong support for the hypothesis that significant technical progress took place in the public accounting industry. The mean relative efficiency change is −2.5%, significantly less than zero only at the 10% level. Also, the median relative efficiency change of 0 is not significantly different from zero. Together, the evidence indicates that the improvement in productivity is due almost entirely to significant technical progress and that the industry experienced very little change in relative efficiency.

The results in Table 4 suggest that while technological improvement afforded all firms opportunities to improve productivity, not all firms exploited these opportunities equally. We hypothesized earlier that accounting firms that focused on building up the MAS part of the business contributed to the technical progress and enjoyed greater productivity improvement. We also expect the accounting firms that emphasized MAS to have experienced significant improvement in relative efficiency when compared to other firms.

7. Impact of Management Advisory Services

The frontier firms are those firms that have a relative efficiency value of 1. We first examine whether there was any systematic difference in initial MAS emphasis between frontier and nonfrontier firms at the beginning of our sample period. There were 26 (out of 64) firms on the 1995 production frontier, and the mean (median) frontier firm derived 21.9% (20%) of revenues from MAS as compared to 19.8% (18%) for the nonfrontier or interior firms. These differences are not significantly different from zero, indicating that there is no systematic association between initial MAS emphasis and initial production efficiency. We also find that the correlations of initial relative efficiency with productivity change and technical change are not significantly different from zero. Initial efficiency and relative efficiency change have a significant correlation of 0.37, suggesting that firms that were more efficient in 1995 were more likely to enhance their edge over those that were not.

We investigate cross-sectional variations in productivity change, technical change, and relative efficiency change in a multivariate setting, where both the initial level as well as the change between 1995 and 1999 in percentage revenue from MAS and A&A are posited to explain the various change measures. We regress each of the three change measures on percentage revenue derived from MAS in 1995, percentage revenue derived from A&A in 1995, change in percentage revenue from MAS between 1995 and 1999, and change in percentage revenue from A&A between 1995 and

1999.[8] We specify the following system of three regression equations:

change measure

$$= \beta_0 + \beta_1 * MAS\% + \beta_2 * A\&A\% + \beta_3 * \Delta MAS\%$$
$$+ \beta_4 * \Delta A\&A\% + \varepsilon_i, \qquad (7)$$

where change measure = productivity change, technical change, and relative efficiency change. We leave TAX% and ΔTAX% out of the specification because the three level variables—A&A%, TAX%, and MAS%—add up to a total of 100 and the three change variables add up to zero. Therefore, the coefficient estimates are interpreted as relative to TAX% and ΔTAX%.

The correlation between MAS% and ΔMAS% is zero. This provides support to our research design, which interprets these measures as distinct proxies for first-mover firms and the early majority that followed the first-movers, respectively. Because we expect that firms with high MAS% (Hypotheses 2a, 2b, and 2c) and with a positive change in MAS% from 1995 to 1999 (Hypotheses 3a, 3b, and 3c) experienced higher productivity change, contributed more to technical progress, and improved their relative efficiency, we expect the regression coefficients β_1 and β_3 to be positive and significantly different from zero. We have no a priori reason to expect that emphasizing A&A as opposed to TAX should have any impact on any of the three change measures. Therefore, we do not expect the coefficients β_2 and β_4 to be significantly different from zero. However, we expect that $(\beta_1 - \beta_2)$ and $(\beta_3 - \beta_4)$ will be positive because MAS is likely to have a more positive impact than A&A for both the first-mover firms as well as the early majority firms.

Because the three regressions in (7) have the identical set of explanatory variables, we can estimate the system with possibly correlated error terms using ordinary least squares (OLS). OLS provides efficient estimators in this special case (Greene 2000, Chapter 15, §4.2). The regression results in Table 5 indicate that productivity change is positively associated with both the early leadership in MAS as well as an increased emphasis on MAS. The significant coefficient of 0.0114 on MAS% indicates that, ceteris paribus, a first-mover firm with a 1% higher MAS% in 1995 enjoyed an extra productivity growth of 1.14%. The significant coefficient of 0.0097 on ΔMAS% indicates that a late-mover firm with an extra growth of 1% in MAS% from 1995 to 1999 experienced an incremental productivity growth of 0.97%. The coefficients

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[8] See Banker and Natarajan (2004) for a proof of conditions under which this two-step procedure involving DEA followed by a regression yields consistent estimators of the regression coefficients.

Table 5 OLS Regression Results for the Determinants of Productivity Change, Technical Change, and Relative Efficiency Change in the Public Accounting Industry

Change measure $= \beta_0 + \beta_1 * \text{MAS\%} + \beta_2 * \text{A\&A\%} + \beta_3 * \Delta\text{MAS\%} + \beta_4 * \Delta\text{A\&A\%} + \varepsilon_i, i = 1, \ldots, 64.$
Each row corresponds to a separate cross-sectional regression.

Dependent variable	Parameter estimates (p values in parentheses, one-sided, and in italics if sign is predicted)							
	Intercept	β_1 (+)	β_2 (0)	P value for test of $\beta_1 = \beta_2$	β_3 (+)	β_4 (0)	P value for test of $\beta_3 = \beta_4$	Adjusted R-square
Productivity change	−0.4267 (0.07)	0.0114*** (*0.00*)	0.0044 (0.23)	*0.01*	0.0097** (*0.03*)	0.0007 (0.91)	*0.02*	0.2012
Technical change	−0.4209 (0.01)	0.0115*** (*0.00*)	0.0047* (0.07)	*0.00*	0.0133*** (*0.00*)	0.0047 (0.23)	*0.00*	0.3911
Relative efficiency change	−0.0057 (0.97)	−0.0002 (*0.97*)	−0.0003 (0.90)	*0.47*	−0.0036 (*0.67*)	−0.0040 (0.34)	*0.45*	−0.0421

Notes. Dependent variable is the firm-specific value of the relevant change measure over the period 1995 to 1999. Variable definitions: MAS% = proportion of MAS revenue in 1995; A&A% = proportion of A&A revenue in 1995; ΔMAS% = change in proportion of MAS revenue from 1995 to 1999; ΔA&A% = change in proportion of A&A revenue from 1995 to 1999.
* Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level for one-sided hypothesis tests.

are not significantly different from zero, suggesting that first-mover firms and late-mover firms derived similar advantages.

In contrast to the significantly positive coefficients on MAS% and ΔMAS%, the coefficients on A&A% and ΔA&A% are not significant. An F-test on the equality of the regression coefficients on MAS% and A&A% rejects the null hypothesis that these coefficients are equal. The difference of 0.0090 between the coefficients on ΔMAS% and ΔA&A% is also significantly positive. Overall, the results provide strong support for Hypotheses 2a and 3a, that firms that initially emphasized MAS by 1995 and those that focused on an MAS growth strategy during 1995–1999 experienced significantly higher productivity improvement than other firms in the industry that focused on traditional services such as A&A and TAX.

In a similar vein, we observe significant positive association between technical change and the initial level of MAS% as well as change in MAS%. Specifically, a first-mover firm with a 1% higher MAS% in 1995 contributed an extra 1.15% to technical progress, and a late-mover firm with an extra growth of 1% in MAS% from 1995 to 1999 contributed an extra 1.33% to the upward shift in the frontier. We also find that the difference of 0.0068 between the coefficients on MAS% and A&A%, as well as the difference of 0.0086 between the coefficients on ΔMAS% and ΔA&A%, are significantly positive. This supports Hypotheses 2b and 3b, that accounting firms that were early movers into MAS and those that emphasized growth in MAS as a differentiation strategy were the ones that contributed significantly to the technical progress in the public accounting industry rather than those that emphasized traditional services such as A&A and TAX. We observe no significant association between relative efficiency change and measures of early

leadership in MAS and increased emphasis on MAS. The results do not support Hypotheses 2c and 3c.

Interestingly, the regression results in Table 5 reveal a significantly positive coefficient on A&A when the dependent variable is technical change. The results suggest a rank ordering among the services in terms of their effect on productivity. Specifically, it appears that firms that channeled additional efforts to auditing and assurance services achieved greater productivity gains when compared to firms that chose to emphasize tax instead. Therefore, the rank order seems to have been MAS followed by A&A, and then TAX for maximizing revenue generated from human resources employed by CPA firms.

8. Robustness Checks

8.1. Number of Branches as a Proxy for Capital Employed

The three inputs that we use in our analysis do not include measures of capital due to the nonavailability of firm-specific data on capital during the sample period. Our study is not alone in exclusively focusing on labor inputs while examining the production function of public accounting firms. All prior studies on audit productivity, such as O'Keefe et al. (1994), Stein et al. (1994), Banker et al. (2003), and Dopuch et al. (2003), have used similar data. However, we repeated the calculations for changes in productivity, technical, and relative efficiency using a four-input-three-output specification, with the number of branches included as an additional input variable to proxy for capital. The results were very similar to those estimated using the three-input-three-output specification. The mean (median) productivity improvement between 1995 and 1999 is 11.8% (10.4%), and this is almost entirely due to technical progress. The mean (median)

technical change is 14.9% (8.5%). The correlations between the change measures calculated using the four-input-three-output specification and the three-input-three-output specification are 0.95, 0.92, and 0.95 for productivity, technical, and relative efficiency change, respectively. We obtain near-identical regression results when we use the relevant change measure from the four-input-three-output model as the dependent variable.

8.2. Impact of Omitted IT Capital Variable

We assess the approximate magnitude of the impact of the omission of IT-related capital expenditures on our estimates of productivity, technical, and relative efficiency change. For this purpose, we impose additional structure on our analysis and use survey data on the change in IT spending in the services industry between 1995 and 1999 together with estimates of output elasticity of computer capital (Brynjolfsson and Hitt 1996). To maintain consistency with the single-output structure of the above study, we consider $\ln y_t = \ln \phi^t(\mathbf{x}_t) + \alpha_K \ln K_t - \varepsilon_t$, $t = 0, 1$ as the functional relationship characterizing the generation of total revenue, $\mathbf{y}_t$, in period t from human resource input vector, $\mathbf{x}_t$ and IT capital input, K_t. Here the base period is denoted by $t = 0$ and a subsequent period by $t = 1$, and α_K represents the output elasticity parameter associated with IT capital. In the above setup, using (2), productivity change estimated using the full set of inputs that includes labor as well as IT capital is

productivity change measured with full set of inputs

$$= \left\{ \ln \mathbf{y}_1 - \ln \phi^0(\mathbf{x}_1) - \alpha_K \ln K_1 \right\}$$
$$\quad - \left\{ \ln \mathbf{y}_0 - \ln \phi^0(\mathbf{x}_0) - \alpha_K \ln K_0 \right\}$$
$$= \left\{ \ln(\mathbf{y}_1/\phi^0(\mathbf{x}_1)) - \ln(\mathbf{y}_0/\phi^0(\mathbf{x}_0)) \right\} - \alpha_K \ln(K_1/K_0)$$
$$= \text{productivity change with only human}$$
$$\quad \text{resource inputs} - \alpha_K \ln(K_1/K_0). \quad (8)$$

Because output elasticity of IT capital α_K is positive, productivity change measured using only human resource inputs overstates the actual productivity change when IT capital input increases over time. Further, the technical change estimator is unbiased in this particular case because α_K, which represents the output elasticity parameter associated with IT capital, is the same in periods 0 and 1. Because technical change and relative efficiency change add up to productivity change, the estimated relative efficiency change measure also overstates the actual relative efficiency change when IT capital increases over time.

We assess the bias in productivity change for the median firm in our sample. We estimate information services spending in 1995 and 1999 for the

median firm in our sample to be $0.617 million and $0.714 million, respectively.[9] Based on Brynjolfsson and Hitt (1996), we estimate that IT capital increased by 37% between 1995 and 1999 (i.e., $K_1/K_0 = 1.37$) and that revenue elasticity of IT capital (α_K) is 0.0169. Therefore, the bias in the productivity change is $0.0169 * \ln(1.37) = 0.005$, compared to the 0.058 median estimated productivity change using total revenue as the single output and the three human resource inputs.[10] Because the Big 5 firms are the biggest users of IT in the public accounting industry, we also collect data on information services spending for three of the Big 5 firms in our sample for the years 1995 and 1996 from the *Information Week* 500 annual surveys.[11] We estimate the average bias in productivity change to be only 0.006 for Ernst & Young, Price Waterhouse Coopers, and KPMG Peat Marwick.

8.3. Inclusion of Big 5 Firms

It is possible that the production correspondence at the scale levels achieved by Big 5 firms may be very different from that for non-Big 5 firms. Therefore, we check the sensitivity of our results by restricting our attention to the non-Big 5 firms and repeat the estimation of the public accounting industry's production function in 1995 and 1999 and estimate productivity, technical, and relative efficiency change.[12] The results (not reported here) are similar in a broad sense to those based on the full sample with some minor differences. The median (mean) productivity change is higher at 13.0% (15.5%), compared to 7.6% (9.5%) for the full-sample. Similar to the full-sample analysis, we also find that technical progress contributed significantly to the productivity change. The multivariate tests based on OLS regressions confirm that the level of MAS% in 1995 and the growth in MAS% are significantly positively associated with improvement in productivity and technical progress.[13] The evidence once again indicates that the rank order for investment importance is MAS, A&A, and TAX.

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[9] Information services spending was 3.65% of total corporate revenue in 1995 and 2.83% in 1999 in the services sector (Center for Research on Information Technology and Organizations, University of California, Irvine).

[10] We use the productivity change estimate based on the one-output-three-input model because Brynjolfsson and Hitt's estimate of revenue elasticity of IT capital is based on a single-output model. The estimated productivity change with our three-output-three-input model is 0.076.

[11] Reliable data are not available for Arthur Andersen and Deloitte & Touche.

[12] The average relative efficiency of the Big 5 firms was 0.995, and it increased to 1 in 1999.

[13] We also formally test whether the Big 5 are different by including intercept and slope dummies in the full-sample regressions where the dummy takes on a 1 if the firm is a Big 5 firm and 0 otherwise. We find that the Big 5 dummy is not significant overall across the various terms.

8.4. Aggregation of the Three Human Resource Input Measures

We also investigate the sensitivity of our results to aggregating the three inputs into a single measure of total employees. High Pearson and Spearman correlations for the three labor inputs for all five years of our sample period suggest that a simple total head count as a single input may yield insights similar to those provided by the analysis based on three inputs.[14] We compared our three-output-three-input specification against a three-output-total-employees specification. We find no difference in univariate comparisons of the performance measures. However, multivariate regression results based on the total-employees specification are counter-intuitive in indicating a *negative* association between increase in relative efficiency and increase in MAS focus. The mix of the three labor inputs has changed significantly over time, and in ignoring this shift, the total-employees specification may provide misleading results.

8.5. Parametric Form for the Production Function

We also estimate the production function for each year by imposing a translog functional form to relate total revenue and the three human resource inputs. We cannot carry out our analysis using a multiple-output parametric form because output prices are not available for the three different types of accounting services. Specifically, OLS regressions of the type

$$\ln(\text{total revenue})$$
$$= \beta_0 + \beta_1 \ln(\text{PARTNERS}) + \beta_2 \ln(\text{PROFESSIONALS})$$
$$+ \beta_3 \ln(\text{OTHERS}) + \beta_{11} (\ln(\text{PARTNERS}))^2$$
$$+ \beta_{22} (\ln(\text{PROFESSIONALS}))^2 + \beta_{33} (\ln(\text{OTHERS}))^2$$
$$+ \beta_{12} \ln(\text{PARTNERS}) \ln(\text{PROFESSIONALS})$$
$$+ \beta_{23} \ln(\text{PROFESSIONALS}) \ln(\text{OTHERS})$$
$$+ \beta_{31} \ln(\text{OTHERS}) \ln(\text{PARTNERS}) + \varepsilon \quad (9)$$

are run and regression coefficients and residuals corresponding to each year are estimated. Firm-specific productivity, technical and relative efficiency change estimators for the periods 1995–1996, 1996–1997, 1997–1998, and 1998–1999 are estimated by combining the results of these regressions. Statistical tests comparing the mean and median of the various change measures estimated using the translog form with their counterparts estimated using DEA reveal some differences. Specifically, translog-based technical change estimates are significantly higher than DEA-based technical change for the 1996–1997 and 1998–1999 periods and significantly lower for the 1997–1998 period. In contrast, DEA-based relative efficiency

change estimates are higher than their translog-based counterparts for 1996–1997 and lower during 1998–1999. These two countervailing effects lead to productivity change estimates being not significantly different under the two methods.

9. Concluding Remarks

The public accounting industry in the United States went through a significant transformation during the late 1990s. There is, however, little empirical evidence available on whether the changes that took place significantly altered the production function of the public accounting industry. Using a balanced panel of data from 64 of the 100 largest public accounting firms in the United States from 1995 to 1999, we estimated productivity change and technological shifts in the public accounting industry.

The productivity of the average firm in our sample improved by 9.5% between 1995 and 1999. The productivity improvement was primarily due to 12% technical progress in the industry production function, offset in part by a decline in relative efficiency. Firms that were early movers into MAS and those that have been aggressively increasing their MAS business enjoyed greater productivity growth than their peers and also significantly contributed to the technical progress in the industry.

There is considerable debate among academics, practitioners, regulators, and legislators about the considerable emphasis many accounting firms had placed on increasing client advisory services. Much of this debate has focused on the potential conflict of interest that may arise when a CPA firm is retained as both an auditor and a management advisor. This has led to some accounting firms divesting their MAS divisions or setting them up as independent companies. Our analysis indicates that there is another dimension to this controversy. Public accounting firms will need to develop new services in the attest and tax areas or improve productivity in these traditional services if they do not provide MAS because of regulatory pressure. This is because the profitability of the CPA firms has been sustained in recent years largely by the impact that MAS have had on their productivity.

References
Banker, R. D. 1993. Maximum likelihood, consistency and data envelopment analysis: A statistical foundation. *Management Sci.* 39(10) 1265–1273.
Banker, R. D., R. Natarajan. 2004. Evaluating contextual variables affecting productivity using data envelopment analysis. Working paper, University of California at Riverside, Riverside, CA, and The University of Texas at Dallas, Dallas, TX.

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[14] The Pearson correlations ranged from 0.88 to 0.97, and the Spearman correlations ranged from 0.60 to 0.80.

Banker, R. D., H. Chang, R. Cunningham. 2003. The public accounting industry production function. *J. Accounting Econom.* **35** 255–281.

Banker, R. D., H. Chang, R. Natarajan. 2002. Nonparametric analysis of productivity change and technical progress. Working paper, The University of Texas at Dallas, Dallas, TX.

Banker, R. D., A. Charnes, W. W. Cooper. 1984. Models for the estimation of technical and scale inefficiencies in data envelopment analysis. *Management Sci.* **30** 1078–1092.

Banker, R. D., S. Das, S. Datar. 1989. Analysis of cost variances for management control in hospitals. *Res. Governmental Nonprofit Accounting* **5** 269–291.

Brynjolfsson, E., L. Hitt. 1996. Paradox lost? Firm-level evidence on the returns to information systems spending. *Management Sci.* **42** 541–558.

Bureau of Labor Statistics. 2002. Productivity and costs by industry, 2000. USDL 02-237. U.S. Department of Labor, Washington, D.C.

Caves, D. W., L. R. Christensen, J. A. Swanson. 1981. Productivity growth, scale economies, and capacity utilization in U.S. railroads, 1955–74. *Amer. Econom. Rev.* **71**(5) 994–1002.

Charnes, A., W. W. Cooper, E. Rhodes. 1978. Measuring the efficiency of decision making units. *Eur. J. Oper. Res.* **2**(6) 429–444.

Chatterjee, D., V. Richardson, R. Zmud. 2001. Examining the shareholder wealth effects of announcements of newly created CIO positions. *MIS Quart.* **25**(1) 43–70.

Craswell, A., J. R. Francis, L. Taylor. 1995. Auditor brand name reputations and industry specializations. *J. Accounting Econom.* **20** 297–322.

Davis, M. 1998. The big picture. *Accounting Today* (October) 12–25.

Dopuch, N., M. Gupta, D. Simunic, M. Stein. 2003. Production efficiency and the pricing of audit services. *Contemporary Accounting Res.* **20**(1) 47–77.

Elliot, R. K. 1992. The third wave breaks on the shores of accounting. *Accounting Horizons* **6**(2) 61–85.

Fare, R., S. Grosskopf, M. Norris, Z. Zhang. 1994. Productivity growth, technical progress, and efficiency change in industrialized countries. *Amer. Econom. Rev.* **84**(1) 66–83.

Firth, M. 1997. The provision of nonaudit services by accounting firms to their audit clients. *Contemporary Accounting Res.* **14**(2) 1–21.

Greene, W. 2000. *Econometric Analysis*, 4th ed. Prentice Hall, Englewood Cliffs, NJ.

Information Week. 1995. The biggest. (545) 38.

Information Week. 1996. The biggest. (596) 60.

Jerris, S., T. Pearson. 1996. Benchmarking CPA firms for productivity and efficiency. *CPA J.* **66**(7) 64–66.

Klein, B., K. Leffler. 1981. The role of market forces in assuring contractual performance. *J. Political Econom.* **89** 615–641.

Lieberman, M. B., D. B. Montgomery. 1988. First-mover advantages. *Strategic Management J.* **9** 41–58.

Malmquist, S. 1953. Index numbers and indifference surfaces. *Trabajos de Estadistica* **4** 209–242.

Melancon, B. C. 1998. The changing strategy for the profession, the CPA and the AICPA: What this means for the education community. *Accounting Horizons* **12**(4) 397–406.

Mingle, J. C. 1994. The shape of firms to come. *J. Accountancy* **178**(1) 39–44.

Nishimizu, M., J. Page. 1982. Total factor productivity growth, technological progress and technical efficiency change: Dimensions of productivity change in Yugoslavia, 1965–78. *Econom. J.* **92**(368) 920–936.

O'Keefe, T., D. Simunic, M. Stein. 1994. The production of audit services: Evidence from a major public accounting firm. *J. Accounting Res.* **32**(1) 241–261.

Parkash, M., C. F. Venable. 1993. Auditee incentives for auditor independence: The case of nonaudit services. *Accounting Rev.* **68**(1) 113–133.

Rankin, L., F. Sharp. 2000. The new mix of client services. *CPA J.* **70**(5) 38–45.

Rogers, E. 1985. *Diffusion of Innovations.* Free Press, New York.

Romer, P. 1987. Growth based on increasing returns due to specialization. *Amer. Econom. Rev.* **77**(2) 56–62.

Schumpeter, J. 1942. *Capitalism, Socialism and Democracy.* Harper and Brothers, New York.

Shapiro, C. 1983. Premiums for high quality products as returns to reputations. *Quart. J. Econom.* **98** 659–679.

Shephard, R. W. 1970. *Theory of Cost and Production Functions.* Princeton University Press, Princeton, NJ.

Siegel, G. 1999. The pace of change in management accounting. *Strategic Finance* **181**(6) 71–72.

Simunic, D. A., M. Stein. 1987. Product differentiation in auditing: Auditor choice in the market for unseasoned new issues. Monograph, Canadian Certified General Accountants' Research Foundation, Vancouver, Canada.

Solow, R. 1957. Technical change and the aggregate production function. *Rev. Econom. Statist.* **39**(3) 312–320.

Stein, M., D. Simunic, T. O'Keefe. 1994. Industry differences in the production of audit services. *Auditing: A J. Practice Theory* **15**(Supplement) 119–134.

Steindel, C., K. Stiroh. 2001. Productivity: What is it and why do we care about it? *Bus. Econom.* **36**(4) 12–31.

Stiglitz, J. 1987. Technological change, sunk costs and competition. *Brookings Papers Econom. Activity* **3**(Special Issue on Microeconomics) 883–937.

Stiroh, K. 2001. Investing in information technology: Productivity payoffs for U.S. industries. *Current Issues Econom. Finance, Federal Reserve Bank NY* **7**(6) 1–6.

Texas Society of Certified Public Accountants. 1999. *Management of an Accounting Practice Survey.* Texas Society of Public Accountants, Dallas, TX.

Wall Street Journal. 1997. Accounting firms poststrong rise in 1996 revenue. (February 3) B6.

Wheelock, D. C., P. W. Wilson. 1999. Technical progress, inefficiency, and productivity change in U.S. banking, 1984–1993. *J. Money, Credit, Banking* **31**(2) 212–234.