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The public accounting industry production function ☆

Rajiv D. Banker*, Hsihui Chang, Reba Cunningham

School of Management, The University of Texas at Dallas, Richardson, TX 75083-0666, USA

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Abstract

A translog function is specified to represent the relation between revenue and human resource inputs in public accounting firms. Estimation of the model using a balanced panel of annual data for 64 large CPA firms for the period 1995–1999 indicates that increasing returns to scale prevail in the public accounting industry, justifying recent merger and acquisition activities among accounting firms. Average marginal revenue product of partners increased monotonically from 1995 to 1998, decreased slightly in 1999, and was about nine times that of other professionals during 1995–1999. The public accounting industry exhibited continuing improvement in productivity over the 5 years.

JEL classification: D24; L11

Keywords: Public accounting; Scale economies; Marginal revenue product; Big five firm; CPA partner compensation; Production function

1. Introduction

Considerable change was evident in the public accounting industry in recent years even before the travails of Andersen made news headlines. The recent increase in merger and acquisition (M&A) activity is often attributed to a Certified Public

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*Corresponding author. Tel.: +1-972-883-4185; fax: +1-972-883-6811.
E-mail address: rbanker@utdallas.edu (R.D. Banker).

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Accounting (CPA) firm's efforts to avail itself of scale economies. Some firms are streamlining their operations by reducing the number of business offices, while others are expanding their network. Considerable difference exists between the compensation levels of partners and other professionals. Are these changes and differences consistent with the underlying economics of a public accounting firm's production function for generating service revenues? We address this question by estimating and analyzing the public accounting industry production function using a panel of data published by *Accounting Today* for the 5 years 1995–99 for the top 100 accounting firms in the United States.

Data are available for these firms only for service revenues generated from each of auditing, tax and consulting practices, and the total number of partners, professionals and other employees. While data availability limits some of the inferences we can draw, the estimated industry production function relating service revenues generated to human resources employed by CPA firms enables us to shed light on a variety of issues: Do economies of scale exist that may justify the recent M&A activity? What are the average marginal revenue products of partners, professionals, and other employees? Are partners, on average, compensated equitably compared to professionals and other employees on the basis of their marginal revenue products? Has the change in the economic and technological environment resulted in improved performance in the public accounting industry?

In recent years there has been increasing M&A activity among CPA firms. The highly publicized events have been those shrinking the "big eight" to the "big five". However, the annual report that each firm files with the AICPA reveals that M&A activity is not limited to the former big eight firms. Synergy resulting in greater productivity is often presented as justification for M&A. Combining two firms can result in substantial savings of fixed costs for knowledge and support personnel. In addition, the merged firm may be better able to exploit opportunities to generate additional revenues because of its size, blend of professional skills and experience. Thus, these synergies may result in cost savings or revenue augmentation and create economies of scale. Whether such scale economies actually occur in the public accounting industry is an important empirical question that has not been addressed by prior empirical research.

CPA firms have three major types of service personnel: partners, professionals, and administrative support staff. Do they contribute marginal revenue to the firm commensurate with their compensation? Partners are the firm's "rainmakers". Their primary job is to retain present business and generate new business. To justify the partners' higher remuneration relative to that of other professionals, we would expect to find that the partners' marginal revenue product is also proportionately higher. However, advances in information technology enable other professionals to work much more efficiently and contribute more revenues to the firm. Also, while services of other professionals are often billed at a rate that far exceeds their salaries, partners spend a significant portion of their time in administration, development, and other non-billable activities. These factors may increase the marginal revenue product of other professionals relative to that of a partner.

Researchers have argued that the market for the services of public accounting firms is competitive (Simunic, 1980). As new opportunities for productivity enhancement become available over time, does the competitive market pressure cause public accounting firms to improve their productivity over time? Since we have access to a panel of annual data over 5 years, we are able to present empirical evidence on this issue.

The remainder of this paper is organized as follows. In Section 2, we discuss conceptual and methodological issues pertaining to the estimation of industry production functions. In Section 3, we develop our research hypotheses for the public accounting industry. In Section 4, we describe the sample data. We describe our estimation model in Section 5 and present the empirical results in Section 6. Finally, we conclude in Section 7 with a summary of the implications of our results in understanding the economics of the production of public accounting services.

2. Industry production functions

Researchers and policy makers have long been interested in the estimation of industry production and cost functions. Numerous studies analyze firm level data for a wide range of industries.[1] Using data on input quantities or costs and output revenue, the principal focus of these studies has been on issues such as the estimation of scale economies, marginal rates of substitution between input factors, and impact of technological progress on productive efficiency.

Scale economies are said to exist in an industry when firms can reduce their average cost or increase their average revenue by expanding their operating size (Christensen and Greene, 1976; Darrough and Heineke, 1978). Existence of scale economies supports natural monopolies and firm mergers that increase operating size. Thus, the results from an investigation of scale economies can guide policy makers in making antitrust decisions and M&As rulings (Berger et al., 1993; Cummins and Weiss, 1993; Mitchell and Onvural, 1996; Shin and Ying, 1992).

Marginal rates of substitution between inputs measure the extent to which the consumption of one input resource must be increased to compensate for a reduction in the consumption of another input resource, while keeping output level constant. Estimation of the marginal rates of substitution between inputs provides insight into the relative importance of those resources in the production of the output, and helps

[1] These include studies of the airlines (Banker and Johnston, 1993; Sickles et al., 1986), banking (Aly et al., 1990; Berger and Humphrey, 1997; Mitchell and Onvural, 1996), consumer finance (Durkin and Elliehausen, 1998), correctional facilities (Hayes and Millar, 1990; Mensah and Li, 1993), dairy farming (Moschini, 1990), electrical utilities (Koh et al., 1996), farming (Parikh et al., 1995), hospitals (Zuckerman et al., 1994), insurance (Berger et al., 1993; Cummins and Weiss, 1993; Gardner and Grace, 1993; Toivanen, 1997), law enforcement agencies (Darrough and Heineke, 1978), motor carriers (Daughety and Nelson, 1988), school districts (Gyimah-Brempong and Gyapong, 1992; Smet and Nonneman, 1998), and telecommunications (Hunt and Lynk, 1991; Shin and Ying, 1992) industries.

determine the least cost input mix given relative input prices (Aly et al., 1990; Berger et al., 1993; Gyimah-Brempong and Gyapong, 1992).

Estimation of technological progress over time is useful because it helps evaluate characteristics that influence productive efficiency (Zuckerman et al., 1994; Berger and Humphrey, 1997). Furthermore, policy makers can evaluate the impact of a policy change such as deregulation by analyzing the observed shift in the production function following the change (Sickles et al., 1986).

While production and cost functions have been estimated for many different industries, to the best of our knowledge, the relation between revenue and input resources has not been previously estimated for the public accounting industry.[2] Our objective in this paper is to empirically estimate such a relationship for public accounting firms in order to examine the impact of factors such as scale on the productivity of a firm in generating revenues, and evaluate the marginal revenue products of various types of service employees.

2.1. Production function analysis

We consider firms producing multiple outputs using multiple inputs. The production function is expressed as $f(y_1, \ldots, y_K; x_1, \ldots, x_I) = 0$, where y_k is the level of output $k = 1, \ldots, K$, and x_i is the level of input $i = 1, \ldots, I$. The output is increasing in the level of input resources so that the marginal product of input i, $\partial f/\partial x_i \geqslant 0$ for all $i = 1, \ldots, I$, and marginal resource requirement of output k, $\partial f/\partial y_k \leqslant 0$ for all $k = 1, \ldots, K$.

By maintaining the assumption that each firm maximizes its revenue for any given level of inputs x_i, $i = 1, \ldots, I$, and output prices p_k, $k = 1, \ldots, K$, we can express a firm's optimal revenue function $R(p_1, \ldots, p_K; x_1, \ldots, x_I)$ in terms of the following output optimization problem:

$$R(p_1, \ldots, p_K, x_1, \ldots, x_I) = \text{Max} \sum_{k=1}^{K} p_k y_k$$
$$\text{subject to} f(y_1, \ldots, y_K, x_1, \ldots, x_I) = 0. \tag{1}$$

Since the envelope theorem provides that $\partial R(.)/\partial x_i = \partial f(.)/\partial x_i$, the marginal rate of substitution between inputs i and j, $\partial x_i/\partial x_j$, while keeping output levels constant, is given by

$$\frac{\partial x_i}{\partial x_j} = -\frac{\partial R(.)/\partial x_j}{\partial R(.)/\partial x_i}. \tag{2}$$

Thus, the marginal rate of substitution between inputs is related to the ratio of their marginal products. If input prices w_i and w_j, such as the compensation levels of

[2] Industry production functions are usually estimated using firm level data on outputs and inputs. It represents a higher level of analysis than the estimation of a production function using job cost data from a production establishment, such as a manufacturing plant. An example of the latter analysis is the estimation of an audit production function by O'Keefe et al. (1994) using data collected from an accounting firm on labor hours and client characteristics for individual audits.

different personnel, are determined in markets exogenous to the firm, then the cost minimizing substitution between inputs requires that the marginal products of inputs are in the proportion of their prices

$$\frac{\partial R(.)/\partial x_j}{\partial R(.)/\partial x_i} = \frac{w_j}{w_i}. \tag{3}$$

Therefore, to justify a higher compensation for partners relative to other professionals, the partners' marginal product should also be proportionately higher than the professionals' marginal product.

The concept of returns to scale pertains to whether the outputs increase more or less than proportionately with inputs. The scale elasticity measure (SCALE) is defined as

$$\text{SCALE} = \lim_{\lambda \to 1} \frac{R(p_1, \ldots, p_K, \lambda x_1, \ldots, \lambda x_I)}{\lambda R(p_1, \ldots, p_K, x_1, \ldots, x_I)}. \tag{4}$$

Then, economies of scale (SCALE) exist given output prices $(p_1, \ldots, p_K)$ if and only if SCALE>1. That is, scale economies prevail if the optimal revenue increases by a proportion greater than λ when all inputs are increased by the proportion $\lambda > 1$.

2.2. The translog model

A common approach for estimating a multiple output multiple input production correspondence is to specify a translog model (Christensen and Greene, 1976; Darrough and Heineke, 1978). The revenue function $R(.)$ is specified as follows:

$$\ln R = \beta_0 + \sum_{k=1}^{K} \alpha_k \ln p_k + \sum_{i=1}^{I} \beta_i \ln x_i + \frac{1}{2}\sum_{k=1}^{K}\sum_{r=1}^{K} \alpha_{kr} \ln p_k \ln p_r$$

$$+ \frac{1}{2}\sum_{i=1}^{I}\sum_{j=1}^{I} \beta_{ij} \ln x_i \ln x_j + \sum_{k=1}^{K}\sum_{i=1}^{I} \delta_{ki} \ln p_k \ln x_i, \tag{5}$$

where ln R is the logarithm of total revenue, ln p_k is the logarithm of the price of output $k = 1, \ldots, K$, and ln x_i is the logarithm of the quantity of input $i, i = 1, \ldots, I$. Linear homogeneity in output prices implies that a proportionate increase in all output prices must result in the same proportionate increase in total revenue for given input levels. This imposes the following restrictions on (5):

$$\sum_{k=1}^{K} \alpha_k = 1, \quad \sum_{r=1}^{K} \alpha_{kr} = 0 \quad \text{for} \quad k = 1, \ldots, K$$

$$\text{and} \quad \sum_{k=1}^{K} \delta_{ki} = 0 \quad \text{for} \quad i = 1, \ldots, I. \tag{6}$$

The symmetry condition for the translog model requires:

$$\alpha_{kr} = \alpha_{rk} \quad \text{for} \quad k, r = 1, \ldots, K \quad \text{and} \quad \beta_{ij} = \beta_{ji} \quad \text{for} \quad i, j = 1, \ldots, I. \tag{7}$$

Applying the definition of scale elasticity in (4) to the translog model and evaluating the limit as $\lambda \to 1$, we obtain:

$$\text{SCALE} = \sum_{i=1}^{I} \beta_i + \sum_{i=1}^{I} \sum_{j=1}^{I} \beta_{ij} \ln x_i + \sum_{i=1}^{I} \sum_{k=1}^{K} \delta_{ki} \ln p_k. \tag{8}$$

Scale economies prevail if SCALE > 1 and scale diseconomies scale prevail if SCALE < 1. Since SCALE is a function of input quantities and output prices, the existence of scale economies or diseconomies may be evaluated statistically by testing whether SCALE evaluated at the sample mean is significantly different than 1. Alternatively, to evaluate whether the null hypothesis of constant returns to scale holds over the entire range of values of x_i and p_k, we may test whether the following conditions are satisfied (Darrough and Heineke, 1978; Christensen et al., 1983):

$$\sum_{i=1}^{I} \beta_i = 1, \ \sum_{j=1}^{I} \beta_{ij} = 0 \quad \text{for} \quad i = 1, \ldots, I \quad \text{and} \quad \sum_{i=1}^{I} \delta_{ki} = 0 \quad \text{for} \quad k = 1, \ldots, K. \tag{9}$$

The endogeneity of the multiple outputs that generate the revenue modeled as the dependent variable in (5) are recognized via additional structure imposed to capture the optimal tradeoffs between outputs. That is, by assuming that each public accounting firm maximizes revenue given output (service) prices p_k and input levels x_i, we can employ Shephard's (1970) Lemma to obtain $\partial R(.)/\partial p_k = y_k$, $k = 1, \ldots, K$. Since $\partial \ln R(.)/\partial \ln p_k = p_k \partial R(.)/R(.)\partial p_k$, we can derive the following expression for the revenue share $\text{SHARE}_k = p_k y_k / R(.)$ for each service k:

$$\text{SHARE}_k = \alpha_k + \sum_{r=1}^{K} \alpha_{kr} \ \ln \ p_r + \sum_{i=1}^{I} \delta_{ki} \ \ln \ x_i \quad \text{for} \quad k = 1, \ldots, K. \tag{10}$$

The translog revenue model in (5) is then estimated together with the endogeneity conditions represented in (10).

3. Public accounting industry

The accounting industry has evolved over centuries, but public accounting firms as we know them today became prominent only after the passage of the Securities Act in 1933 and the formation of the Securities Exchange Commission (SEC) in 1934. The industry was dominated over many years by eight CPA firms that were collectively known as the "big eight".

The recent growth in M&A activity began among the former "big eight" with the merger of Ernst & Whinney and Arthur Young & Company in 1989. The merger of Touche Ross & Company and Deloitte, Haskins & Sells soon followed and the "big eight" were now the "big six". The 1998 merger between Coopers & Lybrand and Price Waterhouse made it the "big five" (Controller Magazine, 1998). Mergers and acquisitions of lesser magnitude continue to occur. For example, Ernst & Young acquired Kenneth Leventhal & Company in 1995 to provide services to the real estate industry (Practical Accountant, 1995). In 1996, Ernst & Young acquired Wright Killen & Company and Marcus & Millichap, two consulting organizations; Coopers & Lybrand acquired Coppi & Associates, Investec and Manufacturers Appraisal Company; Price Waterhouse acquired K.K., a management consulting practice in Japan, Somekh Chaikin, an accounting, auditing, and tax practice in Israel, and Cytrol, a financial and investment management consulting practice in Minnesota; and Deloitte & Touche acquired International Consulting Solutions, an information technology consulting firm.

According to reports of the accounting firms submitted to the American Institute of Certified Public Accountants' (AICPA) Division for CPA Firms, M&A activity is not limited to the former "big eight". A sampling of other "Top 100" firms revealed that 30% either merged with or acquired other firms (AICPA, 1995, 1996, 1997). BDO Seidman merged with Miller, Glusman, Footer & Magarick of Philadelphia in 1997 (Brickley, 1998) eliminating the head to head competition they had engaged in for years. A merger of the Little Rock accounting firms Moore, Stephens & Frost and Cooper Shuffield & Company created the second largest accounting firm in Arkansas. Dennis Cooper, a partner in the merged firm, states: "There are a lot of synergies between our two firms. We have common clients; common business interests. I think by combining the firms, we are combining energies so we can work better for our clients" (Little, 1996). In 1995 Tannebaum Bindler of Dallas merged into Weaver and Tidwell of Fort Worth. Principals cite an opportunity to strengthen the firm's presence in the Dallas-Fort Worth Metroplex and an ability to provide diverse services as the motivation for the merger (Rampey, 1995). The rival firms of Virchow, Kraus and Company of Milwaukee and Conley McDonald of Madison, Wisconsin merged in 1998. "Clients really are expecting specialization. You need to be bigger to do that". said Fred Licau Conley, McDonald's managing partner (Newman, 1998). Executives of four firms in the recent merger activity declare that shrinking the number of big accounting firms is good for clients (Berton, 1998). They contend that economies of scale together with increased capacity to deliver integrated services provide better value to clients.[3] Firm managing partners cite greater efficiency and global reach by larger firms as evidence that clients are better served by the consolidated firms (Berton, 1998).

Scale economies may arise due to factors on either the cost side or the demand side. On the cost side, a larger firm may be able to reduce average costs of production

[3] An alternative way of examining this issue is by investigating whether the consolidated firm charged its clients lower service fees after its merger. This would require the use of firm level data on costs and prices. However, these data are not available to researchers.

by developing and utilizing its input resources more efficiently. In a stochastic environment, a larger firm incurs lower expected costs of unutilized surplus capacity or inadequate committed capacity (Banker and Hughes, 1994). Minimum efficient scale requirements may also limit access to efficiencies from superior technologies, including information technology, to larger firms. Expected benefits of learning and knowledge acquisition in improving operating processes may also be disproportionately greater for larger firms that may be able to implement formal mechanisms for leveraging their more extensive knowledge base (Eccles and Gladstone, 1995). By providing more attractive career opportunities and better pay, larger firms may also be able to attract more productive professional staff (Hiltebeitel and Leauby, 2001; Stimpson, 1999).

On the demand side, expanded scale of operations due to mergers and acquisitions creates opportunities for the larger firm to provide a broader range of professional services to large national and multinational corporations with more complex and geographically dispersed operations. Since competition is relatively less intense in this market segment, a higher price premium may prevail. In fact, according to a survey conducted by the *CFO Magazine*, 68% of financial executives believed that the recent CPA firm mergers would trigger fee increases (Berton, 1998). Also, several studies using audit client level data have empirically documented that the former big eight accounting firms commanded more than proportionate revenue from their services relative to the other accounting firms (Craswell et al., 1995; Francis, 1984; Francis and Stokes, 1986; Palmrose, 1986; Simunic and Stein, 1987). Accordingly, we hypothesize:

H1: Scale economies prevail in the public accounting industry.

As described in the previous section, optimizing substitution between inputs requires that the marginal products of inputs are in the proportion of their prices. Discussion with senior partners at several public accounting firms and analysis of national survey data for public accounting practices larger than $1 million in revenues indicate that compensation differentials between partners, professionals and other employees are in the proportions 6:2:1 (Texas Society of Certified Public Accountants, 1997–2000). Therefore, in order to justify the partners' higher compensation, their contribution to the accounting firm must be considerably more than what professionals and other employees contribute to revenue generation. Also, relatively smaller contribution may be expected from clerical and lower level support personnel to revenue generation compared to partners or professionals. Based on these arguments, we specify the following hypothesis in an ordinal form:

H2: Ceteris paribus, marginal revenue product of partners is greater than that of professionals, and the marginal revenue product of professionals is greater than that of other employees.

Recent advances in information technology have substantially changed the public accounting service operations. On the cost side, technology has enabled more efficient utilization of available human resources. On the demand side, technology-based competition faced by their clients has enabled the CPA firms to provide more differentiated and value-added management advisory and other services that can command a higher price premium than the commoditized audit and tax services. Thus, in this changing environment, many new opportunities have arisen for CPA firms to improve their production efficiency (Elliott, 2000). Prior research also suggests that the market for the public accounting industry's services is competitive (Craswell et al., 1995; Simunic, 1980). Since inefficiency is not likely to survive the disciplining force of a competitive market, we expect that public accounting firms have improved their production efficiency in service delivery. This suggests the following hypothesis:

H3: Ceteris paribus, the public accounting industry has improved its productivity in service delivery over time.

4. Data and variables

The data used in this study were obtained from Accounting Today's annual surveys of the top 100 accounting firms for the 5 years 1995–99.[4] A recent US Commerce Department study estimated that the top 100 firms account for 49% of the industry's total fees of $65 billion (Accounting Today, 1999). *Accounting Today* contacted almost 200 firms for this project. The database was constructed from firms' responses and *Accounting Today*'s own research and estimates. Firms were given an opportunity to comment on the estimates before the publication of the data. This annual survey of the profession's largest practices has now become one of the most often cited benchmarks in the business (Telberg, 1998; Jerris and Pearson, 1996, 1997). All data reported in the annual surveys are for domestic US operations and exclude foreign holdings. Since our analysis is restricted to CPA firms, we eliminated non-CPA firms such as American Express Inc., Padgett Business Services and H&R Block from the database.

To evaluate how scale economies and marginal revenue products have changed over time, we follow Darrough and Heineke (1978) and consider a panel of pooled cross-sectional and time series data for estimation. For this purpose, we construct a balanced panel of 320 observations consisting of the 64 CPA firms that appeared in *Accounting Today*'s list consistently for each of the 5 years from 1995 to 1999. These

[4] An alternative data source on the 100 largest public accounting firms in the US is the *Public Accounting Report* published by Strafford Publications, Inc., Atlanta, GA (PAR Top 100, 1996, 1997, 1998, 1999, 2000). There are 61 firms common to the *Accounting Today* and the *Public Accounting Report* data sets across five sample years. The *Public Accounting Report* did not report the total number of non-professional employees. The correlation coefficients between these two data sets are greater than 0.99 for all available variables for each of these 5 years. The correlations between the number of partners, number of professionals, and number of offices *scaled by total revenue* range between 0.72 and 0.93 (significant at 0.1% level). The correlations between the revenue shares in the two data sets also range between 0.46 and 0.81 (significant at 0.1% level).

64 firms account for about 90% of the total revenues for the entire top 100 firms sample. We consolidate sample firms that were merged in any year between 1995 and 1999 and consider them as a single firm as if the merger took effect in the year 1995. For instance, Coopers & Lybrand merged with Price Waterhouse in 1998 and hence the corresponding data values for these two firms in 1995, 1996 and 1997 are aggregated and considered together with corresponding values for the merged firm for 1998 and 1999 for estimation.[5]

We measure the output of each firm in terms of its net revenue generated from three sources: Accounting and Auditing (A&A), Tax Services (TAX), and Management Advisory Services (MAS). Net revenue is expressed in millions of dollars, after write-ups and write-downs of fees, reimbursements, subcontractor fees and other adjustments, and is deflated by the consumer price index using 1995 as the base year. 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 percentage of revenue derived from each of the three services is represented as A&A%, TAX% and MAS%.

We consider three human resource input variables: the 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 those trained to perform the accounting and other services offered by the firm and includes staff accountants, senior accountants, managers, and consulting personnel. In some firms paraprofessionals are used as well. OTHERS are clerical and support personnel, usually involved in administration, printing of reports, record keeping and the like. A limitation of the database is the lack of information on capital inputs. We do not consider capital inputs in our analysis as they are believed to be of secondary importance (O'Keefe et al., 1994, p. 245). Also, Texas Society of Certified Public Accountants (1997–2000) national surveys of accounting practices larger than $1 million in revenues indicates that rent, depreciation and occupancy costs amount to only about 6.5% of net revenue, whereas human resource compensation accounts for about 75.0% of net revenue. To the extent that omitted capital input variables are positively correlated with the included labor input variables, the estimated coefficients of these labor input variables are likely to be biased upward.

Large CPA firms have numerous locations. Expanding service network by adding business offices, an accounting firm can develop a better connection with local clients. This helps attract new clients and cuts down on travel-related expenses as well. However, given the total number of employees, an increase in the number of

[5] We also estimated alternative models that did not treat the merged firms as if they were one. We employed two different methods. The first method used a smaller sample that excluded all merged firms for all 5 years. The second method included all merged firms as separate firms until they were merged. The results of both of these alternative approaches are very similar to those when we treated the merged firms as if they were one.

Table 1
Variable definitions

Variable	Definition
N	Number of public accounting firms in the sample
REVENUE	Total revenue deflated to year 1995, expressed in million dollars ($M)
A&A%	Proportion of A&A revenue
TAX%	Proportion of TAX revenue
MAS%	Proportion of MAS revenue
EMPLOYEES	Total number of employees including partners
PARTNERS	Number of partners
PROFESSIONALS	Number of professionals
OTHERS	Number of other employees
OFFICES	Number of branch offices
BIG5	A dummy variable that equals one if the firm is one of the Big Five firms, and 0 otherwise
$YEAR_t$	A dummy variable that equals one if year t, $t = 96$, 97, 98 or 99, and 0 otherwise
SCALE	Scale elasticity measure evaluated for each firm or sample mean
MRP(i)	Marginal revenue product in deflated 1995 dollars of input i, i = PARTNERS, PROFESSIONALS, OTHERS

office locations increases the degree of difficulty in coordination, administration and management and, therefore, lowers the productivity. Therefore, we include the number of offices as a control variable in this study, and measure OFFICES as the number of branch offices operated by a firm. In addition, since the Big Five command a premium for both audit and non-audit services (Craswell et al., 1995; Francis and Stokes, 1986; Simunic and Stein, 1987), we evaluate the robustness of our results by estimating additional models that include a dummy variable, BIG5, which equals one if the firm is one of the big five firms.

Variable definitions are summarized in Table 1. Descriptive statistics for the sample data in Table 2 indicate that the median values of all size-related variables are much smaller than the mean values, indicating that the data are skewed to the right.[6] The high standard deviations suggest that the top 100 public accounting firms vary greatly in their size and composition. These statistics also indicate that firm size, measured by either deflated total revenues or total number of employees, increased during the sample period. In fact, results of paired t tests (not reported here) indicate that both total revenue and total number of employees increased significantly from

[6] Logarithmically transformed size-related data used for empirical estimation do not exhibit this skewness.

Table 2
Descriptive statistics on service revenue and human resource variables

Variables	Mean	Std dev.	25%	Median	75%
Panel A: 1995 ($N = 64$)					
REVENUE	$269.7M	$841.7M	$12.25M	$16.9M	$31.8M
A&A%	49.5	11.5	44	50	54.5
TAX%	29.8	9.8	23	30	35
MAS%	20.7	11.7	13	18	28
EMPLOYEES	2210.8	6820.0	139	199	409
PARTNERS	173.8	458.4	18	22.5	57
PROFESSIONALS	1504.0	4719.0	91	126	241.5
OTHERS	533.0	1667.7	27.5	39	80.5
OFFICES	18.5	37.1	2	5	13
Panel B: 1996 ($N = 64$)					
REVENUE	$299.8M	$942.3M	$13.5M	$17.6M	$36.6M
A&A%	48.1	11.0	42.5	49	53.5
TAX%	30.0	9.8	23	30	35
MAS%	21.9	12.4	15	19	27.5
EMPLOYEES	2366.5	7332.7	152.5	201	408.5
PARTNERS	179.4	437.2	18	24.5	59.5
PROFESSIONALS	1597.5	5030.6	100	128.5	251.5
OTHERS	589.6	1864.0	29.5	40	93.5
OFFICES	18.3	35.5	2	5.5	14
Panel C: 1997 ($N = 64$)					
REVENUE	350.3	$1110.4M	$14.4M	$19.8M	$40.9M
A&A%	47.1	11.1	41.5	47.5	54.5
TAX%	29.6	8.9	24	29	35.5
MAS%	23.3	12.8	14.5	20	30
EMPLOYEES	2709.5	8404.7	162	211	435.5
PARTNERS	194.7	519.0	18.5	28	56.5
PROFESSIONALS	1897.3	6030.5	100	144.5	274.5
OTHERS	617.5	1895.1	34	45	97.5
OFFICES	18.6	36.0	2	6	13.5
Panel D: 1998 ($N = 64$)					
REVENUE	$424.9M	$1357.9M	$15.8M	$22.2M	$48.6M
A&A%	45.4	11.3	38.5	46	52
TAX%	29.3	9.0	23.5	29.5	35
MAS%	25.3	13.0	17	23.5	30
EMPLOYEES	3127.7	9874.3	171	225	498.5
PARTNERS	209.9	566.5	19	29.5	58.5
PROFESSIONALS	2218.0	7140.6	107.5	151.5	331.5
OTHERS	699.8	2220.4	35	46.5	114.5
OFFICES	18.6	35.5	2	6	14
Panel E: 1999 ($N = 64$)					
REVENUE	$485.3M	$1544.8M	$17.7M	$25.2M	$55.8M
A&A%	42.2	11.3	36.5	43	48
TAX%	29.2	8.7	24	28	34
MAS%	28.3	13.2	20	25.5	35

Table 2 (*continued*)

Variables	Mean	Std dev.	25%	Median	75%
EMPLOYEES	3456.8	10981.7	183	235	553
PARTNERS	226.8	613.0	21	31	61
PROFESSIONALS	2430.5	7856.8	114.5	175.5	363
OTHERS	800.0	2572.8	38.5	54.5	115.5
OFFICES	18.8	34.2	3	6.5	14.5

Variable definitions appear in Table 1.

year to year over the 5-years period from 1995 to 1999. The mean (median) deflated total revenues for our sample firms increased by about 11 (4) percent from 1995 to 1996, by 17 (12) percent from 1996 to 1997, by 21 (12) percent from 1997 to 1998, and by 14 (13) percent from 1998 to 1999, while the mean (median) number of employees increased by about 7 (1) percent from 1995 to 1996, by 14 (5) percent from 1996 to 1997, by 15 (7) percent from 1997 to 1998, and by 10 (4) percent from 1998 to 1999.

The descriptive statistics for the mix of service revenues reveal a continuing decline in the percentage of revenue generated from A&A from 49.5% to 42.2%, matched by a continuing increase in the percentage of revenue generated from MAS from 20.7% to 28.3% between 1995 and 1999. There was no substantial change in the percentage of revenue generated from TAX and the average number of branch offices per firm.

We report Pearson and Spearman correlations between the big five, average service mix and average branch offices variables over the 5 years in Table 3. Correlations for each individual year are of similar magnitude. The average A&A%, TAX% and MAS% are all negatively correlated with each other, as each represents a share of net revenue. The correlation coefficients between average A&A% and BIG5, and between average TAX% and BIG5 are significantly negative, while the correlation between average MAS% and BIG5 is significantly positive. This suggests

Table 3
Correlation matrix for average service mix, average branch offices and BIG5 variables (*p*-values in parentheses)

	A&A%	TAX%	MAS%	lnOFFICES	BIG5
A&A%	1.0000	−0.0698	−0.6752	−0.3333	−0.3798
	—	(0.583)	(0.001)	(0.007)	(0.002)
TAX%	−0.2457	1.0000	−0.5705	−0.0193	−0.3924
	(0.050)	—	(0.001)	(0.879)	(0.001)
MAS%	−0.7099	−0.5070	1.0000	0.3182	0.4176
	(0.001)	(0.001)	—	(0.010)	(0.001)
lnOFFICES	−0.3950	−0.0533	0.3957	1.0000	0.4652
	(0.001)	(0.675)	(0.001)	—	(0.001)
BIG5	−0.3162	−0.3343	0.5244	0.6194	1.0000
	(0.011)	(0.007)	(0.001)	(0.001)	—

Pearson correlations are below the diagonal, and Spearman correlations are above the diagonal.
Variable definitions appear in Table 1.

that the big five firms rely less on accounting and auditing and taxation services, and more on consulting services for generating revenue than other firms.

5. Estimation model

We specify a translog function to represent the correspondence between total revenue and human resource inputs of public accounting firms. This relation is moderated by factors such as OFFICES that may affect a firm's productivity as described earlier. Since we use a panel of pooled cross-sectional and time series data for estimation, we employ a fixed effects model and include 4 years dummies, YEAR96, YEAR97, YEAR98 and YEAR99 (Greene, 2000, p. 560). A comparison of these year dummies' impact on total revenue also enables us to evaluate whether the performance of the public accounting industry improved on average over time. Since service outputs in our data set are measured in monetary terms, we write the price of each output k in year t as $p_k^t = p_k^{95} * \rho_k^t$ for $k = 1, 2, 3$, and $t = 1996$, 1997, 1998, 1999, where p_k^{95} is the price of output k in the year 1995 and $\rho_k^t > 0$ is the factor measuring the change in the price of output k in year t compared to 1995. We normalize by setting $p_k^{95} = 1$ for $k = 1$, 2, 3. Since output prices are not observed by researchers, we treat the ρ_k^t as parameters to be estimated. The translog revenue function in (5) and the revenue share Eq. (10) can then be rewritten as the following four equations:

$$
\begin{aligned}
\ln \text{REVENUE} = {} & \beta_0 + \beta_1 \ln \text{PARTNERS} + \beta_2 \ln \text{PROFESSIONALS} + \beta_3 \ln \text{OTHERS} \\
& + \tfrac{1}{2}\beta_{11}(\ln \text{PARTNERS})^2 + \tfrac{1}{2}\beta_{22}(\ln \text{PROFESSIONALS})^2 + \tfrac{1}{2}\beta_{33}(\ln \text{OTHERS})^2 \\
& + \beta_{12} \ln \text{PARTNERS} \ln \text{PROFESSIONALS} + \beta_{13} \ln \text{PARTNERS} \ln \text{OTHERS} \\
& + \beta_{23} \ln \text{PROFESSIONALS} \ln \text{OTHERS} + \gamma_1 \ln \text{OFFICES} + \phi^{96}\text{YEAR96} \\
& + \phi^{97}\text{YEAR97} + \phi^{98}\text{YEAR98} + \phi^{99}\text{YEAR99} + \psi_1^{96}\text{YEAR96} \ln \text{PARTNERS} \\
& + \psi_2^{96}\text{YEAR96} \ln \text{PROFESSIONALS} + \psi_3^{96}\text{YEAR96} \ln \text{OTHERS} \\
& + \psi_1^{97}\text{YEAR97} \ln \text{PARTNERS} + \psi_2^{97}\text{YEAR97} \ln \text{PROFESSIONALS} \\
& + \psi_3^{97}\text{YEAR97} \ln \text{OTHERS} + \psi_1^{98}\text{YEAR98} \ln \text{PARTNERS} \\
& + \psi_2^{98}\text{YEAR98} \ln \text{PROFESSIONALS} + \psi_3^{98}\text{YEAR98} \ln \text{OTHERS} \\
& + \psi_1^{99}\text{YEAR99} \ln \text{PARTNERS} + \psi_2^{99}\text{YEAR99} \ln \text{PROFESSIONALS} \\
& + \psi_3^{99}\text{YEAR99} \, ln \, \text{OTHERS},
\end{aligned} \tag{11}
$$

$$
\begin{aligned}
\text{A\&A\%}/100 = {} & \alpha_1 + \delta_{11} \ln \text{PARTNERS} + \delta_{12} \ln \text{PROFESSIONALS} + \delta_{13} \ln \text{OTHERS} \\
& + \tau_1^{96}\text{YEAR96} + \tau_1^{97}\text{YEAR97} + \tau_1^{98}\text{YEAR98} + \tau_1^{99}\text{YEAR99}
\end{aligned} \tag{12}
$$

$$
\begin{aligned}
\text{TAX\%}/100 = {} & \alpha_2 + \delta_{21} \ln \text{PARTNERS} + \delta_{12} \ln \text{PROFESSIONALS} + \delta_{23} \ln \text{OTHERS} \\
& + \tau_2^{96}\text{YEAR96} + \tau_2^{97}\text{YEAR97} + \tau_2^{98}\text{YEAR98} + \tau_2^{99}\text{YEAR99}
\end{aligned} \tag{13}
$$

$$\text{MAS\%}/100 = \alpha_3 + \delta_{31}\ln \text{PARTNERS} + \delta_{32}\ln \text{PROFESSIONALS} + \delta_{33}\ln \text{OTHERS} + \tau_3^{96}\text{YEAR96} + \tau_3^{97}\text{YEAR97} + \tau_3^{98}\text{YEAR98} + \tau_3^{99}\text{YEAR99} \quad (14)$$

where $\phi^t = \sum_{k=1}^{3}\alpha_k \ln\rho_k^t + \frac{1}{2}\sum_{k=1}^{3}\sum_{r=1}^{3}\alpha_{kr}\ln\rho_k^t \ln\rho_r^t + \upsilon^t$ for t = 1996, 1997, 1998, 1999, υ^t is a parameter for the year dummy t, t = 1996, 1997, 1998, 1999, $\psi_i^t = \sum_k \delta_{ki}\ln\rho_k^t$ for t = 1996, 1997, 1998, 1999 and i = 1, 2, 3, $\tau_k^t = \sum_{r=1}^{3}\alpha_{kr}\ln\rho_k^t$ for k = 1, 2, 3.

A&A%/100, TAX%/100 and MAS%/100 represent the revenue shares (SHARE_k in (10)) of the three output services.

Following Christensen and Greene (1976), we add disturbance terms to Eqs. (11)–(14) for estimation. Since the revenue shares sum to one, we exclude one of the three revenue share Eqs. (12)–(14) from the estimation to avoid a singular disturbance covariance matrix. We estimate the system of equations together as seemingly unrelated regressions (SUR) using Zellner's (1962) iterative estimation approach. This estimation procedure produces maximum likelihood estimates and the coefficient estimates are invariant with respect to the deleted revenue share equation (Kmenta and Gilbert, 1968).

For the revenue function in (11), the scale elasticity measure (SCALE) in (8) is given by:

$$\begin{aligned}\text{SCALE} = {} & (\beta_1 + \beta_2 + \beta_3) + (\beta_{11} + \beta_{12} + \beta_{13})\ln \text{PARTNERS} \\ & + (\beta_{22} + \beta_{12} + \beta_{23})\ln \text{PROFESSIONALS} + (\beta_{13} + \beta_{23} + \beta_{33})\ln \text{OTHERS} \\ & + (\psi_1^{96} + \psi_2^{96} + \psi_3^{96})\text{YEAR96} + (\psi_1^{97} + \psi_2^{97} + \psi_3^{97})\text{YEAR97} \\ & + (\psi_1^{98} + \psi_2^{98} + \psi_3^{98})\text{YEAR98} + (\psi_1^{99} + \psi_2^{99} + \psi_3^{99})\text{YEAR99}. \quad (15)\end{aligned}$$

Also, the marginal revenue product (MRP) based on Eq. (11) is expressed as:

$$\begin{aligned}\text{MRP}_i = {} & \partial\text{REVENUE}/\partial\text{INPUT}_i = (\text{REVENUE}/\text{INPUT}_i) \\ & \times (\beta_i + \beta_{i1}\ln \text{PARTNERS} + \beta_{i2}\ln \text{PROFESSIONALS} + \beta_{i3}\ln \text{OTHERS} \\ & + \psi_i^{96}\text{YEAR96} + \psi_i^{97}\text{YEAR97} + \psi_i^{98}\text{YEAR98} + \psi_i^{99}\text{YEAR99}), \quad (16)\end{aligned}$$

where $INPUT_i$ = PARTNERS, PROFESSIONALS and OTHERS.

6. Empirical results

In column (I) of Table 4, we present the parameter estimates and test results for the revenue function.[7] We employed the more flexible translog form rather than the

[7] When we include the variable BIG5 in the model, the coefficient estimate of BIG5 is significantly positive at 10% levels, consistent with findings of earlier studies. Since other results are very similar to those reported in Tables 4–7, we do not present these results here. The coefficient estimate of the ln OFFICES variable is negative and statistically significant, suggesting that the same level of personnel resources spread over a greater number of offices, in fact, generated less service revenue. A senior partner in a big five firm explained that being in the same city with a client and knowing the client's business more intimately is a quality consideration that reduces exposure to litigation. This may also help reduce insurance cost for litigation and may compensate for the lower revenue generation.

Table 4
SUR estimation of translog revenue function for data pooled over 1995–99 (*t*-statistics in parentheses)

$$\begin{aligned}\ln \text{REVENUE} = {} & \beta_0 + \beta_1 \ln \text{PARTNERS} + \beta_2 \ln \text{PROFESSIONALS} + \beta_3 \ln \text{OTHERS} \\ & + \tfrac{1}{2}\beta_{11}(\ln \text{PARTNERS})^2 + \tfrac{1}{2}\beta_{22}(\ln \text{PROFESSIONALS})^2 + \tfrac{1}{2}\beta_{33}(\ln \text{OTHERS})^2 \\ & + \beta_{23} \ln \text{PROFESSIONALS} \ln \text{OTHERS} + \gamma_1 \ln \text{OFFICES} + \phi^{96}\text{YEAR96} \\ & + \phi^{97}\text{YEAR97} + \phi^{98}\text{YEAR98} + \phi^{99}\text{YEAR99} + \psi_1^{96}\text{YEAR96} \ln \text{PARTNERS} \\ & + \psi_2^{96}\text{YEAR96} \ln \text{PROFESSIONALS} + \psi_3^{96}\text{YEAR96} \ln \text{OTHERS} \\ & + \psi_1^{97}\text{YEAR97} \ln \text{PARTNERS} + \psi_2^{97}\text{YEAR97} \ln \text{PROFESSIONALS} \\ & + \psi_3^{97}\text{YEAR97} \ln \text{OTHERS} + \psi_1^{98}\text{YEAR98}\ln\text{PARTNERS} + \psi_2^{98}\text{YEAR98} \ln \text{PROFESSIONALS} \\ & + \psi_3^{98}\text{YEAR98} \ln \text{OTHERS} + \psi_1^{99}\text{YEAR99} \ln \text{PARTNERS} + \psi_2^{99}\text{YEAR99} \ln \text{PROFESSIONALS} \\ & + \psi_3^{99}\text{YEAR99} \ln \text{OTHERS} + \varepsilon \quad (11)\end{aligned}$$

$$\begin{aligned}\text{A\&A\%}/100 = {} & \alpha_1 + \delta_{11} \ln \text{PARTNERS} + \delta_{12} \ln \text{PROFESSIONALS} + \delta_{13} \ln \text{OTHERS} \\ & + \tau_1^{96}\text{YEAR96} + \tau_1^{97}\text{YEAR97} + \tau_1^{98}\text{YEAR98} + \tau_1^{99}\text{YEAR99} + \xi_1 \quad (12)\end{aligned}$$

$$\begin{aligned}\text{TAX\%}/100 = {} & \alpha_2 + \delta_{21} \ln \text{PARTNERS} + \delta_{22} \ln \text{PROFESSIONALS} + \delta_{23} \ln \text{OTHERS} \\ & + \tau_2^{96}\text{YEAR96} + \tau_2^{97}\text{YEAR97} + \tau_2^{98}\text{YEAR98} + \tau_2^{99}\text{YEAR99} + \xi_2 \quad (13)\end{aligned}$$

$$\begin{aligned}\text{MAS\%}/100 = {} & \alpha_3 + \delta_{31} \ln \text{PARTNERS} + \delta_{32} \ln \text{PROFESSIONALS} + \delta_{33} \ln \text{OTHERS} \\ & + \tau_3^{96}\text{YEAR96} + \tau_3^{97}\text{YEAR97} + \tau_3^{98}\text{YEAR98} + \tau_3^{99}\text{YEAR99} + \xi_3 \quad (14)\end{aligned}$$

Variables	(I) lnREVENUE	(II) A&A%/100	(III) TAX%/100	(IV) MAS%/100
Intercept	−0.1401	0.6233***	0.4060***	−0.0293
	(−0.77)	(22.37)	(16.68)	(−1.06)
lnPARTNERS	0.3662**	0.0875***	0.0253	−0.1133***
	(2.51)	(4.51)	(1.49)	(−5.86)

Table 4 (*continued*)

Variables	(I) lnREVENUE	(II) A&A%/100	(III) TAX%/100	(IV) MAS%/100
lnPROFESSIONALS	−0.1147	−0.0172	−0.0263**	0.0428***
	(0.73)	(−1.16)	(−2.03)	(2.90)
lnOTHERS	0.4154***	−0.0846***	−0.0142	0.1000***
	(3.27)	(−6.14)	(−1.18)	(7.31)
$(\text{lnPARTNERS})^2$	0.2734*			
	(1.90)			
$(\text{lnPROFESSIONALS})^2$	0.3022***			
	(3.82)			
$(\text{lnOTHERS})^2$	−0.0906			
	(−1.37)			
lnPARTNERSlnPROFESSIONALS	−0.2247***			
	(−2.71)			
lnPARTNERS lnOTHERS	0.0729			
	(0.79)			
lnPROFESSIONALS lnOTHERS	−0.0413			
	(−1.03)			
lnOFFICES	−0.0897***			
	(−8.31)			
YEAR96	0.0206	−0.0150	0.0027	0.0078
	(0.19)	(−0.59)	(0.18)	(0.44)
YEAR97	0.1074	−0.0158	0.0005	0.0153
	(0.99)	(−0.89)	(0.04)	(0.86)
YEAR98	0.1643	−0.0311*	0.0004	0.0305*
	(1.39)	(−1.74)	(0.03)	(1.72)
YEAR99	0.1400	−0.0578***	0.0013	0.0531***
	(1.11)	(−3.22)	(0.09)	(2.98)
YEAR96lnPARTNERS	0.0115			
	(0.14)			
YEAR96lnPROFESSIONALS	−0.0083			
	(−0.14)			
YEAR96lnOTHERS	0.0021			
	(0.04)			

Table 4 (*continued*)

Variables	(I) lnREVENUE	(II) A&A%/100	(III) TAX%/100	(IV) MAS%/100
YEAR97lnPARTNERS	−0.0145			
	(−0.17)			
YEAR97lnPROFESSIONALS	−0.0220			
	(−0.38)			
YEAR97lnOTHERS	0.0243			
	(0.43)			
YEAR98lnPARTNERS	−0.0314			
	(−0.37)			
YEAR98lnPROFESSIONALS	−0.0211			
	(−0.30)			
YEAR98lnOTHERS	0.0332			
	(0.50)			
YEAR99lnPARTNERS	−0.0712			
	(−0.86)			
YEAR99lnPROFESSIONALS	0.0147			
	(0.19)			
YEAR99lnOTHERS	0.0341			
	(0.48)			
System weighted R-squared	0.978			
System degrees of freedom	917			
Test of log-linear specification ($\beta_{ij}=0$ for all i,j):				
F-statistic	20.68			
Significance level	0.001			
Test of constant returns to scale:				
F-statistic	45.26			
Significance level	0.001			

Variable definitions appear in Table 1.

*indicates significant at 10% level; **indicates significant at 5% level; and ***indicates significant at 1% level for two-sided hypothesis tests.

Table 5
Estimation of productivity improvements over time (significance levels in parentheses)

Year	1995[a]	1996	1997	1998
1996	0.0271			
	(0.142)			
1997	0.0410	0.0139		
	(0.054)	(0.293)		
1998	0.0755	0.0484	0.0345	
	(0.002)	(0.030)	(0.087)	
1999	0.1019	0.0748	0.0609	0.0264
	(0.001)	(0.002)	(0.009)	(0.149)

[a] Productivity improvement between 1995 and year t is estimated as $\partial \ln \text{REVENUE}/\partial \text{YEAR } t$ based on the estimated Eq. (11) reported in Table 4.

simpler Cobb–Douglas (log-linear) form. To evaluate whether the Cobb–Douglas form could have provided an adequate representation of the revenue function, we tested whether the following conditions on (11) are satisfied:

$$\beta_{ij} = 0 \text{ for all } i, j = 1, \ldots, I. \tag{17}$$

The F-test results reported in Table 4 reject the null hypothesis of log-linear specification. We also check whether the estimated translog revenue function is monotonically increasing in each input. The results (not reported here) reveal no violation of monotonicity for PARTNERS, only 1 violation for PROFESSIONALS, and 43 violations out of a total of 320 observations for OTHERS.

6.1. Productivity improvement

Productivity may improve because of more efficient utilization of resources or greater price realizations for output services. The coefficient estimates of the four dummy variables for years 1996–1999 (YEAR96, YEAR97, YEAR98 and YEAR99) reported in Table 4 are all positive. Considering all the interaction terms involving the year dummies, the results of productivity improvements reported in Table 5 indicate that compared to 1995, the average productivity of public accounting firms improved over the 4 years at the rate ranging between 1.4% and 3.5% per year. Pairwise comparisons for consecutive years indicate statistically significant differences between all pairs of years except those between 1995 and 1996, between 1996 and 1997, and between 1998 and 1999.

6.2. Revenue shares

Parameter estimates for the revenue share functions are reported in columns (II), (III) and (IV) of Table 4. The coefficient estimate for PARTNERS is significantly positive in the A&A revenue share equation, and significantly negative in the MAS revenue share equation. In contrast, the coefficient estimate for PROFESSIONALS is significantly negative in the TAX revenue share equation and significantly positive in the MAS revenue share equation, and the coefficient estimate for OTHERS is significantly negative in the A&A revenue share equation and significantly positive in the MAS revenue share equation. These results imply that the smaller firms with disproportionately more PARTNERS deploy them to generate A&A or TAX service revenue, while firms with disproportionately greater numbers of PROFESSIONALS and OTHERS emphasize MAS services.

6.3. Economies of scale

The last section of Table 4 indicates that the conditions described in (9) are not satisfied for the overall sample and, therefore, the underlying production function is not characterized overall by constant returns to scale. Table 6 shows the scale elasticity measure, SCALE, evaluated at the average values of lnPARTNERS, lnPROFESSIONALS and lnOTHERS for the years 1995, 1996, 1997, 1998, and 1999, and all 5 years together. Scale elasticity is significantly greater than one for each year, indicating that increasing returns to scale have prevailed in the public accounting industry in recent years. When SCALE is evaluated individually for each firm, the number of firms with scale elasticity significantly greater than one overwhelmingly exceeds the number of firms with scale elasticity significantly less than one for each of the 5 years and when all 5 years are considered together. Thus, all evidence consistently points to the public accounting industry production function exhibiting significant scale economies throughout our sample period.

Table 6
Estimation of scale elasticity measures

	1995	1996	1997	1998	1999	All 5 years
Scale elasticity (SCALE) at sample mean	1.0560	1.0636	1.0499	1.0493	1.0535	1.0545
standard error of estimate	(0.0210)	(0.0209)	(0.0207)	(0.0211)	(0.0204)	(0.0168)
Significance level (SCALE = 1)	0.007	0.003	0.016	0.020	0.008	0.001
Number of firms with SCALE > 1	34	41	35	37	38	185
(significant at 5%)	(21)	(22)	(20)	(21)	(25)	(109)
Number of firms with SCALE < 1	30	23	29	27	26	135
(significant at 5%)	(6)	(3)	(8)	(2)	(10)	(29)

Variable definitions appear in Table 1.

$$\begin{aligned} \text{SCALE} = {} & (\beta_1 + \beta_2 + \beta_3) + (\beta_{11} + \beta_{12} + \beta_{13}) \ln \text{PARTNERS} \\ & + (\beta_{22} + \beta_{12} + \beta_{23}) \ln \text{PROFESSIONALS} + (\beta_{13} + \beta_{23} + \beta_{33}) \ln \text{OTHERS} \\ & + (\psi_1^{96} + \psi_2^{96} + \psi_3^{96})\text{YEAR96} + (\psi_1^{97} + \psi_2^{97} + \psi_3^{97})\text{YEAR97} \\ & + (\psi_1^{98} + \psi_2^{98} + \psi_3^{98})\text{YEAR98} + (\psi_1^{99} + \psi_2^{99} + \psi_3^{99})\text{YEAR99} \end{aligned}$$

6.4. Marginal revenue products

From panel A of Table 7, we observe that the marginal revenue product of partners calculated at sub-sample means has increased monotonically over time from \$740,902 in 1995 to \$922,522 in 1998 and decreased slightly to \$897,514 in 1999. The average marginal revenue product of partners was about nine times that of professionals and about eighteen times that of other employees. Also, the average marginal revenue product of professionals was about twice as large as that of other employees.

Panel B of Table 7 reports pairwise comparisons of marginal revenue products evaluated at sample mean for the three types of human resources. These comparisons indicate a statistically significant difference between partners and professionals as well as partners and other employees for the years 1995–1999, and all 5 years together. These comparisons also indicate a statistically significant difference between professionals and other employees for the years 1995 and 1996, and all 5 years together. Collectively, thus, the results support our second hypothesis.

Since national survey data indicate that compensation differentials between partners, professionals and other employees are in the proportions 6:2:1, we also conduct tests of whether their marginal revenue products display similar proportions (results not reported here). We find that the marginal revenue product of partners significantly exceeded 3 times the marginal revenue product of professionals as well as 6 times the marginal revenue product of other employees, indicating that partners were, in fact, under-compensated relative to professionals and other employees. In contrast, the marginal revenue product of professionals was not significantly different from 2 times the marginal revenue product of other employees, indicating that professionals were fairly compensated relative to other employees.

6.5. Ordinary least squares estimation

All of the parameter estimates required to calculate the scale elasticity and the marginal revenue product can be obtained from the estimation of only the revenue equation. Therefore, instead of estimating the system of Eqs. (11), (13) and (14) as SUR, we also estimate the revenue equation alone using OLS. The estimation results are very similar to those discussed earlier and are not reported. When we apply the criteria proposed by Belsley et al. (1980) to identify influential observations, and re-estimate this single equation after removing seven outliers, the results are also qualitatively similar to those discussed earlier, and are omitted.

The residual term $\varepsilon = \ln(\mathrm{REVENUE}_j/\mathrm{REVENUE}_j^*)$ measures the revenue generation productivity of firm j, where $\mathrm{REVENUE}_j^*$ denotes the estimated total revenue for firm j. We find that the revenue generation productivity is significantly and positively correlated with MAS% ($p = 0.019$) and A&A% ($p = 0.080$), but significantly and negatively correlated with TAX% ($p = 0.001$).

Table 7
Estimation of marginal revenue products

	1995	1996	1997	1998	1999	All 5 Years
Panel A: Marginal revenue products (MRP) evaluated at sub-sample means (standard errors in parentheses)						
MRP(PARTNERS)	\$740,902	\$825,272	\$854,355	\$922,522	\$897,514	\$848,113
	(\$92,475)	(\$104,264)	(\$109,695)	(\$129,204)	(\$131,307)	(\$57,694)
MRP(PROFESSIONALS)	\$89,429	\$92,854	\$89,361	\$95,812	\$109,683	\$95,428
	(\$8764)	(\$9451)	(\$8564)	(\$10,975)	(\$12,931)	(\$5854)
MRP(OTHERS)	\$40,169	\$38,791	\$51,320	\$56,614	\$51,237	\$47,626
	(\$20,715)	(\$21,996)	(\$25,532)	(\$33,833)	(\$35,698)	(\$17,948)

$$\mathrm{MRP}_i = \partial \mathrm{REVENUE}/\partial \mathrm{INPUT}_i = (\mathrm{REVENUE}/\mathrm{INPUT}_i) \times (\beta_i + \beta_{i1} \ln \mathrm{PARTNERS} + \beta_{i2} \ln \mathrm{PROFESSIONALS} + \beta_{i3} \ln \mathrm{OTHERS} + \psi_i^{96}\mathrm{YEAR96} + \psi_i^{97}\mathrm{YEAR97} + \psi_i^{98}\mathrm{YEAR98} + \psi_i^{99}\mathrm{YEAR99})$$

where INPUT_i = PARTNERS, PROFESSIONALS and OTHERS.

Panel B: Test of equality of MRP evaluated at sub-sample means	1995	1996	1997	1998	1999	All 5 Years
Significance level of test of						
MRP(PARTNERS) = MRP(PROFESSIONALS)	0.001	0.001	0.001	0.001	0.001	0.001
MRP(PROFESSIONALS) = MRP(OTHERS)	0.045	0.038	0.188	0.333	0.190	0.011
MRP(PARTNERS) = MRP(OTHERS)	0.001	0.001	0.001	0.001	0.001	0.001

Variable definitions appear in Table 1.

6.6. Stochastic frontier estimation

Economic theory defines the production function as the *maximum* output possible from a given level of inputs. In practice, however, firms may differ in their productivity in transforming the inputs into the outputs due to managerial inefficiencies or random factors. Therefore, we also employ a stochastic frontier model that specifies the error term ε as being composed of two independent components, u and v as follows:

$$\varepsilon = v - u, \tag{18}$$

where u is a one-sided error term that measures the shortfall of revenue from the maximum possible value given the frontier revenue function and input values, and v is a symmetric two-sided error term which captures the effects of random factors beyond the firm's control such as measurement error and other statistical noise. The error component v allows the frontier to vary across the public accounting firms, thus providing a stochastic nature to the frontier. The symmetric error v is distributed as $\mathrm{N}(0, \sigma_v^2)$, and the non-negative error u is distributed independently of v and derived from a $\mathrm{N}\ (0, \sigma_u^2)$ distribution truncated below at zero. Then, the density function of the composed error term $\varepsilon = v - u$ is given by

$$f(\varepsilon) = \frac{2}{\sigma\sqrt{2\pi}}[1 - F(\varepsilon\lambda/\sigma)]\exp\left[-\frac{\varepsilon^2}{2\sigma^2}\right], \tag{19}$$

where $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\lambda = \sigma_u/\sigma_v$ and $F(.)$ is the standard normal distribution function. This density function is asymmetric around zero, with mean $E(\varepsilon)$ and variance $\mathrm{Var}(\varepsilon)$ given below:

$$\mathrm{E}(\varepsilon) = \mathrm{E}(u) = -\sigma_u\sqrt{2/\pi}$$

$$\mathrm{Var}(\varepsilon) = \mathrm{Var}(u) + \mathrm{Var}(v) = \left(\frac{\pi - 2}{\pi}\right)\sigma_u^2 + \sigma_v^2. \tag{20}$$

We estimate the stochastic frontier using the maximum likelihood criterion, and evaluate hypotheses such as constant returns to scale based on the likelihood ratio $\lambda = L_\mathrm{R}/L_\mathrm{U}$, where L_U is the maximized value of the likelihood function for the unrestricted model and L_R for the model with restrictions that correspond to the hypothesis being evaluated. The test statistic $-2\ln\lambda$ is distributed asymptotically as chi-squared with degrees of freedom equal to the number of restrictions being imposed (Greene, 2000, p. 152).

Parameter estimates of the stochastic frontier model (not reported here) are similar to those reported in Table 4. As before, we find that the null hypothesis of log-linear specification is rejected. The estimates of both σ_u and σ_v are statistically significant, indicating the existence of inefficiency among the public accounting firms. Further, the estimate of σ_u (0.167) is not significantly different than that of σ_v (0.094), indicating that the variation among firms is attributed equally to inefficiency and random factors.

As before, we find that the performance of the public accounting industry improved from 1995 to 1999. The null hypothesis of constant returns to scale is rejected. Estimates of scale elasticity (not reported here) are significantly greater than one for all 5 years, supporting our hypothesis that economies of scale prevail in the public accounting industry. Stochastic frontier estimates of marginal revenue products of partners are also very similar to those reported earlier in Table 6 and hence are omitted.

6.7. Translog profit contribution functions specification

We specified the objective function of the accounting firms to be revenue maximization rather than profit maximization because accounting firms must commit to capacity levels for their professional staff in anticipation of service demand and it is difficult for them to adjust the capacity levels at short notice once these professional resources are committed. Therefore, the input quantities, especially the number of partners and the number of professionals, are considered to be exogenous in the short term. We maintain only the weaker assumption of revenue maximization (rather than profit maximization) embodied in the revenue function specification because of doubts about firms' ability to optimally adjust these inputs in the short run. Also, revenue maximization is a necessary condition for and consistent with profit maximization.

An additional practical problem that we must consider in our context of public accounting firms is that data on output prices and input prices is not available for individual firms. Therefore, while we consider these prices to be exogenous in each firm's optimization decision, for econometric estimation we need to impose additional structure as observed price data are not available. In particular, it is not feasible to estimate a profit function specification in which all input and output quantities are considered endogenous because the only remaining exogenous variables would be the prices for which data are not available for estimation. Therefore, as a compromise between the two extremes of a profit function that is not feasible to estimate and a revenue function that we estimated earlier, we also specified and estimated a translog profit contribution function by treating partners and professionals as exogenous variables, but allowing other employees to be an endogenous variable.

The results (not reported here) from the SUR estimation of the translog profit contribution function and the associated output profit contribution share equations and input profit contribution share equations as a system of equations are generally consistent with those discussed earlier for the translog revenue function specification. For instance, as before we find evidence supporting increasing returns to scale in all five sample years. The average marginal revenue product of partners increased monotonically from 1995 to 1997 and decreased slightly in 1999. Further, the public accounting industry exhibited continuing improvement in productivity over the 5 years.

7. Concluding remarks

In this study, we employed a translog revenue function to estimate the relation between service revenue generated and human resources employed by public accounting firms. We used a balanced panel of annual survey data for 64 of *Accounting Today*'s top 100 accounting firms for the period 1995–1999. Our study is perhaps the first in accounting research to estimate a public accounting industry production function.

Our results indicate that merger activities among accounting firms are justified by the existence of scale economies for our sample. The public accounting industry improved its productivity in delivering services over the period 1995–1999. On average, partners contributed 9 times more to generating revenues than professionals and 17–22 times more than other employees. These results suggest that partners were, on average, not over-compensated compared to both professionals and other employees. Empirical evidence about the production economics of public accounting firms thus helps explain observed phenomena in the industry, such as mergers and acquisitions, increased profitability in the late 1990s, and substantial compensation differentials between partners and other types of personnel.

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