A COMPARISON OF THE OPERATING PERFORMANCE OF ACCOUNTING INDUSTRY AMONG THE U.S., CHINA, AND TAIWAN

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ABSTRACT

In this study we employ the stochastic metafrontier (SMF) production function developed by Huang et al. (2011) to assess the technical efficiencies of accounting firms (AFs) among the U.S., China, and Taiwan, when operating under different technologies. Although AFs play an important role in a nation's capital market, the accounting industry has not attracted much attention from researchers. We collected panel data of the leading AFs in the three countries from 2007 to 2009, and the same output and three inputs can be identified. Taiwan's AFs are found to have the highest average overall efficiency and technology gap ratio (TGR), followed by the U.S. and Chinese AFs. The low performance of Chinese AFs may be attributed to government regulations and the lack of market competition. In addition, the three accounting industries show decreasing returns to scale, implying that mergers and acquisitions may not be advantageous for expanding and seizing a larger market share. Instead, we recommend these firms reduce their production scale to decrease the average long-term costs.

Keyword: Accounting Industry, Efficiency, Stochastic Metafrontier Approach

1. Introduction

A comparative study of operating performance on multi-country public accounting industry, with the important practical value, not only provided the important information for management of accounting firms, but also provided reference of control or guidance policy for the government authorities. However, prior literatures seldom focus on the comparative study of operating performance by multi-country public accounting industry.

Greenwood, Prakash and Deephouse (2005) and Bröcheler, Maijoor and Witteloostuijn (2004) pointed out that the accounting firms' performance and its determinants in academic literatures are relatively little to discuss, so scholars should be more effort for this issue. This has led to scholars from various dimensions to explore the related operating performance in the CPA industry, efficiency is one of them.

Review of literatures related to operating efficiency in public accounting industry found that Banker, Chang and Natarajan (2005), Chang, Choy, Cooper, Parker, and Ruefli (2009) and Knechel, Rouse, Schelleman (2009) explored the object based on US samples. Besides, Chang Chen, Duh, and Li (2011) used the samples according to Taiwan's 51 accounting firms. Chinese government also announced inputs and outputs data related to the top 100 CPA firms in China. However, so far, empirical literatures still lack to explore the efficiency issues on Chinese accounting firms. In short, prior studies related to one country's public accounting industrial research, have not yet extended to the comparative study of operating performance by multi-country public accounting industry.

The comparison of accounting industrial efficiency in multiple countries needs to adopt a reasonable benchmark, the metafrontier production function is one of them. Metafrontier production function was first proposed by Hayami (1969) and Hayami and Ruttan (1970, 1971), by Battese et al. (2004) and O'Donnell, et al (2008) improved it. Recently, Huang et al. (2011) proposes a two-step stochastic frontier approach that differs from Battese et al. (2004) and O'Donnell, et al (2008) mainly in the second step, where a SFA model is formulated and applied to obtain the estimates of the metafrontier, instead of relying on programming techniques. Furthermore, the so-derived estimators have the desirable statistical properties and separate the random shocks from the technology gap, so there is stochastic metafrontier method for reference among the comparison of cross-country efficiency.

As the CPA industry of each country in which the economic environment, legal regulations, national policies and operating systems is not the same. Therefore, public accounting industry of every country provides either content of professional services or structure of the input may also be different, namely the formation of heterogeneous production technologies. Up to now, the differences related to public accounting industry efficiency and productivity changes are still rare to explore in literatures based on the situation of heterogeneous production technologies. The purpose of this study uses by stochastic metafrontier production with the analytical heterogeneous production and technical capabilities to analyze and compare with the situation of efficiency difference on overall performance among the public accounting industry in three countries (USA, China and Taiwan).

In this paper we exploit a stochastic metafrontier production to estimate the country-specific frontier and the metafrontier, respectively, and to decompose the production efficiency scores of various groups into technical efficiencies and technology gaps. At the same time, we also provide another estimated result by employing an alternative method proposed by Battese et al. (2004) and O'Donnell et al. (2008). Our empirical results find that Taiwan's accounting firms has the highest average overall efficiency and technology gap ratio, followed by the U.S. and China. Conversely, the latter's result shows that the Chinese accounting firms still has the lowest performance and the U.S. accounting firms outperform Taiwan's accounting firms. However, compared with the results of the SMF model, QP model has the three countries lower average TGR and the larger standard deviation. Because that the technology gaps obtained from the programming technique may be contaminated by random shocks. This research hopes to provide a reference to the relevant decision-makers and fill the gap of the literatures.

The rest of the paper is organized as follows. Section 2 reviews prior literature regarding efficiency analysis research of accounting industry and metafrontier approach. Section 3 formulates the employed SMF method to estimate the metafrontier production function. Section 4 describes the data sources, sample selection, and descriptive statistics of an output and inputs of three countries. The empirical estimation and results are present in section 5. In Section 6, we summarize and conclude the paper.

2. Literature review

2.1 The efficiency analysis of the accounting industry among United States, Taiwan and China.

Scholars often study top 100 CPA firms in the United States for example, Banker, Chang and Cunningham (2003) initially studied those firms and found that the top 100 CPA firms in the U.S. between 1995-1999 years, due to a number of corporate mergers and acquisitions events, existing the incremental economies of scale and productivity improvements. Banker, Chang and Natarajan (2005) further explored factor decomposition of productivity change, found that productivity growth mainly comes from technical progress rather than efficiency upgrade. Chang, Choy, Cooper, Parker, and Ruefli (2009) selected 56 of top 100 CPA firms in the United States for study and found that the productivity gains was mainly attributed to technological progress rather than relative efficiency change before and after the Sarbanes-Oxley Act. Further, Chang, Choy, Cooper, and Ruefli (2009) also selected 62 of top 100 CPA firms in the United States for study and found that after the Sarbanes-Oxley Act, production efficiency of accounting industry is more improved, and efficiency change of that has significantly associated with the revenue growth on management & consultation in sample firms. Banker, Chang and Natarajan (2007) argued that the top 100 CPA firms exist significantly allocative inefficiency from 1995 to 1998.

In addition to prior studies, there are a number of articles related to efficiency analysis based on the case of large U.S. accounting firms. For example, Banker, Chang and Kao (2002) explored the relationship between information technology investment and technical efficiency on branch of large accounting firms in the United States. Dopuch, Gupta, Simunic and Stein (2003) analyzed input and output data of the internal audit cases by a large and representative accounting firm in the U.S. and explored the relationship between its production efficiency and the audit fee pricing. Knechel, Rouse, Schelleman (2009) assessed the relative efficiency of the internal audit cases using an international CPA firm by data envelopment analysis (DEA).

Except the efficiency research of the American Institute of Certified Public Accountants industry, the efficiency analysis of the accounting industry in other countries is relatively rare due to the limit on the obtained data. For instance, Cheng, Wang and Weng (2000a) used the two-stage DEA to assess technical efficiency of Taiwan’s CPA firms in 1994 and estimated the impact factor by Tobit model. Cheng, Wang and Weng (2000b) used the same period CPA firm data to conduct empirical analysis and found that the output of the audit, tax and management & consultant services with economies of scale, there are economies of scope in providing tax and management & consultant services. Recently, Chang Chen, Duh, and Li (2011) used DEA to measure Taiwan’s 51 CPA firms from 1993 to 2003, found the relationship between income growth of management & consultation services and changes of production efficiency is not a significant correlation.

Chinese government also announced inputs and outputs data related to the top 100 CPA firms in China. However, so far, empirical literatures still lack to explore the efficiency issues on Chinese CPA firms.

Reviewing prior studies, in summary, its object of efficiency research related to CPA industry is mainly on US and Taiwan, and the empirical literatures related to China’s CPA firms are still rare. Besides, the sample and method of efficiency researches are almost single country and DEA-based.

2.2 Literature review of metafrontier approach

The purpose of this paper is to compare production efficiency of CPA industries in three countries (United States, China and Taiwan), using a stochastic metafrontier frontier production function. Hayami (1969) first proposes the meta-frontier production function to examine the causes of agricultural productivity differences among developed and less developed countries, followed by Hayami and Ruttan (1970, 1971). Hayami and Ruttan (1970, 1971) make a crucial assumption that the technological possibilities available to all agricultural producers in different countries can be characterized by the same production function - namely, the meta-production function. This concept is theoretically attractive, because it is based on the simple hypothesis that all producers in different countries have potential access to the same technology and it allows for the comparisons of production efficiencies among producers operating under different technologies. It is pivotal to note that the framework of the meta-production function does not necessarily imply that all producers operate on a universal production function. The meta-production function, proposed by Ruttan et al. (1978), is an envelope curve of production points of the most efficient countries.

Each country may choose to operate on different part of the production possibility curve, depending on its resource endowments, adoption and diffusion of technology, and economic environments. Following Hayami and Ruttan (1970, 1971), Lau and Yotopoulos (1989) employ the meta-production function approach to compare agricultural productivity across countries. This approach is econometrically advantageous due to its competence to collect data from different countries so that the scope of variations of the dependent and independent variables and the number of observations can be dramatically increased. Moreover, it reduces the possibility of multicollinearity among inputs, as the key inputs are usually changing together. Several limitations exist inherent to this approach. However, the incomparability of data, the differences in the basic economic environment, and the specification of an appropriate production function pose some difficulties.

Battese and Rao (2002) attempt to compare the technical efficiencies of firms in different groups that may not have the same technology on the basis of the stochastic meta-frontier production function. They assume that there are two different data generation mechanisms for the data: one with respect to the stochastic frontier that is estimated using data belonging to that group, and the other with respect to the meta-frontier model that is estimated using entire sample data. The estimation of the technology gap provides information on the ability of the firms in one group to compete with other firms from different groups within an industry (a region or a nation). Battese et al. (2004) modify the above model by assuming that data generation processes are only applied to the frontier models for the firms in the different groups. The meta-frontier production function is an overarching function of a given mathematical form that envelopes the deterministic parts of a set of stochastic frontier production functions for firms that operate under different technologies involved. O'Donnell et al. (2008) also adopt similar concept.

However, due to Battese et al. (2004) and O'Donnell et al. (2008) proposed the use of mathematical planning through the second step estimated the metafrontier, so there is always unable to remove the influence of random factors, also failed to deal with the statistical inference of estimated results. According to this problem, Huang et al. (2011) based on the basis of the SFA, the parameter estimates of the metafrontier on second step also use SFA to estimate. So, in the estimation of the metafrontier or random factors included in the estimation of the efficiency values, it can exclude extreme values. In addition, the estimated results can also be related to testing and analysis. So, production efficiency estimation of this method is used in this article.

3. Methodology

The metafrontier production function model for firms in different groups adopting heterogeneous technologies, developed by Battese et al. (2004) and O'Donnell et al. (2008), is suggested to be estimated by a two-step procedure. In the first step the group-specific stochastic frontier is estimated for each group and the mathematical programming technique is applied to estimate the metafrontier in the second step. Following Battese et al. (2004) and O'Donnell et al. (2008), a stochastic group-specific production frontier is formulated as

$$y_{jit} = f_t^{\,j}(x_{1jit}, x_{2jit}, ..., x_{Mjit}; \beta^j)\, e^{V_{jit}-U_{jit}}, \qquad (1)$$
$$j = 1, 2, ..., J; \quad i = 1, 2, ..., N_j; \quad t = 1, 2, ..., T$$

where y_{jit} denotes the output of the i^{th} firm in the j^{th} group at the t^{th} period; x_{mjit} is the m^{th} input quantity of the i^{th} firm in the j^{th} group at the t^{th} period; β^j is an unknown technology parameter vector associated with the j^{th} group. Note that the production function $f_t^{\,j}(.)$ is both subscripted by t and superscripted by j, characterizing that the individual group-specific production function can vary across groups and over time. The random errors V_{jit}s represent statistical noise and are assumed to be independently and identically distributed as $N(0, \sigma_v^{j2})$; U_{jit}s represent technical inefficiency and are assumed to be a truncated normal random variable as $|N(\mu_{it}^j, \sigma_u^{j2})|$, where the μ_{it}^ks are defined by some appropriate inefficiency model (e.g., the model of Battese and Coelli, 1995). After taking the natural logarithm on the both sides of (1), the transformed regression model can be estimated by the maximum-likelihood (ML). A firm's technical efficiency (TE) is defined as:

$$TE_{it}^j = \frac{y_{jit}}{f_t^j(X_{jit})\, e^{V_{jit}}} = e^{-U_{jit}}, \quad (2)$$

where X_{jit} denotes the input vector of the i^{th} firm in the j^{th} group at the t^{th} period.

The common underlying metafrontier production function for all groups in the t^{th} period is defined as $f_t^M(X_{jit})$, $j = 1, 2, \ldots, J$. The metafrontier $f_t^M(X_{jit})$ by definition envelops all individual group's frontier $f_t^j(X_{jit})$. Their relationship is formulated as follows.

$$f_t^j(X_{jit}) = f_t^M(X_{jit})\, e^{-U_{jit}^M}, \quad \forall\ j,\ i,\ t \quad (3)$$

where $U_{jit}^M \geq 0$, implying that $f_t^M(.) \geq f_t^j(.)$ and the ratio of the j^{th} group's production function to the metafrontier is defined as the technology gap ratio (TGR),[1] i.e.,

$$TGR_{it}^j = \frac{f_t^j(X_{jit})}{f_t^M(X_{jit})} = e^{-U_{jit}^M} \leq 1. \quad (4)$$

At any given input level X_{jit}, the gap between a firm's observed output y_{jit} and the metafrontier $f_t^M(X_{jit})$ can be decomposed into three components, i.e.,

[1] Readers are suggested to refer to Battese and Rao (2002), Battese et al. (2004), O'Donnell et al. (2008), and Huang et al. (2011) for the detailed formulation and interpretation of the TGR.

$$\frac{y_{jit}}{f_t^M(X_{jit})} = TGR_{it}^j \times TE_{it}^j \times e^{V_{jit}}. \quad (5)$$

The three components are referred to as the i^{th} firm's TGR_{it}^j, technical efficiency, and random noise $e^{V_{jit}}$.

It should be emphasized that, although both the technology gap ratio TGR_{it}^j and the firm's production efficiency TE_{it}^j are bounded between zero and unity, the metafrontier $f_t^M(X_{jit})$ does not necessary envelop all firms' observed outputs y_{jit} due to the possible random noise. The unrestricted ratio in (3) distinguishes the metafrontier modeling using the stochastic frontier analysis (SFA) from using the data envelopment analysis (DEA). To account for the random noise component, (5) can be re-expressed as:

$$MTE_{jit} \equiv \frac{Y_{jit}}{f_t^M(X_{jit})\, e^{V_{jit}}} = TGR_{it}^j \times TE_{it}^j \quad (6)$$

where MTE_{jit} denotes the i^{th} firm's production efficiency with respect to the metafrontier production technology, $f_t^M(.)$, rather than the group-*j* production technology $f_t^j(.)$.

Empirical measurement of the above metafrontier efficiency consists of two steps. Following Battese et al. (2004) and O'Donnel et al. (2008), the first step requires the use of the ML estimation to estimate each group-specific frontier like (1). Let $\hat{f}_t^j(X_{jit})$ be the fitted value of the group-*j*'s production function and $T\hat{E}_{it}^j$ the group-*j*'s estimated technical efficiency score. In the second step, the metafrontier function $f_t^M(.)$ is obtained by minimizing the sum of absolute deviations or the sum of squares of the deviations between $f_t^M(.)$ and $\hat{f}_t^j(X_{jit})$. Standard errors for the parameter estimates of the metafrontier function can be obtained using simulation or bootstrapping methods.

The so-derived deterministic metafrontier function $f_t^M(.)$ from the mathematical programming technique may have some inherent drawbacks worth mentioning. First of all, it is difficult to give a meaningful statistical interpretation to the computed metafrontier function, since the statistical properties of the parameter estimates are unknown. Second, the programming approach is unable to distinguish the random shocks from the model such that the estimated metafrontier efficiency score is likely to be confounded with the shocks. We therefore utilize a new method to estimate the metafrontier production function in the second step, which is first proposed by Huang et al. (2011). The method suggests estimating the metafrontier function under the framework of the stochastic frontier approach, rather than the mathematical programming technique in the second step.

On the basis of (3), the following relation is held, i.e.,

$$\ln f_t^j(X_{jit}) = \ln f_t^M(X_{jit}) - U_{jit}^M \quad (7)$$

The group-specific frontier $f_t^j(X_{jit})$ is not observable, but it can be estimated in the first step. Since the fitted value of $f_t^j(X_{jit})$, $\hat{f}_t^j(X_{jit})$, differs from the true frontier of $f_t^j(X_{jit})$ randomly, (7) can then be re-written as:

$$\ln \hat{f}_t^j(X_{jit}) = \ln f_t^M(X_{jit}) - U_{jit}^M + V_{jit}^M, \quad (8)$$

where the added symmetric error V_{jit}^M is exactly the noise representing the deviation between $\hat{f}_t^j(X_{jit})$ and $f_t^j(X_{jit})$, i.e.,

$$\ln \hat{f}_t^j(X_{jit}) = \ln f_t^j(X_{jit}) + V_{jit}^M \quad (9)$$

Equation (8) resembles the conventional stochastic frontier model and $\ln f_t^M(X_{jit}) + V_{jit}^M$ is referred to as the stochastic metafrontier (SMF). Since $\ln \hat{f}_t^j(X_{jit})$ is obtained by the ML, the parameter estimates are consistent and asymptotically normally distributed. It is legitimate to assume that the error V_{jit}^M is normally distributed as $N\left(0, \sigma_v^{M2}\right)$. The non-negative technology gap component $U_{jit}^M (\geq 0)$ is assumed to be distributed as truncated-normal, i.e.,

$U_{jit}^{M} \sim N^{+}\left(\mu^{M}, \sigma_{u}^{M2}\right).$

The new two-step stochastic frontier approach allows for the estimated group-specific frontier to be either less than or larger than the metafrontier, due to the presence of the error V_{jit}^{M} in (8). However, the metafrontier is always higher than the true group-specific frontier by construction, i.e., $f_t^{\,j}(X_{jit}) \le f_t^{M}(X_{jit})$. The estimated TGR is computed according to the following formula:

$$T\hat{G}R_{it}^{j} = \hat{E}\left(e^{-U_{jit}^{M}} \mid \hat{\varepsilon}_{jit}^{M}\right) \le 1 \qquad (10)$$

where $\hat{\varepsilon}_{jit}^{M} = \ln \hat{f}_t^{\,j}(X_{jit}) - \ln \hat{f}_t^{M}(X_{jit})$ is the estimated composite residuals of (8).

In sum, the main difference between the new two-step approach proposed by Huang et al. (2011) and the one proposed by Battese et al. (2004) and O'Donnell et al. (2008) lies in the second step, where the original deterministic programming technique is replaced by the SMF approach. The new approach is preferable, because it allows for the presence of the random error V_{jit}^{M}, such the estimated TGR in (10) immunes from the influence of random shocks, as opposed the programming method. In addition, since (8) has to be estimated by the ML, the resulting parameter estimates have the usual statistical properties that allow for conducting statistical inferences.

4. Variable definitions and data sources

4.1. Data Sources

The purpose of this study is to compare the overall technical efficiency scores against the metafrontier (MTE) and technology gap ratio (TGR) of the accounting industry in United States, China and Taiwan. In preparing for our empirical estimations, we have collected data of the outputs and inputs respectively from Top-100 CPA firms of the three countries, which are ranked by total revenue. In reaching comparing basis of the same inputs and outputs from the three countries' accounting industries, the sample is an unbalanced panel structure, taken from the different sources ranging from 2007 to 2009.

First, the U.S. sample is taken from Accounting Today's annual surveys of the Top-100 accounting firms. After excluding firms with missing values, the final sample consists of 109 CPA firms, totaling 297 firm-years. Secondly, Taiwan accounting industry data used for this study is obtained from Annual Survey of Accounting Firms in Taiwan, which is published by the Financial Supervisory

Commission ROC. After excluding firms with 0 professionals, the final sample consists of 50 CPA firms, totaling 105 firm-years.

Finally, in response of the international trend and the basis for the formulation development policy as a CPA industry, the Chinese Institute of Certified Public Accountants (CICPA) begun in 2003 to publish the top accounting firms ranking based on the comprehensive evaluation. However, the items reported on the annual ranking publication are inconsistent, therefore, the Chinese sample of 142 accounting firms, totaling 300 firm-years, is eventually collected.

4.2. The Output

Previous studies on technical efficiency of the U.S. accounting industry mostly use the three outputs variables, which include accounting and auditing (A&A), tax services (TAX), and management advisory services (MAS) (i.e., Banker et al. 2003, 2005, Chang et al. 2009). However, the total revenue data released by CICPA in total includes only audit services and non-audit services revenues. It is a difficulty to compile the US and Chinese data to the only two items, audit service and non-audit service revenues. Different from US and Chinese data, the revenue items released by Taiwan are much more complete. Therefore, in order to be able to compare the various production efficiency scores of the accounting industry in the United States, China and Taiwan, this study uses a single output variable.

We use accounting firms' total revenue as the output variable. In order for the consistent comparing basis of the three countries data, Firstly, total revenue is converted to real variables by deflating the consumer price index deflator of each country with the base year of 2005. After deflating, an output variable is measured in millions of U.S. dollars which are translated by the annual average exchange rate of the NT and the RMB.

4.3. Input Variables

Following the accounting research literature (Banker et al. 2003, 2005, Chang et al. 2009) , the inputs we considered represent three key categories of a firm's human resources, including "Partners" representing the number of partners, owners and/or shareholders, "Professionals" representing the number of other professionally qualified staff who are not partners, and "Others" representing all other employees who are not included in either of the first two sets.

4.4. Descriptive Statistics

Panel A of Table 1 shows sample statistics of all variables in the three countries. The table shows that the average total operating revenue of the US accounting firms (388.24 million U.S. dollars) is the highest. This is respectively 15.8 times to the Chinese accounting firms (the mean of 24.51 million U.S. dollars), and 27.3 times to

Taiwan accounting firms (the mean of 14.22 million U.S. dollars). However, for the firm's manpower invested individually by the three countries, the mean of partners are still the most in the US accounting firms. This is about 9 times to Chinese firms and 10.6 times to Taiwan firms, respectively. In addition, the average difference of the professional assistant numbers between the three countries is dissimilar. The average number of professional assistants in U.S. is 1,304.20, followed by the Chinese firms, and the one of Taiwan firms is the smallest. The difference of average professional assistant number between the US and Taiwan is 42.9 times. Finally, the number of other employees and executives of the accounting firms, is about the same among the three countries.

In order to obtain productivity information of individual input variables, we further calculate the average output that three national accounting industries each put into the parameter and tabulate in the panel B of table 1. As a whole, the average the output which created by the partners of Chinese firms is the highest (6.94 million U.S. dollars), followed by U.S. firms (1.68 million U.S. dollars), and Taiwan firms (0.45 million U.S. dollars). Secondly, the mean for output which created by the professional assistants of Taiwan firms is the highest (1.00 million U.S. dollars), followed by U.S. firms (0.24 million U.S. dollars), and Chinese firms (0.09 million U.S. dollars). Finally, if ranking by the mean for output which created by the other employees, the U.S. (0.97 million U.S. dollars) is the best, followed by China (0.05 million U.S. dollars) and Taiwan (0.04 million U.S. dollars). The results reveal that the three countries are comparable with different input variables to create operating revenue. Therefore, it is not possible using only a single ratio to determine which one is better. It is required to simultaneously consider all input and output method which can correct comparison. This is the main cause of this study to use the stochastic frontier method.

In addition, to understand the significant differences between the input and output variables of accounting firms existing by the factors of country and the firm's operating environment etc., the study employs the mean difference test, and the test results are summarized in Table 2. It is shown on the Table 2 that there is no significant difference of other employees and executives of the firm between different countries. However, the significant difference ($p<0.01$) exists among the three countries for the three variables: the firms' total revenue, total number of partner, and total number of professional assistants. The results imply that the CPA firm production technology in these three countries is the potential difference. In order to compare three countries accounting industries under the common basis, the better assessment method adopted would be stochastic metafrontier method, which takes the heterogeneous production technology into consideration.

Table 1. Descriptive Statistics

Panel A: Summary statistics of the accounting industry data

Variables	U.S. Accounting Firms (number of observations=297)			R.O.C. Accounting Firms (number of observations=105)			China Accounting Firms (number of observations=300)		
	Mean (St. Dev.)	Min	Max	Mean (St. Dev.)	Min	Max	Mean (St. Dev.)	Min	Max
Output variable									
Total revenue (y)	388.24	25.22	10,309.86	14.22	0.52	190.05	24.51	2.33	357.26
	(1,431.88)			(37.43)			(60.29)		
Input variable									
Partners (X1)	153.87	8	2,949	14.50	2	136	17.14	2	46
	(444.77)			(26.85)			(11.11)		
Professionals (X2)	1,304.20	48	32,857	30.43	1	551	200.08	9	1,228
	(4,378.96)			(93.65)			(191.61)		
Other employees (X3)	384.48	11	9,123	229.99	11	2,281	479.41	20	5,490
	(1,269.22)			(511.05)			(847.18)		

Panel B: Average output per unit of input

	U.S. Accounting Firms			R.O.C. Accounting Firms			China Accounting Firms		
	X1	X2	X3	X1	X2	X3	X1	X2	X3
Total revenue (y)	1.68	0.24	0.97	0.45	1.00	0.04	6.94	0.09	0.04

Note: All dollar-valued variables are measured in millions of real U.S. dollars with base year 2005.

Table 2. Joint Tests for Equality of Mean Output and Inputs among Countries

Variables	U.S.	R.O.C.	China	F-stat. (p-value)
Total revenue (y)	388.24	14.22	24.51	13.22 (< 0.001)
Partners (X1)	153.87	14.50	17.14	19.28 (< 0.001)
Professionals (X2)	1,304.20	30.43	200.08	14.02 (< 0.001)
Other employees (X3)	384.48	229.99	479.41	2.43 (0.089)

Note: Total revenue is measured in millions of real U.S. dollars (US$) with base year 2005.

5. Empirical Results

5.1. Results of Group Frontier Estimation

This study employs the two-step metafrontier production function developed by Huang et al. (2011) to assess the overall technical efficiencies of accounting firms among the U.S., China, and Taiwan, when operating under different technologies. First of all, the first-step is to use SFA method to estimate parameter of country-specific production frontier. Secondly, to merge all samples in the second-step, SFA method is still used to estimate parameter of metafrontier. The second-step our study uses is different to Battese et al. (2004) and O'Donnell et al. (2008). The latter utilizes the linear programming method to estimate the metafrontier. However, as the shortcomings of mathematical programming methods, this model does not consider the random effect. This is not only excluding the impact of random disturbance term on the coefficient estimates, but also unable to use each estimated coefficient value for statistics inferences. In order to clearly compare the difference of the metafrontier, the estimation results and efficiency scores from the two methods are provided as follows.

As mentioned earlier, limited by inconsistent information provided by the national database so as to lack of cross-nation comparability, this study uses three inputs and single output variable. Therefore, the quite flexible translog production function is employed as the study’s empirical model. The changes in production technology captured by time trend are also considered. The functional form is as follows:

$$\ln Y_{it} = \beta_0 + \sum_{j=1}^{3}\beta_j \ln x_{jit} + \sum_{j=1}^{3}\sum_{k=1}^{3}\beta_{jk} \ln x_{jit} \ln x_{kit} + \alpha_0 t + \alpha_1 t^2 + \sum_{j=2}^{4}\alpha_j \ln x_j t + V_{it} - U_{it} \quad (11)$$

5.2. Results of Group Frontier Estimation

Before performing estimates of the production frontier from each group in the first stage, we must confirm whether there are differences of the accounting firms’ production technology between the accounting industries of the three countries. If there is no difference among these countries, it is not necessary to use the two-stage estimate method, and needs no calculation of the technology gap ratio. We use the likelihood ratio test to clarify this point. The test statistic is $\lambda = -2\{ln[L(H_0) - L(H_1)]\}$, which $ln[L(H_0)]$ is log likelihood function value merging from the three countries and $ln[L(H_1)]$ is the sum of the individual country-specific frontier log likelihood function value. The study obtains λ of the function equal to 700.31, and the degree of freedom of 36, at 1% level of significance level. This result does reveal the technical differences existing among the three countries, and technical differences should be considered in the analytical model.

Table 3 shows the parameter estimates of the country-specific frontier by using SFA method. In each group, more than half of the estimated coefficient reaches at least 10% level of significance. This indicates that function relationship exists between the independent variables and the dependent variables, in accordance with the requirements of the production theory. However, among the three nations, each variable has the different direction and extent of the impact, which means that the significant differences may exist in the production technology or characteristics of each nation, and results in the significantly difference of technical parameter estimates.

Table 3. The Parameter Estimates of Group-specific Production Frontiers

Variables	U.S.		R.O.C.		China	
	parameter	St. Err.	parameter	St. Err.	parameter	St. Err.
Constant	5.177***	0.419	3.107***	0.456	6.752***	0.787
$\ln x_1$	-0.279	0.271	-0.270	0.316	-0.300	0.237
$\ln x_2$	0.555*	0.295	-0.097	0.158	-0.127	0.266
$\ln x_3$	0.327***	0.133	0.532	0.350	-0.460	0.293
t	-0.144***	0.039	0.155**	0.077	0.080	0.153
$\ln x_1 \times \ln x_1$	0.028	0.047	-0.030	0.062	0.146***	0.037
$\ln x_2 \times \ln x_2$	0.001	0.059	0.024	0.023	0.121*	0.073
$\ln x_3 \times \ln x_3$	0.048***	0.019	-0.033	0.067	0.106***	0.039
t^2	0.016***	0.006	-0.027*	0.014	-0.038**	0.021
$\ln x_1 \times \ln x_2$	0.071	0.093	-0.162**	0.074	-0.081	0.064
$\ln x_1 \times \ln x_3$	0.001	0.043	0.183*	0.103	-0.021	0.043
$\ln x_1 \times t$	-0.050***	0.013	-0.046*	0.027	0.056***	0.022
$\ln x_2 \times \ln x_3$	-0.100**	0.057	0.090	0.065	-0.063	0.106
$\ln x_2 \times t$	0.060***	0.013	0.023*	0.015	0.004	0.049
$\ln x_3 \times t$	-0.013	0.009	0.007	0.020	-0.003	0.038
σ^2	0.151***	0.024	0.176***	0.040	0.319***	0.062
γ	0.984***	0.003	0.982***	0.006	0.944***	0.016
η	0.044**	0.022	-0.010	0.042	0.122***	0.043
Log-Likelihood	261.07		69.32		-1.89	

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

5.3. Results of MetaFrontier Estimation

Secondly, all the samples are combined in the second stage. The parameter estimates of the metafrontier proposed by Huang et al. (2011) are presented in the left of Table 4. In order to clearly understand the comparison of the methods employed to estimate metafrontier parameter on the previous studies, for example Battese et al. (2004) and O'Donnell et al. (2008) uses mathematical programming method to find the metafrontier production function. The results of their studies are presented in the right of Table 4. In order to be able to correct the shortcomings of mathematical planning approach failing to consider the random factors, and to gain the estimated standard error by coefficient estimate from the QP model for the test, the study uses bootstrapping methods, suggested by Battese et al. (2004), to obtain the parameter estimates.

Table 4. Parameter Estimates of the Metafrontier Production Function

Variables	SMF Approach		QP Approach	
	parameter	St. Err.	parameter	St. Err.
Constant	4.843^{***}	0.214	3.958^{***}	0.483
$\ln x_1$	0.517^{***}	0.079	0.027	0.266
$\ln x_2$	0.965^{***}	0.055	0.944^{***}	0.140
$\ln x_3$	-0.763^{***}	0.082	0.184	0.249
t	-0.246^{***}	0.080	-0.069	0.365
$\ln x_1 \times \ln x_1$	0.083^{***}	0.016	0.176^{***}	0.062
$\ln x_2 \times \ln x_2$	0.098^{***}	0.009	0.004	0.025
$\ln x_3 \times \ln x_3$	0.229^{***}	0.011	0.056^{*}	0.030
t^2	0.066^{***}	0.015	0.020	0.089
$\ln x_1 \times \ln x_2$	0.001	0.024	-0.072^{**}	0.032
$\ln x_1 \times \ln x_3$	-0.114^{***}	0.015	-0.046^{*}	0.026
$\ln x_1 \times t$	-0.010	0.012	-0.054	0.038
$\ln x_2 \times \ln x_3$	-0.257^{***}	0.015	-0.087^{***}	0.018
$\ln x_2 \times t$	0.003	0.008	0.035^{*}	0.021
$\ln x_3 \times t$	-0.001	0.009	-0.004	0.031
σ^2	0.150^{***}	0.010	-	-
γ	0.822^{***}	0.028	-	-
η	0.081	0.030	-	-
Log-Likelihood	-137.65		-	

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

5.4. Various Efficiency Measures

Table 5 reports the sample estimates of various efficiency scores, including TGR, TE, and MTE for three countries. For the purpose of comparison, estimates obtained from the mixed approach of Battese et al. (2004) and O’Donnell et al. (2008) are listed the left of Table 5 and estimates obtained from the stochastic frontier approach are listed the right of Table 5. Since the country-specific frontier is specified exactly the same as O’Donnell et al. (2008), the technical efficiency scores of each country by both approach are the same.

Taiwan's accounting firms are found to have the highest average overall efficiency (0.67), followed by the U.S. (0.60) and Chinese accounting firms (0.38). Besides, Taiwan's accounting firms are also found to have the highest average technology gap ratio (0.88) followed by U.S (0.82) and China (0.59).

Otherwise, the metafrontier model used by Battese et al. (2004) and O'Donnell et al. (2008) has different outcome. Although Chinese accounting firms still has the lowest performance, the U.S. accounting firms outperform Taiwan's accounting firms, and the variances of overall efficiency and TGR increase. Following, figure 1 to 6 show the sample estimates of various efficiency scores, including TGR, GTE, and MTE for three countries and three year. As mentioned earlier, the low performance of Chinese accounting firms may be attributed to government regulations and the lack of market competition. In addition, the three accounting industries show decreasing returns to scale, implying that mergers and acquisitions may not be advantageous for expanding and seizing a larger market share. Instead, we recommend these firms reduce their production scale to decrease the average long-term costs.

Table 5. Summary statistics of various accounting industry efficiency measures

	SMF Estimates				QP Estimates			
	Mean	St. Dev.	Min	Max	Mean	St. Dev.	Min	Max
Panel A: 2007-2009								
U.S. Accounting Firms:								
TGR	0.82	0.17	0.12	1.00	0.86	0.09	0.46	1.00
GTE	0.74	0.14	0.22	0.99	0.74	0.14	0.22	0.99
MTE	0.60	0.16	0.03	0.91	0.64	0.14	0.10	0.95
R.O.C. Accounting Firms:								
TGR	0.88	0.06	0.66	0.97	0.59	0.21	0.25	1.00
GTE	0.76	0.16	0.38	0.98	0.76	0.16	0.38	0.98
MTE	0.67	0.14	0.36	0.93	0.44	0.17	0.16	0.90
China Accounting Firms:								
TGR	0.59	0.12	0.34	0.96	0.25	0.12	0.12	1.00
GTE	0.63	0.18	0.15	0.98	0.63	0.18	0.15	0.98
MTE	0.38	0.16	0.07	0.88	0.16	0.11	0.02	0.74
Overall:								
TGR	0.73	0.18	0.12	1.00	0.56	0.31	0.12	1.00
GTE	0.69	0.17	0.15	0.99	0.69	0.17	0.15	0.99
MTE	0.52	0.20	0.03	0.93	0.40	0.26	0.02	0.95

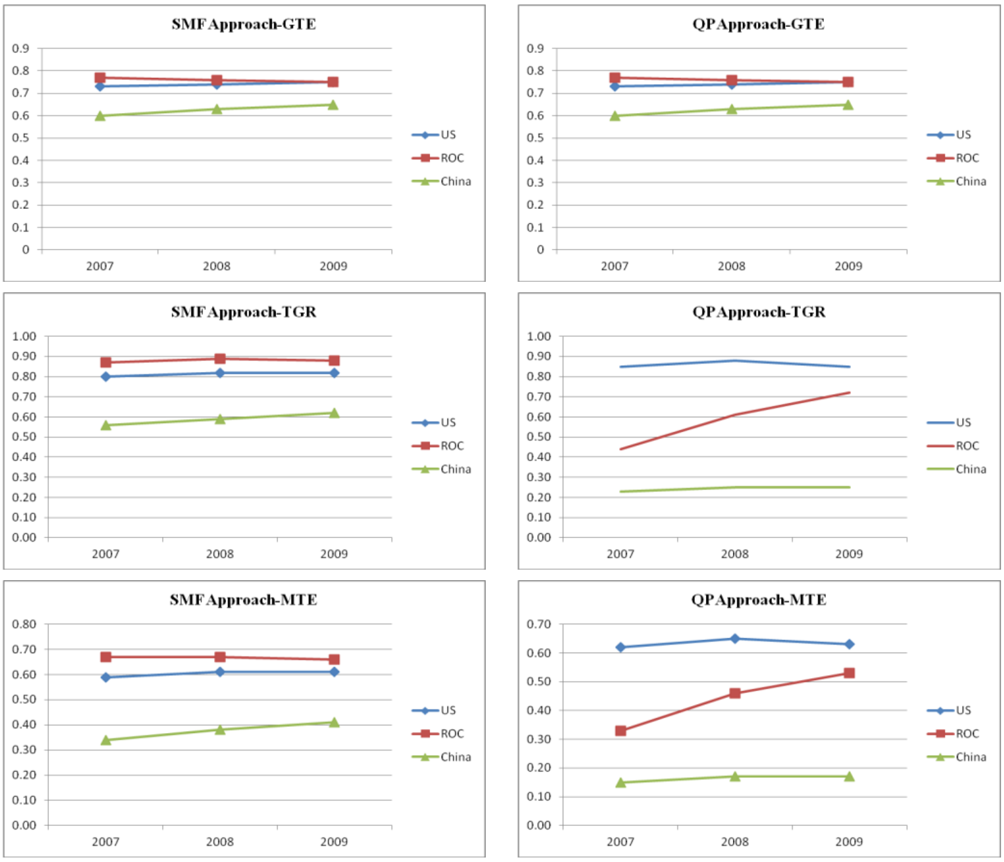

Figure 1 - 6 Summary statistics of various accounting industry efficiency measures

5.5. Hypothesis Testing

In order to detect whether the technical efficiency and TGR among each country in the same year have significant differences. Table 6 shows the significance tests for measures of TGR and MTE across countries. It is shown on the Table 6 that there is significant difference of TGR and MTE in three countries. This result is still provide an evidence to show Taiwan's accounting firms operating performance is better than U.S. accounting firms, and Chinese accounting firms has the lowest performance.

Table 6. Significance Tests for Measures of TGR and MTE Across Countries

Variables	T-test						F-test	
	U.S. & R.O.C		U.S. & China		R.O.C. & China		Among	
	t-stat.	P-value	t-stat.	P-value	t-stat.	P-value	F-stat.	P-value
Period : 2007-2009								
TGR	-5.777	< 0.001	18.747	< 0.001	32.043	< 0.001	276.605	< 0.001
MTE	-3.543	< 0.001	17.400	< 0.001	16.699	< 0.001	212.698	< 0.001
Period: 2007								
TGR	-3.025	0.003	10.605	< 0.001	17.908	< 0.001	88.660	< 0.001
MTE	-2.409	0.017	10.678	< 0.001	10.919	< 0.001	82.487	< 0.001

Period: 2008								
TGR	-3.491	0.001	11.732	< 0.001	20.332	< 0.001	107.470	< 0.001
MTE	-2.091	0.038	10.529	< 0.001	10.007	< 0.001	77.459	< 0.001
Period: 2009								
TGR	-3.562	0.001	10.346	< 0.001	17.951	< 0.001	88.546	< 0.001
MTE	-1.592	0.114	9.082	< 0.001	8.263	< 0.001	55.659	< 0.001

Note： Average values of TGR and MTE are calculated on the basis of SMF model.

6. Conclusions and Recommendations

The aim of this study was to compare the overall efficiency and technology gap ratio of the accounting industry in China, Taiwan and the U.S. Because the stages of economic development (developing and developed nations), systems of governance (democratic and socialist systems), regulations and standards in these countries are all considerably different, there are potential differences in the production technology of their accounting industries. In seeking to employ an approach suited to analysing variant production technology, this study used the two-stage stochastic frontier approach developed by Huang et al. (2011) to compare overall efficiency in the accounting industries of Taiwan, China and the U.S. Apart from remedying gaps in existing research, we hope that the results of this study will provide valuable reference for governing bodies and managerial staff in the accounting industry.

The key findings of this study are as follows:

Taiwan scored highest in average technical efficiency, followed by the U.S. and then China. Likewise, the technology gap ratio was the highest in Taiwan, followed by the U.S and lastly China. This shows that the accounting industry in Taiwan surpasses the U.S. in overall production technology but ranks closer to the U.S. in terms of digital levels. The accounting industry in China scored the lowest in both indicators of technical efficiency.

From the angle of technology gap ratio, the results showed marked growth in the accounting industry of China each year, indicating that its production technology is continually moving toward the boundary. With growth and expansion policy promoted by the Chinese government, it may be that this rapid concentration is driven by the overall force of the socialist system of China. Compared to China, the average technology gap ratios of Taiwan and the U.S. showed scant increase, indicating that these two nations are closer to the boundary and their pace of progress will naturally be slower than that of China.

This study analysed and compared the production efficiency of the accounting industries in only three nations. Future studies may wish to research other relevant and interesting topics which are not fully explored in this study, such as productivity variation in multiple nations or comparison of production technology features. Obtaining accounting industry data from a higher number of countries would facilitate more diverse and comprehensive analysis of the transnational operational performance of the accounting industry.

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