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THE EFFICIENCY OF FREEWAY BUS SERVICE INDUSTRY AS FACING THE ENTRANCE OF HIGH SPEED RAIL: TAIWAN'S CASE

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Abstract
This study explores the production efficiency of Taiwan's freeway bus service (FBS) industry in response to entrance of Taiwan High-Speed Rail (THSR). We employ data envelopment analysis to investigate the production efficiency and Tobitto identify the factors influencing efficiency level. Our results show that, after the emergence of the THSR, the production efficiency of Taiwan's FBS industry didn't alter obviously before 2007, but get improved in a longer time period. However, the competitiveness of FBS industry declined over time due to the accumulated worsening of technological change from 2007.

Keywords: High-speed rail, Freeway bus service, Trade-off type competition, Product differentiation, Data envelopment analysis (DEA)

JEL classification: L25, L91, N75

1. Introduction

Before January 2007, the freeway bus service (FBS) industry was one of the most important transportation services in Taiwan for people travelling between western cities from the north (south) to the south (north) via Freeway No. 1. Alternative transport services included several airlines and the train service offered by the Taiwan Railways Administration (TRA), a government-owned railroad company. Taiwan's FBS industry was monopolized by the government-owned Taiwan Motor Transport Company (TMTC) until 1985. Subsequently, the market structure of the FBS industry changed to an oligopoly with the entrance of the Ubus Company. To increase competition in this industry, the Taiwanese government afforded all bus service companies the road right-of-way on highways and reviewed their operating proposals for specific routes beginning in 1996. If their proposals were approved, the company won the right to offer a bus service for the specified freeway routes, which significantly increased competition in this market. Furthermore, because of its continued annual loss since the 1980s, the TMTC was privatized and renamed the Kuo-Kuang

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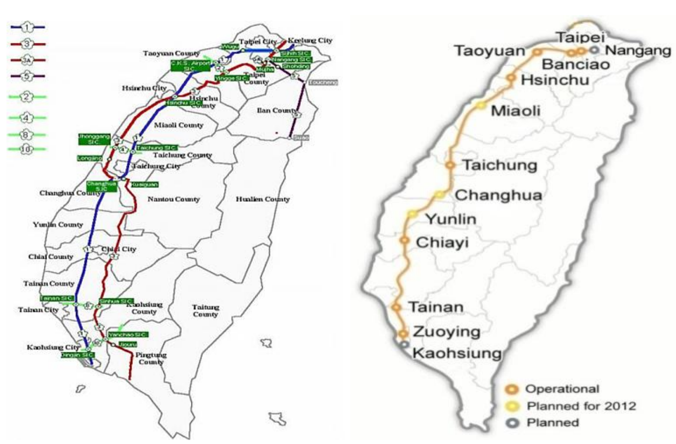
Motor Transportation Company in 2001. After these changes in market conditions, the FBS industry had the highest market share of north-south intercity transportation in western Taiwan despite competition from various airlines and the TRA.

However, in January 2007, this market share equilibrium was disrupted by the trial operation period of the Taiwan High-Speed Rail (THSR). Since the normal operation of the THSR began in March 2007, the market share of the FBS industry and other modes of north-south intercity transportation have continuously declined (Cheng, 2010).[1] For the FBS industry, the incumbent firms initially believed that the ticket prices of the THSR were too high to affect their market share. However, their market share decreased by 24% between January 2007 and October 2007. The FBS industry was further damaged by the implementation of the THSR's non-reserved seat policy on November 12, 2007, where THSR tickets were offered at an 80% discount on week days (Monday to Thursday).[2] Travellers who purchase this type of ticket can board any THSR train on the day of purchase but are limited to travelling in the non-reserved seating cars (cars 10 to 12). The emergence of the THSR disrupted the market structure of north-south intercity transportation in western Taiwan and had an overwhelmingly negative impact on Taiwan's FBS industries. What the worse, it also faced the economic tsunami from 2008. The "double strikes" of the entrance of THSR and economic shock harmed Taiwan's FBS industries seriously. As showed in Figure 1, the transport routes of freeway bus service and THSR in western Taiwan are very similar. Therefore, they serve the same intercity transportation market from the perspective of their serving regions. Thus, as facing such a market challenge, what are the influences of this negative shock on the efficiencies of FBS industry is an important research topic.



A. Freeways B. THSR

Figure 1 - The maps of Taiwan's Freeway and THSR

[1] For further details of changes in market share after the entrance of the THSR, including other routes and transportation modes, please refer to Table 4 in Cheng (2010).

[2] The non-reserved seat policy is still working but the discount pricing was stopped at the end of October 2008. This non-reserved seat with 20% prices discount policy was considered as the promotion strategy of THSR at that time. Please refer to the pricing history of THSR on the Wikipedia website (section 5.3, in Chinese): http://zh.wikipedia.org/wiki/%E5%8F%B0%E7%81%A3%E9%AB%98%E9%80%9F%E9%90%B5%E8%B7%AF.

The standard economic argument said that the positive influence of competition on firms' performance because the firms have to avoid waste by achieving the maximum possible output from a given set of inputs or by minimising the inputs given an achievable set of outputs (Nickell et al., 1997; Casu and Girardone, 2012). Such argument is usually concerning with the firms in the same industry, which is different from the competition between the THSR and the FBS. They are different industries which compete in the same "market". For example, a firm in the FBS industry have to not only compete with "other FBS firms" but also THRS. Therefore, whether the standard economic argument of competition on firms' performance is also applicable here is another issue. In addition, the competition between FBS and HSR lines on the choices trade-off between cost-saving/time-consuming (FBS) and time-saving/cost-consuming (HSR) from the perspective of passengers. Such competition is like the sort of product differentiation and is different from the competition concepts in conventional economics. No previous research has discussed before. Therefore, what are the influences of such new competition on efficiency of FBS industry in response to this newly trade-off type competition need further investigation and justification.

Thus, in this study, we compare the efficiency performance of the FBS industry before and after the emergence of the THSR by constructing a panel dataset for 2005 to 2010. We also explore the factors influencing the efficiency performance indices with special focusing on the years after THSR operations. Our results show that, as facing the entrance of the THSR into the north-south intercity transportation market in western Taiwan in 2007, the average TE of FBS industry is almost the same to 2006. However, the empirical results of Tobit regression indicate that year 2007 and market share negatively significantly influence the efficiency performance of Taiwan's FBS industry in 2005-2010.

The remainder of this paper is organized as follows: Section 2 contains a review of literature on the competitive effects new entrants have on an industry's incumbent firms and the studies on the technical efficiency of bus studies. Then we discuss the possible influences of trade-off competition and its influences on efficiency of FBS industry in section 3. The methodology used in this study is presented in Section 4. For the discussion of empirical results I section 5, section 5.1 discusses the data and variables used in this study; section 5.2 focus on the estimated results of TE scores in DEA models respectively; section 5.3 explains the regression results of Tobit model, which identify the factors affecting efficiency and efficiency changes. Finally, the study conclusions, policy implications, and suggestions for further research are presented in Section 6.

2. Literature review

Previous studies on the emergence of a new transportation service primarily explored how the market structure changes in response to the new service. Some of them are focusing on the efficiency performance of firms in incumbent industries after the entrance of new competitive transportation service. Thus, we will categorize these studies into two groups, the first group is about the studies related to the analysis on the efficiency of bus industry and the second is related to changes of market structure between incumbent and entrant service mode and other influences brought by the entrant.

2.1. Productivity and efficiency of bus service industry

The analysis of productivity and efficiency of bus service industry is always an important issue from the perspective of academic research because it is part of public transportation system in nowadays. Its productivity and efficiency imply whether it is under well operation to fulfill the transport demand of passengers. Take for example, Roy and Yvrande Billion (2007), Odeck (2008), and Barros and Peypoch (2010) investigate the productivity changes of bus companies in European countries. Roy and Yvrande Billion (2007) related the productivity growth in the French bus industry to the outsourcing of the public transport at municipal level. They use the original panel data set covering 135 different French urban transport networks over the period 1995-2002 and apply a stochastic frontier methodology. Their results show that the technical efficiency of urban public transport operators depends on the ownership regime and on the type of contract governing their transactions. Odeck (2008) use Norwegian data to assess the impact that mergers on the performances of bus companies in Europe. It is found that the merger process led to productivity improvements in the post-merger periods for the reasons that merged companies utilized their scale economies to improve efficiencies while the non-mergers significantly became more technically innovative in order to be competitive. Barros and Peypoch (2010) applied the Luenberger productivity indicator is used to estimate and decompose productivity growth on a sample of Portuguese bus companies between 1995 and 2008. The productivity growth in the Portuguese bus industry is small and public and private bus companies have similar levels of productivity. As for other countries, Badami and Haider (2007) used the financial and operational performance of the public bus transit service in the four metropolitan centers and four secondary cities during the 1990s to explore the public bus transit performance in Indian cities. They show that, in overall, there were persistent losses in public bus transit, owing to increasing input costs and declining productivity. Iseki (2008, 2010) examines how the cost efficiency of providing fixed-route bus transit service varies by the degree of contracting. He points out that the level of contracting is an important factor to influence the transit cost structure and the combined effects of contracting lower operating costs by $4.09 and $2.89 per vehicle hour for partial and full-contracting agencies in the average.

In addition, some studies explore the productivity and efficiency of bus service industry from the view of deregulation. Take for examples; Hensher and Daniels (1995) investigate the relative performance of urban bus operators in Australia. Their results show that the relative productivity of operators in the private and public sector are influenced by the varying institutional and regulatory regimes. Yu and Fan (2008) apply a hyperbolic graph efficiency approach to measure “return to the dollar” at the station-level of the Taiwan Motor Transport Company before and after privatization. They found a statistically significant increase in technical efficiency took place following privatization, implying that the private firm converted input resources into output more effectively than its predecessor. Finally, Sakai and Takahashi (2013) examines the impact of deregulation which has been implemented from 2002 on local bus market in Japan. They focus on the influences of market structure and the operators’ cost efficiency over the last ten years. Their results suggest that cost efficiency decreases as the subsidy ratio increases and has improved by contracting out strategy, but not significantly affected by deregulation policy.

2.2. Changes of market structure with HSR

Several previous studies investigated the changes of market structure on airline industry with the entrance of HSR. In Europe, Roman et al. (2007) constructed a mode choice model to analyze the potential competition between a HSR and air transport for the Madrid–Barcelona corridor in Spain. Their estimated results indicated that the HSR would obtain a minor market share (relative to air transport) for long-distance trips, but may be more competitive for shorter distances, obtaining the market share from cars and bus transportation. Dobruszkes (2011) compared the overall supply dynamics of air transport in Europe compared to high-speed trains (HST). For a given city-pair, the number of flights decline under competition from the HST. However, this decline in the number of flights depends on the length of the HST journey and the strategies adopted by the airlines. Behrens and Pels (2011) examined inter- and intra-modal competition between HSR and air transport for the London-Paris passenger market from 2003 to 2009.3 The HSR link between the two cities began operations in November 2007 and has continuously increased the demand gap between the two transportation modes. They also stated that, after the estimation of multinomial and mixed logit models, the frequency, total travel time, and distance to the UK port as the main determinants of UK passengers' modal choice behaviours. Adler et al. (2010) developed a game theory method to assess infrastructure investments and their effects on transport equilibria considering the competition between HSR, hub-and-spoke legacy airlines, and regional low-cost carriers. They concluded that when travel time is significantly reduced by the establishment of an HSR service, the HSR obtains a large market share of long-distance travel markets. As for cases from China, Mao (2010) examined the air-rail competition pattern and predicted the future competition conditions between the civil aviation and the railway industry in response to the Beijing-Shanghai high-speed railway. Mao (2010) concludes that the pricing of the high-speed railway tickets combined with airfare policies has a significant effect on the transport mode used by passengers to travel this route. Fu et al. (2012) also investigates the effects of China's HSR service, named the "China railway high speed (CRHS) services on Chinese domestic airlines. They also conclude that the expansion of CHSR services has significantly negative impacts on China's domestic air travel industry.

In addition, some studies focus on the market changes of railway industry as facing the impact of HSR. For example, Hsu et al. (2010) developed a game theory model to describe the pricing strategies of the railway industry under a two-part tariff pricing structure using a case study of Taiwan's HSR and conventional rail system (TRA). Their model indicated that if the THSR's relative operating costs increased, it became less efficient compared to the TRA, and would be forced to increase its ticket prices. Besides, Sanchez-Borras et al. (2010) discussed the rail access charges4 for high-speed trains on new high-speed lines in Europe and their impact on the market position of the HSR industry. They examines the actual prices charged in the main European countries operating high speed trains and the impact these are likely to have on traffic levels and mode split and found that the price hikes of high-speed train tickets often exceed the optimal Ramsey level, significantly affecting rail volumes and market share.

[3] The HSR link was opened in full in November 2007 with the completion of the Channel Tunnel link on the UK side. However, parts of the link already existed prior to 2007 due to HSR in France and Belgium.
[4] Rail access charge means the payment which railway operators are charged by the infrastructure managers.

As a standalone analysis on the travel demand induced by the HSR service, Yao and Morikawa (2005) investigated the demands for HSR service provided between Tokyo and Osaka (Tokaido corridor) using magnetically levitated trains. According to their estimation results, the HSR will earn customer preference for both business and non-business travel when compared to other modes. They also concluded that intercity travel between Tokyo and Osaka will increase with decreasing travel time, travel costs, and access time, as well as improved service frequency.

Finally, as concerning with the impact of the HSR's entrance on the FBS industry, Cheng (2010) shows that the impact of the THSR on the Taiwan's FBS industry was relatively low compared to its impact on domestic airlines, but the FBS industry's share of the intercity transportation market was seriously damaged by the entrance of THSR.

3. New competition and the efficiency of incumbent industry

From the standard economic argument of economics, competition in the market have a positive influence on firms' performance because it will enforce the firms to avoid waste by achieving the maximum possible output from a given set of inputs or by minimizing the inputs given an achievable set of outputs. In other words, the existence of competition in market can prevent firms from x-inefficiency because the exposure to competition compels firms to exert greater effort at improving their efficiency (Scotti et al., 2012). Besides, without competition, employees of a firm take their customers for granted, do "business as usual" or "work to rule", and generally lack the proper incentives to increase productivity, improve quality, develop new products, and so forth. Competition also improves social welfare because it ensures that only the most efficient and innovative firms survive (Sjöström and Weitzman, 1996). Therefore, the competition in a market can enhance the efficiency performance of firms not only from the management of resources but also the progress a better production technology.

In this study, the entrance of THSR is a new transportation mode for the intercity transportation market in Taiwan. As we mentioned before, the difference between this study and the conventional analysis is that the service method of THSR is totally different from the incumbent firms/industries but serve the same market for Taiwan's intercity passengers at the same time. In other words, they are in the same demand market and the conventional economic statements related to the relationship between the market competition and firms' efficiency performance seems applicable here. However, the competition between THSR and FBSI is different from above conventional views in actual. They supply different types of service for the passengers. The former is more time-saving with much higher prices than the later; the later is more cost-saving with longer transportation time. Obviously, such competition is a sort of trade-off type product differentiation. THSR and FBSI compete in Taiwan's intercity transportation market but actually serve in different segmental submarket. The real competition degree depends on the trade-off level of their service. The higher the trade-off level between their services are, the more market segmentation of their competition, the less competition of FBSI faces after the entrance of THSR and the less efficiency FBSI changes. As consider the arguments in conventional economics and such trade-off competition at the same time, the net impacts of THRA on FBSI's efficiency is not clear at all. To figure out the net effects of these two sorts of competition, we will firstly employ DEA and Malmquist index to explore the production efficiency of the FBS industry between 2005 and 2010 by compare the efficiencies before and after 2007. Then, we apply Tobit regression to identify the factors that determine the level of efficiency.

4. Methodology

4.1. Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA)5 is one of the methods to estimate the production efficiency of a decision making unit (DMU).[6]The methods proposed by Charnes et al. (1978) (called CCR model) and Banker et al. (1984) (called the BCC model) are often used in studies. The former assumes a constant returns-to-scale production technology for all DMUs, but the later allows the production technology to be variable returns-to-scale by adding a convexity condition in the model. Both the CCR and the BBC models contain two estimation concepts, the input orientation (IO) and output orientation (OO) estimation. For the freeway bus services firms, they are run for profit. Thus the analysis of OO would be more adequate than IO. In the following sections, we provide a detailed discussion OO models.[7]

For the output orientation of the CCR model, the linear optimization problem becomes

$$\begin{aligned} &Max_{h,\lambda}\, h_k \\ &s.t. X_{ki} \geq \textstyle\sum_{i=1}^{n} \lambda_i\, X_{ij}\,, && j = 1,2,\dots,J \\ &hY_{kr} \leq \textstyle\sum_{i=1}^{n} \lambda_i\, Y_{ir}\,, && r = 1,2,\dots,R \\ &\lambda_i \geq 0, && i = 1,2,\dots,N \end{aligned} \qquad (1)$$

5 We choose these DEA models because they are well developed and often used models. There are alternative DEA models too, such as "Additive Model" and "Slacks-Based Measure of Efficiency Model (SBM)". The former combines both IO and OO orientation in a single model and the later is a product of input and output inefficiencies whose efficiency evaluation is invariant to the units of measure used for the different inputs and outputs. Cooper et al. (2000) had proved that a DMU is additive-efficient if and only if it is BCC-efficient and is CCR-efficient if and only if it is SBM-efficient through mathematics. Accordingly, we don't need to estimate all DEA models at the same time. For more details, please refer to chapter 4 in Cooper et al. (2000).

6 Another similar discussion concerns "productivity"; however, its analysis methods, such as total factor productivity (TFP), differ significantly from those of DEA. For efficiency analysis, DEA and stochastic frontier analysis (SFA) are often employed. This study explains the basic principles of DEA only. For further information regarding the difference between DEA and SFA, please refer to Ceolli et al (2005). Generally, compared to SFA, estimates of the production function and probability distribution of disturbance are not required when applying DEA. Especially when an analysis comprises multiple outputs and inputs in an analysis, the calculation of DEA is significantly easier than that of SFA. However, DEA always assumes that a firm cannot achieve optimal production because of inefficient inputs and outputs without considering other factors, such as the measurement errors of inputs and outputs; therefore, it may exaggerate the level of production inefficiency.

7 As for the IO models, please refer to texts in Coelli et al. (2005) and Cooper et al. (2000).

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where λ_i is the weight of a single DMU, i = 1, 2, 3, ….N; X_{ij} is the j the input of DMU i, including the number of buses for transportation services, the number of drivers, and the quantity of gasoline used; h_k indicates that, considering the input levels of DMU k as X_{kj}, output should increase as $h_k Y_{kr}$ if X_{kj} is used efficiently. Consequently, the relative technical efficiency is estimated as

$$TE = \frac{1}{h_k} \quad (2)$$

When h_k = 1, the DMU k is at the efficiency frontier. In other words, the DMU has optimal efficiency. However, if h_k >1(TE<1), the production of DMU k is comparatively inefficient. By including the convexity constraint $\sum_{i=1}^{n} \lambda_i = 1$ in this model, it becomes the output-oriented BBC model. In addition, we also divide the TE value in OO CCR with the BCCTE value to capture the adequateness of operation scale and called it as scale efficiencies (SE).[8]

$$SE = \frac{OO\ TE\ in\ CCR}{OO\ TE\ in\ BCC} \quad (3)$$

4.2. Tobit regression models with panel data

To identify the factors influencing the level of TE, we firstly applied the Tobit panel data model with random effects. This method is widely applied for analysis finding out the factors which influence the DEA scores (Merkert and Hensher, 2011; Coelli et al., 2005; Kirjavainen and Loikkanent, 1998; Afonso and Fernandes, 2008; Wang et al., 2011). As we know, TE score of an FBS company is between 0 and 1. Conventional ideas considered that the DMUs with better efficiency might get a TE score higher than 1, but actually be censored at 1. Therefore due to this censoring property, the Tobit models are applied to investigate the factors influencing the TE levels in traditional DEA analysis. In addition, our dataset contains 32 FBS companies in Taiwan from 2005 to 2010; thus a Tobit model specific for panel data is required. Even though McDonald (2009) argued that the scores of TE are not generated from a censoring processes or corner solution data but are fractional data. He mentioned that, the TE scores in DEA are produced from a "normalization process" which limit the TE scores between 0 and 1. Thus, such normalization process is not a censoring process and consequently the Tobit regression is inadequate for the second stage DEA analysis. Instead, he proposed that the ordinary least squares (OLS) is an unbiased and a consistent estimator; if heteroskedasticity is allowed for, hypothesis tests (usually for large sample) can be validly undertaken. However, Coelli et al. (2005) mentioned that the prediction of OLS on TE scores might exceed 1 and thus suggested to use Tobit regression in second stage DEA analysis. Therefore we only apply the Tobit model in this study and introduce the linear regression models with panel data and its estimated results in appendix.

[8] Usually, the TE values of the OO CCR model are also known as global TE and the TE in OO BCC model as the local TE or pure TE. If a DMU's TE values in OO CCR and BCC are 1, the operation scale of this DMU is at the most productive scale. Otherwise, this DMU only achieves local TE but not overall TE, which means its operation scale is inadequate compared to the optimal operation scale.

Briefly, Tobit regression is defined as

$$TE_{it} = \begin{cases} \beta' X_{it} + u_i + \varepsilon_{it}, & if\ TE_{it} < 1, \forall i,t;\ i = 1,2,\dots,N;\ t = 1,2,\dots,T; \\ 1, & if\ TE_{it} \geq 1, \forall i,t;\ i = 1,2,\dots,N;\ t = 1,2,\dots,T. \end{cases} \quad (4)$$

where TE_{it} is the technical efficiency value of firm i at time t. Then, assume that the joint probability distribution of firm i with panel data is

$$\Pr(TE_{it} \mid \boldsymbol{X}_{it}) = \int_{-\infty}^{\infty} \frac{e^{\frac{-u_i^2}{2\sigma_u^2}}}{\sqrt{2\pi}} \left\{ \prod_{t=1}^{T} F(\beta' \boldsymbol{X}_{it} + u_i) \right\} du_i \quad (5)$$

where

$$F(\beta' X_{it} + u_i) = \begin{cases} \frac{1}{\sqrt{2\pi}\sigma_u} e^{\frac{-(TE_{it} - \beta' X_{it} - u_i)^2}{2\sigma_\epsilon^2}}, & \text{if } TE_{it} < 1 \\ 1 - \Phi\left(\frac{TE_{it} - \beta' X_{it} - u_i}{\sigma_\varepsilon}\right), & \text{if } TE_{it} \geq 1 \end{cases} \quad (6)$$

$\boldsymbol{X}_{it}$ is the vector of all independent (explanatory) variables; β is the vector of estimated parameters; and u_i and ε_{it} represent a firm's specific effect and error term, respectively, which are assumed to have a normal distribution at $N(0, \sigma_u^2)$ and $N(0, \sigma_\epsilon^2)$. $Var(u_i) = \sigma_u^2$, $Var(\varepsilon_{it}) = \sigma_\epsilon^2$, and Φ is the accumulated normal distribution function.

5. Empirical Results

5.1. Data process and descriptive statistics

The data used in this study are collected and operated from the yearly statistic book of National Federation of Bus Passenger Transportation of Taiwan from 2005-2010. Passenger-kilometre was used as the output variable, and the number of buses, number of drivers, and gasoline consumption were used as input variables for the DEA model. As for the data applied as exogenous variables in Tobit and linear regression models with panel data, Coelli et al. (2005) demonstrated that input/output variables used in the first stage DEA score estimation are unsuitable to be used in the second stage regression model because the estimated results in 2nd stage might be biased due to the high correlation of variables between 1st and 2nd stage. Therefore, the dummies of year 2007, year 2008 and year 2007-2010 and non-dummy variable of growth rate of gross domestic product (GDP), market share, diversification, sales expense, management expense and total asset of a firm are used in this study. We reorganized the raw data and focused solely on bus companies that offered FBS. Firms that left the market or entered the market during this period were eliminated. Our dataset adopted the panel data form and contained 32 FBS companies. Table 1 shows descriptive statistics of the variables used in the estimation processes of DEA, Tobit and linear regression models with panel data.

Briefly, the input and output variables of the DEA model must be in quantities used during the production process and not in monetary form. Excluding the number of drivers, the variable values specific for FBS were obtained directly from the statistical yearbooks. Then, we averaged the ratios of the number of FBS buses/total number of buses and the number of FBS vehicles/total number of vehicles to determine the percentage of FBS drivers. We multiplied this value with the total number of drivers for each firm to obtain the number of FBS drivers.[9]The other exogenous variables counted in their monetary form were depreciated using the traffic price index provided by the Directorate General of Budget, Accounting, and Statistics, Executive Yuan, Taiwan.[10] The base year was set as 2006.

Table 1 - Descriptive statistics of variables

Variable	Obs.	Mean	Min	Max	Std. Dev.
Passenger-km	192	2.22E+08	697851	3.02E+09	5.86E+08
Bus	192	96.95313	4	1083	212.7374
Driver	192	104.3281	2	1015	224.6433
Gasoline (l)	192	4456895	54891	5.09E+07	9895649
GDP growth rate (%)	192	3.045	-2.25	8.58	3.7347
Market share	192	60.32772	0	1184.767	207.5695
Diversification	192	155.2455	100	300.0451	57.03197
Ln (sales expenses)	192	16.71582	10.78941	19.71247	1.423973
Ln (management expenses)	192	16.85802	11.82	19.74922	1.362933
Ln(Assets) (NT$)	192	1.05E+09	0	5.18E+09	1.11E+09

As for the growth rate of GDP, it was adopted from the website of macro database maintained by Directorate General of Budget, Accounting and Statistics, Executive Yuan, Taiwan.[11] Market share was calculated using the revenues of bus firms that offered FBS services by dividing to the total revenue of the whole FBS industry. The result was multiplied by 100 and then squared to provide the index used in this study. In industrial economics, a firm's market share is also referred to its market

[9] For the second question, according to Table 2 in Barros and Peypoch (2010), we should use the "total employees" of FBS firms as the input in our DEA model. But in the original data, there is no such statistic number that we can adopt directly because most of the FBS firms also operate the business of local or city bus transportation. Thus the total staffs are difficult to attribute to different departments. In spite of this situation, we still tried two methods to calculate alternative proxy variables of total employment for the FBS department. One is to multiple the bus number used in FBS with the average staff used in a bus of each FBS firms. The other is to multiple the total staffs with the percentage of FBS drivers we calculated. Unfortunately, some firms' calculated results of these two methods vary too much and are difficult to have a reasonable explanation as comparing to the output variable passenger-kilometer. On the contrary, the number of drivers we calculated is more stable and reasonable as comparing with the results from previous two methods. Therefore, we use the number of drivers as our proxy variable for the labor factor in DEA model.

[10] Please refer to the website for the National Statistics of Taiwan at http://ebas1.ebas.gov.tw/pxweb/Dialog/statfile1L.asp?.lang=1&strList=L (accessed on 01/25/2012). We recalculated the traffic price index after eliminating items related to the communication tools.

[11]http://ebas1.ebas.gov.tw/pxweb/Dialog/statfile1L.asp?lang=1&strList=L. (accessed on 09/30/2014).

power which could help it to operate with fewer constraints and more advantages, such as lower price to buy the inputs and higher price to sell outputs, which result in a better efficiency performance.

The diversification means how the variety and importance are of all types of bus service in a FBS firm, such as local bus, urban bus, highway bus and tour bus services. We measure this index by firstly inversing the summation of squared ratios of revenue of the local bus, urban bus, highway bus and tour bus services to the total revenue of a FBS firm respectively and then multiplied by 100. Thus, the lowest value of this variable was 100, which indicates that a company only offered one of the four bus service types. The higher the value of this variable, the greater the firm's diversification is. In our opinion, a firm with higher diversification would enjoy the economy of scope and a better resource allocation because the slack inputs in one department can transfer to another instantly. Thus, a firm with higher diversification would be more efficient because of the easiness of resource reallocation.

Finally, total sales expenses were calculated based on sales persons' salaries and business promotion costs. Similarly, total management expenses were calculated based on the salaries of management personnel and business management costs. "Total asset" is the summation of "fixed assets", "current assets" and "other asset" which FBS firms announced on the statistical yearbooks of the National Federation of Bus Passenger Transportation. All these three variables are transformed into natural logarithm form for linearization. The expansion or increase of the first two variables of a FBS firm is assumed to improve its efficiency because it spends more effort on its operation by outside sales promotion and inside management adjustment. As for the asset variable, Halkos and Tzeremes (2007) argued that the impact of firm size on productivity growth is ambiguous. On one hand, it is claimed that large firms could be more efficient in production because they could use more specialized inputs, better coordinate their resources, etc. On the other hand, it is emphasized that small firms could be more efficient because they have flexible, non-hierarchical structures, and do not usually suffer from the so-called agency problem. Therefore, the impact of asset scale on the efficiency of FBS industry will be justified after the empirical study.

In addition, we also add three dummy variables, year 2007, year 2008 and year 2007-2010 to capture the influence of THSR's entrance in short term, the influence of financial tsunami and the longer effects of THSR's entrance on the TEs of FBS industry. Table 1 are the descriptive statistics of non-dummy variables and table 2 list our sign expectation of each variables in Tobit and linear regression models

Table 2 - The details and expected signs of variables

Variable	Definition	Calculation Method	Predicted Sign	Source
Passenger-km	Product of the distance FBS bus travels times the number of passengers travelling that distance	Original data	-	Statistic book of National Federation of Bus Passenger Transportation of Taiwan
Bus	Quantity of bus used by a FBS firm in a year	Original data	-	
Driver	Quantity of driver used by a FBS firm in a year	{[(number of FBS buses/total number of buses)+(number of FBS vehicles/total number of vehicles)]/2}x total number of drivers	-	
Gasoline (l)	Quantity of Gasoline used by a FBS firm in a year	Original data		
2007	Dummy for year 2007	Dummy	-	-
2008	Dummy for year 2008	Dummy	-	
2007-2010	Dummy for period between 2007-2010	Dummy	-	
GDP growth rate	Taiwan's annual GDP growth rate from 2005-2010	%	Positive	Directorate General of Budget, Accounting and Statistics, Executive Yuan, Taiwan
Market share	Ratio of a firm's revenue to the revenue of whole industry	[(a firm's FBS services revenue dividing to the total revenue of the whole FBS industry)x100]2	**P**ositive	Statistic book of National Federation of Bus Passenger Transportation of Taiwan
Diversification	Diversification of a FBS firm	(1/summation of squared ratios of revenue of the local bus, urban bus, highway bus, and tour bus services to the total revenue)x100	**P**ositive	
Ln (Sales Expenses)	Expenses for service promotion	Summation of salespersons' salaries and business promotion costs.	**P**ositive	
Ln (Management Expenses)	Expenses for internal management	Summation of salaries of management personnel and business management costs	**P**ositive	
Ln (Asset)	Total asset of a FBS firm	Asset amount which FBS firms announced on the statistical yearbooks	?	

5.2. Technical efficiency analysis

We estimated the TE and Malmquist index using DEAP software in version 2.1.[12] Table 2 shows the average TE and SE (scale efficiency) values for the FBS industry from 2006 to 2010. The average TE values are also shown in Fig. 1, and the scale efficiency values are shown in Fig. 2.[13] The results in Figs. 2 and 3 show that, from 2005 to 2006, the average TE of the FBS industry improved obviously.

Then, as facing the entrance of the THSR into the north-south intercity transportation market in western Taiwan in 2007, the average TE is almost the same to 2006, regardless of CRS or output-oriented VRS (OO VRS). However, these trends diverge in 2008 because the TE in CRS model improved obviously. On the contrary, the TEs in OO VRS are almost similar to 2007. Due to this divergent developments of CRS and VRS TEs, the average SE improved obviously, which means that the scales of firms are closer to the optimal scale after one year's adjustment after the entrance of the THSR. But in 2009, the divergent trends of CRS and VRS TEs continued, but in the opposite ways.

The TEs in VRS improved obviously but CRS became stable, which worsened the scale efficiency correspondingly. Finally, trends of TEs in CRS and VRS inversed again in 2010, which resulted in the improvements of SEs consequently.

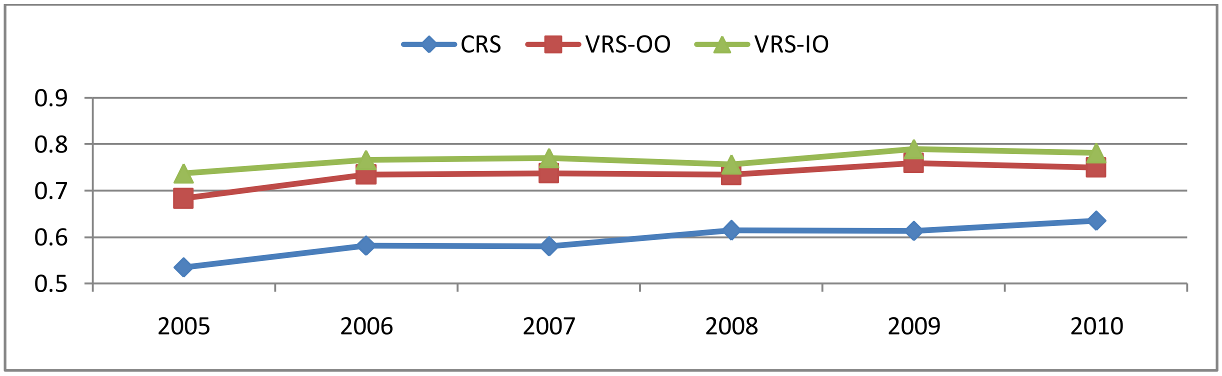
Table 3 - The TE and scale efficiency of Taiwan's FBS industry from 2005 to 2010

Year	CRSVRS							No. of IRS (DRS)	
	Average	Minimum	Std Dev.	IO	OO	S.E. -IO	S.E.-OO	IO	OO
2005	0.535	0.194	0.251	0.737	0.683	0.750	0.811	25(2)	24(4)
2006	0.581	0.165	0.243	0.767	0.735	0.775	0.820	27(0)	26(2)
2007	0.580	0.173	0.261	0.771	0.737	0.776	0.821	26(5)	25(6)
2008	0.614	0.131	0.243	0.757	0.734	0.838	0.868	27(2)	25(3)
2009	0.613	0.158	0.244	0.79	0.759	0.796	0.828	25(4)	25(4)
2010	0.635	0.175	0.253	0.781	0.750	0.832	0.857	23(5)	21(7)

Note: IO and OO represent the input orientation and output orientation, respectively.

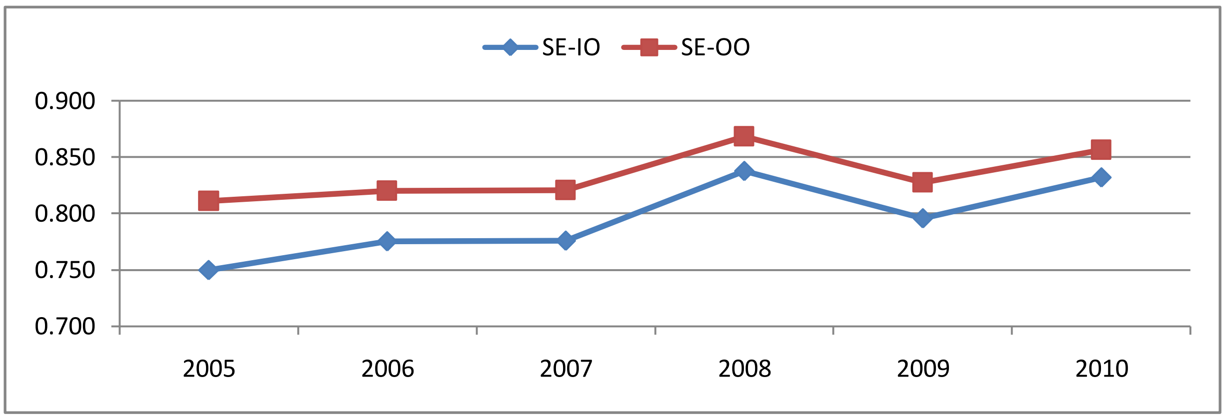
[12]Computer program DEAP Version 2.1 was developed and written by Tim Coelli (1996) and maintained be the Centre for Efficiency and Productivity Analysis (CEPA) in The University of Queensland, Australia. This program is used to construct DEA frontiers for the calculation of technical and cost efficiencies and also for the calculation of Malmquist TFP Indices. For more details of this computer program, please refer to the website:
http://www.uq.edu.au/economics/cepa/deap.htm (accessed on 01/25/2013).

[13]Our analysis will focus on CRS and output-oriented VRS only. The values of input-oriented VRS list in Table 3 are for referenceonly because we demonstrated the model setting of output-oriented VRS only.



Note: IO and OO represent the input orientation and output orientation, respectively.

Figure 2 - The TE of Taiwan's FBS industry from 2005 to 2010



Note: I-O and O-O represent the input orientation and output orientation, respectively.

Figure 3 - The scale efficiency of Taiwan's FBS industry from 2005 to 2010

If we observe the longer trends of TEs from 2007 to 2010 from Table 3 and Figure 2, the average TEs of FBS industry get improved gradually in this period. Similar observations exist in SEs in Table 3 and Figure 3. That is to say, as facing the entrance competition of THSR, the TEs and SEs of FBS industry get improved in the longer run. These results are consistent with our prediction in section 3, which forecasts that the TEs of FBS industry will get improved after the entrance of THSR.

Another interesting result is the numbers of firms which produced in the phase of decreasing return to scale (DRS) of their production technology. Before 2007, the maximum of this number is 2 in IO and 4 in OO. But in 2007, the number of firm with DRS jumped to 5 in IO and 6 in OO. Although this number lowered to 2 in IO and 3 in OO in 2008, it seemed to increase again from 2009 and 2010. If this trend is continuous, we could conclude that, from the entrance of THSR, more and more FBS firms produce in the stage of DRS, which means that the entrance of THSR in the

The Economic Research Guardian – Vol. 4(2)2014
Semi-annual Online Journal, www.ecrg.ro
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Econ Res Guard 4(2): 74-96

intercity transportation market suddenly forced more FBS firms to increase their output at a percentage which is less than the percentage of inputs increase.

One might suspend that why the entrance of THSR did not result in a negative influence on TEs of FBS industry obviously in 2007 if the market of intercity transportation changed so dramatically after 2007, as described in Cheng (2010)? Our opinion is as follows. Because the DEA scores are measured on the concept of relative efficiencies of every firm in each year, which means that the TE scores are estimated independently in every year. Thus, as facing the exogenous shocks, such as the service competition resulted from the operation of THSR, all FBS firms might face the similar changes in market and the correspondingly negative impacts on their outputs. As long as their percentage of outputs shrunk are similar to each other, the relative TEs will not change too much, as comparing to the relative TEs in previous year. This is the reason for what we have observed in 2007 from Figure 2 and Figure 3. The TEs in 2007 are almost the same to the ones in 2006, whether the CRS or OO VRS. No obvious lower down happened here. A similar explanation might apply to the situation of OO VRS in 2008.

5.3. Tobit regression with panel data

In this subsection, we investigate the factors influencing the level of TE of Taiwan's FBS industry using random-effect Tobit panel data and the linear regressions. The estimation processes were conducted employing STATA software version 11. We also employed other exogenous variables for our estimation processes. Table 4 shows the regression results of different TE measurements in RE Tobit regression models.[14] From the testing results of Table 4, the significance for model fitness of likelihood-ratio and Wald test show that three regression models are adequate. These models are also significantly statistically different from the pooled data because the likelihood-ratio test results $\sigma_u=0$ significantly rejectH_0, indicating that the applications of Tobit panel data regression are appropriate.

According to the results in Table 4, the year 2007 and 2008 dummy variables were both insignificantly negative for all models, which showed that the entrance of the THSR and the financial tsunami negatively affected the TEs of the FBS industry, nut not significant enough. The reason for this phenomenon might due to the relative concept of calculating TE, as pointed out in subsection 5.2. As the negative impacts resulted from the entrance of the THSR were similar to the firms in FBS industry, the production frontier of edge firms might also shift inside at the same time. As long as the degree of such frontier shift is not far from the ones of inefficiency firms, TEs would not lower down obviously. In addition, if our observation period extended to a longer period, such as from 2007-2010, the coefficient of this dummy was positive and significant. Thus, combining the estimated results of year 2007 and period 2007-2010 dummies, we might conclude that, as facing the entrance and the consequent competition of the THSR, the TEs of Taiwan's FBS industry is negatively and slightly impacted in the short run but then improved significantly in the longer period with the response of the of technical efficiency improvement of TFP.

[14]The user guide of STATA points out that the estimation results of FE Tobit regression are still inefficient and inconsistent nowadays. Thus we don't implement its estimation procedures in this study.

Table 4 - Estimation results of Tobit panel data regression

Variables	TE (CRS) Coefficient (t-value)	TE (OO-VRS) Coefficient (t-value)	TE (IO-VRS) Coefficient (t-value)
Constant	0.4602 (1.16)	1.066** (2.64)	1.0307** (2.80)
2007	-0.0461* (-1.74)	-0.0198 (-0.63)	-0.0146 (-0.59)
2008	0.0085 (0.27)	-0.0237 (-0.63)	-0.0319 (-1.08)
2007 to 2010	0.0655** (3.08)	0.0485* (1.90)	0.0341* (1.71)
GDP growth rate	0.0034 (1.10)	0.0003 (0.09)	0.0001 (0.04)
Market share	0.0003** (2.34)	0.0003* (1.91)	0.0001* (1.66)
Diversification	-0.0007* (-1.66)	-0.0008* (-1.68)	-0.0007* (-1.66)
Ln(Sales Expenses)	0.0263* (1.74)	0.0034 (0.19)	0.0084 (0.60)
Ln(Management Expenses)	0.0355** (2.35)	0.0437** (2.47)	0.0345** (2.44)
Ln (Asset)	-0.0432* (-1.85)	-0.0524** (-2.12)	-0.0456** (-2.11)
σ_u	0.1814** (7.38)	0.1665** (7.03)	0.1656** (7.36)
σ_e	0.1179** (17.85)	0.1412** (17.84)	0.1105** (17.85)
$\varrho = \sigma_u / \sigma_u + \sigma_e$	0.7031	0. 5817	0. 6920
Likelihood-ratio test of σ_u=0:$X^2(01)$/P(X^2>$X^2(01)$)	142.74**/0.000	92.20**/0.000	134.59**/0.000
Log likelihood (0)/log likelihood (β)	78.474/94.550	58.052/67.636	98.756/107.739
LR test of model fitness/ p(X^2>LR)	35.11**/0.0002	19.17**/0.0238	17.97**/0.0356
Wald (X^2) /p(X^2> Wald (X^2)	35.74**/0.0000	20.07/0.0175	18.74**/0.0275
# of observations/# of groups	192/32	192/32	192/32

Note: * represents a 10% level of significance; ** represents a 5% level of significance.

The Economic Research Guardian – Vol. 4(2)2014
Semi-annual Online Journal, www.ecrg.ro
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Econ Res Guard 4(2): 74-96

As for other non-dummy exogenous variables, the GDP growth rate did not influence the efficiency performance of FBS industry significantly, even though the sign is positive. This result might due to the highly correlation between this variable and year 2008 (-0.6357). Furthermore, the market share of an FBS company positively influenced their TE significantly; that is, the higher the market share held by an FBS company, the higher its TE level. Thus, the hypothesis of firm's market share mentioned in subsection 5.1 is supported by our estimated results. Thus, a FBS firm with higher market power could operate with fewer constraints and more advantages, which result in a better efficiency performance. On the contrary, the estimated coefficient of diversification variable is negative and insignificant, which means that the FBS firms in Taiwan not only have not enjoyed the economy of scope but the diversification of different bus service types might bring some internal inefficiency because of the complexes of resources adjusting between different departments.

Furthermore, the estimated results also indicate that the higher the management expenses of a FBS company, the higher its TE value is. This is reasonable because the heavy damages occurred after the entrance of THSR enforces the FBS firms to react severely to maintain their competitiveness. Take for example, the expense of KKMT's layoff mentioned in previous subsection might increase the management cost of KKMT and resulted in a better efficiency performance. The estimated coefficients of Sales Expenses are positive but not significant in all regression models. Thus the strategy of increasing the Sales Expenses could not improve the TE significantly. Finally, the more total assets owned by a FBS company, the lower its TE level is because of the positive and significant coefficient of ln(Asset) variable. This result showed that, from the empirical results of regressions, smaller FBS firms are more efficient because of the exception from suffering the so-called agency problem. Thus, as combining the estimated results of Market Share and Asset, the TEs of FBS industry will increase if the firms can expand their sales with lower operation scales at the same time.

6. Conclusion and suggestions

This study investigated the efficiency changes of Taiwan's FBS industry in response to competition resulted from the entrance of THSR in Taiwan's western North-South intercity transportation market. Traditional DEA was applied to calculate the TE, Malmquist index, and its decomposition for each FBS company from 2005 to 2010. The results were used to compare the TE changes of FBS firms before and after 2007. We also applied Tobit regression with panel data to identify the factors which influence the efficiency levels.

The results indicate that the THSR's entrance into the north-south intercity transportation market in western Taiwan in 2007 did not significantly influence the TE of the FBS industry. But in the longer time period, the trends of TE suggest that the entrance of THSR in western Taiwan can improve the TE of the incumbent services, the FBS industry. Such results are also supported from the estimated coefficients in Tobit regression models. Besides, the estimated results of Tobit and linear regression also indicated that the increase of market share and management expenses of a firm can significantly improve its TE but the higher scale of asset will reversely influence the TE. Our empirical results support our theoretical prediction on the relationship between the competitive entrant of another transport mode, THSR, and the TE of incumbent industry, FBS industry, in section 3: the entrance of THSR into the north-south intercity transport market in western Taiwan improves the TEs of FBS industry in the longer period.

According to these strategies of FBS firms, the government can help the firms to integrate their routes and coordinate the reallocation of route rights between different FBS firms, to construct the public own operation stations for FBS firms to offer their service at the same place without repeated investments between firms, to coordinate and encourage the cooperations between the FBS firms and THSR and then forming up the united operation network which are based on THSR's stations, to subsidize firms which develop the apps for mobile phones and the Internet for offering more instant and detail information for passengers etc. With these efforts and cooperations between FBS firms, THSR and the government, the production technology of FBS would get shift upward continuously.

The DEA model employed in this study was extremely conventional and can be used to evaluate a single bus service market. Future studies can use network DEA to analyze the TE of firms in several different markets because a number of FBS companies also offer other bus services in Taiwan. Furthermore, during analysis, this study assumed that the operation environment was identical for all FBS companies. However, some differences in the operation environment exist among these firms. Thus, these firms should be separated into clusters to increase the accuracy of TE estimates using meta-DEA.

Regarding the transportation policy, this study demonstrates that the entrance of new transportation services can influence the market and the operation efficiency of established firms. The damages in the market enforce the established firms in incumbent industries to adjust their management strategies. Therefore, the introduction of new competitors into a market, from either the same or different industries, can improve firm efficiency.

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The Economic Research Guardian – Vol. 4(2)2014
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Econ Res Guard 4(2): 74-96

Appendix

Linear regression models with panel data

There are several different linear models for panel data, but the fundamental distinction is that between fixed effects (FE) and random effects(RE) models. The most difference between these two models is their assumption on the relationship between the individual-specific effects and regressors (Cameron and Trivedi, 2010). To understand this, we model our linear regression models with panel data as (14), according to (10):

$$TE_{it} = \beta' X_{it} + u_i + \varepsilon_{it} \qquad \forall i,t;\ i = 1,2,\dots,N;\ t = 1,2,\dots,T;. \qquad (A1)$$

All the definitions of variables are the same as in (10). In the FE model, the time-invariant components u_i in (A1) are permitted to be correlated with the regressors $\boldsymbol{X}_{it}$ but not the idiosyncratic error ε_{it} , which allows a limited form of endogeneity. Therefore the consistent estimation of regression parameters requires eliminating or controlling the fixed effects. One possible estimation method is to jointly estimate u_1,…u_N andβ. But for a short panel, asymptotic theory relies on $N \to \infty$, which brings the incidental-parameters problem. Therefore, the possibility of consistently estimating$\beta$is to eliminate u_i by differencing transformation on (A1). But in the RE model, it is assumed that u_i is purely random, a stronger assumption implying that u_i is uncorrelated with the regressors. Estimation of the RE model is by a feasible generalized least-squares (FGLS) estimator.[15]

Which model is appropriate for a panel dataset is usually based on the Hausman x^2 test which compares two estimators where one is consistent under both H_0 and H_a while the other is consistent under H_0 only. If the two estimators are dissimilar, then H_0 is rejected. In our case, if H_0 is rejected, we should choose the estimated results in RE model for our analysis. Otherwise, FE is the adequate one. Besides, if RE model is more appropriate than the FE model, we will also apply the Breusch and Pagan Lagrangian Multiplier test to investigate the adequateness between RF and pooled(simple) OLS regression.

Appendix Table A is the estimated results of this model. As for the model fitness, the test results in RE models are more fitted than the FE's because the results of F tests for the significance of all coefficients in FE model are not significant enough in regressions on TEs of OO-VRS and IO-VRS. Besides, the insignificant results of Hausman test also indicated that the RE model is more adequate than FE models.

[15] For more details, please refer to section 8.5, 8.6 and 8.9 in Cameron and Trivedi (2010).

The Economic Research Guardian – Vol. 4(2)2014
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Econ Res Guard 4(2): 74-96

Appendix

Table A - Estimation results of linear panel data regression

Variables	TE (CRS) Coefficient (t-value)		TE (OO-VRS) Coefficient (t-value)		TE (IO-VRS) Coefficient (t-value)	
	RE	FE	RE	FE	RE	FE
Constant	0.45 (1.07)	0.62 (0.87)	1.07** (2.54)	1.74** (2.04)	1.03** (2.74)	1.39** (2.08)
2007	-0.04 (-1.51)	-0.04 (-1.41)	-0.02 (-0.61)	-0.02 (-0.61)	-0.01 (-0.58)	-0.01 (-0.57)
2008	-0.01 (-0.43)	-0.01 (-0.43)	-0.03 (-0.81)	-0.03 (-0.94)	-0.03 (-1.31)	-0.04 (-1.38)
2007 to 2010	0.07** (3.01)	0.06** (2.81)	0.05* (1.87)	0.05* (1.73)	0.03* (1.67)	0.03 (1.58)
Market share	3-e4** (2.16)	1-e4 (1.49)	3-e4* (1.82)	2-e4 (0.56)	2-e4 (1.62)	1-e4 (0.58)
Diversification	-7-e4 (-1.67)	-8-e4 (-1.46)	-8-e4* (-1.67)	-0.001* (-1.85)	-6-e4* (-1.64)	-9-e4* (-1.73)
Ln (Sales Expenses)	0.03* (1.70)	0.03* (1.86)	0.003 (0.18)	0.002 (0.11)	0.01 (0.58)	0.007 (0.49)
Ln (Management Expenses)	0.04** (2.25)	0.04** (2.13)	0.04** (2.54)	0.05** (2.48)	0.03** (2.40)	0.04** (2.53)
Ln (Asset)	-0.04* (-1.69)	-0.05 (-1.41)	-0.05** (-2.06)	-0.08* (-1.94)	-0.5** (-2.07)	-0.06* (-1.87)
σ_u	0.198	0.202	0.177	0.199	0.170	0.183
σ_e	0.121	0.121	0.144	0.144	0.113	0.113
$\varrho = \sigma_u / \sigma_u + \sigma_e$	0.729	0.737	0.600	0.655	0.694	0.724
R^2 within	0.124	0.129	0.085	0.091	0.085	0.089
R^2 between	0.264	0.173	0.158	0.083	0.119	0.072
R^2 overall	0.233	0.163	0.132	0.078	0.109	0.072
Wald (x2(8)) / Pr(x2> Wald (x2(8))a	31.80**/0	-	19.14**/0.01		17.96**/0.02	
Breusch and Pagan Lagrangian Multiplier test b	228.56**/0	-	149.92**/0		207.21**/0	
F(8,152)/Pr(F>F(8,152))c	-	2.81**/0.01		1.91/*0.06		1.86*/0.07
F(31, 152)/Pr(F>F(31,152))d	-	14.58**/0		9.02**/0		13.71**/0
Hausman test(x2(8))/ Pr(x2> x2(8))e	1.72/0.998		3.61/0.891		5.14/0.742(5.28/0.383)f	
# of observations/# of groups	192/32		192/32		192/32	

Note: * represents a 10% level of significance; ** represents a 5% level of significance. [a]: test for all coefficients are different from 0 in random effect model; [b]: LM test for choosing regression model between random effect and pooled(simple) OLS; [c]: test for all coefficients are different from 0 in fixed effect model; [d]:test for all u_i=0; [e]: test forchoosing regression model between random effect and fixed effect; [f]: the numbers in parentheses are the test result without dummies due to the covariance matrix in testing process of model with dummy variables is not positive definite.