The High-Speed Rail and the Productivity of Freeway Bus Service Industry: Taiwan's Case[i]

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Abstract: *This study explores the productivity of Taiwan's freeway bus service (FBS) industry in response to competition from the Taiwan High-Speed Rail (THSR). We employ the Malmquist index to investigate the productivity of Taiwan's FBS industry and apply the dynamic panel data (DPD) model to identify the factors influencing its productivity. The emergence of THSR initially worsened the total factor productivity of the FBS industry firstly and stimulated it in a longer time period. We also find that year 2007, sales and management expense, the total assets, and capital/asset ratio of an FBS company are the primary factors positively influencing the productivity. However, lagged 1 period Malmquist index service and service diversity reversely influence it significantly.*

Keywords: *High-speed rail, freeway bus service, Malmquist index, dynamic panel data (DPD) model, system GMM*

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Introduction

Before January 2007, the freeway bus service (FBS) industry was one of the most important transportation services in Taiwan for people traveling between western cities from the north (south) to the south (north) via Freeway No. 1 (also known as the Sun Yat-Sen Freeway). 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 by reviewing their operating proposals for specific routes beginning in 1996. 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 domestic airlines and the TRA.

However, in January 2007, this market 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. In 2008, Taiwan's domestic airline industry was significantly impacted by the emergence of the THSR and closed the flying routes in western Taiwan, except the one to Penhu County. Besides, the average number of passengers traveling between Taipei and Kaohsiung from January 2007 to November 2007 decreased 33% as comparing to the same period in 2006 for TRA. Similar to the airline industry, the TRA was also significantly impacted by the THSR. For the FBS industry, the incumbent firms initially believed that the increased 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. Travelers who purchase this type of ticket can board any THSR train on the day of purchase but are limited to traveling in the non-reserved seating cars (cars 10 to 12).

The construction of THSR in the western Taiwan corridor was considered as a new tool to trigger new waves of Taiwan's economic growth. During the latter half of the twentieth century, Taiwan's speedy economic growth led to the saturation of highways, conventional rail, and domestic airline traffic systems in the western transport corridor, which threatened to impede further growth. To solve this problem, the Executive Yuan in Taiwan's government announced a plan for construction THSR in 1990 by using the private finance and allowing the company to operate it for 35 years. THSR began its construction from 1999 and started its test operation in January 2007, which caused tremendous influences on the inter-city transportation markets in western Taiwan.[ii]

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 minimizing 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". Besides, the competitions between FBS and HSR and conventional rail and HSR line on the choices trade-off between cost-saving/time-consuming (FBS or conventional rail) and time-saving/ cost-consuming (HSR) from the perspective of passengers. Besides, as comparing with other potential solutions to traffic problems in the corridor, a high-speed rail was considered to offer the highest transit volume, lowest land use, highest energy savings, and least pollution.

FBS industry, the largest intercity industry before the operation of THSR, the effects of this shock on its productivity is an extremely important research topic. In addition, it's current operation areas in western Taiwan are also similar to THSR (see figure 1). Therefore, in this study, we compare the productivity of the FBS industry before and after the emergence of the THSR by constructing a panel dataset for 2005 to 2011. We also explore the factors influencing its productivity by applying the dynamic panel data (DPD) model. The remainder of this paper is organized as follows: Section 2 reviewed the literatures on the competitive effects new entrants of transportation mode have on an incumbent industries. The study methodology is presented in Section 3. Section 4.1 discusses the empirical results of productivity for Taiwan's FBS industry between 2005 and 2011, which includes the years before and after the emergence of the THSR. Section 4.2 explains the results of DPD model. Finally, the study conclusions, policy implications, and suggestions for further research are presented in Section 5.

Figure 1. The maps of Taiwan's Freeway and THSR
A.Freeways B. THSR

Literature Review

Previous studies on the emergence of a new transportation service primarily explored how the market structure changes to compete with the new service. For example, Cheng (2011) conducted an ex post cost-benefit analysis of the operation of the THSR in Taiwan, examining the impact of the THSR on the intercity transportation market. The results obtained during the first stage of this study indicate that the net present value (NPV), which considers both the financial and social benefits of the THSR, will not be positive until 2024.[iii] He contended that the impact of the THSR on the FBS industry was relatively low compared to its impact on domestic airlines because of the price elasticity of bus passengers.[iv]

Mao (2011) examined the current 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. He determined that if all the airlines discounted airfares by 30%, and if the ticket price for the high-speed railway service was lower than airline ticket prices, 40% of passengers would use the high-speed railway and 60% would travel by airplane. Therefore, 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. In addition, Chang and Chang (2004) proposed static traffic assignment methods to predict the market share of the HSR in the northwest–southeast corridor of South Korea. Under specific fare structures and capacity constraints for all competing transportation modes, such as airplanes, trains, and highways, they predicted that the market share of traditional transport modes would decline substantially after the emergence of the HSR and that the market share of the conventional railway service for this corridor would almost disappear. 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 market share of the aviation industry would decrease faced with competition from the HSR.

Hsu et al. (2011) 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. Consequently, with less competition from the THSR, the TRA would increase its prices and profits. Additionally, because the THSR is faster and has higher ticket prices, demand increases for the THSR and decreases for the TRA as the time value increases. 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. Dobruszkes also stated that the development of low-cost airlines may affect the market competition structure between the aviation and the HST industries in Europe. Adler et al. (2011) developed a game theory method to assess infrastructure investments and their effects on transport equilibria (especially social welfare) 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, where passengers would have traveled by air had the high-speed alternative not been available.

Behrens and Pels (2011) examined inter- and intramodal competition between HSR and air transport for the London-Paris passenger market from 2003 to 2009. 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 the travel time and frequency of the HSR are the primary determinants of travelers' behavior. Finally, Fu et al. (2012) investigates the effects of HSR services on Chinese airlines. Although China's HSR service, named the "China railway high speed (CRH)," began operations less than one decade ago, in October 2011, more than 8,000 km of HSR lines were in service. The impact of the air-HSR competition on air traffic has already been experienced for a number of routes. In 2005, all flights between Shanghai and Ningbo were terminated because of the establishment of the Shanghai-Ningbo CRH service. Similarly, the introduction of the CRH Qingdao-Jinan service in 2008 forced airlines to withdraw from the area.

Most of the studies discussed previously emphasized the market impact of introducing HSR/HST services on other competition modes, such as the conventional rail and air travel industries. Few have examined the productivity changes of established industries faced with competition from HSR/HST services. Therefore, we investigate the productivity changes of Taiwan's FBS industry in response to competition from the THSR.

Methodology

We applied the Malmquist productivity change index to investigate the first question and employed a Tobit panel data model and DPD with system generalized method of moments (GMM) estimation to investigate the second question. We discuss the DEA and Malmquist index in Section 3.1 and DPD with system GMM in Section 3.2.

DEA Distance Functions and Malmquist Productivity Index

DEA Models

To calculate the Malmquist productivity, we have to introduce the distance functions in DEA model. DEA is one of the methods to estimate the production efficiency of a decision making unit (DMU).[v] 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. The BCC model suggests that DMU may be affected by other factors to produce output in an increasing/decreasing returns-to-scale situation.

In addition, both the CCR and the BBC models contain two estimation concepts. The first considers the production level to achieve relative efficiency by reducing input usage, called input orientation estimation. The second concept considers the input usage level to achieve relative production efficiency by increasing the production level, called output orientation estimation. In this study, we only concern the output-oriented DEA only because the firms in FBS industry have to maximize its profit by attract more passengers to use their service.

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

$$\begin{aligned} &\mathrm{Max}_{h,\lambda} \quad h_k \\ &\mathrm{s.t.}\ X_{ki} \geq \sum_{i=1}^{n} \lambda_i X_{ij}, && j = 1,2,\dots,J \\ &\quad hY_{kr} \leq \sum_{i=1}^{n} \lambda_i Y_{ir}, && r = 1,2,\dots,R \\ &\quad \lambda_i \geq 0, && i = 1,2,\dots,N \end{aligned} \tag{1}$$

where λ_i is the weight of a single DMU, i = 1, 2, 3, ….N; X_{ij} is the jth 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

$$\mathrm{TE} = \frac{1}{h_k} \tag{2}$$

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. Therefore, a TE value below 1 indicates that, even if all current inputs (both variable and fixed) were used efficiently, the output is less than optimal. By including the convexity constraint $\sum_{i=1}^{n} \lambda_i = 1$ in this model, it becomes the output-oriented BBC model.

In these models, 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, the production of DMU *k* is comparatively inefficient.

Malmquist Productivity Index

According to Färe et al. (1994), the Malmquist productivity change index (M(.)) of a DMU can be defined as

$$M(Y^{t+1}, X^{t+1}, Y^t, X^t) = \left[\frac{D_o^t(X^{t+1}, Y^{t+1})}{D_o^t(X^t, Y^t)} \frac{D_o^{t+1}(X^{t+1}, Y^{t+1})}{D_o^{t+1}(X^t, Y^t)}\right]^{\frac{1}{2}} \tag{3}$$

where $D_t^0(X_t, Y_t)D_o^t(X^t, Y^t)$ and $D_{t+1}^0(X_{t+1}, Y_{t+1})$ are the output orientation distance functions of this DMU, which represent the relative production efficiency at time *t*; *t*+1 is the inverse output orientation of CCR TE. $D_{t+1}^0(X_t, Y_t)$ $D_o^{t+1}(X^t, Y^t)$and $D_t^0(X_{t+1}, Y_{t+1})$ represent the relative production efficiency of input/output at time *t* and *t*+1 and compared to the production frontier input/output at time *t*+1 and *t*. If M $(Y_{t+1}, X_{t+1}, Y_t, X_t)$ is higher (less) than 1, the DMU productivity increases (declines). In addition, under the assumption of CRS, we can decompose the Malmquist index as the product of technical change (TECH) and TE change (TEEFFCH):

$$M(Y_{t+1}, X_{t+1}, Y_t, X_t) = \frac{D_{t+1}^0(X_{t+1},Y_{t+1})}{D_t^0(X_t,Y_t)}\left[\frac{D_t^0(X_{t+1},Y_{t+1})}{D_t^0(X_t,Y_t)}\frac{D_{t+1}^0(X_{t+1},Y_{t+1})}{D_{t+1}^0(X_t,Y_t)}\right]^{\frac{1}{2}} \tag{4}$$

where

$$\mathrm{TECH} = \left[\frac{D_t^0(X_{t+1},Y_{t+1})}{D_t^0(X_t,Y_t)}\frac{D_{t+1}^0(X_{t+1},Y_{t+1})}{D_{t+1}^0(X_t,Y_t)}\right]^{\frac{1}{2}} \tag{5}$$

$$\mathrm{TEEFFCH} = \frac{D_{t+1}^0(X_{t+1},Y_{t+1})}{D_t^0(X_t,Y_t)} \tag{6}$$

TECH represents the production frontier shift; if the value is higher (lower) than 1, the DMU production technology increases (declines). TEEFFCH represents the changes of DMU resource management capability. When the value of TEEFFCH is higher (lower) than 1, the production technology is closer (farther) to the optimal at time *t*+1 than at time *t*.

Furthermore, by applying the TE of a DMU with the assumption of variable returns-to-scale, TEEFFCH can be decomposed as the product of pure technical efficiency change (PTECH) and scale efficiency change (SECH), which are defined as

$$\mathrm{PTECH(VRS)} = \frac{D_{t+1}^0(X_{t+1},Y_{t+1}|\mathrm{VRS})}{D_t^0(X_t,Y_t|\mathrm{VRS})} \tag{7}$$

$$\mathrm{SECH(VRS)} = \frac{\frac{D_{t+1}^0(X_{t+1},Y_{t+1}|\mathrm{CRS})}{D_{t+1}^0(X_{t+1},Y_{t+1}|\mathrm{VRS})}}{\frac{D_t^0(X_t,Y_t|\mathrm{CRS})}{D_t^0(X_t,Y_t|\mathrm{VRS})}} \tag{8}$$

where $D_t^0(X_t, Y_t|VRS)$ and $D_{t+1}^0(X_{t+1}, Y_{t+1}|VRS)$ are the distance functions under VRS assumptions, which equal the inverse of TE values in BBC model at time *t* and *t*+1. PTECH (VRS) measures whether the input and output efficiency increases from *t* to *t*+1, thus, it is also known as management efficiency change. If the value of PTECH (VRS) is higher (lower) than 1, the pure technical (management) efficiency of a DMU has improved (worsened). Conversely, SECH (VRS) refers to the proximity of the DMU's current production scale to the optimal long-term production scale. If the value of SECH (VRS) is larger (smaller) than 1, the production scale at time *t*+1 is closer (further) than the scale at time *t*.

Dynamic Panel Data Model

The general panel data regression form is as follows:

$$y_{it} = \beta' X_{p,it} + \alpha y_{it-1} + \mu_i + \omega_t + \varepsilon_{it} \forall i, t. \tag{9}$$

where y_{it} represents the Malmquist productivity change index of firm i at time *t*; $\boldsymbol{X}_{p,it}$ is the vector of all exogenous explanatory variables which are different from the input variables in DEA models. We also included the lagged variable y_{it-1} to facilitate the autocorrelation of the Malmquist index. Because of the involvement of this variable, (9) became a dynamic panel data model. Typically, we assumed that the absolute value of α was less than 1; however, it is determined by economic activity. If the estimation results for this parameter are significant, it indicates that the effectiveness of the FBS productivity changes continued intertemporally. The definition of u_i, w_i, and ε_{it} differ from the notations of the general panel data model; instead, they represent the effects of FBS companies, time effects, and error terms, respectively.

For the estimation of (9), we adopted the system generalized method of moments (system GMM) approach used by Arellano and Bover (1995) and Blundell and Bond (1998). The difference between system GMM and the difference generalized method of moments (difference GMM) proposed by Arellano and Bond (1991) is that the instrument matrix of system GMM contains not only the difference form of variables, but also the level form, whereas difference GMM contains only the difference form of variables. Thus, system GMM requires the following orthogonal conditions: $E\left(Z'_{di,s}\Delta\varepsilon_{it}\right) = 0$, $E\left(Z'_{li,s}\Delta\varepsilon_{it}\right) = 0$, and $s < t$.[vi] $Z_{si,s}$ in (10) is the instrument matrix of orthogonal conditions in difference GMM:

$$Z_{di,s} = \left[\left(\left(\begin{bmatrix} y_{i1} & X_{i1} & 0 & 0 & 0 & 0 & \cdots & 0 & \dots & 00 & \dots & 0 \\ 0 & 0 & y_{i1} & y_{i2} & X_{i1} & X_{i2} & & 0 & \dots & 00 & \dots & 0 \\ & & \vdots & & & & \ddots & & & \vdots & & \\ 0 & 0 & 0 & 0 & 0 & 0 & \cdots & y_{i1} & \cdots & y_{it-2} X_{i1} & \dots & X_{it-2} \end{bmatrix}\right)\right)\right] \quad (10)$$

As shown in (10), the explained and explanatory variables at and before the *t*-2 period are instrumental variables in the instrument matrix. Difference GMM is estimated based on this matrix. To estimate system GMM, (11) must be included in the estimation process.

$$Z_{di,s} = \left[\left(\left(\begin{bmatrix} \Delta y_{i1} & \Delta X_{i1} & 0 & 0 & 0 & 0 & \cdots & 0 & \dots & 00 & \dots & 0 \\ 0 & 0 & \Delta y_{i1} & \Delta y_{i2} & \Delta X_{i1} & \Delta X_{i2} & & 0 & \dots & 00 & \dots & 0 \\ & & \vdots & & & & \ddots & & & \vdots & & \\ 0 & 0 & 0 & 0 & 0 & 0 & \cdots & \Delta y_{i1} & \dots & \Delta y_{it-2} \Delta X_{i1} & \dots & \Delta X_{it-2} \end{bmatrix}\right)\right)\right] \quad (11)$$

Additionally, (11) is the instrument matrix that contains the Δy_{i1} and ΔX_{i1} at and before the *t*-2 period. System GMM uses (10) and (11) to estimate the parameters of (9).

Empirical Results

Data process and descriptive statistics

Table 1 shows descriptive statistics of the variables used in the estimation processes of DEA, Tobit, and system GMM dynamic panel data regression. Passenger-kilometer 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. Other data were applied as exogenous variables in Tobit and system GMM dynamic panel data regression. The data used in this study was at the firm level and collected from the statistical yearbooks of the National Federation of Bus Passenger Transportation in Taiwan from 2006 to 2011. We reorganized the raw data and focused solely on bus companies that offered FBS. We examined the bus companies that operated in the FBS industry throughout 2006 to 2011. 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 after deleting 7 firms with missing or incomplete 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. 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.[vii] The base year was set as 2006.

Market share was calculated using the revenues of bus firms that offered FBS services by dividing the number of passengers by the total revenue of the FBS industry. The result was multiplied by 100 and then squared to provide the index used in this study. For the diversity variable, we first summed the revenue of the general intercity bus, urban bus, highway bus, and tour bus services divided by the squared value; the total value was then inversed and 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 diversity is. Total sales expenses were calculated based on salespersons' salaries and business promotion costs. Similarly, total management expenses were calculated based on the salaries of management personnel and business management costs. Table 1 shows the descriptive statistics of all variables used in this research. Total observations are 224 (32 FBS firms×7 years). We find that the standard deviations are very large. There are two reasons for this phenomenon. One is that our data is in the form of panel data. Thus the distance between an observation i at time t and the overall mean in table 1 includes that distance between the observed value of observation i and group mean at time t and the distance between the group mean at time t to the overall mean in table 1. Two differences possibly exaggerate its calculated variance (and standard deviation) eventually. The other reason is that the high variability of data could be attributed to the tremendous influences resulted from the entrance of THSR, which resulted in immense changes of market in FBS industry.

Table 1. Descriptive statistics of variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Passenger-km(billion)	224	222.1084	578.8819	0.248823	3015.412
Bus	224	96.47179	210.9193	1	1083
Gasoline (l)	224	4394538	9773634	18563	50900000
Driver	224	103.7446	223.4293	1	1015.274
Market share	224	56.44189	193.0203	0	1184.767
Diversity	224	158.0642	67.26538	100	650.31
ln (sales expenses)	224	16.71548	1.441279	10.78941	19.71247
ln (management expenses)	224	16.88235	1.333462	11.82	19.74922
Assets (billion NT$)	224	1072.337	1121.569	13.23431	5183.153
Catipal/Assets	224	0.50136	0.57356	0.00107	3.04155

Source: Yearly Operation Statistics of National Federation of Bus Passenger Transportation of Taiwan(R.O.C.), 2005-2011.

Analysis of the Malmquist index

Regarding the Malmquist index and its decomposition, our estimation results are showed in Table 2 and Figs. 2 and 3. For Table 2, the Malmquist index, TECH, and TEEFFCH were estimated under CRS assumptions, whereas PTECH and SECH are decompositions of the TEEFFCH under VRS assumptions. The estimated values in Table 2 show that the Malmquist index increased in 2006/2007 compared to 2005/2006. However, from 2007/2008, the Malmquist index decreased to lower than the level in 2005/2006, indicating that the competitiveness of the FBS industry decreased in the longer term after the emergence of the THSR. Finally, it recovered to be higher than 1 in 2011. To sum up, even the FBS industry is not dead after the entrance of THSR, its productivity decreased gradually in the first few years and recovered after a longer time passed. The conventional economics indicates that the new competition in the market will improve the productivity of incumbent firms or industries. Our empirical results support the predicted productivity impacts of conventional economics of the competition brought by a new entrant industry on incumbent firms or industries, but it happens in the longer time period.

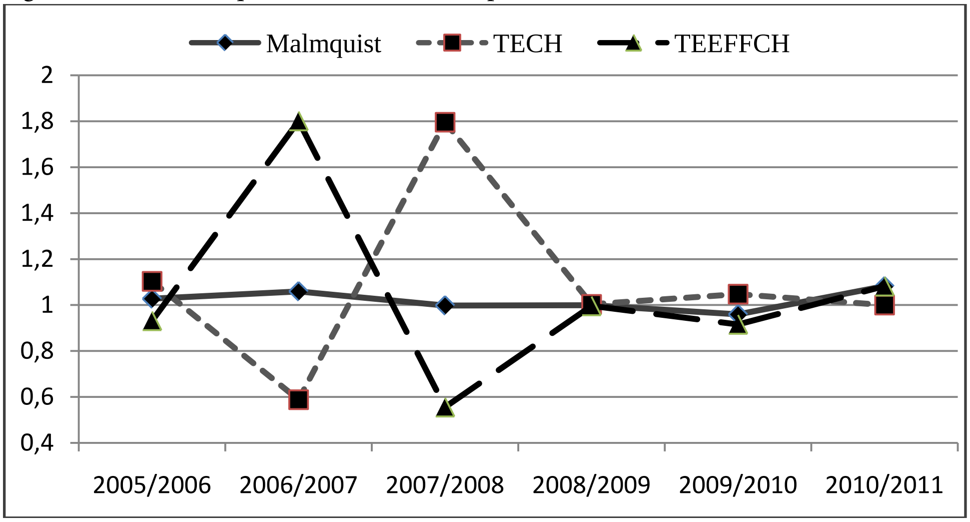
The changes of Malmquist decomposition indices are also very significant in 2005-2011. In 2006/2007, after the entrance of the THSR, the FBS industry increased its productivity by adjusting its resource management instead of production technology, as shown by the high TEEFFCH level (1.80) and the low TECH level (0.59). However, this situation was reversed in 2007/2008. After adjusting its resource management in 2007, the FBS industry improved its productivity by shifting its production technology, which is demonstrated by a comparatively lower TEEFFCH level (0.556) and a higher TECH level (1.79). This strategy lasted from 2008-2011. In summary, the analysis results show that, in response to the emergence of the THSR, the FBS industry first rearranged its internal resource management (production function) and then adjusted production technology to improve its productivity and maintain competitiveness with the THSR.

Table 2. The Malmquist productivity index and decompositions: industry

Year	Malmquist (TFP change)	TECH	TEEFFCH	PTECH		SECH	
				I-O	O-O	I-O	O-O
2005/2006	1.0277	1.1034	0.9315	1.0543	1.1088	1.0465	0.9951
2006/2007	1.0593	0.5881	1.8013	0.7737	0.6998	0.7601	0.8404
2007/2008	0.9980	1.7960	0.5557	1.2733	1.4392	1.4105	1.2479
2008/2009	0.9993	1.0031	0.9962	1.0568	1.0461	0.9492	0.9589
2009/2010	0.9592	1.0475	0.9157	0.9887	0.9968	1.0594	1.0509
2010/2011	1.0821	1.0001	1.0001	0.9339	0.9233	1.0709	1.0832

Note: I-O and O-O represent the input orientation and output orientation, respectively; TFP represents total factor productivity.

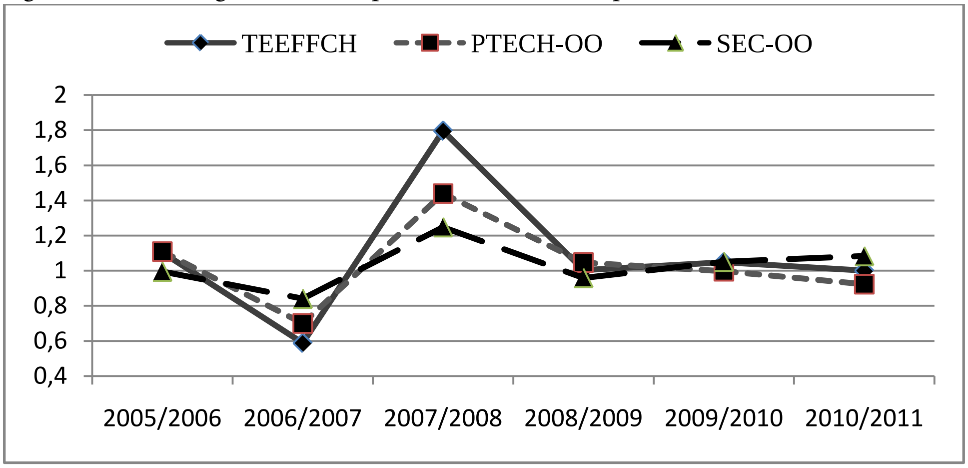
Figure 2. The Malmquist index and decompositions under CRS



Source: Table 2

For the decompositions of TEEFFCH, the PTECH and SECH in 2006/2007 were obviously lower than the values in 2005/2006, which reflects the negative impact of the THSR's emergence in 2007. Fortunately, these indices not only recovered but also surpassed their levels prior to the entry of the THSR, improving TEEFFCH in 2008. After 2008, these indices improved slightly, indicating that the development of TEEFFCH was stable because no sudden shocks occurred. Finally, the scale efficiency gradually lead the improvement of TEEFFCH from 2009.

Figure 3. The change and decomposition of TE in output-oriented VRS



Source: Table 2

Now we move our focuses to the productivity changes of the first two large FBS companies in Taiwan, the UBUS and Kuo-Kuang Motor (K-K Moter). We showed their self-own and aggregate market share on Table 3. We find that their aggregated market share was decreasing, except in year 2008. We cannot conclude that this decreasing trend of their aggregate market share was resulted from the entrance in 2007 directly because Taiwan's macro-economy was also attacked by the global financial tsunami from 2008. The slumped economy had not yet totally recovered to the level before 2008. The worse economy in Taiwan might also decreases their market demands and market shares in advance.

Table 3. Market Share Change of Kuo-Kuang Motor and UBUS (%)

Company	UBUS	K-K Moter	Total
2005	33.48	27.78	61.26
2006	34.42	24.98	59.40
2007	29.81	25.42	56.23
2008	31.05	28.21	59.26
2009	29.55	26.40	55.95
2010	26.24	27.43	53.67
2011	25.55	26.85	52.40

Source: calculated from Yearly Operation Statistics of National Federation of Bus Passenger Transportation of Taiwan(R.O.C.), 2005-2011.

As for their productivity changes in 2005-2011, we find that the K-K Motor and UBUS also improved their resource management in 2006/2007 as facing the entrance of THSR and then shifted their production technology in 2007/2008. This is consistent with the actions taken from the perspective of whole industry. In addition, the K-K Moter continuously improved its productivity from 2008 through the shifting of technology.

Table 4. The Malmquist productivity index and decompositions: Kuo-Kuang Motor and UBUS

Year	**Malmquist (TFP change)**		**TECH**		**TEEFFCH**		**PTECH**				**SECH**			
							I-O		**O-O**		**I-O**		**O-O**	
Company	K-K	UBUS	K-K	UBUS	K-K	UBUS	K-K	UBUS	K-K	UBUS	K-K	UBUS	K-K	UBUS
2005/ 2006	1.0409	0.713	1	1	1.0409	0.713	1	1	1	1	1	1	1	1
2006/ 2007	0.8733	1.0277	0.5894	0.5608	1.4817	1.8324	1	1	1	1	0.5894	0.5608	0.5894	0.5608
2007/ 2008	0.8252	1.0148	1.4844	1.7831	0.5559	0.5691	0.8751	1	0.875	1	1.6963	1.7831	1.6965	1.7831
2008/ 2009	1.1525	1.0179	1.0729	1	1.0741	1.0179	1.0732	1	1.0732	1	0.9997	1	0.9997	1
2009/ 2010	0.9124	0.904	1.0046	1	0.9083	0.904	1.027	1	1.0327	1	0.9781	1	0.9728	1
2010/ 2011	1.0249	1.0979	0.9307	1	1.1012	1.0979	0.9193	1	0.9308	1	1.0124	1	1	1

Note: I-O and O-O represent the input orientation and output orientation, respectively; TFP represents total factor productivity. K-K: Kuo-Kuang Motor.

Dynamic Panel Data Regression

Finally, this study explored the factors influencing the Malmquist index values. We used two estimation methods to estimate the dynamic panel data regression, namely difference GMM and system GMM. The estimated results are shown in Table 3. The Wald test results are significant in for both regression models, indicating that the estimation of these models is adequate. However, the results of the Sargan test are not significant but supportH_0, which suggests that the constraints are valid and the models are not over identified. Finally, the Arellano-Bond test results revealed the optimal period lagged dependent (explained) variables, which were included in the DPD model as lagged period 1. Finally, the estimated Malmquist index parameter at t-1 for system GMM is higher than that for difference GMM. According to Blundell and Bond (2000), this finding indicates that system GMM is more suitable for the DPD model compared to difference GMM because the values of estimated parameters of Malmquist index at t-1 in system GMM is less than the one in difference GMM (Blundell and Bond, 2000). Thus, we explored the variables that are significant to the system GMM estimation process.

According to the estimated results of system GMM shown in Table 5, the Malmquist index parameter at t-1 negatively influenced the Malmquist index at t, which indicates that the effectiveness of FBS productivity changes continued from time t-1 to t, but negatively influenced the productivity changes in the following period. The variable of year 2007 influenced the productivity changes of FBS companies positively and significantly, which means that the entrance of a new transport mode in a specific transportation corridor market stimulates the productivity of the established modes. According to our discovery in section 4.2, it showed that the FBS industry increased its productivity by adjusting its resource management instead of production technology. In addition, the significantly and negatively estimated result for the diversity variable suggests that FBS companies should increase their specialization by offering fewer types of bus services. Furthermore, the estimated results also showed that FBS companies should increase their sales and management expenses to improve productivity. Finally, the more assets an FBS company owns, the higher their productivity improvement is, because more assets provide an FBS company with more resources to adopt strategies for improving productivity. Finally, capital/asset ratio of an FBS company positively influences its productivity significantly. Usually, the capital is used by FBS companies as one of the inputs to offer services. The higher level of capital/asset ratio indicates the FBS companies leave more resources for the managers to employ as facing the market competition. With the support of capital resource to manage a FBS company, a manager could operate will higher degree of freedom in management and result in a higher productivity.

Table 5. Estimation results of dynamic panel data regression

Variable		Difference GMM	System GMM
Constant		-5.8808**(-7.44)	-4. 6782**(-11.49)
Malmquist index at t-1		-0.1298**(-13.02)	-0.1524**(-19.69)
2007		0.1173**(2.72)	0.1050**(4.28)
Market share		-0.2.76e-06(-0.02)	-0.00003(-0.30)
Diversity		-0.0002(-0.56)	-0.00098 **(-4.26)
ln (sales expenses)		0.2350**(10.14)	0.1973**(14.99)
ln (management expenses)		0.1796**(5.80)	0.1595 **(9.41)
Assets		8.90e-11(1.38)	4.99e-12**(0.13)
Capital/asset ratio		0.1276(1.42)	0.1512**(2.43)
Wald (x^2) (*p*(x^2 > Wald (x^2))		358.86**(0.00)	1434.31 **(0.00)
Sargan test	x^2 (*p*-value)	18.4549 (0.1410)	18.9623 (0.3941)
Arellano-Bond test Z (*p*-value)	First order	-1.6322(0.1026)	-1.6303 (0.1030)
	Second order	0.0985(0.9216)	0.1748(0.8612)

*Note: * represents a 10% level of significance; ** represents a 5% level of significance. The Sargan statistical test results was used to investigate model overidentification. The Arellano-Bond test was used to determine whether autocorrelation existed in the error terms.*

Conclusion and Suggestions

This study investigated the productivity changes of Taiwan's FBS industry in response to competition from the entrance of THSR. We use Malmquist index to understand the productivity level and applied the DPD regression to identify the factors influencing the productivity changes. Our results indicate that the FBS industry generally increased its productivity by improving its resource management in 2007 and adjusting its production technology (production function) in 2008 after the THSR's entrance into the north-south intercity transportation market in western Taiwan in 2007. In addition, the aggregate market share of first 2 large FBS firms, UBUS and K-K Moter, decreased more than 3% in 2007 and continuously to lower down after 2008. As regarding the factors influencing its productivity, the lagged Malmquist index (t-1) and service diversity would decreased the productivity level and year 2007, sales and management expenses, assets, and the capital/asset ratio could positively influence the Malmquist index values. Finally, the estimated results also indicated that the DPD of system GMM was superior to the difference GMM.

According to our estimated results, to increase the productivity, the FBS firms are better to increase the sales and management expense, amount of asset, and capital/asset ratio to support the firms' adjustment in response to the challenge brought by market competition, such as the entrance of THSR. They also should concentrate on less service categories and be more specialized in a specific bus service instead of offering diverse activities. In other words, there is no economy of diversities (scopes) for FBS industry in our observation periods.

As regarding the transportation policy, this study demonstrates that the entrance of new transportation services will lower the productivity of incumbent industry for several years and get improved later. The losing competitiveness in the market of FBS industry in the first 4 years (2007-2010) of THSR's entrance implied that the incumbent industry might disappear in the long run if it cannot find ways to reverse the situation. From this perspective, the policy for introduction of new transportation mode might have to evaluate and assess more before constructing it to prevent the damage imposed on the incumbent ones. However, our empirical results of total factor productivity of FBS industry slightly increased in 2011. It implies that, as long as the incumbent industry could sustain and survive long enough after the entrance of new competition industry, the incumbent industry could regain its competitiveness after a longer period. It also implies that the observation period is an important issue. If we can extend the observation period as long as possible, the impacts of THSR on the productivity of FBS industry might be consistent with the prediction of conventional industrial economics: the introduction of a new industry could improve the productivity of incumbents.

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[ii]Please refer to the introduction of THSR on Wikipedia: Taiwan High-Speed Rail, http://en.wikipedia.org/wiki/Taiwan_High_Speed_Rail. (Last retrieval on 12/19/2013).

[iii] In this study, the original NPV was estimated for 2001 through to 2033 under a 6% discount rate and 3% GDP growth.

[iv] The market share of domestic airlines was 24.95% for the Taipei-Kaohsiung route, 11.44% for the Taipei-Tainan route, 4.10% for the Taipei-Chiayi route, and 0.20% for the Taipei-Taichung route. After the emergence of the THSR in January 2007, the domestic airlines' market shares for these routes decreased to 13.00%, 7.66%, 1.64%, and 0.01%. By April 2008, their market share had declined further to 4.97%, 2.20%, 0%, and 0%. The domestic airline industry serving air routes between cities in western Taiwan was almost destroyed. The railway industry's market share for these routes was also impacted by the THSR. Consider the Taipei-Kaohsiung route for example, the railway industry's market share declined from 9.71% in April 2006 to 5.31% in April 2007 and 2.50% by April 2008. 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 (2011).

[v] 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 Cullinane et al. (2002). 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.

[vi]According to Blundell and Bond (2000), whether the results of system GMM estimation are more precise than those of the difference GMM depends on whether the estimated parameter of the explained variables lagged by one period in system GMM is higher than that in difference GMM.

[vii] Please refer to the website (http://ebas1.ebas.gov.tw/pxweb/Dialog/statfile1L.asp?lang=1&strList=L) for the National Statistics of Taiwan (lasted retrieved on 12/19/2013). We recalculated the traffic price index after eliminating items related to the communication tools.