

THE OPERATION OF NEW TRANSPORTATION INFRASTRUCTURE AND REGIONAL ECONOMIC EFFICIENCY: A CASE STUDY OF TAIWAN HIGH SPEED RAIL ON REGIONS IN WESTERN TAIWAN

Chih Cheng CHEN*

Abstract

This research explores the relationship between the operation of new transportation infrastructure and regional economic efficiency with specific case of Taiwan High Speed Rail (THSR) on regions in western Taiwan by using the annual data from 2004 to 2010 and applying the method of data envelopment analysis (DEA) and Tobit regression model. We discovered that the average EEs for these regions have been deteriorating since the initial operation of THSR in 2007, which indicate that the negative influences are more serious than the positives after THSR's operation. Besides, we also found that the EEs for these regions has been improved shortly but worsened in a longer term according to the estimated results of Tobit regressions, which implies the construction of transportation infrastructure would not stimulate the regional economic development. We also find that the ratio of employees with college/university education and firm number with R&D activity in a region will stimulate its regional EE significantly.

Keywords: transportation infrastructure, high speed railway, regional economic efficiency, data envelopment analysis, Tobit regression.

JEL: O18, P25, R11.

1. Introduction

The influences and importance of transportation infrastructure investment (TII) on regional economic development have attracted academic attention for a long time. For example, Meijers et al(2012) evaluated the influences of a new tunnel in Netherland and discussed whether the opening of this tunnel would affect the local employment and population; Chandra and Thompson (2000) stated that the construction of highways in the USA have impeded the allocations of economic activities among different geographic areas; D'émurger(2001) considered the relevancy between infrastructure investment and economic growth in China and concluded that the investment on traffic and transportation infrastructure could explain the growth gaps in economies among provinces in China. Boopen(2006) explored how the transportation infrastructure would have influenced the economic growth in Africa; with applying the

* Assistant Professor, Graduate Program of Social Informatics, Yuan Ze University, Taiwan. Contacting information: address: No.135, Yuan-Tung Road, Chung-Li City, Taoyuan County, Taiwan. Email: chihcheng@saturn.yzu.edu.tw.

Acknowledgement: The first version of this paper is presented in 2nd Annual International Conference on Qualitative and Quantitative Economics Research(QQE 2012), May 21-22 2012, Singapore. We appreciate the fund support from National Science Committee for the presentation of this paper(NSC 101-2914-I-155-002-A1). We also thank the National Federation of Bus Passenger Transportation of Taiwan(R.O.C.) for the supply of original data.

dynamic panel data model, he concluded that the development of transportation capital has accelerated the productivity and economic development. These studies all indicate that the investigation of influences of TII on regional economic development is an important issue.

In Taiwan, the Taiwan High Speed Rail (hereinafter as THSR) is constructed along the western corridor of Taiwan which lines across the counties and cities with the highest population density in Taiwan. Since its initial operation on January 5th, 2007, the THSR has emerged as one of the pivotal intercity transportation systems in western Taiwan. Its average daily transportation capacity up to 120,000 passengers in 2012 and has accumulated the total transportation passengers more than 100 million (THSR, 2012). The operation of THSR implies the advance of the public transportation system in western Taiwan and accelerates the north-south transportation of passengers and cargos. It has changed the transportation structure and completely restructured the south-north bound transportation industry in western Taiwan. Takes for example, all domestic airlines had terminated their flights in western Taiwan at the end of 2008. Besides, the north-south bound freeway bus service industry and railway service in the same area also have been destroyed significantly (Cheng, 2010). In other words, the operation of THSR brings not only the convenience of north-south transportation in western Taiwan but also damaged the conventional transportation service. Therefore, how does such “creative destruction” the THSR brought influence the economic development of regions its route passes through is an important issue.

Previous researches related the impacts of HSR on regional economic development are inconclusive. Takes for example, Blum et al.(1997) mentioned that the high speed railway can link the major living circles in a country and shape them as a pearl-chain like “functional regions”. Therefore, the high speed railway can play an important role in integrating the development nationwide and shrink the development gaps among regions. Nakamura and Ueda(1989) find that the population of regions with construction of Japan Shinkansen system grow obviously because of the more rapid and convenient local transportation network to connect with the Shinkansen’s stations. However, after evaluating the influences of Japan’s Shinkansen rail system on regional development, Sasaki et al.(1997) have concluded that the high speed railway can only be the auxiliary catalyst for regional development. Historical factors of each area influence the region development are more than the operation of high speed rail. They also pointed out that government can shrink the development gaps among regions systematically by implementing the nationwide developing plans. In addition, Vickerman(1997) also concluded that, as the high speed railway stations are built only in few major metropolitan areas, it may further worsen the economic development gaps among the regions with and without a high speed railway stations located.

In addition, people in Taiwan always have a myth that a new construction of transportation system can be helpful for the regional economic development. Thus, at the planning phase of THSR, counties and cities in western Taiwan strived for the location of THSR’s stations. Actually, the operation of THSR could fasten the transportation of resources, such as people and commodities, no matter the inflows or outflows. If the inflows of resources dominate the outflows, then the expectation of this myth can be held. However, if the inflows of resources are dominated by the outflows, the location of THSR’s station might worsen the regional economic development and

the expectation of this myth is reversed. Therefore, to investigate the side of influences resulted from THSR's operation on the regional development of western Taiwan is an importation issue.

To sum up, we can conclude that the construction and operation of the high speed railway can definitely influence the economic development of regions along their route but there has not yet reached a consistent conclusion in respect of what and how the influential consequences would be. In this research, we are going to apply the annual economic statistics of regions in western Taiwan between from 2004 to 2010 to explore what and how the THSR has influenced the EEs for these regions in western Taiwan.

The structure and contents of this research are composed as follows: section 2 will introduces the location of THSR and the regions its route passed through and section 3 will review the literatures which are related to the relevancy between the new transportation system and the regional economic efficiency. In section 4 introduces the research methodology we adopted in this studies, including the data envelopment analysis (DEA) and Tobit regression model; We will describe the origins and operation of the variables in this research in section 5; section 6 discusses our empirical results and their implications; finally, in section 7, we conclude our study results and propose some suggestions for future studies.

2. The Operation of HSR in Taiwan

As being 345 kilometers in total, the Taiwan High Speed Rail (hereinafter as THSR) is constructed along the western corridor of Taiwan which lines across the counties and cities with the highest population density in Taiwan.

Figure 1 illustrates the regions with THSR service provision ranges in western Taiwan, which include Keelung City, Taipei City, Taipei County, Taoyuan County, Hsinchu City, Hsinchu County, Maoli County, Taichung City, Taichung County, Chungghwa County, Nanto County, Yunlin County, Chiayi City, Chiayi County, Tainan City, Tainan County, Kaohsiung City, Kaohsiung County, and Pingtung County from northern to southern Taiwan. As for the level of economic development of these counties/cities, the regions in northern Taiwan(i.e. Taipei City, Taipei County, Taoyuan County, and Hsinchu City) are more developed than the middle and southern ones(i.e. the regions after Maoli County) in average.

The operation of THSR implies the advance of the public transportation system in western Taiwan and will accelerate the north-south transportation of passengers and cargos. The transportation time between Taipei to Kaohsiung had been shortened from 4 hours to 1.5 hours. It also has changed the transportation structure and completely restructured the south-north bound transportation industry in western Taiwan. Takes for example, all domestic airlines had terminated their flights in western Taiwan at the end of 2008. Besides, the north-south bound freeway bus service industry and railway service in the same area also have been destroyed significantly (Cheng, 2010). Therefore, the operation of THSR brings not only the convenience of north-south transportation in western Taiwan but also damaged the conventional transportation service. Finally, the construction of THSR is thus considered as a new engine to stimulate further development of the middle and southern regions. Therefore, whether this goal is achieved or not is an important issue.

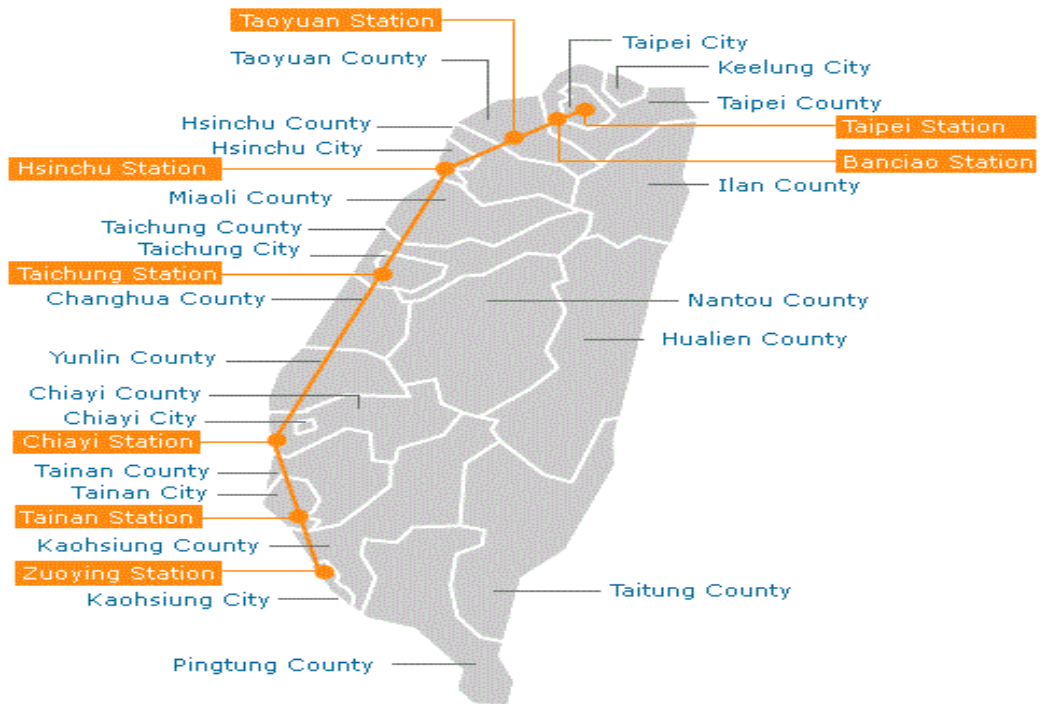


Figure 1 Geographical location of each station of THSR

Source: <http://moneyandtravel.files.wordpress.com/2013/06/taiwan-hsr-map.gif>

3. Literature Review

3.1 Operation of HSR and Regional Economic Development

Firstly, Monzón et al(2013) indicated that the urban areas will benefit from the improvement of traffic accessibility resulted from the construction of high speed railways, such as efficiency improvement, regional production advantage, and attractiveness enhancement, which all will enhance the competitiveness and economic growth. In addition, the construction of the high speed railways includes many districts in a country, thus, the geographic equality can be promoted accordingly. Willigers and van Wee(2011) analyzed the relationship between the construction of high speed railways and firms' location choices. Their research results showed that the accessibility to the high speed railway in an area will be more attractive for a firm to set up a factory. Similarly, the multinational enterprises prefer to locate in the cities with better international transportation accessibility; however, in Netherland, the high speed railway is too short to affect the location choices of enterprises significantly.

Besides, Button(2012) discussed that if there are the economic reasons for United StaEEs to construct the high speed railways. He assumes that, in spite of the construction of the high speed railways is prevail in several countries, the U. S. should not follow their steps to construct the self-own high speed railways. The traffic authorities should not only concern of economic development effects of high speed rail but also the overall social demands and investment benefits. Finally, Ha et al.(2011)

analyzed the social efficiency derived from the rail transportation services in Japan. By comparing to the social efficiency brought by the high speed railways and aviation transportation, they found that the service of JR-East is most efficient one while the JR-West is the worst. JR-Tokai perpetually improved its social efficiency and has become the most efficient service provider in 2007.

3.2 TII and Regional Economic Efficiency

Alam et al(2004) examined the role of transportation investment in the regional economic development of Bangladesh in detail. They applied the data envelopment analysis (DEA) technique to examine the technical efficiency of investment in transportation infrastructure development for each region of the country and found that Investment in infrastructure development of the less-efficient regions is found to be more effective by providing a higher rate of return. Alam et al(2005) furthermore proposed a framework for evaluating the relationship between transportation investment and economic return with time lag effect based on the data envelopment analysis(DEA) technique that captures the dynamic relationship between transportation investment and economic development. They confirmed that a lag time existed between investment and the materialization of economic return and the dynamic characteristics of time lag also associated with spatial variation. Besides, Percoco(2004) applied stochastic frontier analysis in comparing the regional production efficiencies in Italy during 1970~1994. He discovered that the new traffic infrastructure contributed to the regional economic growth greatly in Italy. If there could have more railway, EEs would be improved more.

3.3 Summary: HSR and Regional Economic Efficiency

After the reviews in above subsections, we find that the transportation infrastructure can influence to the overall and regional economic development and EEs significantly and, specifically and inherently, the operation of HST could affect regional economic development either. Less study focused on the impacts of regional EEs brought by the operation of HSR. Therefore, to connect this gap, we focus on the EEs changes of regions located in western Taiwan where lines the route of THSR to understand the influences of regional EEs resulted from the introduction of the THSR.

4. Methodology

This study primarily explores the following two questions: How the efficiency level of all the regions in western Taiwan changed after the emergence of the THSR? What factors influence the efficiency level changes? To investigate these questions, following the method proposed by Charnes et al (1989) and Stolp (1990) and used by Desai et al(1994), Desai and Storbeck(1990), Susiluoto(2003), Alam et al(2004) and Alam et al(2005), we applied DEA to investigate the first question and employed a Tobit panel data model to investigate the second question. We discuss the DEA and Malmquist index in Section 3.1 and the Tobit panel data model in Section 3.2.

4.1 DEA Model

DEA is one of the methods to estimate the production efficiency of a decision making unit (DMU). 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 the following sections, we discuss the output orientation model only because the economic performance of a county is to maximize its outputs, such as the income of residents and revenue of firms. The estimation concepts of input orientation is left for readers to refer to Coelli et al. (2005) or Cooper et al.(2000). In this study, we focus on output-oriented estimation method only because the regions always purchase the goal of economic development.

The linear optimization problem of an output-oriented CCR model is

$$\begin{aligned} \text{Max } (h, \lambda) \quad & \text{s.t.} \quad X - h_i \geq \sum_{i=1}^n \lambda_i X_{ij}, \quad j=1, \dots, J \\ & \sum_{i=1}^n \lambda_i = 1 \end{aligned} \quad (1)$$

where h_k indicate that, considering the input levels of county k as X_{kj} , output should increase as $h_k Y_{kr}$ if X_{kj} is used efficiently. In these models, when $h_k = 1$, the county k is at the efficiency frontier. In other words, the county has optimal efficiency. However, if $h_k > 1$, the production of county k is comparatively inefficient. λ_i is the weight of a single county, $i = 1, 2, 3, \dots, n$; λ is the vector containing all the λ_i ; X_{ij} is the j -th input of county i (assuming it has J input for production), including the employment, registered corporate capital, and consumed electricity in county i ; Y_{ir} is the r th output of county i (assuming it has R output types). This study also employs the regional income, sales volumes, registered enterprises numbers between 2005 and 2010. Consequently, the relative output economic efficiency (EE) is estimated as $EE = 1/h_k$. Therefore, an EE value below 1 indicate that, even if all current inputs were used efficiently, the output is less than the optimal. By including the convexity constraint

$$\sum_{i=1}^n \lambda_i = 1$$

in this model, it becomes the output-oriented BBC model. If we divide the TE value in CCR with the one in BCC, we can estimate the value of scale efficiencies (SE). Thus, (2) provides the definition of SE.

$$SE = \frac{EE \text{ in CCR}}{EE \text{ in BCC}} \quad (2)$$

Generally, SE is less than or equal to 1. If the EE values of a county for both CCR and BCC equal 1, then their SEs are also equal to 1, which means that the county is operating at optimal scales.

4.2 Tobit Regreesion with Panel Data

Briefly, Tobit regression is defined as

$$TE_{it} = \begin{cases} \beta' X_{it} + u_i + \varepsilon_{it}, & \text{if } TE_{it} < 1, \forall i, t; i = 1, 2, \dots, N; t = 1, 2, \dots, T; \\ 1, & \text{if } TE_{it} \geq 1, \forall i, t; i = 1, 2, \dots, N; t = 1, 2, \dots, T. \end{cases} \quad (3)$$

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

$$\Pr(TE_{it}|X_{it}) = \int_{-\infty}^{\infty} \frac{e^{\frac{-u_i^2}{2\sigma_u^2}}}{\sqrt{2\pi}} \left\{ \prod_{t=1}^T [F(\beta'X_{it} + u_i)] \right\} \quad (4)$$

where

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

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 county's specific effect and error term, respectively, which are assumed to have a normal distribution at $N(0, \sigma_u^2)$ and $N(0, \sigma_\varepsilon^2)$. $\text{Var}(u_i) = \sigma_u^2$, $\text{Var}(\varepsilon_{it}) = \sigma_\varepsilon^2$, and Φ is the accumulated normal distribution function. We integrated (10) with the M-point Gauss-Hermite quadrature proposed by Liu and Pierce (1994). To reflect the unobserved differences between each county, we estimated the random-effects Tobit panel data model.

5. The Data

5.1 Input and Output Variables

Banker et al.(1989) and Cooper et al.(2000) have emphasized that, as considering the numbers of input/output variables applied to measure the technical efficiency scores in DEA models, the number of decision making units should be more than 3 times of total input and output variables numbers for insuring the validity of estimation results. In this study, the number of decision making units is 20. Therefore, the total number of input and output variables should not exceed 6 at most.

As for the selection of input variables, we use the total employment and registered corporate capital as the proxy variables for the number of labor and capital used in the production function. In addition, the amount of electricity consumption is also included in the input variables because it is used in the production processes. As for the output variables, previous researches usually adopted the regional gross domestic product (regional GDP) or regional gross national product (regional GNP) as the output variable. But there is no such economic statistic data for regions in Taiwan. The only way to get the proxy variable for regional output is to calculate from other available data, such as family income and expenditure. We name this variable as "regional income" (we show the calculation processes in details in next paragraph). Besides, the data provision organization indicated that, as the samples in some regions are not large enough, the data of family income and expenditure may be meaningless in statistics, which might cause some bias and error in calculating "regional income". Thus, to avoid such deviation, we add "sales of enterprises" and "registered enterprise numbers" as additional output variables for supplementing the possible shortages of calculated

“regional income” variable.

The data we used in this study are collected from the sub-website of “major statistics indicators of county and city” shown in the website of The National Statistics, Taiwan.¹ We can find the data of number of employees (in unit of 1,000 people), registered enterprise capital, and electricity consumption, sales volumes of enterprises, and numbers of registered enterprises of every county and city directly from this website. As for the calculating processes of “regional income” in each county and city, as applying the “income approach” concept generally used in calculating national GDP, we firstly multiplied the “disposable income per household” and “total households” in regional level as the “regional disposable income” for all cities and counties. Besides, we multiplied the “personal average taxation payment” and “average number of residents per household” as the “average taxation payment per household” and they multiplied this number with “total households” as “total taxation payment” for each county and city. Then we summed up the “regional disposable income” and “total taxation payment” as the “regional income” for each counties and cities. Finally, we adjusted this variable according to the “consumer price index(CPI)” published by Taiwan’s Directorate- General of Budget, Accounting and Statistics in Executive Yuan. Similarly, the sales volumes of enterprises are also adjusted by the “wholesale price index(WPI)”.

Based on the procedures as interpreted above, we apply a 3 input and 3 output variable data envelopment analysis (DEA) in which the research period spans between 2004 to 2010.³ The reason for selecting this period is on the purpose of exploring the subsequent economic performance in each county and city in western Taiwan before and after the operation of THSR. The THSR initiated trial and official operation in year 2007, this period contains 3 years before and after 2007 respectively and offer us the opportunity to compare the economic performance in counties and cities.

Table 1 Statistics descriptions of input and output variables for DEA model

Variable	Obs.	Mean	Stand. Dev.	Min.	Max.
Regional Income (Million)	140	393225.2	414177.6	67921.63	1817074
Sales Volumes(Million)	140	1656.285	2548.876	153.1344	13865.33
Registered Enterprises	140	29542.49	40914.01	3635	167623
Employment(Thousand)	140	494.9357	384.4703	108	1796
Registered corporate capital (Million)	140	892559.7	1943619	38914	9491512
Consumed Electricity (Million Watt)	140	6078.05	4964.302	467	21452

5.2 Independence Variables in Tobit Model

In this study, we set year 2007 as a dummy variable for observing whether the operation of the THSR has influenced the EEs for regions in western Taiwan in 2007. Besides, as experienced the financial tsunami in 2008, the global economy had suffered the recession. Taiwan was not the exception. Therefore, the dummy of year 2008 can observe whether the regions in western Taiwan have suffered the negative impacts of financial tsunami on their economic efficiency. In addition, to observe the long term effect of THSR’s operation, we also include a dummy for year 2007-2010 in Tobit model. Finally, to confirm that whether the cities and counties with THSR stations

¹ Please refer to <http://ebas1.ebas.gov.tw/pxweb/Dialog/Statfile9O.asp> (in Chinese).

located would improve their EEs or not, these regions are specially marked by dummy variable after year 2007.

Moreover, previous studies indicate that the regional population will positively significantly influence the local economic efficiency. Thus, we employ it as one of the explanatory variables. Meanwhile, to understand whether the education level in a county/city would influence its economic efficiency, we employ the ratio of employees who graduated from colleges or universities in our regression model too, which features the human resource capital quality. The better labor quality is, the higher the technical efficiency. Furthermore, to investigate the influences of industry specialization, we calculate the ratio of employees in manufacturing and service sectors to total employees in a county/city respectively to capture the effects of specialization economics.

Also as shown in many previous studies, the R&D activities in a county/city promote the EEs in general. Therefore, we incorporate the number of enterprises conducting R&D, the ratio of enterprise number in information and communication technology (ICT) sector to the number of enterprises conducting R&D and the total registered patents for regions for exploring whether the R&D activities could influence their economic efficiency significantly. The first two variables are collected and calculated from the Factory Correction and Operation Census in year 2004-2005 and 2007-2010. Their data in 2006 were collected from Industry, Commerce and Service Census implemented in 2006. Total number of registered patents in a county/city was collected from Taiwan Patent Search, Intellectual Property Office, Ministry of Economic Affairs (MOEA). Table 2 shows the basic descriptive statistics of these non-dummy variables in the Tobit Model.

Table 2 Statistics descriptions for non-dummy variables in the Tobit model

Variable	Obs.	Mean	Stand. Dev.	Min.	Max.
Local population	140	1109076	852274.4	270341	3897367
Employment Ratio of Manufacturing Sector	140	36.444	8.741015	18.79	52.78
Employment Ratio of Service Sector	140	56.471	10.99422	42.36	80.98
Ratio of Employee with College/University Education	140	36.153	11.76227	17.11	69.92
Patents	140	1749.729	1985.59	96	9503
Number of R&D firm	140	304.714	350.1561	12	1391
Ratio of ICT firms in all R&D firm	140	0.265	0.212658	0.0167	0.792

6. Empirical Research Results Analysis

This research is composed of two sectors in which the first sector is the EEs of county/city between year 2004 and 2010; and the second sector is what factors would affect the level of technical efficiency. For the first sector, we apply the DEAP Software (Version 2.1)² which is developed by Coelli(1996) to estimate the DEA models and, the statistics software Stata(version 12) for the estimation of Tobit panel data model.

6.1 Economic Efficiency Analysis

As shown in the Table 3 and Figure 2, the average EEs in CRS is slightly-downward in 2004-2010. Likewise, the ones of IO (Input-Oriented) and OO (Output-

² <http://www.uq.edu.au/economics/cepa/deap.php>. Latest retrieved at: 2012/10/08.

Orientated) in VRS model also show the similar patterns but their reaction directions are divergent in 2008. As for the scale efficiencies, as Figure 4 shows that, even though lowered down obviously in year 2005, it returned in 2006 and 2007. In 2008, it plunged again due to global financial tsunami. It slightly rose in 2009 but then dropped back in 2010.

Tale 3 Average EEs of regions in western Taiwan in 2004-2010

Year	CRS	VRS	Scale Efficiency	Return to scale: irs(drs) *
2004	0.941	0.961	0.978	3(7)
2005	0.922	0.955	0.963	3(8)
2006	0.933	0.954	0.976	4(5)
2007	0.932	0.952	0.978	3(8)
2008	0.927	0.953	0.972	3(8)
2009	0.931	0.954	0.975	5(7)
2010	0.925	0.949	0.973	2(8)

Statement: * represents the number of regions with increasing return to scale(irs) and decreasing return to scale(drs).

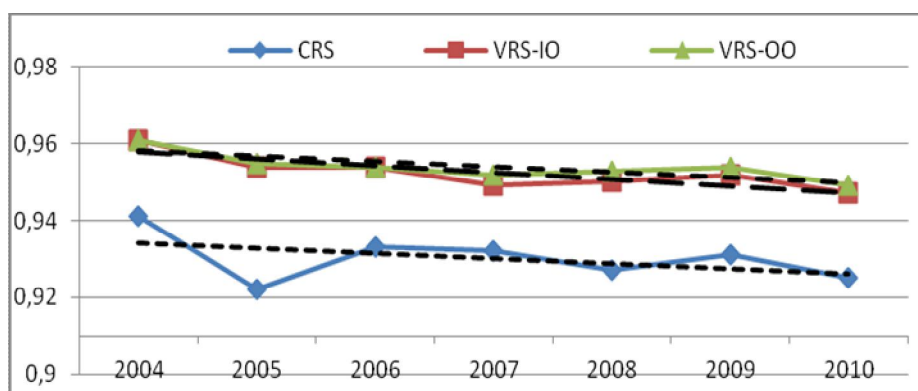


Figure 2 Average EEs for county/cities in western Taiwan in 2004-2010

The lowered down of EEs in 2005 was due to the temporally worsened macroeconomic environment in Taiwan. Moreover, we conducted the t-test on the average EEs for regions before and after the initial operation of the THSR in year 2007. The results are list in the Table 4 and indicate that, the average efficiencies in 2004-2006 are slightly higher than that between 2007-2010, even though the t-test results are insignificant.

Table 4 t-test for average EEs before and after 2007

Items	CRS	VRS	Scale Efficiency
2004-2006(1)	0.9318	0.9566	0.9737
2007-2010(2)	0.9287	0.9519	0.9751
Mean deviation((1)-(2))	0.0031	0.0046	-0.0014
t-value	0.2104	0.3616	-0.1996

In addition, we also investigate the differences between average EEs of regions with/without the THSR's stations before and after 2007. The results are shown in the Table 5.

Table 5 Differences of average EEs of regions with/without the THSR stations

Period	Items	CRS	VRS-OO	Scale Efficiency
2004 2006	Without station	0.9164	0.9466	0.9682
	With station	0.9549	0.9716	0.9819
	Difference	-0.0384	-0.0249	-0.0136
	t-value	-1.6937	-1.3653	-1.0508
2007 later	Without station	0.9232	0.9461	0.976
	With station	0.9368	0.9608	0.9739
	Difference	-0.0136	-0.0147	0.0021
	t-value	-0.6758	-0.8147	0.266

Table 6 Differences of average EEs of regions with the THSR stations

Items	CRS	VRS	Scale Efficiency
2004-2006	0.9549	0.9716	0.9819
2007 later	0.9368	0.9608	0.9739
Difference	0.0180	0.0108	0.0080
t-value	0.8603	0.6643	1.0038

According to this table, we found that the differences of average EEs between two groups before and after 2007 are shrunk, even though the differences are insignificant. We also discovered that the average EEs in the regions without THSR's stations improved slightly since 2007. On the contrary, these in the regions with the THSR stations are lower down slightly in 2007-2010. In our opinion, such results indicate that the negative impacts resulted from the location of THSR's stations might overcome the positive advantages for the regions with the THSR stations located. The outflows of resources are severe than the inflows due to the convenience of resource transportation. We also conducted the t-test on the difference of average EEs of regions with the THSR stations before and after 2007 in Table 6. The results showed that the average EEs for these regions were worse in 2007-2010, even though the t-test results are insignificant. To sum up, after the initial operation of the THSR in 2007, the trends of overall average EEs of regions in western Taiwan are decreasing. The differences between the average EEs of regions with and without the THSR stations located are shorted after 2007, even though the values of regions with THSR stations located are higher than the ones of without. Finally, the average EEs of regions with the THSR stations after 2007 are lower than the average values in 2004-2006.

6.2. Analysis of Tobit Regression with Panel Data: The estimated results of Tobit model with panel data are shown in the Table 7.

There are 3 estimated models in Table 10 due to the different dependent variable. The overall fitness of these model estimation indicated by Wald and Likelihood Ratio test shows that the estimated results of these models are adequate. Meanwhile, we also find that the model of Tobit with panel data is more adequate as comparing with pooled regression with data according to the LR test results of $\sigma_u = 0$. Finally, we also found that the significant variables in each model are slightly different. Thus, only the estimated parameters of variables which are significant at least in two models simultaneously will be discussed in the follows.

From Table 7, the 2007 dummy is positively significant in all models, which

indicates that the EEs for western Taiwan regions are generally positively stimulated due to the first year operation of THSR. However, if we extend the observation period from 2007-2010, we discovered that all EEs were significantly negatively influenced by the operation of THSR. It implies that, even though the operation of THSR stimulated the EEs of regions in western Taiwan, such impacts were temporal because it turned reversely as the operation period of THSR getting longer. If we further considered the influences of regions with THSR stations for the overall economic efficiency, we are impressed that the regions with the THSR stations significantly negatively influenced the overall EEs in western Taiwan regions since 2007. Such empirical results are consistent with the analysis in section in 5.1 and 5.2. Therefore, according to the estimated results of dummy variables, we conclude that, although the operation of the THSR improved the overall EEs of regions in western Taiwan in the short term, it worsened them in a longer period.

Table 7 Estimation results of Tobit regression with panel data

Variables	CRS	VRS-OO
Constant	1.823(4.60)**	2.109(4.96)**
Dummy 2007	0.040(2.02)**	0.071(2.72)**
Dummy 2008	-	0.041(2.06)**
Dummy 2007 later	-0.043(-1.46)	-0.108(-2.57)**
Dummy 2007 later with THSR station	-0.047(-2.17)**	-0.027(-1.19)
Demographic variables		
Population	2.49e-07(3.18)**	1.00e-07 (1.05)
Ratio of Employees with College/University Education	0.004(1.24)	0.011(2.01)**
Employment Ratio of Manufacturing Sector	-0.025(-3.20)**	-0.026(-3.14)**
Employment Ratio of Service Sector	-0.027(-2.35)**	-0.028(-2.36)**
HHI	0.0002(2.09)**	0.0002(1.46)
R&D		
Firm number with R&D activity	0.00004(0.39)	0.0003(1.85)*
ICT firm ratio in all firms with R&D activity	0.226(1.61)	0.134(0.79)
Number of Patents	-0.00008(-3.41)**	-0.00004(-1.55)
σ_{η}^2	0.075(3.88)**	0.101(3.69)**
σ_{ε}^2	0.048(10.98)**	0.041(9.21)**
$\rho = \sigma_u / (\sigma_u + \sigma_{\varepsilon})$	0.701	0.857
LR test of $\sigma_{\eta}^2 = 0: \chi^2(01)/P(\chi^2 > \chi^2(01))$	41.24/0.00**	63.97/0.00**
Log likelihood (0)/Log likelihood (β)	74.631/93.614	53.985/ 67.969
LR test of model significance/ $P(\text{LR}(\chi^2))$	37.97/0.00**	27.97/0.0001**
Wald(χ^2)/ $P(\chi^2 > \text{Wald}(\chi^2))$	39.64/0.00**	22.11/0.006**

Note: numbers in parentheses are the t statistics; * represents 10% significance level and ** represents 5% significance level; $P(\cdot)$ means the probability value.

As considering the demographic variables, we found that larger the population a county/city own, the higher the EEs in CRS models only. Furthermore, as regard to the quality of population, we found that the higher ratio of population with university/college education background, which represents the higher quality of population or labor capital, the better economic efficiency. The higher quality of population or labor capital implies the better capacity of utilizing and managing

resources and thus results in the higher Economic efficiency. Finally, as considering to the economies of specialization, the estimation results show that, regardless of the employee's ratio in the manufacturing sectors or in the service sectors, they all negatively influence the EEs of regions in western Taiwan in 2004-2010. Such results indicate that there is no economy of specialization in these regions in the period.

Finally, as consider the influences of R&D activities implemented in a county/city, we find that only the number of registered patents significantly influences the EEs in a county/city, but the direction is contrary to the prediction sigh mentioned in section 4.1. It negatively influences the EEs of regions in western Taiwan in 2004-2010. The explanation for such result might be that, as lacking the feasible economic linkages between the patents invented and the local economic activities in a county/city, those patents cannot be transformed into the energy or capacities of local economic development. Too many registered patents in a county/city represent some sort of resources misuse and results in a lower TE. Therefore, the local government of regions in western Taiwan should find out the mechanisms which are helpful in linking the invention and the improvement of regional economic development.

7. Conclusions and Suggestions

This research explored what a new public transportation infrastructure, the THSR, would impact the EEs and productivities on the regions along its operation route as comparing the EEs of these areas before and after its operation in 2007. We also investigated other factors influencing their EEs in this period by estimating the Tobit regression in panel data. We discovered that the average EEs are slightly downward in 2004-2010. The scale average efficiencies lowered down in 2005 due to the worse macroeconomic environment of Taiwan and plunged again in 2008 due to global financial tsunami. We also discovered that, after the initial operation of THSR in 2007, the average EEs decreased more for the regions with the THSR stations located than these in the regions without THSR stations located, which imply that the goal of choosing the stations located in non-urban counties-to speed up their economic development- was fail according to their losses of efficiencies in our empirical investigation.

Furthermore, according to the regression results in Tobit models, we found that the EEs for the regions in western Taiwan's improved shortly with THSR's beginning operation; in the long term, its operation damaged the EEs of these regions . The regions with the location of THSR's stations negatively influence the overall EEs in Taiwan's western regions since year 2007 because its decrease of EEs more than those without the THSR's stations located. In addition, the quality of population also benefits the EEs for those regions significantly, but the concentration in manufacturing and service sector and the amount of patent numbers hurt the overall EEs significantly.

For the myth for the construction of a transportation infrastructure mentioned in section 1, our empirical results clearly showed that, the improved transportation convenience brought by the operation of new transportation infrastructure might only benefit the regional development in the short term but damage in the longer period because the inflows of outside resources might be dominate by the outflows of local resources due to the improved convenience. The responsibilities of developing the non-urban areas where the THSR's stations located undertaken by the construction and operation of THSR is not achieved according to our investigation. Therefore, the myth

for the construction of a new transportation infrastructure should be broken accordingly. In addition, to improve the regional economic efficiencies, the improvements of labor capital and the mechanism for linking the R&D inventions and economic developments are main important factors to achieve the goal. Therefore, the policies related to these two points might be more practical for the strategies of regional developments.

As for the future studies, we only concerned with economic influences of THSR's operation on the western regions in Taiwan in 2004-2010. If possible, future studies could consider a longer period for observation to investigate the long-term influences of THSR's operation. In addition, its impacts on other social dimensions of these regions are still unclear. Future researches can therefore discuss these impacts, such as the life quality for the citizens in these regions. Finally, future studies can investigate the topics of environmental effects resulted from THSR's operation because of its usage of electricity instead of the consumption of gasoline, such as the emission quantities of CO₂.

Reference

- Alam1, J. B., Sikder, S. H. and Goulias, K. G. (2004), Role of Transportation in Regional EEs in Bangladesh: Data Envelopment Analysis, *Transportation Research Record: Journal of the Transportation Research Board*, 1864/2004, Transportation Finance, Economics, and Economic Development 2004, 112-120.
- Alam1, J. B., Sikder, S. H. and Goulias, K. G. (2005), Assessing the Time Lag Between Transportation Investment and Economic Development by the Data Envelopment Approach, *Transportation Research Record: Journal of the Transportation Research Board*, 1932/2005, Finance, Economics, and Economic Development, 79-88.
- Banker, R. D., Charnes, A., Cooper, W. W.(1984), Some models for estimating technical and scale inefficiencies in data envelopment analysis, *Management Science*, 30, 1078-1092.
- Blum, U., Haynes, K.E. and Karlsson, C. (1997). Introduction to the special issue: The regional and urban effects of high-speed trains, *The Annals of Regional Science*, 31:1, 1-20.
- Boopen, S.(2006), Transport infrastructure and economic growth: evidence from Africa using dynamic panel estimaeconomic efficiency, *The Empirical Economic Letters*, 5:1, 37-52.
- Button, K.(2012). Is there any economic justification for high-speed railways in the United Staeeconomic efficiency? *Journal of Transport Geography*, 22, 300-302.
- Chandra, A. and Thompson, E. (2000), Does public infrastructure affect economic activity? evidence from the rural interstate highway system, *Regional Science and Urban Economics*, 30:4, 457-490.
- Charnes, A., Cooper, W. W., Rhodes, E.(1978), Measuring the efficiency of decision making units, *European Journal of Operational Research*, 2, 429-444.
- Charnes, A., W. W. Cooper and S. Li, (1989), Using data envelopment analysis to evaluate efficiency in the economic performance of Chinese cities, *Socio-Economic Planning Sciences*, 6, 325-344.

- Cheng, Y.-H. (2010). High-speed rail in Taiwan: new experience and issues for future development, *Transport Policy* 17:2, 51-56.
- Coelli, T. J. (1996), *A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program*, Centre for Efficiency and Productivity Analysis, University of New England, Working paper, No. 8/96, Available at <http://www.owl.net.rice.edu/~econ380/DEAP.PDF>.
- Coelli, T., D. Rao, S. P., O'Donnell, C. and Bateconomic efficiency, G. E. (2005), *Introduction To Efficiency And Productivity Analysis*, Springer, Heidelberg, 2nd edition.
- Cooper, W. W., Seiford, L. M., and Tone, K. (2000), *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References, and DEA-Solver Software*, Boston: Kluwer Academic.
- D'Emurger, S. (2001). Infrastructure Development and Economic Growth: An Explanation for Regional Disparities in China? , *Journal of Comparative Economics*, 29:1, 95-117.
- Desai, A., K. Haynes and J. Stobeck, (1994), A spatial efficiency framework for the support of locational decision", in Charnes *et al.*, ed., *Data Envelopment Analysis: Theory, Methodology and Applications*, Boston: Kluwer Academic Publishers, 223-249.
- Desai, A. and Storbeck, J. E. (1990). Data envelopment analysis for spatial efficiency. *Computers, Environment and Urban Systems*, 14:2, 145-156.
- Färe, R., Grosskopf, S., Norris, M. and Zhang, Z., (1994), Productivity growth, technical progress, and efficiency change in industrialized countries, *American Economic Review*, 84:1, 66-83.
- Ha, H.K., Yoshida, Y., and Zhang, A. (2011), Social efficiency benchmarking of Japanese domestic transport services: A comparison of rail and air. *Transportation Research Part D*, 16:7, 554-561.
- Meijers, E., Hoekstra, J., Leijten, M., Louw, E., Spaans, M. (2012). Connecting the periphery: distributive effects of new infrastructure, *Journal of Transport Geography*, 22, 187-198.
- Monzón, A., Ortega, E. and López, E. (2013), Efficiency and spatial equity impacts of high-speed rail extensions in urban areas, *Cities*, 30, 18-30.
- Nakamura, H. and Ueda, T. (1989), The impacts of the Shinkansen on regional Development. *The Fifth World Conference on Transport Research*, Yokohama, v. III, Western Periodicals, Ventura, California.
- Percoco, M. (2004) A Statistical Model for the Identification of Key Sectors in I-O Models, ERSA conference papers ersa04p90, European Regional Science Association.
- Sasaki, K., Ohashi, T. and Ando, A. (1997), High-speed rail transit impact on region system: does the Shinkansen contribute to dispersion, *The Annals of Regional Science*, 31, 77-98.
- Stolp, C. (1990), Strengths and weaknesses of data envelopment analysis: An urban and regional perspective, *Computers, Environmental and Urban Systems*, 14:2,

103-116.

Taiwan High Speed Rail (2012), *Yearly Operation Report*,

[http://www.thsrc.com.tw/tw/Article/Article Content/1e07f685-045e-403c-bf92-88c2d86bf826](http://www.thsrc.com.tw/tw/Article/Article%20Content/1e07f685-045e-403c-bf92-88c2d86bf826). Last retrieved on 2013/10/02.

Vickerman, R. (1997). High-speed rail in Europe: experience and issues for future development, *The Annals of Regional Science*, 31, 21-38.

Willigers, J. and van Wee, B.(2011), High-speed rail and office location choices: a stated choice experiment for the Netherlands, *Journal of Transport Geography*, 19:4, 745-754.