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The Regional Economic Impacts of Taiwan High Speed Rail

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Abstract

Starting her business operation on January 5 2007, Taiwan High Speed Rail (THSR) shapes a new time-space frame for Taiwan western corridor, where more than 90% of national population lives around and more than 95% gross domestic product created from. Comparing with the four-hour traveling time by highway before 2007, THSR reduces the time required to one and half hours from Taipei to Kaohsiung. It will not only benefit the communication along the island from north to south, but also change the location advantages/disadvantages for all cities in these regions. Therefore, this paper establishes a spatial computable general equilibrium model (SCGE Model) to simulate the economic effect of High Speed Rail (HSR). This SCGE model divides Taiwan economy into fifteen geographic regions and thirteen industries. Each region has three sectors: household sector, transportation sector, and industries sector. Following the behavior function of economic theories, the general equilibrium can be achieved simultaneously. Thus, gross regional product (GRP), capital formation, employment income and welfare/utility level can be all observed by calculating the different economic result between cases with-/ without-HSR. Besides, this model presents the social welfare benefit from HSR operation, the polarization phenomenon among regions and within certain region, unbalance distribution of welfare along the HSR line, and industries development divergence among regions etc. These major findings should be useful for regional development policy making.

Keywords : *HSR, SCGE model, Regional economics*

1. Introduction

Some 40 years ago, the operation of the Shinkansen in Japan marked the beginning of the modern high-speed rail (HSR) era. Since then HSR services have been introduced and are planning in many countries, and with her high-speed advantage, HSR usually becomes the dominant mode of transport on many routes.

On January 5 2007, Taiwan High Speed Rail (THSR) shapes a new time-space frame for Taiwan western corridor, where more than 90% of national population lives around and creates more than 95% gross domestic product. Comparing with the four-hour traveling time by highway before 2007, THSR reduces the time required to one and half hours from Taipei to Kaohsiung. It will not only benefit the communication along the island from north to south, but also change the location advantages/disadvantages for all cities in these regions.

Therefore, the purpose of this paper is to establish a spatial computable general equilibrium model (SCGE Model) to simulate the economic effect of HSR. This SCGE model divides Taiwan economy into fifteen geographic regions and thirteen industries. Each region has three sectors: household sector, transportation sector, and industries sector. Following the behavior function of economic theories, the general equilibrium can be achieved simultaneously. Thus, gross regional product (GRP), capital formation, employment income and welfare/utility level can be all observed by calculating the different economic result between cases with-/ without-HSR.

The remainder of this paper is structured in the following way. Section 2 outlines the model. Sections 3 and 4 describe the data and the simulation procedure. Section 5 summarizes the results.

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2. The Model

2.1 Outline and Assumptions

Based on Ueda et al. (2005), we formulated a SCGE model with the following major assumptions:

(1) The model spatially covers regions labeled by $s \in S = \{1,2,3,\ldots,15\}$. In each region, a representative household, a transportation sector, and industrial sectors exist. The industrial sectors are labeled by $i \in \{1,2,3,\ldots,13\}$.

(2) Each industry produces commodities/services by x_i inputting factors, labor L_i and capital K_i, and intermediate goods traded between sectors.

(3) The household earns income by supplying factors, consumes commodities/services provided by industries, and takes private trips labeled by *TP* provided by the transportation sector.

(4) The transportation sector labeled $i=T$ provides passenger transportation services to households and industrials. The passenger transportation service includes several modes labeled by $m \in \{1,2,3\}$. Excess profit of the transportation sector is divided and distributed to households.

(5) Any markets in the economy are assumed to be in long-run competitive equilibrium.

(6) Trading with other countries is not considered in this model, so it is assumed there is no direct impact on the trading by the operation of THSR.

2.2 The Formation of SCGE Model in Taiwan

2.2.1 Household Behavior

We assume that a representative household residing in region pursues to maximize its utility by consuming commodities/services x_i^s and recreation in its leisure time L_e^s. The household spends time working, traveling, sleeping, and so on. So its leisure time is equal to disposable time $\overline{L}_R^s$ minus working time L^s and private trip time. Thus, its leisure time L_e^s can be formalized as:

$$Le^s = \overline{L}_R^s - L^s - \sum_i \sum_r \sum_m t_{rm}^s Tp_{rm}^s \rightarrow Le^s = Le^s(L^s, Tp_{rm}^s) \tag{1}$$

where t_{rm}^s means private trip time from region *s* to *r* by transportation mode *m*, and Tp_{rm}^s means the number of private trip times. As to the business trip time Tb_{irm}^s, it is included in working time L^s.

Since we are unable to estimate Tp_{rm}^s directly by formula (1). Thus the demand of composite private trip, Tp^s, will be first estimated, then Tp_r^s, the demand of private trip from region *s* to *r*, and finally Tp_{rm}^s, the demand of private trip from region *s* to *r* by transportation mode *m*. The processes are as follows:

1) First Stage

It is assumed that the utility function of the household in regionis Cobb-Douglas type. Thus the utility function is:

$$U^s(x_i^s, Le^s, Tp^s) = \phi_1 \prod_{i=1}^{13} {x_i^s}^{\alpha_i} {Le^s}^{\alpha_{14}} {Tp^s}^{\alpha_{15}}, \quad \sum_{j=1}^{15} \alpha_j = 1 \tag{2}$$

The household faces budget and time constraints, so we can formulate a utility maximizing problem as:

$$V^s(p_i^s, p_{Tp}^s; I) = \underset{x_i^s, Le^s, Tp^s}{Max}\ U^s(x_i^s, Le^s, Tp^s)$$

$$\text{s.t.} \sum_i p_i^s x_i^s + P_{Tp}^s Tp^s \le I^s, \text{ and}$$

$$I^s = w^s \sum_i L_i^s + r\left(\sum_i k_i^s + K_T^s\right) + \pi_T^s \tag{3}$$

where p_i^s means the price of x_i^s commodities/services of industry *i* consumed in residing region *s*; p_{Tp}^s means the price for Tp^s private trips of the household residing in region *s*; I^s means the household income; w^s means the wages for L_i^s, working time input to industry *i* in region; *r* means the rent of the capital; K_i^s means the capital input to industry *i* in region; K_T^s means the capital input to the transportation sector in region; π_T^s means the profit of the transportation sector in region *s*.

Then we can get:

$$x_i^s = \frac{\alpha_1}{p_i^s} I^s, \ i \in \{1,2,3,\ldots,13\}, \text{ and } Tp^s = \frac{\alpha_3}{p_{Tp}^s} I^s \tag{4}$$

2) Second Stage

Since the composite private trip Tp^s are composed of Tp_r^s and $s \in S$, the household determines its Tp^s to minimize representative price p_{Tp}^s. Next, we reformulate the minimization problem by specifying the aggregation structure of Tp^s as a Cobb-Douglas function:

$$p_{Tp}^s = \min_{Tp_r^s, r \in s} \sum_s p_{Tpr}^s, Tp_r^s, \text{s.t. } (Tp^s =)\ \phi_2 \prod_{j=1}^{15} {Tp_j^s}^{\beta_j} = 1,$$

$$\text{and } \sum_{j=1}^{15} \beta_j = 1 \tag{5}$$

where p_{Tpr}^s is the price for private trips from region *s* to *r*. Then we can get:

$$Tp_r^s = \frac{1}{\phi_2} \frac{\beta_r}{p_{Tpr}^s} \Delta_1, \text{ and } \Delta_1 = \frac{\prod_{j=1}^{15} {p_{Tpj}^s}^{\beta_j}}{\prod_{j=1}^{15} \beta_j^{\beta_j}}, \ r \in \{1,2,\ldots,15\} \tag{6}$$

And finally we get: $$p_{Tp}^s = \frac{\Delta_1}{\phi_2} \tag{7}$$

3) Third Stage

Similarly, Tp_r^s are composed of Tp_{rm}^s and $s \in S$, the household determines his TP_r^s to minimize representative price p^s_{Tpr}. Next, we reformulate the minimization problem by specifying the aggregation structure of Tp^s_r as a Cobb-Douglas function:

$$p^s_{Tpr} = \min_{Tp^s_{rm}} \sum_{m \in M} (p^s_{rm} + t^s_{rm} w^s) Tp^s_{rm}$$

$$\text{s.t. } (Tp^s_r =)\ \phi_3 Tp^{s\,\gamma_1}_{r1} Tp^{s\,\gamma_2}_{r2} Tp^{s\,\gamma_3}_{r3} = 1, \text{ and } \gamma_1 + \gamma_2 + \gamma_3 = 1 \tag{8}$$

where p^s_{rm} means the price of transportation mode m from region s to r.

So we can get:

$$Tp^s_{rm} = \frac{1}{\phi_3} \frac{\gamma_m}{(p^r_{rm} + t^s_{rm} w^s)} \Delta_2, \text{ and}$$

$$\Delta_2 = \frac{(p^r_{r1} + t^s_{r1} w^s)^{\gamma_1} (p^r_{r2} + t^s_{r2} w^s)^{\gamma_2} (p^r_{r3} + t^s_{r3} w^s)^{\gamma_3}}{\gamma_1^{\gamma_1} \cdot \gamma_2^{\gamma_2} \cdot \gamma_3^{\gamma_3}}$$

$$m \in \{1, 2, 3\} \tag{9}$$

Next, we deduce that: $p^s_{Tpr} = \dfrac{\Delta_2}{\phi_3}$ (10)

Finally, we can get the value of x_i, Tp^s and Le^s by deducing from the first and second stage.

2.2.2 Industries' Behavior

An industry produces a commodity or a service by inputting factors and intermediate goods. Industry i in regionproduces output Q^s_i. We adopt a Leontief-type technology for the intermediate goods provided from industry i, $x^s_{i'i}$, and value-added VA^s_i. The input coefficients, a^s_{va} and $a^s_{i'i}$, are constant. Then output Q^s_i is formulized as the function:

1) First Stage

$$Q^s_i = \min_{VA, x_{1i}, \ldots, x_{ii}, \ldots x_{Ii}} \left[\frac{VA^s_i}{a^s_{va}}, \frac{x^s_{1i}}{a^s_{1i}}, \ldots, \frac{x^s_{ii}}{a^s_{ii}}, \ldots, \frac{x^s_{Ii}}{a^s_{Ii}} \right] \tag{11}$$

Value-added VA^s_i is regarded as a composite factor whose ingredients are inputs, labor and capital. We assume that value added follows Cobb-Douglas type:

$$VA^s_i = \rho_{1i} L^{s\,\sigma_1}_i K^{s\,\sigma_2}_i Tb^{s\,\sigma_3}_i \text{ and } \sigma_1 + \sigma_2 + \sigma_2 = 1 \tag{12}$$

where ρ_{1i} is constant parameter for industry i.

We assume that an industry behaves to minimize production costs for a unit of value-added as follows:

$$\min_{L^s_i, K^s_i, Tb^s_i} w^s L^s_i + r K^s_i + p^s_{Tbi} Tb^s_i,$$

$$\text{s.t. } (VA^s_i =)\ \rho_{1i} L^{s\,\sigma_1}_i K^{s\,\sigma_2}_i Tb^{s\,\sigma_3}_i = 1 \tag{13}$$

Then we can get the optimal quantity of labor, capital, composite business trip of industry i in region s, and the fees of the composite business trip respectively as:

$$L^s_i = \frac{1}{\rho_{1i}} \frac{\sigma_1}{w^s} \Lambda_1,\ K^s_i = \frac{1}{\rho_{1i}} \frac{\sigma_2}{r} \Lambda_1,\ Tb^s_i = \frac{1}{\rho_{1i}} \frac{\sigma_3}{p^s_{Tpi}} \Lambda_1,$$

$$p^s_i = \frac{1}{\rho_{1i}} \Lambda_1, \text{ and } \Lambda_1 = \frac{w^{s\,\sigma_1} \cdot r^{\sigma_2} \cdot p^{s\,\sigma_3}_{Tbi}}{\sigma_1^{\sigma_1} \cdot \sigma_2^{\sigma_2} \cdot \sigma_3^{\sigma_3}} \tag{14}$$

where L^s_i represents the quantity of labor for industry i in region s; w^s represents the wages in region s; K^s_i represents the quantity of capital for industry i in region s; r represents the rent of capital; p^s_{Tbi} represents the fee of the composite business trip goods for industry i in region s; Tb^s_i represents the quantity of the composite business trip goods for industry i in region s.

2) Second Stage

Since the composite business trip Tb^s_i is composed of Tb^s_r, $s, r \in S$, the household determines his Tb^s to minimize representative price p^s_{Tb}. Next, we reformulate the minimization problem by specifying the aggregation structure of Tb^s as a Cobb-Douglas function:

$$p^s_{Tbi} = \min_{Tb^s_{ir}, r \in s} p^s_{Tbir} Tb^s_{ir}, \quad \text{s.t } (Tb^s_i =) \rho_2 \prod_{j=1}^{15} Tb^{s\,\lambda_j}_{j1} = 1,$$

$$\text{where } \sum_{j=1}^{15} \lambda_j = 1 \tag{15}$$

Similarly, we can get:

$$Tb^s_{ir} = \frac{1}{\rho_2} \frac{\lambda_r}{p^s_{Tbir}} \Lambda_2, \text{where } \Lambda_2 = \frac{\prod_{j=1}^{15} p^{s\,\lambda_j}_{Tb_{ij}}}{\prod_{j=1}^{15} \lambda_j^{\lambda_j}},\ r \in \{1, 2, \ldots, 15\} \tag{16}$$

$$\text{and } p^s_{Tbi} = \frac{\Lambda_2}{\rho_2} \tag{17}$$

where Tb^s_{ir} represents the quantity of the composite business trip for industry i from region s to region r; p^s_{Tbir} represents the fee of one unit of Tb^s_{ir}.

3) Third Stage

Similarly, Tb^s_{ir} are composed of Tb^s_{irm}, $s, r \in S$, and m, the household determines his Tb^s_{ir} to minimize representative price p^s_{Tbir}. Next, we reformulate the minimization problem by specifying the aggregation structure of Tb^s_{ir} as a Cobb-Douglas function:

$$p^s_{Tbir} = \min_{Tb^s_{irm}} \sum_{m \in M} (p^s_{rm} + t^s_{rm} w^s)\ Tb^s_{irm}$$

$$\text{s.t. } (Tb^s_{ir} =)\ \rho_3 Tb^{s\,\omega_1}_{ir1} Tb^{s\,\omega_2}_{ir2} Tb^{s\,\omega_3}_{ir_3} = 1, \text{ and } \omega_1 + \omega_2 + \omega_3 = 1 \tag{18}$$

Then we can get:

$$Tb^s_{irm} = \frac{1}{\rho_3} \frac{\gamma_m}{(p^r_{rm} + t^s_{rm} w^s)} \Lambda_3, \quad \text{and}$$

$$\Lambda_3 = \frac{(p^r_{r1} + t^s_{r1} w^s)^{\omega_1} (p^r_{r2} + t^s_{r2} w^s)^{\omega_2} (p^r_{r3} + t^s_{r3} w^s)^{\omega_3}}{\omega_1^{\omega_1} \cdot \omega_2^{\omega_2} \cdot \omega_3^{\omega_3}},$$

$$m \in \{1, 2, 3\} \tag{19}$$

$$\text{and } p^s_{Tbir} = \frac{A_3}{\rho_3} \tag{20}$$

where Tb^s_{irm} represents the quantity of the composite business trip for industry i from region s to region r by transportation mode m.

Finally, we can deduce the function of L^s_i, K^s_i, and Tb^s_i from the first stage.

Besides, the total labor time spent for industries by the household should be equal to the aggregated labor time hired by the industrial and the transportation sectors adds the time for business trips. Thus we can formulate the function:

$$L^s = \sum_i \left(L^s_i + \sum_r \sum_m t^s_{rm} Tb^s_{irm} \right) + L^s_T \tag{21}$$

2.2.3 Transportation Sector's Behavior

The transportation sector in regionproduces transportation services Q^s_T aggregated from several modes. We specify the production function of the transportation sector as a Leontief-type technology to input factors, labor L^s_T and capital K^s_T.

$$Q^s_T = \min \left[\frac{L^s_T}{b_L}, \frac{K^s_T}{b_K} \right] \tag{22}$$

where is the coefficient for L^s_T; b_k for K^s_T.

The price of transportation services is set as a part of policy scenario as well as physical improvement of transportation infrastructure. The transportation sector has to supply an amount of services equal to the aggregated demand as stated in the following equation:

$$Q^s_T = \sum_r \sum_m Tp^s_{rm} + \sum_i \sum_r \sum_m Tb^s_{irm} \tag{23}$$

Excess profit from the transportation sector is expressed as:

$$\pi^s_T = \max_{L^s_T, K^s_T} p^s_{rm} Q^s_T - (w^s L^s_T + r k^s_T) \tag{24}$$

$$L^s_T = b_L Q^s_T, \text{ and } K^s_T = b_K Q^s_T \tag{25}$$

$$L^s_T = b_L \left(\sum_r \sum_m Tp^s_{rm} + \sum_i \sum_r \sum_m Tb^s_{irm} \right),$$

$$\text{and } K^s_T = b_K \left(\sum_r \sum_m Tp^s_{rm} + \sum_i \sum_r \sum_m Tb^s_{irm} \right) \tag{26}$$

where Q^s_T represents the aggregated quantity for transportation services in region s; π^s_T represents the profit of the transportation sector in region s; L^s_T represents the labor input for the transportation services departing from region s; represents the capital input for the transportation services departing from region s.

2.3 Equilibrium Conditions and Benefit Definition

In this model, once the commodity/service market, the labor market, and the capital market achieve the equilibrium, the transportation sector will achieve, too. The equilibrium happens only when the former three markets meets the conditions as follows:

2.3.1 The Commodity/Service Market

$$Q^s_i = x^s_i + \sum_{r \in S} x^r_{ir} \tag{28}$$

$$Q^s_T = \sum_r \sum_m Tp^s_{rm} + \sum_i \sum_r \sum_m Tb^s_{irm} \tag{29}$$

2.3.2 The Labor Market

$$\bar{L}_R = \sum_s L^s + \sum_s \sum_i \sum_r \sum_m t^s_{rm} Tp^s_{rm} + \sum_s Le^s \tag{30}$$

By formula (30), we can get the wage rate in every region because of:

$$\sum_i p^s_i x^s_i + \sum_r \sum_m p^s_{tm} Tp^s_{rm} \le w^s \left(\bar{L}^s_R - Le^s - \sum_r \sum_m t^s_{rm} Tp^s_{rm} \right)$$

$$+ r \left(\sum_i K^s_i + K^s_T \right) + \pi^s_T,$$

Thus, when the equilibrium happens, we can get the wage rate in region s:

$$w^s = \frac{\left(\bar{L}^s_R - Le^s - \sum_r \sum_m t^s_{rm} Tp^s_{rm} \right) + r \left(\sum_i K^s_i + K^s_T \right) + \pi^s_T}{\sum_i p^s_i x^s_i + \sum_r \sum_m p^s_{rm} Tp^s_{rm}} \tag{31}$$

2.3.3 The Capital Market

$$K_R = \sum_s \left(\sum_i K^s_i + K^s_T \right) \tag{32}$$

where K_R represents the aggregated capital stock of private sector in the beginning benchmark; it is equal to the total capital invest amount aggregated from very industry in every region and the transportation sector.

2.3.4 Consumer Surplus (Social Welfare Variation)

We define the benefit of a project as equivalent variation (EV). Since the household utility level has been already formalized as the indirect utility function in formula (33), EV satisfies the equation:

$$\begin{aligned} EV^s = {} & V^s\Big(p_i^{s^{WO}}, p_{Tp}^{s^{WO}};\ w^{s^{WO}}, L^{s^{WO}} \\ & + r\Big[\sum_i (k_i^s+\bar{k}_i^s)^{WO} + k_T^{s^{WO}}\Big] + \pi_T^{s^{WO}}\Big) \\ & - V^s\Big(p_i^{s^{W}}, p_{Tp}^{s^{W}};\ w^{s^{W}}, L^{s^{W}} \\ & + r\Big[\sum_i (k_i^s+\bar{k}_i^s)^{W} + k_T^{s^{W}}\Big] + \pi_T^{s^{W}}\Big) \end{aligned} \tag{33}$$

where WO and W denote “without” and ”with THSR”, respectively. EV, which should be measured per household, can be decomposed into several items of benefit/cost and aggregated to region or national benefits.

3. The Data

3.1 The Regions and the Industries in Taiwan

The regions in Taiwan adopted by the model are as Fig. 1 and Table 1. And, the industries in Taiwan adopted by the model are as Table 2.

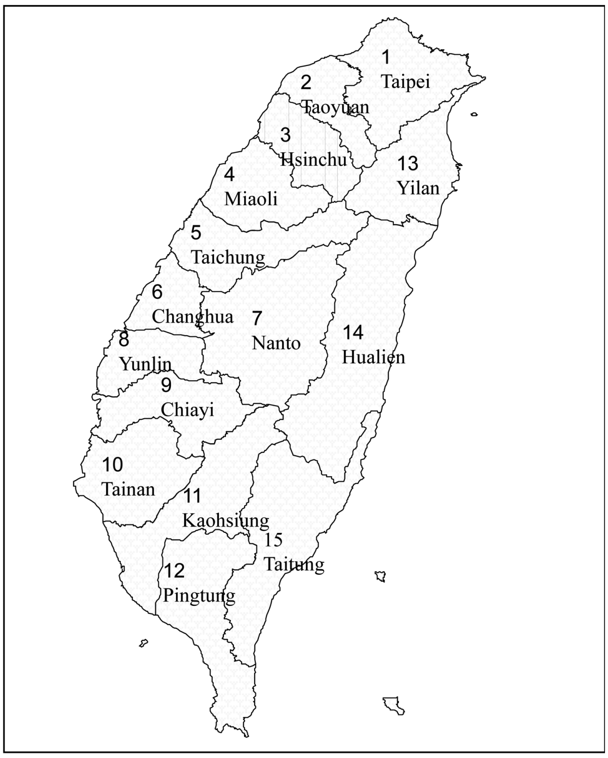

Fig. 1 Regions in Taiwan for the model

Table 1. Regions and Administration regions

Number (s)	Region	Administration region in Taiwan
1	Taipei	Taipei City, Taipei County, Keelung City
2	Taoyuan	Taoyuan County
3	Hsinchu	Hsinchu County, Hsinchu City
4	Miaoli	Miaoli County
5	Taichung	Taichung City, Taichung County
6	Changhua	Changhua County
7	Nanto	Nanto County
8	Yunlin	Yunlin County
9	Chiayi	Chiayi City, Chiayi County
10	Tainan	Tainan City, Tainan County
11	Kaohsiung	Kaohsiung City, Kaohsiung County
12	Pingtung	Pingtung County
13	Yilan	Yilan County
14	Hualien	Hualien County
15	Taitung	Taitung County

Source: The present Research.

Table 2. Industries

Number (i)	Industry category
1	Primary
2	Essential Goods
3	Chemical
4	Metal and Machinery
5	Information and Electronic
6	Utilities and Construction
7	Wholesale an Retail Trade
8	Accommodation and Food Services
9	Transportation and Communication
10	Commercial Service
11	Social Service
12	Recreation
13	Other Service

3.2 Source of Parameters & Variables for the Model

The sources of the parameters and the variables adopted by the model are as Table 3.

4. Simulation Design

In order to accurately reflect the possible impact to the spatial industry in Taiwan after the Taiwan High Speed Rail begins its operation, the present research will per-

Table 3. Source of Parameters & Variables

Data classification	Parameters/Variable	Source
The value-added from labor and capital input to industries is classified by region	$Q_i^s, \pi_i^s, w_i^s L_i^s, r\sum_i K_i^s, rK_T^s$	● 2001 Industry, Commerce and Service Census. ● Agricultural Statistic Yearbook, 2001. ● The production cost of unhusked rice in Taiwan, 2001.
Household labor time is classified by region	$\overline{L}_R^s, \sum_i L_i^s$	● 2005 Human Resource Statistic Yearbook
Related data of railway transportation	$Q_T^s, Tp_{rm}^s, Tb_{irm}^s, p_{rm}^s, t_{rm}^s$	● Taiwan Railway Administration's O-D Trip Data of Passenger Traffic, 2005 ● Taiwan Railway Administration's latest ticket price and timetable, 2005.
Related data of air transportation	$Q_T^s, Tp_{rm}^s, Tb_{irm}^s, p_{rm}^s, t_{rm}^s$	● O-D Trip Data of Passenger Traffic of Taiwan domestic air lines, 2005. ● Airline companies' latest ticket price and timetable, 2005.
Related data of highway transportation	$Q_T^s, p_{rm}^s, t_{rm}^s$	● Bus Passenger Traffic in Taiwan, 2005. ● Movement of Highway Trucking Goods by Origin and Destination (Total Ton), 2005.
Related data of High Speed Railway transportation	p_{r3}^s, t_{r3}^s	● THSR's latest ticket price and timetable, 2005.

form predictions under the two following models as the basis of recommendations:

4.1 Base Model (Before THSR)

Under the Base Model, three transportation models are planned as the connecting channels on the island: railway, aviation, and highway. The time required and cost for each type of transportation will become the commuting cost for business and private travels between areas.

4.2 Control Model (After THSR)

In consideration of the current situation of relying on the highway system for transportation in Taiwan and in addition to the comparatively lesser utilization of the railway as a replacement transportation method, therefore the hypothesis assumes that the greatest impact the THSR will mainly be focused on the aviation and mid-to-long distance highway transportation methods. On the aviation front, locations are geographically separated from the available station facilities, where the data for traffic time and cost of the THSR is substituted in. On the highway front, the ratio between the amounts of passengers provided by THSR compared to the highway system, where the geographical locations are separated by the available station facilities and the resulting traffic time and cost can be calculated. The resulting data will become the traffic cost data analysis for spatial movements to accounting arms and industrial departments.

In each of the above-mentioned models, the model outputs will include the following results:

1. Variation in the Gross Regional Product (GRP) categorized by region,
2. Variation in the Private Capital (Investment Levels) categorized by region,
3. Variation in the Labor Income (or the presented result of population/home relocations) categorized by region,
4. Variation in the Welfare Standards categorized by region.

The follow-up research will evaluate the results derived from the SCGE model by the following two layers:

Layer 1: All industry data for investigation into the differences of time cost and regional labor income between different regions, where the impact to the overall welfare standards in Taiwan under each scenario is investigated after the THSR begins operation.

Layer 2: The differences between the private investments and employments are compared with analysis of the scale of impact for the industry under each scenario.

5. Simulation Results

According to the above-mentioned configurations, the following results can be obtained for each economic item after the specific model is derived:

Table 4. Overall Economical Welfare

Year	2006	2009	2014	2024	2034
Number of passengers per day (10,000 persons)	14.8	23.1	27.0	29.8	32.0
Overall Economical Welfare (NTD$ billion)	13.4	21.1	24.8	27.5	29.8

Reference: This present research.

5.1 Economic Welfare Rises as THSR Passengers Grow

On the aspect of overall social welfare, the overall effect will gradually increase along with the number of passengers for THSR. According to the business roadmaps of THSR Company, the predicted capacity will reach 148k passengers per day, where the number will gradually increase to 320 k passengers per day. Tying in with this trend, the overall increase of excess consumers (economical welfare variation) will gradually increase from NTD$13.4 billion to NTD$29.8 billion (see Table 4); in other words, with the addition of THSR without considering the changes from new industries and foreign trade conditions, the original economic practices will experience a 0.2%~0.3% growth rate. If the overall impact of THSR to the spatial distribution of industries and state owned land can be further expanded, or even breaking free from the traditional industrial structures and improve the overall industrial competitiveness, the foreseeable impact will be even greater than the predicted model.

Furthermore, this data also provides another angle for consideration to the investment return of the THSR. Up to the year 2006 when construction completed, the predicted NTD$640 billion cost for the THSR (including the NTD$480.6 billion investment from THSR Company, and NTD$150 billion from the government invested outer connecting traffic) can be compared with the BOT projects for the financial analysis, where these data can be used to indicate the increased amount of social welfare standards. Overall speaking, if the government funding covered the full amount of the cost, then whether if this amount of welfare increase is sufficient to balance the investment return will yet to be determined. If the crowding out effect of the budges is also taken into the calculation, then the total investment return for the entire project will become even lower. Fortunately, the award participation method is implemented in Taiwan that will not only more effectively distribute the cost and risk in between private organizations and government funding, but will better introduce the excess investment funds from the banking system into constructions that will improve the nation's competitiveness worldwide. If the social welfare standard is used to evaluate the government investment funding, and the private organizations can be held to the contracts to execute their responsibilities, then an investment to the amount of less than NTD$200 billion, will likely to result in gradual improvements of excess social welfare standards to the amount of NTD$20~30 billion per year. This can prove that the present project is a good investment for the nation.

5.2 Regional Distribution of Economical Welfare after THSR - Trends of "Straw Effect"

Further investigation of the distribution of social welfare results shows the following characteristics (see Table 5):

(1) Overall speaking, the two Northern and Southern cores hold the highest standards of social welfare; but for the matter of increased welfare standard per home, Kaohsiung and Taichung hold the top two positions for excessive consumers.

With the exclusion of Eastern regions that will not be completely impacted by the THSR due to factors of distance and course, the 45% allocated to Northern regions approximately equals the ratio of population for the region to the entire nation. Whereas in the Southern region the allocated amount is greatly higher than the ratio of available population, and the Central region lags behind all other regions the most. In other words, allocation of the entire economical welfare will be more uniform between the Northern and Southern regions from the operation of THSR, but the Central region may fall even further behind.

The average variation of welfare per home shows the highest values from Kaohsiung and Taichung regions, indicating the possible attraction force of population migration in the future.

(2) Uniform distribution in the Northern region, but polarized situation in the Central and Southern regions.

As indicated in Table 5, the Northern regions include Taipei, Hsinchu, and Taoyuan where the THSR provides convenience of services to the general public, will be positive benefits to the development of uniformed regions. At the same time, the greater Northern metropolitan regions will further be expanded from the current circle of Keelung to Taoyuan, and into the region from Keelung to Hsinchu with greater development opportunities.

Conversely, the THSR will strengthen the regional functionalities of main stations in Central and Southern regions, but may also introduce the straw effect to the surrounding regions. With the exception of Taichung, Tainan, and Kaohsiung, other Western cities will further become hollow regions after THSR; and the complete suite of governmental policies will be required to strengthen development of Central and Southern regions; at the same time preventing the dual adverse situation of polarized development between the Northern and Southern, as well as within the region.

(3) Only “main” stations in the region will experience improvements.

As indicated in Table 5, not all stations will experience the same impacts for the welfare standards, taking an example for the Chiayi Taibao Station where the characteristics of the local region are less sensitive to the traffic costs. Therefore, other than the passing of new bills that will have significant impacts to the industrial structure (for example South National Palace Museum to effective attract visitors), otherwise the THSR will not have actual benefits to the regions.

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