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Benefit evaluation of the Japanese Maglev (Linear Chuo Shinkansen) with the SCGE model

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Abstract

The Maglev called by the Linear Chuo Shinkansen is going to open from Tokyo to Nagoya by 2027, and from Nagoya to Osaka by 2045 in Japan. The required time from Tokyo to Nagoya will be from about 90 minutes to 40 minutes (ratio reduced required time is 56%), and the one from Tokyo to Osaka will be from about 190 minutes to 70 minutes (ratio reduced required time is 63%) by being inaugurated the Maglev. Tokyo is Japanese capital, and Osaka is the second, and Nagoya is the third biggest city in Japan. The Maglev will connect those cities, so exchange of people will be more active than other areas, and it is expected that large economic effects for sightseeing, business and so on are generated.

These economic effects are tried to measure by the Ministry of Land, Infrastructure, Transport and Tourism (MLITT) or some researchers by using spatial computable general equilibrium (SCGE) approach. But these researches have some common problems that, first, they do not formulate exactly producing behavior of transportation sector, second, they is not incorporated to bear the fixed costs such as construction costs. The issue on bearing the fixed costs causes problems with setting efficient pricing.

This paper tries, first, to build a SCGE model incorporated producing behavior of transport sector, second, to include bearing fixed costs in SCGE model, and to clarify efficient pricing by measuring benefits for each pricing.

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1. Introduction

The Maglev called by the Linear Chuo Shinkansen is going to open from Tokyo to Nagoya by 2027, and extended until Osaka by 2045 in Japan. The required time by open of the Maglev from Tokyo to Nagoya will be about 40 minutes from 90 minutes that is the present required time of Tokaido Shinkansen. Its reduced ratio of required time is 56%. The required time from Tokyo to Osaka by extended the Maglev until Osaka will be about 70 minutes from 190 minutes that is present time. Its reduced ratio of required time is 63%. The Japanese Maglev is going to connect Tokyo largest metropolitan area, Chukyo metropolitan area and Kinki metropolitan area in around one hour. So exchange of people will be more active, and it is expected that large economic effects for sightseeing, business and so on are generated.

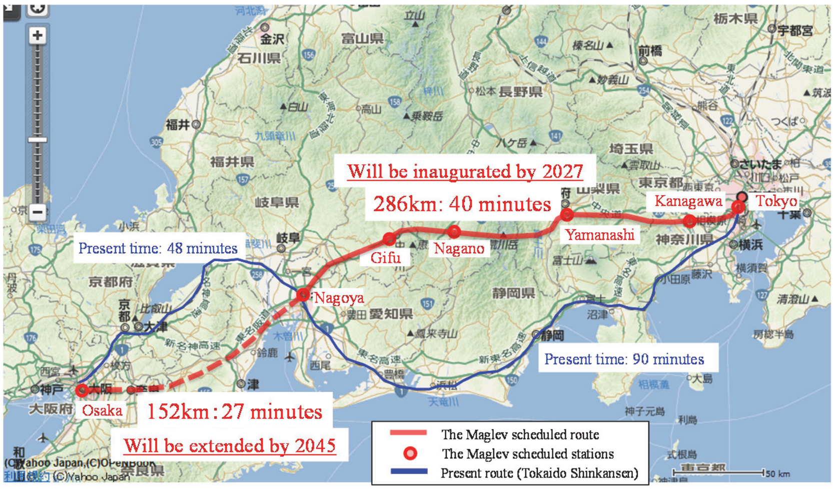

Fig. 1. Scheduled route of the Japanese Maglev.

SCGE (Spatial Computable General Equilibrium) model have been applied to evaluate economic effects by being inaugurated high speed railways or build expressway networks [Bröcker (1998), Miyagi (1998), Chen (2013), Ando and Meng (2006) , Tavasszy et al. (2003), Tavasszy et al. (2011)]. Bröcker and Schneekloth (2005) evaluated Trans-European Networks of Transport (TEN-T) projects that build up European railway and expressway networks. Though they applied a nested logit model for formulating passenger transport behavior to evaluate effects of railway network construction, they did not describe introducing methods to produce transport services. Bröcker et al. (2010) built more detail passenger transport models in their SCGE model. But they said that those were modeled in simple partial equilibrium way, so it is thought that transport costs were exogenous in Bröcker's SCGE models. The completion of railway networks will improve the efficiency to produce transport services, and improvement of producing efficiency will reduce the costs to produce transport services. So the producing costs should be modeled endogenously to evaluate exactly the transport improving projects.

Oosterhaven and Knaap (2003) or Knaap and Oosterhaven (2011) measured the effects of constructing a high-speed rail link between the West and North in Netherland by the Dutch SCGE model called by RAEM model. The both of freight and passenger transport behavior's models are formulated by iceberg type in RAEM model. Because there are no need to explicitly model transport sectors in iceberg type model, transport sectors do not exist in REAM model. This means that transport costs are not endogenous in RAEM model, too.

Kim et al. (2011) or Kim et al. (2015) evaluated the benefits of highway projects or railway projects respectively in Korea by using the SCGE model integrated transport network. However a transport sectors do not exist in its integrated SCGE model. In their SCGE model, it is assumed that producing efficiency of each industrial sector which is not transport sector, depends on accessibility index. So if transport improving projects are carried out, producing efficiencies of industrial sectors improve directly. But improving mechanism of those efficiencies is not explained definitely, and transport costs are not treated endogenously.

The Japan MLITT (Ministry of Land, Infrastructure, Transport and Tourism) measured economic effects of the Japanese Maglev by using SCGE model, though the theoretical structure of the model is not necessarily clarified. They were going to show those economic effects by an increment of the GDP with being inaugurated the Maglev. But the concepts of an increment of the GDP and a benefit are deference strictly, so it is thought that economic effects should be evaluated by benefits.

The SCGE model described above also have the problem that fixed costs such as constructing costs were not incorporated. The issue on bearing fixed costs causes the problems of setting efficient pricing.

In this paper, we try to build a SCGE model incorporating transport networks, such as high speed railway network, and introduced explicitly a producing behavior of transport sector. And we model the impacts of transport projects by improving products efficiency in transport sector. As a result, we become able to treat transport cost endogenously that must change by carrying out transport projects. Next we will incorporate bearing fixed costs to SCGE model. And we will evaluate benefits for each pricing to clarify efficient pricing.

2. Outline of the SCGE modelling

2.1 Assumption of SCGE model

This SCGE model considers an economy divided some regions, and in each region, there are some industrial sectors, transport sectors, represent household, government and invest sector. Transport sectors consist of railway or road transport and self-transport sectors for both of passenger and freight respectively, an operating expressways sector and other transport service sectors.

Firms provide commodities/services by inputting factors which is supplied by the household. Household gains income by supplying factors, and consumes commodities/services provided by firms under the budget constraint. Firms and household are also able to input or consume commodities/services produced at another region by input freight transport service. Markets of commodities and factors are cleared at each region.

Transport sectors produce freight or passenger transport services. When firms and household purchase commodities, it is necessary to input freight transport services, and when firms and household move spatially, it is necessary to input passenger transport services.

2.2 Transport sector's producing behavior

Passenger or freight transport sectors supply for each OD transport. And it is assumed that the OD required time influence their productivity on inputting factors. This point is formulated as follow.

The composite factor function of passenger or freight transport sectors is assumed to be related to OD required time, labor and capital, and its function form is assumed homogeneity of degree zero. The composite factor function is formulated as below.

$$cf_T^{j,k}\left(t^{j,k}, l_T^{j,k}, k_T^{j,k}\right) = cf_T^{j,k}\left(\lambda t^{j,k}, \lambda l_T^{j,k}, \lambda k_T^{j,k}\right) \tag{1}$$

Where, $cf_T^{j,k}$: composite factor volume of transport sector supplying to OD *j-k*, $l_T^{j,k}$: labor inputting volume, $k_T^{j,k}$: capital inputting volume, $t^{j,k}$: OD (*j-k*) required time.

Next, it is assumed $\lambda = \dfrac{\left\{t^{j,k}\right\}^A}{t^{j,k}}\left(\equiv eff^{j,k}\right)$, where A : without case. Equation (1) is shown as,

$$cf_T^{j,k} = cf_T^{j,k}\left(eff^{j,k} l_T^{j,k}, eff^{j,k} k_T^{j,k}\right) \tag{2}$$

When a OD required time reduction generated by transport facility construction, the $eff^{h,a}$ is to be larger than 1, so inputting efficiency of labor and capital is improved.

A tree structure of producing behavior of transportation sectors is shown as Fig.2, and input volumes of labor and capital is determined from next cost minimization behavior as below [Hosoe, Gasawa and Hashimoto (2010)],

$$pf_T^{j,k} cf_T^{j,k} = \min_{l_T^{j,k}, k_T^{j,k}} \left[w_T^{j,k} l_T^{j,k} + r_T^{j,k} k_T^{j,k} \right] \tag{3a}$$

$$\text{s.t. } cf_T^{j,k} = \gamma_{CFT}^{j,k} \left[\alpha_{LT}^{j,k} \left\{ \beta_{LT}^{j,k} eff_T^{j,k} \cdot l_T^{j,k} \right\}^{\frac{\sigma_{CFT}^{j,k}-1}{\sigma_{CFT}^{j,k}}} + \left(1-\alpha_{LT}^{j,k}\right)\left\{\left(1-\beta_{LT}^{j,k}\right) eff_T^{j,k} \cdot k_T^{j,k}\right\}^{\frac{\sigma_{CFT}^{j,k}-1}{\sigma_{CFT}^{j,k}}} \right]^{\frac{\sigma_{CFT}^{j,k}}{\sigma_{CFT}^{j,k}-1}} \tag{3b}$$

Where, $w_T^{j,k}, r_T^{j,k}$: labor wage and capital rent, $\alpha_{LT}^{j,k}, \beta_{LT}^{j,k}, \gamma_{CFT}^{j,k}$: share parameters and scale parameter, $\sigma_{CFT}^{j,k}$: elasticity of substitution.

We assumed the Barro type CES function for a firm's producing technology [Barro and Sara-i-Martin (2004)], and solving programming in (3), we obtain factor demand function as below,

$$l_T^{j,k} = \frac{1}{\gamma_{CFT}^{j,k}\left(\beta_{LT}^{j,k} eff_T^{j,k}\right)^{1-\sigma_{CT}^{j,k}}} \left(\frac{\alpha_{LT}^{j,k}}{w_T^{j,k}}\right)^{\sigma_{CFT}^{j,k}} {\Psi_{CFT}^{j,k}}^{\frac{\sigma_{CFT}^{j}}{1-\sigma_{CFT}^{j}}} \cdot cf_T^{j,k} \tag{4a}$$

$$k_T^{j,k} = \frac{1}{\gamma_{CFT}^{j,k}\left(\left\{1-\beta_{LT}^{j,k}\right\} eff_T^{j,k}\right)^{1-\sigma_{CT}^{j,k}}} \left(\frac{1-\alpha_{LT}^{j,k}}{r_T^{j,k}}\right)^{\sigma_{CFT}^{j,k}} {\Psi_{CFT}^{j,k}}^{\frac{\sigma_{CFT}^{j,k}}{1-\sigma_{CFT}^{j,k}}} \cdot cf_T^{j,k} \tag{4b}$$

Where, $\Psi_{CFT}^{j,k} = \left(\alpha_{LT}^{j,k}\right)^{\sigma_{CT}^{j,k}} \left(\dfrac{w_T^{j,k}}{\beta_{LT}^{j,k} eff_T^{j,k}}\right)^{1-\sigma_{CFT}^{j,k}} + \left(1-\alpha_{LT}^{j,k}\right)^{\sigma_{CFT}^{j,k}} \left(\dfrac{r_T^{j,k}}{\left\{1-\beta_{LT}^{j,k}\right\} eff_T^{j,k}}\right)^{1-\sigma_{CFT}^{j,k}}$.

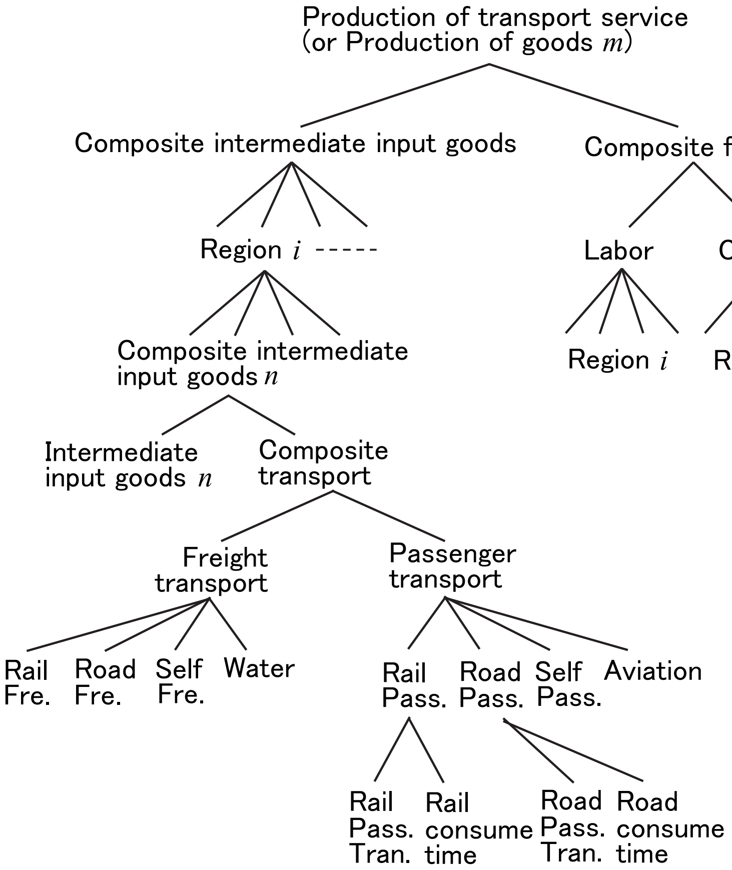

Fig. 2. Tree structure of producing behavior of transport sector

By substituting (4) into (3), we obtain composite factor price,

$$pf_T^{j,k} = \frac{1}{\gamma_{CFT}^{j,k}} \Psi_{CFT}^{j,k\ \frac{1}{1-\sigma_{CFT}^{j,k}}} \tag{5}$$

Next, we show the formulation on producing transportation service, where is highest level in Fig.2.

$$C_T^{j,k} = \min_{Z_T^{j,k}, cf_T^{j,k}} \left[q_{ZT}^{j,k} z_T^{j,k} + \left(1+\tau_T^{j,k}\right) pf_T^{j,k} cf_T^{j,k} + FC \right] \tag{6a}$$

$$\text{s.t. } y_T^{j,k} = \gamma_T^{j,k} \left[\alpha_{ZT}^{j,k} \left\{ \beta_{ZT}^{j,k} z_T^{j,k} \right\}^{\frac{\sigma_T^{j,k}-1}{\sigma_T^{j,k}}} + \left(1-\alpha_{ZT}^{j,k}\right) \left\{ \left(1-\beta_{ZT}^{j,k}\right) cf_T^{j,k} \right\}^{\frac{\sigma_T^{j,k}-1}{\sigma_T^{j,k}}} \right]^{\frac{\sigma_T^{j,k}}{\sigma_T^{j,k}-1}} \tag{6b}$$

Where, $C_T^{j,k}$: production cost of transport sector, $z_T^{j,k}, q_{ZT}^{j,k}$: inputting volume of composite intermediate input goods and its price, $\tau_T^{j,k}$: net indirect tax rate, *FC*: fixed cost, $\alpha_{ZT}^{j,k}, \beta_{ZT}^{j,k}, \gamma_T^{j,k}$: share parameters and scale parameter, $\sigma_T^{j,k}$: elasticity of substitution.

Solving programming in (6), we obtain each demand function as below,

$$z_T^{j,k} = \frac{1}{\gamma_T^{j,k} \left(\beta_{ZT}^{j,k}\right)^{1-\sigma_T^{j,k}}} \left(\frac{\alpha_{ZT}^{j,k}}{q_{ZT}^{j,k}} \right) \Psi_T^{j,k\ \frac{\sigma_T^{j,k}}{1-\sigma_T^{j,k}}} y_T^{j,k} \tag{7a}$$

$$cf_T^{j,k} = \frac{1}{\gamma_T^{j,k}\left(1-\beta_{ZT}^{j,k}\right)^{1-\sigma_T^{j,k}}}\left(\frac{1-\alpha_{ZT}^{j,k}}{pf_{ZT}^{j,k}}\right)\Psi_T^{j,k\frac{\sigma_T^{j,k}}{1-\sigma_T^{j,k}}} y_T^{j,k} \tag{7b}$$

Where, $\Psi_T^{j,k} = \left(\alpha_{ZT}^{j,k}\right)^{\sigma_{Tm}^{j,k}}\left(\frac{q_{ZT}^{j,k}}{\beta_{ZT}^{j,k}}\right)^{1-\sigma_T^{j,k}} + \left(1-\alpha_{ZT}^{j,k}\right)^{\sigma_T^{j,k}}\left(\frac{pf_T^{j,k}}{1-\beta_{ZT}^{j,k}}\right)^{1-\sigma_{ZT}^{j,k}}$.

By substituting (7) into (6), we obtain transport production cost,

$$C_T^{j,k} = \frac{1}{\gamma_T^{j,k}}\Psi_T^{j,k\frac{\sigma_T^{j,k}}{1-\sigma_T^{j,k}}} y_T^{j,k} + FC \tag{8}$$

Profit of transport sector is as below,

$$\pi_T^{j,k} = p_T^{j,k} y_T^{j,k} - C_T^{j,k} \tag{9}$$

So, by maximizing the profit, we can get marginal cost fee,

$$p_T^{j,k} = \frac{1}{\gamma_T^{j,k}}\Psi_T^{j,k\frac{\sigma_T^{j,k}}{1-\sigma_T^{j,k}}} \tag{10a}$$

When transport price is set by marginal cost, profit of transport sector becomes negative. So we think the case of profit equal zero, it is a pricing by average cost approach.

$$p_T^{j,k} = \frac{1}{\gamma_T^{j,k}}\Psi_T^{j,k\frac{\sigma_T^{j,k}}{1-\sigma_T^{j,k}}} + \frac{FC}{\sum_j\sum_k y_T^{j,k}} \tag{10b}$$

The right-hand second term of equation (11) is unit fixed cost for transport sector products. The price by average cost is higher than the marginal cost by this amount.

2.3 Firm's producing behavior

We show a behavior of firm *m*, which produces commodity/service *m*. A framework of its behavior is same as one of transport sector that is shown in Fig.2.

At first step, a firm *m* determines inputting volume of composite intermediate input goods and composite factor. At second step, he choose a region from which he inputs composite intermediate input goods, and he determines inputting volume of composite intermediate input goods *n*, respectively. This study assumes that it is a necessity to input composite transport service to input intermediate input goods, so he decides inputting volume of intermediate input goods *n* and composite transport service. For inputting composite transport service, he determines inputting volume of passenger and freight transport service. And for each inputting transport service, he chooses transport mode, respectively.

We show the transport demand behavior model. The following is formulation to determine inputting volume of intermediate input goods *n* and composite transport service.

$$q_{n\,m}^{ij} z_{n\,m}^{ij} = \min_{x_{n\,m}^{ij},\, z_{Tm}^{ij}}\left[p_n^i x_{n\,m}^{ij} + q_{Tm}^{ij} z_{Tm}^{ij}\right] \tag{12a}$$

$$\text{s.t. } z_{n\,m}^{ij} = \gamma_{n\,m}^{ij}\left[\left(1-\alpha_{Tm}^{ij}\right)\left\{\left(1-\beta_{Tm}^{ij}\right)x_{n\,m}^{ij}\right\}^{\frac{\sigma_{n\,m}^{ij}-1}{\sigma_{n\,m}^{ij}}} + \alpha_{Tm}^{ij}\left\{\beta_{Tm}^{ij}\, z_{Tm}^{ij}\right\}^{\frac{\sigma_{n\,m}^{ij}-1}{\sigma_{n\,m}^{ij}}}\right]^{\frac{\sigma_{n\,m}^{ij}}{\sigma_{n\,m}^{ij}-1}} \tag{12b}$$

Where, $z^{ij}_{n\,m}, q^{ij}_{n\,m}$: inputting volume of composite intermediate input goods *n* and its price, $x^{ij}_{n\,m}, p^{i}_{n}$: inputting volume of intermediate input goods *n* and price of commodity *n*, z^{ij}_{Tm}, q^{ij}_{Tm} : inputting volume of composite transportation service and its price, $\alpha^{ij}_{Tm}, \beta^{ij}_{Tm}, \gamma^{ij}_{n\,m}$: share parameters and scale parameter, $\sigma^{ij}_{n\,m}$: elasticity of substitution.

Solving programming in (12), we obtain each demand function as,

$$x^{ij}_{n\,m} = \frac{1}{\gamma^{ij}_{n\,m}\left\{1-\beta^{ij}_{Tm}\right\}^{1-\sigma^{ij}_{n\,m}}} \left(\frac{1-\alpha^{ij}_{Tm}}{p^{i}_{n}}\right)^{\sigma^{ij}_{n\,m}} \Psi^{ij}_{n\,m}{}^{\frac{\sigma^{ij}_{n\,m}}{\sigma^{ij}_{n\,m}-1}} \cdot z^{ij}_{n\,m} \tag{13a}$$

$$z^{ij}_{Tm} = \frac{1}{\gamma^{ij}_{n\,m}\left\{\beta^{ij}_{Tm}\right\}^{1-\sigma^{ij}_{n\,m}}} \left(\frac{\alpha^{ij}_{Tm}}{q^{ij}_{Tm}}\right)^{\sigma^{ij}_{n\,m}} \Psi^{ij}_{n\,m}{}^{\frac{\sigma^{ij}_{n\,m}}{\sigma^{ij}_{n\,m}-1}} \cdot z^{ij}_{n\,m} \tag{13b}$$

Where, $\Psi^{ij}_{n\,m} = \left(1-\alpha^{ij}_{Tm}\right)^{\sigma^{ij}_{n\,m}} \left(\frac{p^{i}_{n}}{1-\beta^{ij}_{Tm}}\right)^{1-\sigma^{ij}_{n\,m}} + \left(\alpha^{ij}_{Tm}\right)^{\sigma^{ij}_{n\,m}} \left(\frac{q^{ij}_{Tm}}{\beta^{ij}_{Tm}}\right)^{1-\sigma^{ij}_{n\,m}}$.

By substituting (13) into (12), we obtain composite intermediate input goods *n*'s price as,

$$q^{ij}_{n\,m} = \frac{1}{\gamma^{ij}_{n\,m}} \Psi^{ij}_{n\,m}{}^{\frac{1}{1-\sigma^{ij}_{n\,m}}} \tag{14}$$

Next formulation is to determine inputting volume of passenger and freight transport service.

$$q^{ij}_{Tm}\, z^{ij}_{Tm} = \min_{z^{ij}_{TFm},\, z^{ij}_{TPm}} \left[q^{ij}_{TFm}\, z^{ij}_{TFm} + q^{ij}_{TPm}\, z^{ij}_{TPm}\right] \tag{15a}$$

$$\text{s.t. } z^{ij}_{Tm} = \gamma^{ij}_{Tm}\left[\alpha^{ij}_{TFm}\left\{\beta^{ij}_{TFm}\, z^{ij}_{TFm}\right\}^{\frac{\sigma^{ij}_{Tm}-1}{\sigma^{ij}_{nTm}}} + \left(1-\alpha^{ij}_{TFm}\right)\left\{\left(1-\beta^{ij}_{TFm}\right)z^{ij}_{TPm}\right\}^{\frac{\sigma^{ij}_{Tm}-1}{\sigma^{ij}_{Tm}}}\right]^{\frac{\sigma^{ij}_{Tm}}{\sigma^{ij}_{Tm}-1}} \tag{15b}$$

Where, $z^{ij}_{TFm}, q^{ij}_{TFm}$: inputting volume of freight transport service and its price, $z^{ij}_{TPm}, q^{ij}_{TPm}$: inputting volume of passenger transport service and its price, $\alpha^{ij}_{TFm}, \beta^{ij}_{TFm}, \gamma^{ij}_{Tm}$: share parameters and scale parameter, σ^{ij}_{Tm} : elasticity of substitution.

Solving programming in (15), we obtain each demand function as,

$$z^{ij}_{TFm} = \frac{1}{\gamma^{ij}_{Tm}\left\{\beta^{ij}_{TFm}\right\}^{1-\sigma^{ij}_{Tm}}} \left(\frac{\alpha^{ij}_{TFm}}{q^{ij}_{TFm}}\right)^{\sigma^{ij}_{Tm}} \Psi^{ij}_{Tm}{}^{\frac{\sigma^{ij}_{Tm}}{\sigma^{ij}_{Tm}-1}} \cdot z^{ij}_{Tm} \tag{16a}$$

$$z^{ij}_{TPm} = \frac{1}{\gamma^{ij}_{Tm}\left\{1-\beta^{ij}_{TFm}\right\}^{1-\sigma^{ij}_{Tm}}} \left(\frac{1-\alpha^{ij}_{TFm}}{q^{ij}_{TPm}}\right)^{\sigma^{ij}_{Tm}} \Psi^{ij}_{Tm}{}^{\frac{\sigma^{ij}_{Tm}}{\sigma^{ij}_{Tm}-1}} \cdot z^{ij}_{Tm} \tag{16b}$$

Where, $\Psi^{ij}_{Tm} = \left(\alpha^{ij}_{TFm}\right)^{\sigma^{ij}_{Tm}} \left(\frac{q^{ij}_{TFm}}{\beta^{ij}_{TFm}}\right)^{1-\sigma^{ij}_{Tm}} + \left(1-\alpha^{ij}_{TFm}\right)^{\sigma^{ij}_{Tm}} \left(\frac{q^{ij}_{TPm}}{1-\beta^{ij}_{TFm}}\right)^{1-\sigma^{ij}_{Tm}}$.

By substituting (16) into (15), we obtain composite transport service price as,

$$q^{ij}_{Tm} = \frac{1}{\gamma^{ij}_{Tm}} \Psi^{ij}_{Tm}{}^{\frac{1}{1-\sigma^{ij}_{Tm}}} \tag{17}$$

Next, for inputting freight or passenger transport service, firm m chooses transport mode, its path and link, respectively. At first, we show a formulation of mode choice for passenger transport service.

$$q_{TPm}^{ij} z_{TPm}^{ij} = \min_{x_{TP_n m}^{ij}} \left[\sum_{TP_n} \left(p_{TP_n}^{ij} + w^j \xi_{TP_n m} t^{ij} \right) x_{TP_n m}^{ij} \right] \tag{18a}$$

$$\text{s.t.} \;\; z_{TPm}^{ij} = \gamma_{TPm}^{ij} \left[\sum_{TP_n} \alpha_{TP_n m}^{ij} \left\{ \beta_{TP_n m}^{ij} x_{TP_n m}^{ij} \right\}^{\frac{\sigma_{TPm}^{ij} - 1}{\sigma_{TPm}^{ij}}} \right]^{\frac{\sigma_{TPm}^{ij}}{\sigma_{TPm}^{ij} - 1}} \tag{18b}$$

Where, TP_n : subscript expressing a mode of passenger transport service, $x_{TP_n m}^{ij}, p_{TP_n}^{ij}$: inputting volume of passenger transport service for each mode and transport service price, $w^j, \xi_{TP_n m}, t^{ij}$: wage, transfer parameter from passenger transport service inputting volume to transport trip and required time of OD, $\alpha_{TP_n m}^{ij}, \beta_{TP_n m}^{ij}, \gamma_{TPm}^{ij}$: share parameters ($\sum_{TP_n} \alpha_{TP_n m}^{ij} = 1$, $\sum_{TP_n} \beta_{TP_n m}^{ij} = 1$) and scale parameter, σ_{TPm}^{ij} : elasticity of substitution.

Solving programming in (18), we obtain each demand function as,

$$z_{TP_n m}^{ij} = \frac{1}{\gamma_{TPm}^{ij} \left\{ \beta_{TP_n m}^{ij} \right\}^{1-\sigma_{TPm}^{ij}}} \left(\frac{\alpha_{TP_n m}^{ij}}{q_{TP_n m}^{ij}} \right)^{\sigma_{TPm}^{ij}} \Psi_{TPm}^{ij} {}^{\frac{\sigma_{TPm}^{ij}}{\sigma_{TPm}^{ij} - 1}} \cdot z_{TPm}^{ij} \tag{19}$$

Where, $\Psi_{TPm}^{ij} = \sum_{TP_n} \left(\alpha_{TP_n m}^{ij} \right)^{\sigma_{TPm}^{ij}} \left(\frac{q_{TP_n m}^{ij}}{\beta_{TP_n m}^{ij}} \right)^{1-\sigma_{TPm}^{ij}}$.

By substituting (19) into (18), we obtain composite passenger transportation service price as,

$$q_{TPm}^{ij} = \frac{1}{\gamma_{TPm}^{ij}} \Psi_{TPm}^{ij} {}^{\frac{1}{1-\sigma_{TPm}^{ij}}} \tag{20}$$

2.4 Household's consuming behavior

We formulate a consuming behavior of household. A household gains income by providing labor and capital stock. This labor providing time is determined by deducting leisure time and transport consuming times from the endowment time. Next, he decides of consuming volume of commodities/services so as to minimize his expenditure under keeping constant his utility level. The consuming behavior tree of household is shown in Fig.3. Here, we indicate only formulation of highest level in Fig.3, because frameworks of other formulation are same to one of firm's behavior.

Household's income gained by providing factors is shown as below,

$$\Omega_H^j = \left[\left(w^j T_H^j + r^j K_H^j \right) \left(1 - \tau_H^j \right) \right] - S_H^j \tag{21}$$

Where, Ω_H^j : household disposable income in region j, T_H^j, w^j : endowment time and labor wage, K_H^j, r^j : capital stock and capital rent, τ_H^j : income tax rate, S_H^j : amount of savings.

The formulation of determining the volume of composite consumption goods and leisure is following as,

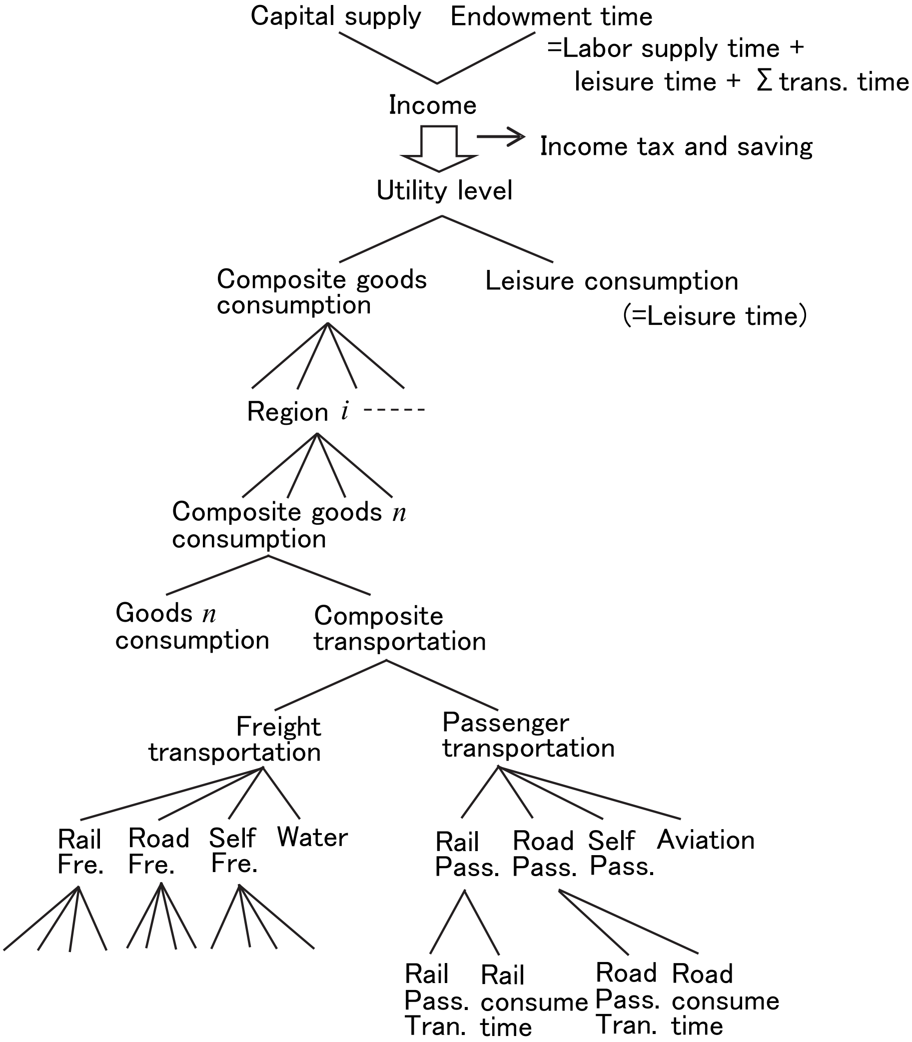

Fig. 3. Tree structure of consuming behavior of household

$$p_{UH}^{j} U_{H}^{j} = \min_{z_{H}^{j}, l_{SH}^{j}} \left[q_{ZH}^{j} z_{H}^{j} + w^{j} l_{SH}^{j} \right] \tag{23a}$$

$$\text{s.t.}\, U_{H}^{j} = \gamma_{H}^{j} \left[\alpha_{ZH}^{j} \left\{ \beta_{ZH}^{j} z_{H}^{j} \right\}^{\frac{\sigma_{H}^{j}-1}{\sigma_{H}^{j}}} + \left(1-\alpha_{ZH}^{j}\right) \left\{ \left(1-\beta_{ZH}^{j}\right) l_{SH}^{j} \right\}^{\frac{\sigma_{H}^{j}-1}{\sigma_{H}^{j}}} \right]^{\frac{\sigma_{H}^{j}}{\sigma_{H}^{j}-1}} \tag{23b}$$

Where, U_{H}^{j}, p_{UH}^{j} : household utility level and utility price, z_{H}^{j}, q_{ZH}^{j} : consuming volume of composite goods and its price, l_{SH}^{j}, w^{j} : leisure consumption and labor wage (leisure price), $\alpha_{ZH}^{j}, \beta_{ZH}^{j}, \gamma_{H}^{j}$: share parameters and scale parameter, σ_{H}^{j} : elasticity of substitution.

Solving programming in (23), we obtain each demand function as below,

$$z_{H}^{j} = \frac{1}{\gamma_{H}^{j} \left\{ \beta_{ZH}^{j} \right\}^{1-\sigma_{H}^{j}}} \left(\frac{\alpha_{ZH}^{j}}{q_{ZH}^{j}} \right)^{\sigma_{H}^{j}} \Psi_{H}^{j\,\frac{\sigma_{H}^{j}}{\sigma_{H}^{j}-1}} \cdot U_{H}^{j} \tag{24a}$$

$$l_{SH}^{j} = \frac{1}{\gamma_{H}^{j}\left\{1-\beta_{ZH}^{j}\right\}^{1-\sigma_{H}^{j}}}\left(\frac{1-\alpha_{ZH}^{j}}{w^{j}}\right)^{\sigma_{H}^{j}} \Psi_{H}^{j\,\frac{\sigma_{H}^{j}}{\sigma_{H}^{j}-1}} \cdot U_{H}^{j} \tag{24b}$$

Where, $\Psi_{H}^{j} = \left(\alpha_{ZH}^{j}\right)^{\sigma_{H}^{j}}\left(\frac{q_{ZH}^{j}}{\beta_{ZH}^{j}}\right)^{1-\sigma_{H}^{j}} + \left(1-\alpha_{ZH}^{j}\right)^{\sigma_{H}^{j}}\left(\frac{w^{j}}{1-\beta_{ZH}^{j}}\right)^{1-\sigma_{H}^{j}}$.

By substituting (26) into (25), we obtain a utility price as,

$$p_{UH}^{j} = \frac{1}{\gamma_{H}^{j}} \Psi_{H}^{j\,\frac{1}{1-\sigma_{H}^{j}}} \tag{25}$$

An equation (23a) means an expenditure level of household. Because amount of expenditure of household is equal to net income net which is except saving and tax payment, household utility function is expressed as,

$$U_{H}^{j} = \frac{\Omega_{H}^{j}}{p_{UH}^{j}} \tag{26}$$

2.5 Market equilibrium conditions

Market equilibrium conditions in this SCGE model are shown below,

$$y_{n}^{i} = \sum_{j}\left[\sum_{m} x_{nm}^{ij} + \sum_{k} x_{nT}^{ij,k} + x_{nH}^{ij}\right] \tag{27a}$$

$$y_{T}^{i,j} = \left[\sum_{m} x_{Tm}^{ij} + \sum_{k} x_{TT}^{ij,k} + x_{TH}^{ij}\right] \tag{27b}$$

$$T_{H}^{j} - \left(l_{H}^{j} + \sum_{i} t^{ij} x_{TH}^{ij}\right) = \sum_{m}\sum_{i} l_{m}^{ji} + \sum_{i} l_{T}^{ji} \tag{27c}$$

$$K_{H}^{j} = \sum_{m}\sum_{i} k_{m}^{ji} + \sum_{i} k_{T}^{ji} \tag{27d}$$

Equation (27a) is market of goods *m*, equation (27b) is market of transport service, equation (27c) is market of labor and equation (27d) is market of capital.

2.6 Benefit definition

We define a benefit with a household utility that is shown in equation (26). A incidence benefits for each region is described by basing on the concept of equivalent variation (EV) as following [Morisugi and Ohno (1995)],

$$EV^{j} = p_{UH}^{j\;A}\left(U_{H}^{j\;B} - U_{H}^{j\;A}\right) \tag{28}$$

Where, A, B : subscript expressing without projects case and with one, respectively.

By substituting household utility of (26) into (28), the EV becomes like below,

$$EV^{j} = \frac{p_{UH}^{j\;A}}{p_{UH}^{j\;B}}\left(\Omega_{H}^{j\;B} - \Omega_{H}^{j\;A}\right) \tag{29}$$

Equation (29) indicate that EV can be also interpreted as deference of actual income.

3. Benefit evaluation of the Maglev

3.1 Measurement of interregional required times

The SCGE model that we were built at section 2, is applied to evaluate benefits of the Maglev for 9 regions, those are North-Japan, Kanto, Yamanashi, Shizuoka, Nagano, Gifu, Chubu, Kinki, West-Japan.

We show the results of interregional required times by opening the Maglev from Tokyo to Nagoya in high speed railway network, which are estimated by the shortest path search method. The reducing rates of interregional (OD) required time in table 1 and the average required OD times are indicated in Fig.4.

Table 1 Reduction rates of interregional required time (From Tokyo to Nagoya)

	North-Japan	Kanto	Yamanash	Shizuoka	Nagano	Gifu	Chubu	Kinki	West-Japan
North-Japan	0.00%	-0.04%	-29.91%	0.00%	-2.30%	-26.37%	-22.81%	-21.86%	-11.72%
Kanto	-0.04%	0.00%	-45.30%	-0.11%	-5.01%	-36.85%	-41.08%	-31.16%	-15.56%
Yamanashi	-29.41%	-45.29%	0.00%	-7.64%	-12.59%	-50.89%	-53.25%	-45.22%	-26.41%
Shizuoka	0.00%	-0.11%	-7.64%	0.00%	-3.20%	-1.98%	0.00%	0.00%	0.00%
Nagano	-2.25%	-5.02%	-12.59%	-3.20%	-5.93%	-27.49%	-22.82%	-25.06%	-14.92%
Gifu	-26.27%	-36.83%	-50.89%	-1.98%	-27.49%	-0.72%	-5.21%	-2.07%	-0.69%
Chubu	-22.12%	-41.05%	-53.66%	0.00%	-22.43%	-5.21%	0.00%	0.00%	0.00%
Kinki	-21.53%	-31.12%	-45.22%	0.00%	-25.06%	-2.07%	0.00%	0.00%	0.00%
West-Japan	-11.58%	-15.52%	-26.41%	0.00%	-14.92%	-0.69%	0.00%	0.00%	0.00%

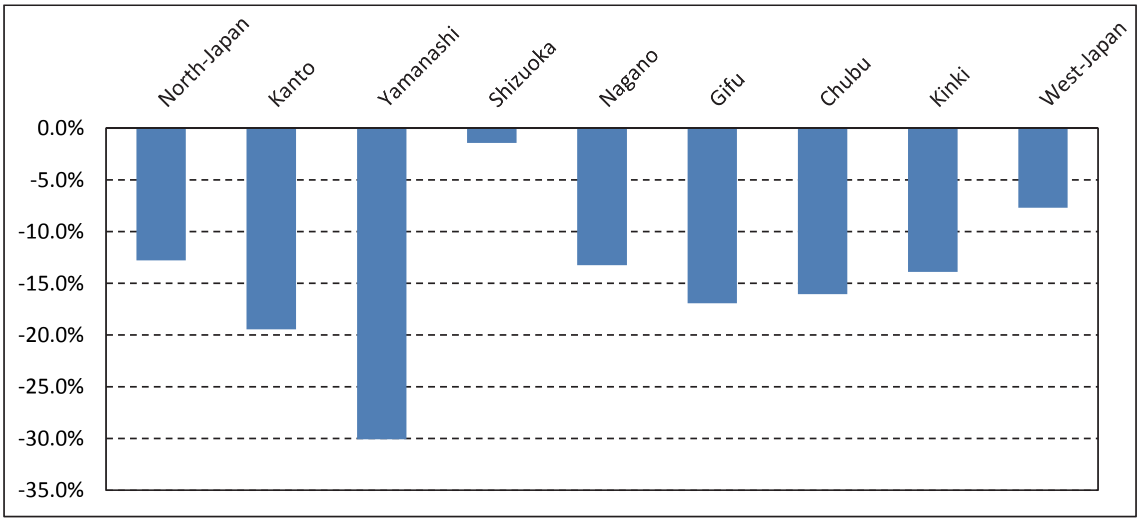

Fig. 4 Reducing rate of average required time (From Tokyo to Nagoya)

3.2 Setting of impacts of the Maglev in SCGE model

The impacts by being opened the Maglev are inputted to SCGE model by two factors. At first, we set the $eff^{j,k}$ of equation (2) by required OD times with opening Maglev case, because it is assumed to improve the producing efficiency of railway transport sector in our SCGE model. Improvement of $eff^{j,k}$ will be down railway transport price as well as will be down required time cost in generalized price in equation (18a). At second, we set *FC* in equation (6a), that is the burden of constructing and operating costs.

3.3 Numerical results

We show the results of calculating SCGE model. The change rates of OD transport volumes for railway passenger transport are indicated in Table 2 and the change volumes

Table 2 Change rates of railway passenger transport OD in case of marginal cost pricing (From Tokyo to Nagoya)

	North–Japan	Kanto	Yamanashi	Shizuoka	Nagano	Gifu	Chubu	Kinki	West–Japan	Average
North–Japan	0.01%	0.03%	36.55%	0.00%	2.02%	31.20%	27.43%	25.85%	14.03%	0.95%
Kanto	0.04%	0.02%	70.18%	0.10%	4.47%	49.85%	65.71%	42.01%	20.18%	2.46%
Yamanashi	40.21%	74.72%	0.44%	7.48%	12.55%	83.50%	117.36%	79.16%	41.33%	21.17%
Shizuoka	0.01%	0.10%	6.52%	0.03%	2.77%	1.54%	0.00%	0.00%	0.01%	0.08%
Nagano	2.12%	4.78%	11.88%	3.02%	3.14%	32.68%	27.45%	31.55%	19.26%	5.20%
Gifu	33.93%	53.34%	82.76%	1.75%	33.59%	0.23%	4.85%	1.96%	0.76%	3.64%
Chubu	27.09%	62.89%	90.13%	0.01%	24.98%	4.31%	0.03%	0.01%	0.01%	1.90%
Kinki	25.72%	40.99%	70.08%	0.00%	29.77%	1.75%	0.00%	0.01%	0.00%	1.70%
West–Japan	12.42%	17.00%	31.83%	0.00%	15.84%	0.61%	−0.01%	0.00%	0.00%	0.31%
Average	0.75%	1.51%	13.86%	0.13%	3.95%	1.90%	3.52%	3.31%	1.68%	2.11%

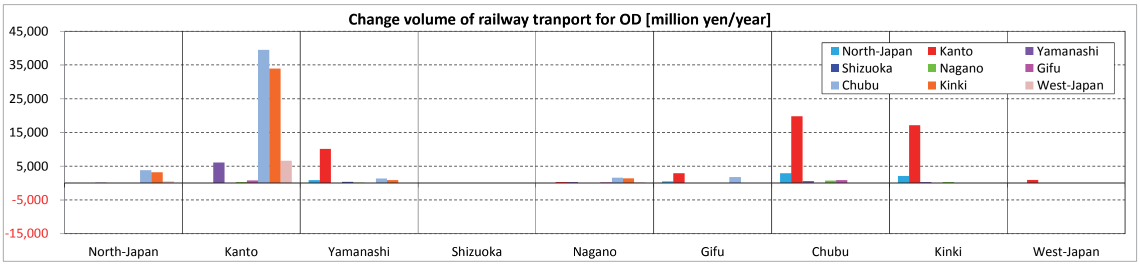

Fig.5 Change volumes of railway passenger transport OD in case of marginal cost pricing (From Tokyo to Nagoya)

Table 3 Change rates of railway passenger transport OD in case of average cost pricing (From Tokyo to Nagoya)

	North–Japan	Kanto	Yamanashi	Shizuoka	Nagano	Gifu	Chubu	Kinki	West–Japan	Average
North–Japan	0.01%	0.04%	30.21%	−8.10%	−3.58%	23.37%	9.56%	15.87%	3.52%	0.39%
Kanto	0.06%	0.02%	47.79%	−17.08%	−12.79%	22.22%	6.56%	18.98%	1.82%	0.46%
Yamanashi	25.98%	42.55%	0.40%	−13.88%	−3.57%	15.17%	13.79%	42.15%	24.02%	9.62%
Shizuoka	−11.76%	−18.94%	−11.12%	−0.01%	−13.16%	−11.74%	0.02%	0.04%	0.02%	−3.09%
Nagano	−6.09%	−12.71%	−8.41%	−7.62%	3.13%	1.42%	−11.57%	15.20%	10.74%	1.94%
Gifu	16.06%	1.45%	14.34%	−11.53%	11.61%	0.19%	−19.24%	−7.19%	−4.37%	−4.63%
Chubu	10.06%	17.86%	13.97%	0.04%	−2.26%	−13.04%	0.03%	0.03%	0.03%	0.33%
Kinki	17.65%	26.30%	47.56%	0.02%	23.57%	−3.95%	0.01%	0.02%	0.01%	1.10%
West–Japan	7.73%	8.17%	26.91%	0.02%	13.93%	−1.81%	0.00%	0.01%	0.01%	0.16%
Average	0.23%	0.33%	7.49%	−2.31%	2.14%	−1.78%	−0.15%	1.50%	0.18%	0.32%

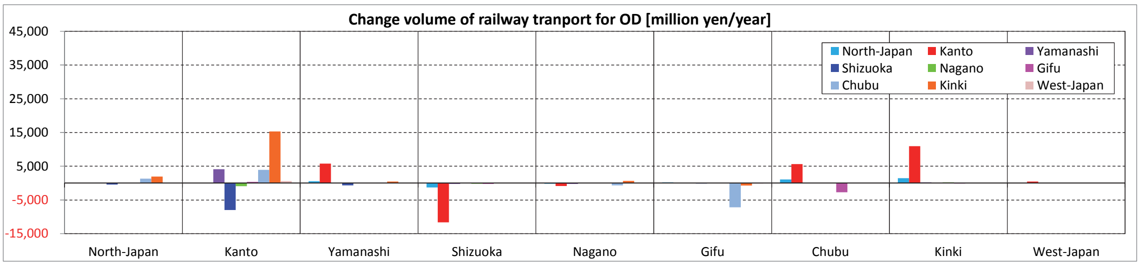

Fig.6 Change volumes of railway passenger transport OD in case of average cost pricing (From Tokyo to Nagoya)

of those are indicated in Fig.5. at case of marginal cost pricing for being opened Maglev from Tokyo to Nagoya. The increasing rate and volume are shown at case of average cost pricing in Table 3 and in Fig. 5, respectively. These results imply to generate effects of increasing transport volumes in regions along the Maglev. And these results indicated that the increasing rate and volume at average cost pricing are littler than marginal cost pricing. This is caused by the burden of fixed or renewal costs.

The open of Maglev will change the railway transport price through changing efficiency of products in the railway transport sector, and will change also some commodity prices. The change rates of commodity prices are shown at case of marginal cost pricing in Fig. 7, and at case of average cost pricing in Fig.8. The commodity prices go down in many regions. That reason is thought that improvement of producing efficiency go down by required times reduction. But at average cost pricing, the prices of some region are up. Because the impacts by burdens of some costs are larger.

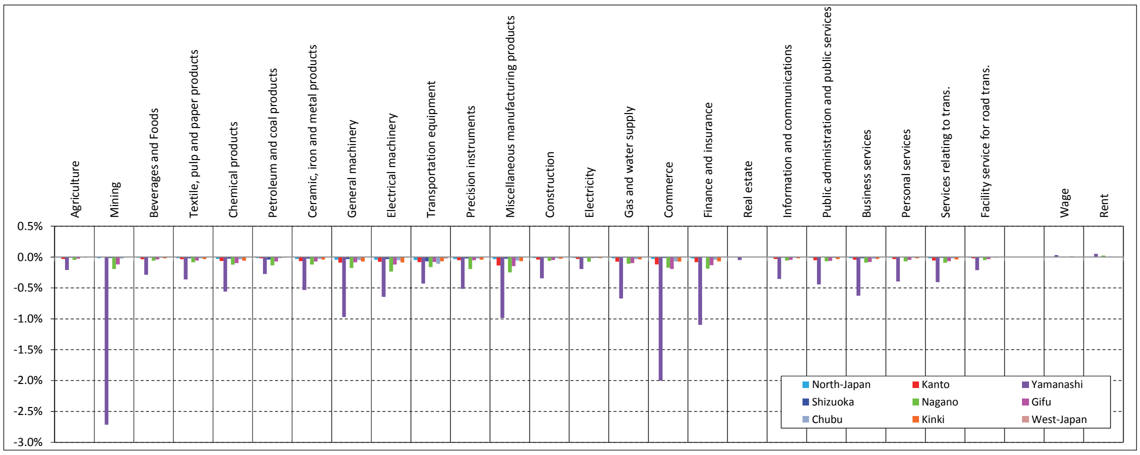

Fig.7 Change rete of commodity price at case of average cost pricing (From Tokyo to Nagoya)

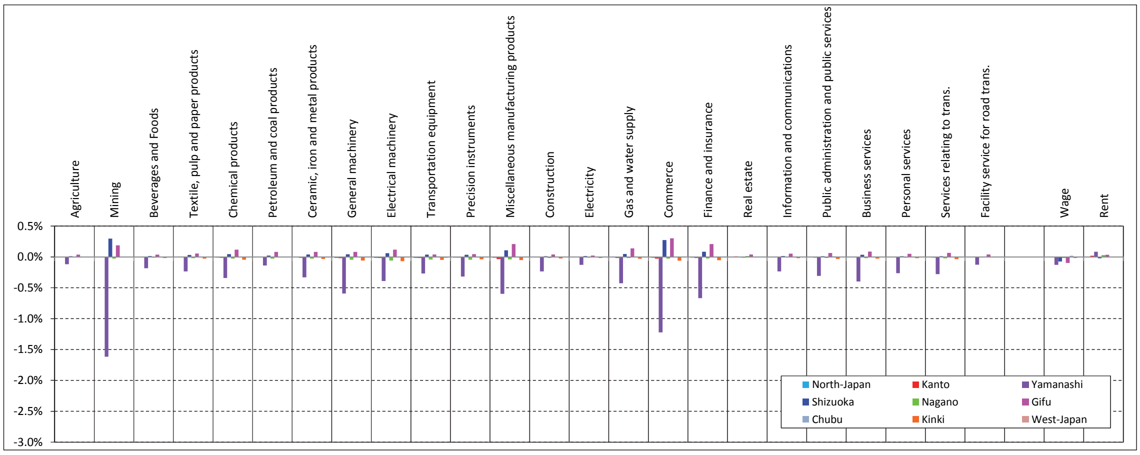

Fig.8 Change volumes of railway passenger transport OD in case of average cost pricing (From Tokyo to Nagoya)

Next, we show the results of benefits evaluation. In Fig.9, the benefits measured by equation (30) are indicated. In there, the both cases marginal costs pricing and average costs pricing are shown. Final, we will show the results of cost/benefit analysis that total benefit at case of marginal cost pricing is 6.90 trillion yen, and the one at case of average cost pricing is 1.65 trillion yen. And total construction cost is 5.20 trillion yen. So net benefit at case of marginal cost pricing is 1.70 trillion yen. The deadweight loss is 0.05 trillion yen by average cots pricing.

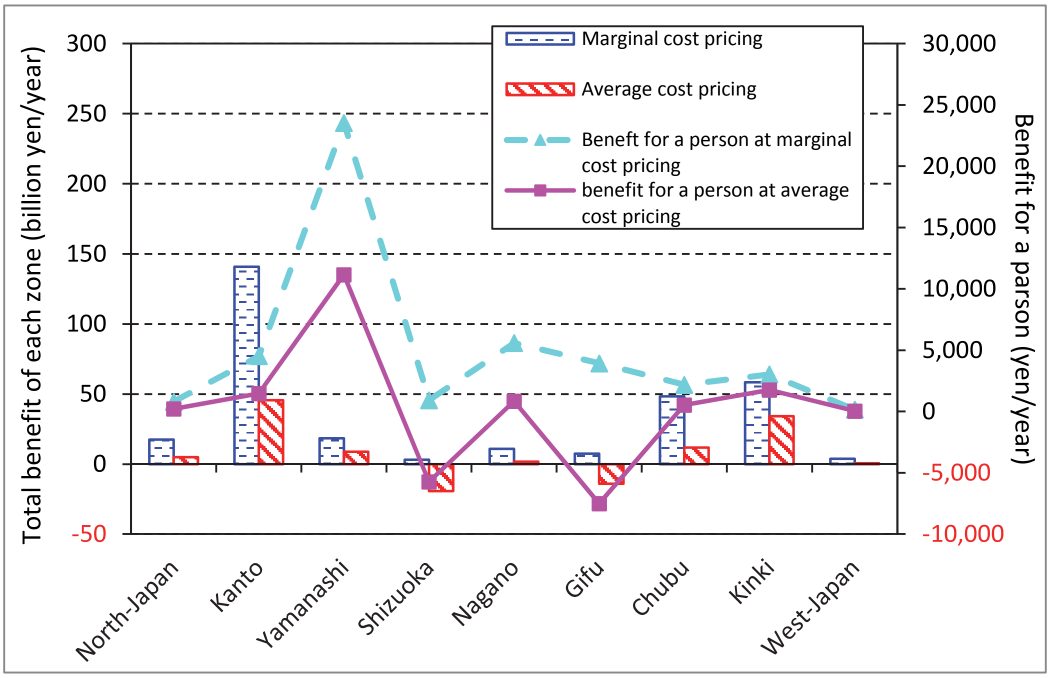

Fig.9 Benefits evaluation results(From Tokyo to Nagoya)

4. Conclusion

We built the SCGE model introduced explicitly a producing behavior of transport sector. In the SCGE model, transport sectors provide transport service to each OD in transport network, and when transport improving projects such as constructing the Maglev, are carried out, productivities of transport sectors are improved depending on decrease of required OD time. This improvement of productivities decreases transport service prices, increases transport service demands and decreases also another commodity prices. These effects arise household’s utility and benefits are generated.

We applied this SCGE model to evaluate economic effects of opening the Japanese Maglev that is called Linear Chuo Shinkansen in Japan. From the numerical simulation of SCGE model, we clarified that an opening of the Maglev generated the economic effects of not only increasing the interregional transport volumes but also bringing the incidence benefits for each region. When the Maglev open from Tokyo to Nagoya, the total benefit is evaluated 6.9 trillion yen at case of marginal cost pricing, and 1.65 trillion yen at case of average cost pricing. The deadweight loss is 0.05 trillion yen by average cots pricing.

It is remained as future tasks that are expansion to dynamic analysis of this SCGE model, because the evaluation of this paper remains statics analysis. And we try to apply this SCGE model to evaluate the other transport projects such as expressway, airport or port improvement.

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