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## Conference Paper

An Analysis on Differences in Spatial Computable General Equilibrium Models by Market Structure Assumption -A Comparison of Perfect Competition Modeling and Monopolistic Competition Modeling-

52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia

## Provided in Cooperation with:

European Regional Science Association (ERSA)

*Suggested Citation:* Ishikura, Tomoki; Koike, Atsushi; Sato, Keisuke (2012) : An Analysis on Differences in Spatial Computable General Equilibrium Models by Market Structure Assumption -A Comparison of Perfect Competition Modeling and Monopolistic Competition Modeling-, 52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia, European Regional Science Association (ERSA), Louvain-la-Neuve

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An Analysis on Differences in Spatial Computable General Equilibrium Models by Market  
Structure Assumption

-A Comparison of Perfect Competition Modeling and Monopolistic Competition Modeling-

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**Abstract**

Spatial Computable General Equilibrium (SCGE) models are convenient methods of the analysis of the change of inter-regional economic interaction or regional benefit by policy shocks. Recent SCGE models have two main streams in terms of the assumption of market structure; perfect competition models and monopolistic competition models. Benefit measured by perfect competition based models is usually independent of economy of scale and therefore the policy assessment result is consistent with normal cost-benefit analysis. It is an important factor for practical welfare analysis when validity of policy implementation is discussed from a point of view of efficiency. On the other hand, monopolistic competition based models is suitable to theoretical framework of new economic geography field which highlights the economic agglomeration. Agglomeration effect is also an important factor from a point of view of regional economic development effects.

Thus the both of two types of models have theoretical and practical merits respectively. However, the results of the model analyses of course depend on the model formulations and can be different in not only detail but also feature of benefit distribution. Understanding the difference of the model outputs by theoretical assumption is crucial theme of practical policy assessment. This paper attempts to compare the economic effects of a road transport

development project estimated by a perfect competition based SCGE model and a monopolistic competition based SCGE model quantitatively. Our analysis emphasizes especially the differences in the magnitude of benefit and the regional distribution pattern of benefit because they are usually the largest interests of actual policy assessments. The results show that elasticity of substitution, which is a dominant parameter of monopolistic competition models as a key factor of markup, sensitively affects to benefit and its distribution. It mainly causes the difference of the outputs of the perfect competition based SCGE model and the monopolistic competition model, which implies that the elasticity parameter should be chosen carefully. We furthermore analyze the relationship between size of analysis target region and benefit as well as sensitivity analysis of model parameters. The analysis shows that the regional scale also influences to the benefit estimation in particular by monopolistic competition model.

Finally, we summarize the tendency of model outputs of the two types of the models and points to keep in mind for the practical policy analysis by SCGE models.

*Key words: Spatial Computable General Equilibrium model, Perfect Competition, Monopolistic Competition*

JEL Classification: C68, R13, O18

## **1. Introduction**

Transport investment project changes the situations of regional economy, sometimes even in the region far away from invested region. Although traditional Cost Benefit Analysis (CBA) by means of consumers' surplus measures the direct effects as benefit of a project, the method does not mention the change in other economic situations. Furthermore, target of traditional CBA is only overall efficiency of the project and it excludes the assessment of the spatial distribution of benefit. Actually, policy maker often have interests in the spatial distribution of benefit rather than the pure benefit. Spatial Computable General Equilibrium

(SCGE) analysis is a convenient method for the analysis of the benefit distribution.

A lot of SCGE models have been applied to the assessment of actual transport investment projects. Recent SCGE models have two main streams in terms of the assumption of market structure; perfect competition and constant return to scale technology (PC-CRS) models and monopolistic competition (MC) models. Benefit measured by PC-CRS based models is usually independent of economy of scale and therefore the policy assessment result is consistent with normal cost-benefit analysis. It is an important factor for practical welfare analysis when validity of policy implementation is discussed from a point of view of efficiency. On the other hand, MC based models is suitable to theoretical framework of new economic geography field which highlights the economic agglomeration. Agglomeration effect is also an important factor from a point of view of regional economic development effects.

Thus the both of two types of models have theoretical and practical merits respectively. However, the results of the model analyses of course depend on the model formulations and can be different in not only detail but also feature of benefit distribution. Understanding the difference of the model outputs by theoretical assumption is crucial theme of practical policy assessment. This paper attempts to compare the economic effects of a road transport development project estimated by a PC-CRS based SCGE model and a MC based SCGE model quantitatively.

## **2. SCGE Models for Analysis of Transport Investment Projects**

In Japan, SCGE models based on PC-CRS have been mainly applied to transport investment project assessments. The SCGE analyses for the investment projects of long haul inter-city transport system could use multiregional Input-Output (MRIO) Table (e.g. Koike et al.(2000)) because Japan developed well designed MRIO data. However, policy assessment for relatively narrow region (e.g. urban expressway project) needs spatial economic analysis

with higher resolution regional classification. In that case both the scope of target region and the scale of unit of regional classification are small and then MRIO is not usually available. The traditional MRIO based SCGE models therefore cannot be applied to such analyses.

Recently, a new framework of SCGE model RAEM-Light has been developed (Koike et al.(2008)), which is independent of the availability of MRIO. RAEM-Light incorporates logit model to describe the substitution of goods produced in different regions. This makes RAEM-Light be able to choose the resolution of regional classification freely and the relationship between transport cost and demand share of tradable goods in each region is reflected more precisely. RAEM-Light also assumes PC-CRS economy.

On the other hand, many MC based SCGE models for transport investment assessment have been developed mainly by European researchers. Most of the MC type SCGEs incorporate well known "Dixit-Stiglitz" format. This formulation method is consistent with New Economic Geography (Krugman(1991), Fujita et al.(1999)) theory, which highlights the effect of "economy of agglomeration". Analysis of effects of EU integration of some countries by Bröcker(1998) and evaluation of rail development project in Netherlands by Oosterhaven et al.(2001) are earlier works of this type of models.

Both of PC-CRS models family and MC models family have variations of model formulation. Therefore one specific model does not always show the representative characteristics of a category of modeling framework. Analytical research by a conceptual model assuming a small virtual economy may be enough to understand the differences of results by modeling technique qualitatively. However geographic structure of regional economy is also an important factor that can dominate the aspects of economic impacts by transport development projects. In other words characteristics of model application results can be different by analysis target region even by same model. Comparative study of results of different types of models is almost meaningless if the application region is not specified. Thus we study the difference of the model analysis results between the different market structure

models incorporating same regional economic data. Our analysis adopts two specific SCGE models to utilize common data. Selection of the model is important for such a study because data requirement for the calibration depends on formulation of the model. Our approach shows not a general knowledge about the aspects of SCGE analyses but some examples of comparison of the results between the different market structure models. When practical model application or policy assessment is implemented, the practitioner is often interested in the knowledge about the aspects of SCGE analysis based on the quantitative study. It can help to consider how the model results have consistency.

This paper picks up Koike et al.(2008) and Bröcker(1998) as the SCGE models based on PC-CRS assumption and MC assumption respectively. We apply these models to an actual Japanese expressway investment project and observe the aspects of the evaluation results. The following sections present the basic form of these SCGE models.

### **3. A Perfect Competition-Constant Return to Scale SCGE Model (RAEM-Light)**

#### 3.1 Assumptions and General Structure

RAEM-Light assumes competition market and constant return to scale technology and then it is consistent with the standard cost benefit analysis assumption. The economy is classified into multiple regions on which multiple types of industrial sector are located. Labor market is closed in the region, namely wage rate differs by region. Households own capital stock as mobile factor whose rent is common in all regions in the economy. Transport margin is described as "Iceberg" type, which transport of the tradable goods consumes a part of the goods itself.

#### 3.2 The Model Formula

For the detail of RAEM-Light model, see Koike and Kawamoto (2006). We show only the important formula in this section.

We start from the expression of behavior of firm. Let  $m$ ,  $n$ ,  $i$  and  $j$  denote the scripts of sector of goods, industrial sector, region in which goods are produced and region in which goods are consumed respectively. The production technology is two level nested Leontief-Cobb Douglas function. The upper Leontief technology nest describes the composition of value added and intermediate inputs.

$$Y_j^n = \min \left\{ \frac{v_j^n}{a_j^{0n}}, \frac{x_j^{1n}}{a_j^{1n}}, \dots, \frac{x_j^{mn}}{a_j^{mn}}, \dots, \frac{x_j^{Mn}}{a_j^{Mn}} \right\} \quad (1)$$

$Y_j^n$  is the outputs,  $v_j^n$  and  $x_j^{mn}$  are value added and intermediate inputs respectively.  $a_j^{mn}$  and  $a_j^{0n}$  denote input coefficients. The lower CD nest transforms factor inputs, labor  $L_j^n$  and capital  $K_j^n$  into value added,

$$v_j^n = A_j^n (L_j^n)^{\alpha_j^n} (K_j^n)^{1-\alpha_j^n} \quad (2)$$

where  $A_j^n$  is the productivity parameter and  $\alpha_j^n$  denotes the parameter corresponding input share. Solving the cost minimization with above technological assumptions gives the f.o.b. price  $q_j^n$  for  $Y_j^n$ .

Regional households maximize the log linear utility function by choosing the level of consumption demand  $d_j^m$  under the income constraint. Every household gains income from labor supply and capital stock which is owned evenly over regions. Let  $\beta^m$  denote share parameter of utility function  $U$ , with  $\sum_{m \in M} \beta^m = 1$ . The optimization problem for individual household is formulated as

$$\begin{aligned} \max_{d_j^m} U_j(d_j^1, d_j^2, \dots, d_j^M) &= \sum_{m \in M} \beta^m \ln d_j^m \\ \text{s.t. } \bar{l}_j w_j + r \frac{\bar{K}}{T} &= \sum_{m \in M} p_j^m d_j^m \end{aligned} \quad (3)$$

$\bar{l}_j$ ,  $\bar{K}$  and  $T$  are labor endowment per capita in region  $j$ , sum of capital stock endowment

in all region and sum of population (labor) in all region respectively. The population of each region is given and labor is immobile factor. Therefore

$$T = \sum_{j \in J} N_j$$

and

$$\bar{l}_j = \sum_{n \in N} L_j^n / N_j$$

are satisfied.  $p_j^m$  is c.i.f. price of goods given by the following interregional trade model.

The interregional trade model is an important characteristic of RAEM-Light. Consumers, households and firms, choose the region of production of goods stochastically. The choice probability is influenced by f.o.b. price and transport cost margin, which reflects the substitution between goods classified by production region. Applying logit type model of choice (Harker(1987), Mun(1998)), the probability is formulated by the following equation.

$$s_{ij}^m = \frac{Y_i^m \exp(-\lambda^m q_i^m (1 + \psi^m t_{ij}))}{\sum_{k \in I} Y_k^m \exp(-\lambda^m q_k^m (1 + \psi^m t_{kj}))} \quad (4)$$

In (4)  $s_{ij}^m$  is the probability that goods produced in region  $i$  is consumed by consumer of region  $j$ .  $t_{ij}$  denotes transport cost margin given as exogenous condition.  $\lambda^m$  and  $\psi^m$  are parameters of the logit model. The logit model gives the volume of trade by multiplying the probability and the level of demand. Then c.i.f. price  $p_j^m$  is formulated as average price.

$$p_j^m = \sum_{i \in I} s_{ij}^m q_i^m (1 + \psi^m t_{ij}) \quad (5)$$

Let  $X_i^m$  denotes sum of demand for goods  $m$  produced in region  $i$ . Input-Output balance of goods and demand supply equilibrium of goods are represented by

$$\begin{bmatrix} 1 - a_i^{11} & \cdots & 0 - a_i^{1N} \\ \vdots & \ddots & \vdots \\ 0 - a_i^{m1} & \cdots & 1 - a_i^{MN} \end{bmatrix}^{-1} \begin{bmatrix} N_i d_i^1 \\ \vdots \\ N_i d_i^m \\ \vdots \\ N_i d_i^M \end{bmatrix} = \begin{bmatrix} X_i^1 \\ \vdots \\ X_i^m \\ \vdots \\ X_i^M \end{bmatrix} \quad (6)$$

and

$$Y_i^m = \sum_{j \in J} (1 + \psi^m t_{ij}^m) s_{ij}^m X_j^m \quad (7)$$

The last equation of the system of RAEM-Light is equilibrium condition of labor market,

$$\sum_{m \in M} L_i^m = \bar{L}_i \quad (8)$$

where  $\bar{L}_i$  is supply of labor in region  $i$ .

#### 4. A Monopolistic Competition SCGE Model (Bröcker(1998))

##### 4.1 Assumptions and General Structure

Among number of models with MC based SCGE models we choose Bröcker(1998) as an example, because its system is simple and tractable for computation. Another reason is that data requirement for building the model is almost similar level to RAEM-Light.

Bröcker(1998) assumes there exist two kinds of goods, non-tradable local goods and tradable goods. Firms in each region produce the two kinds of goods using immobile production factor and intermediate inputs, both of local goods and tradable goods. Firms face free entry-monopolistic competition markets, therefore prices equal to average cost and profit is zero. Cost structure for producing tradable goods assumes to have the characteristics of economy of scale, average cost decreasing. Furthermore, Dixit-Stiglitz format is assumed in utility function of households and production function, nested Cobb Douglas-CES function. Local goods are bought only in the own produced region, while tradable goods are consumed everywhere in whole economy. Transport margin is described as "Iceberg" type as well as RAEM-Light. These general assumptions are consistent with the standard New Economic Geography (NEG) family of models. The SCGE models describe short run equilibrium of NEG theory.

##### 4.2 The Model Formula

We here express the necessary formulations of the model for calculation, for full explanation of the model system see Bröcker(1998). Let  $M_j$  and  $c_j$  denote consumption of composite tradable goods and consumption of local goods respectively, with  $j$  denoting region in which goods are consumed as well as index of RAEM-Light. The upper Cobb Douglas nest is represented by

$$U_j = M_j^{\mu_j} c_j^{1-\mu_j}, \quad (9)$$

with  $\mu_j$  denoting share of tradable goods consumption. Let  $q_{ij}$  denotes a variety of tradable goods produced in  $i$  and consumed in  $j$ . The lower CES nest represents the preference for consuming a diversified bundle of tradable goods.

$$M_j = \left[ \sum_i \int_0^{n_i} q_{ij}(k)^{\frac{\sigma-1}{\sigma}} dk \right]^{\frac{\sigma}{\sigma-1}} \quad (10)$$

$n_i$  is number of tradable goods produced in region  $i$ , and  $\sigma$  is elasticity of substitution. This Dixit-Stiglitz format is also utilized for production function.

We summarize only core equations for equilibrium of the model system. Price index for tradable goods in region  $j$ ,  $H_j$ , is

$$H_j = \frac{1}{\psi_j} \left( \sum_i S_i \pi_i^{-\sigma} T_{ij}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \quad (11)$$

In (11),  $\psi_j$ ,  $S_i$ ,  $\pi_i$  and  $T_{ij}$  denote productivity parameter, value of output of tradable goods in  $i$ , price of local goods and mark-up factor representing trade costs respectively. Let  $Y_j$  and  $L_j$  denote regional factor income and endowment of production factor respectively.

Regional factor income is a function of prices,

$$Y_j = L_j \phi_j^{-\frac{1}{\alpha_j}} \pi_j^{\frac{1}{\alpha_j}} H_j^{1-\frac{1}{\alpha_j}}, \quad (12)$$

with a parameter  $\alpha_j$ . Let  $I_j$  denotes disposal income, equal to value of final demand.

Relationship between value of output of tradable goods, factor income and disposal income is represented by

$$S_j = \frac{1}{\alpha_j} Y_j - (1 - \mu_j) I_j. \quad (13)$$

Total value of demand for tradable goods in region  $j$ ,  $D_j$  is also function of factor income and disposal income.

$$D_j = \mu_j I_j + \left( \frac{1}{\alpha_j} - 1 \right) Y_j \quad (14)$$

Let  $\lambda_j$  denotes be the ratio of net transfer payment to regional GDP in the base year. Then the balances of regional accounts are

$$I_j = (1 - \lambda_j) Y_j \quad (15)$$

for surplus regions and

$$I_j = \left( 1 + \frac{\sum_{j \in SR} \lambda_j Y_j}{\sum_{j \in DR} \lambda_j Y_j} \lambda_j \right) Y_j \quad (16)$$

for deficit regions.  $SR$  and  $DR$  denote the sets of regions in surplus and deficit regions respectively.

Final equations of the model system are concerning interregional trade. Value of interregional trade from region  $r$  to region  $s$ ,  $t_{ij}$ , is

$$t_{ij} = \frac{S_i (T_{ij} \pi_i)^{-\sigma}}{\sum_i S_i (T_{ij} \pi_i)^{-\sigma}} D_j, \quad (17)$$

and finally, the equilibrium of supply of tradable goods and sum of demand for tradable goods is

$$S_i = \sum_j t_{ij} \quad (18)$$

## 5. Application Results and Comparison

### 5.1 Application Region and Calibration

We apply the above two models to actual expressway investment project in Japan, as an example of exogenous shock by a policy. The expressway project is planned to implement in Shikoku region, an island of southeast Japan. Shikoku region is one of the lowest population density areas in Japan. Shikoku region has strong economic relationship with Chugoku region, the western part of mainland Japan (north of Shikoku). Sanyo region, southern coastal parts of Chugoku region, has relatively large population and economy. The both edges of the application region, Fukuoka and Osaka, have much larger economies.

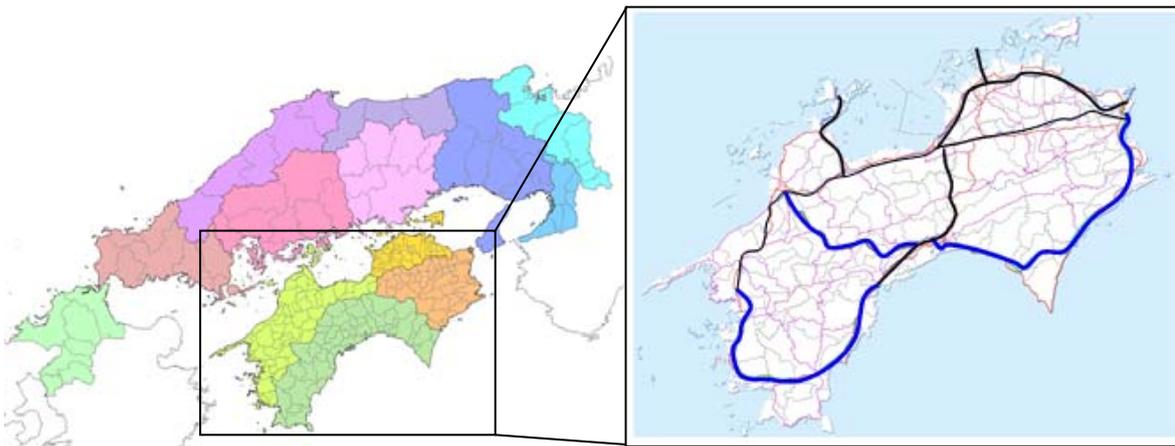


Figure 1 Application Region and Sample Road Investment Policy

Our application study classifies Shikoku island region into municipal units and other regions into relatively larger economic zones based on definition of governmental census.

Calibration of both of the PC-CRS model and the MC model is based on mainly regional economic accounts data. In Japan, regional GDPs for prefecture level are officially available. Regional GDPs for municipal level are partially available, however it can be estimated by population share in the prefecture even when the regional GDP data is not directly available. Every parameter for preference and production technology are calibrated by prefectural Input-Output table, by assuming that regions are homogenous in the belonging prefecture.

Concerning interregional trade,  $\lambda^m$  and  $\psi^m$  of the PC-CRS model in (4) are estimated by maximum likelihood method because full data for calibration is not available. Then the trade cost factor for the MC model  $T_{ij}$  are also estimated to fit the trade value of the PC model. We assume the following transport margin function as well as Bröcker(1998) and Oosterhaven et al.(2001).

$$T_{ij} = \xi(d_{ij})^\omega + 1 \quad (19)$$

The regression estimation, assuming the basic equilibrium trade value of the PC-CRS model as the actual value, gives the parameters  $\xi$  and  $\omega$ .

Unknown parameter is only  $\sigma$ , elasticity of substitution for the MC model. However, as well known in NEG field, it is the most important value which substantially influences results of MC models, especially to magnitude of benefit and geographical distribution of benefit. Actually this aspect is our main interest.

## 5.2 Comparison of the PC-CRS results and the MC results

We focus on the sensitiveness of the elasticity to the results of the MC model and how different from the PC-CRS model. Our discussion especially emphasizes the aspects of total benefit brought by the policy and regional distribution of the benefit, measured as equivalent variation (EV). Welfare index of Bröcker(1998) is basically relative benefit by region, therefore we calculate regional benefit by multiplying disposal income.

Figure 1 shows the results of the PC-CRS model and the MC model in terms of total benefit, sum of all regional benefit. In case of the MC model applications, we calculated some alternative versions by changing elasticity of substitution. PC-CRS market assumption is consistent with Marshallian consumers surplus, index of the standard cost benefit analysis. Therefore we regard the result of the PC-CRS model as a benchmark since it would be almost same magnitude as the benefit measured by consumers surplus.

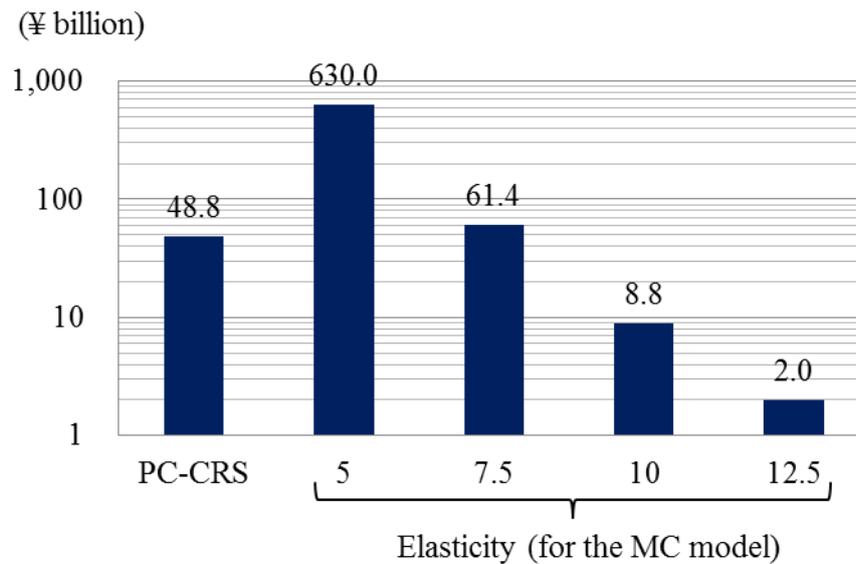


Figure 1 Comparison of Total Benefit

It is widely known that increasing return property is the major source of benefit in Dixit-Stiglitz type monopolistic competition models. The results in Figure 1 describe notably this aspect of the MC model. When the elasticity is 5, thus mark-up factor is 1.25, total benefit measured by the MC model exceeds ten times of the benefit measured by the PC-CRS model. On the other hand, the benefit in case of 12.5 of the elasticity marks only 2 billion yen. Thus elasticity of substitution influences the magnitude of total benefit in the MC model very sensitively.

The results imply remarkable characteristics of the relationship between market assumption of SCGE model and benefit measure from a point of view of practical use for policy assessment. As shown in Figure 1, the results of the MC based model can be affected by assumption of elasticity of substitution sensitively. If the magnitude of total benefit is one of the critical points of the policy assessment, analysts should carefully choose the value of elasticity of substitution. Evaluation of the project strongly depends on how large the elasticity is, and therefore inadequate assumption of the elasticity can cause to mislead the evaluation. Instead, we also have to note the PC-CRS assumption omits the effect of economy

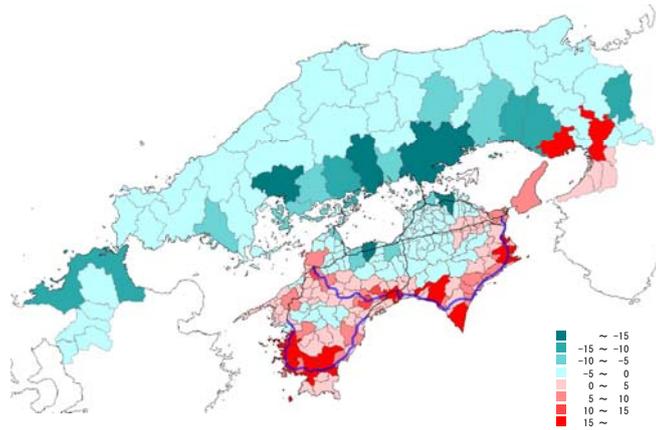
of agglomeration in the context of new economic geography. The lack of explicit agglomeration effects can cause underestimation of the results of transport investment project.

Regional distribution of benefit incidence shows clear difference between the PC-CRS results and the MC results (see Figure 2). The result of the PC-CRS model illustrates that larger benefit arises along the new expressway route. The eastern zones of the application region, Osaka and Kobe, also enjoy larger benefit. The fact that Kinki area including Osaka and Kobe is the second largest economy in Japan contributes to the aspects of the results. On the other hand, Sanyo area, southern coast of Chugoku, loses welfare by the expressway investment project. This reflects the shift of interregional trade balance to the condition that southern Shikoku regions have advantages in transport cost, in other words, the interregional competitive relationship is changed.

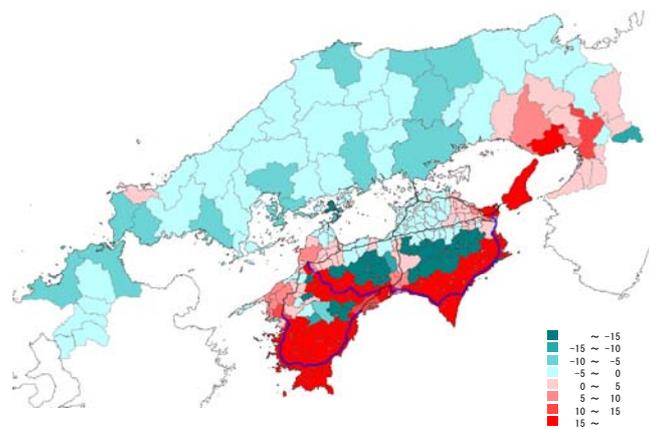
Figure 2 displays moreover the results in two cases of the MC model applications. The upper picture represents the regional benefit distribution of the MC model results when the elasticity of substitution is 5, and the lower one is for the case when the elasticity is 10. These results display quite different aspect of the distribution pattern of benefit.

When elasticity of substitution is lower, namely higher mark-up rate, the benefit distribution is relatively similar to that of the MC model. The larger benefit arises along the region where the new expressway is invested. However neighbor regions of the large benefit regions mark greater loss of welfare in contrast with the PC-CRS result.

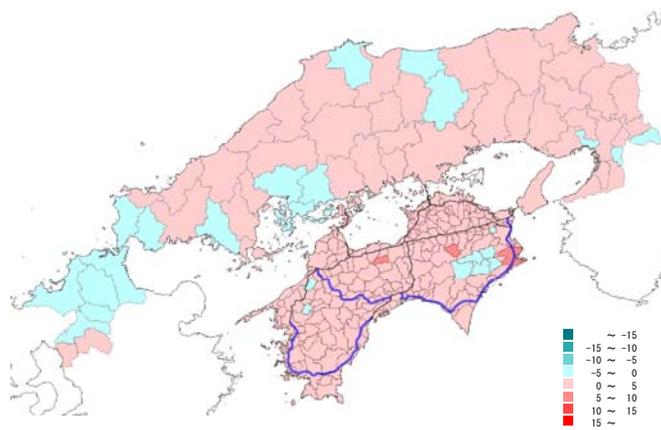
When the elasticity is higher, namely lower mark-up rate, the advantage regarding transport cost does not work well in the invested regions. It causes relatively flat distribution of benefit in all around the application area.



PC-CRS (RAEM-Light)



MC (Bröcker(1998)) Sigma=5



MC (Bröcker(1998)) Sigma=10

Figure 2 Distribution of Benefit in Each Model Result

Lower elasticity of substitution means stronger effect of monopolistic power of firms producing the variety of tradable goods. And the number of variety increases, then total outputs of tradable goods also increases. As a result, transport cost reduction highly contributes to reduce expenditure in tradable goods. That is one reason why the more benefit arises along the invested regions in case of lower value of the elasticity.

In contrast, higher elasticity of substitution causes less demand for interregional trade due to weakness of the effect of economy of agglomeration. In that case, the large part of tradable goods is consumed in the own, produced, region. Therefore the improvement of interregional transport does not influence drastically. Geographical aspects of benefit distribution have less relationship to the expressway investment regions.

RAEM-light, used as an example of PC-CRS models in our study, models tradable goods choice behavior of consumers, including intermediate consumption, as logit model which is popular in transport modeling. Logit model is a tractable form to deal with the relationship between share regarding transport behavior and factors which influence to the choice behavior. In contrast to pure economic modeling, such as iceberg format, which usually assumes the consolidated transport margin including cost, time, non-tariff barrier and so on, logit model therefore explicitly reflects the factors other than prices of goods well. However logit type function is not homogenous of degree zero in price variables. It means RAEM-Light is not a strict general equilibrium model, if the share, represented by logit function, is endogenously changed according to change in prices. Even though this point is a theoretical problem, the estimated benefit can be an approximation of pure general equilibrium approach. Actually RAEM-Light is a real SCGE model when the logit share is given as constant parameters.

## **6. Concluding Remarks**

Our analysis shows quantitative differences of the benefit estimation between a PC-CRS model and a MC model. Although it is obvious that theoretically different model gives

different outputs, the degree of difference and understanding the aspects of the difference are important matters from a point of view of practical policy assessment. We investigate the model application results of the two models using the actual regional data and the actual expressway investment plan, then the geographical aspects of the benefit distribution are compared.

The aspect that benefit of the investment project is not stable depending on the elasticity parameter is a problem for project evaluation. However omitting the agglomeration effects is also a crucial problem if the analysis is interested in spatial property of regional development effects by the project. Although there exist a lot of types of SCGE models, the property of the model analysis results can be quite different depending on the economic assumptions, especially market structure. Matching the purpose of the policy assessment with the methodology of the analysis should be carefully considered.

### **Acknowledgment**

The authors are very grateful to Nobuhide Kawamoto for his help of processing the regional economic data and GIS data. Financial support from Grants-in-Aid for Scientific Research by Japan Society for the Promotion of Science is gratefully acknowledged.

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