Regional competition and cooperation on provision of inter-regional transportation infrastructures

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Abstract

A two-region general equilibrium model is presented to investigate the effects of regional/distributive construction schemes of interregional infrastructures. Two different specific schemes are especially investigated, namely the property-based scheme where each region constructs its own part of the infrastructure, and the pooling scheme where the both regions invest into the one common large project. The effects of these schemes are compared and the policy implications for regional provision of inter-regional infrastructure are induced. It is especially shown that the intervention by the upper authority (by means of income transfer) has totally different effects on resulting infrastructure service level depending on the scheme that determines competitive/cooperative relationships among the regions.

I. INTRODUCTION

Recently, Japanese government is straggling to reform many traditional political, fiscal and economic institutions that had once surely contributed to Japanese ‘miracle growth’ but are now claimed as in ‘institutional fatigue’. Among others one of the most fundamental issues of the national institutional reform is the ‘decentralization of authority’ from central to local governments (prefectures). Also, Japanese Ministry of Internal Affairs and Communications had recently started to study the possibility of Japanese federal system (Do-Shu Sei) in which current 47 prefectures will be rearranged into several states. The process of economic and political integration in Western Europe through the institutions of the EU can also be viewed as emergence of a larger federal-type of collective system. Of cause the two mature North American federations had experienced the federal systems for many years. All these phenomena of emergence of federal-type institutions worldwide raise basic questions about the role of the nation and regions in the modern world.

The unity of such collective bodies is sustained by mobility of money, goods, and people. The flows of goods and people are enabled by appropriate transportation services (transportation infrastructures) connecting member regions each other . One specific question arises when considering the federalism under open economy sustained by transportation infrastructure; who will be in charge of the transportation network system (infrastructure) in order to sustain the connection of regions as an efficient one united economic institution. The naïve answer will be ‘by the national or central authority’. If the central government or upper authority has full information and its object is ‘right’ and ‘fair’ (such as maximization of social welfare, which reflects welfare of each member region fair enough), it can provide the socially efficient level of transportation infrastructure. Unfortunately, it is often pointed out, sometimes by the name of ‘failure of government’, that central authority fails to provide efficient solutions for this kind of resource allocation problems due to luck of information needed for right decision, political and other incentives, and others. For example, one of the heaviest criticisms for decisive reform goes to highway constructions that have been solely determined under the governmental agency of centralized Japanese government.

This study tries to analyze the policy decisions by sub-national governments (regions) in the federalism setting under open economy. This setting can be interpreted as a nation of fiscally independent states and regions, or politically and economically unified countries like EU. In this setting, critical policy decision by regions is on contribution to the service of interregional economic 'openness' (namely, interregional transportation infrastructures). The effects of improvement of interregional transportation infrastructure are studied in regional economics including [1], [2], [3], [4], and [5]. What makes this work different from theirs is the endogenous determination of the interregional infrastructure which is a resultant of regional decisions in competition and cooperation. The resultant efficacy of this fiscally competitive environment is clarified. More precisely, the spatial general equilibrium model is constructed for a system of two regions connected by one transportation infrastructure. The decisions by each region are on local tax which is used for the contribution to construction/maintenance of the interregional transportation infrastructure. While the decisions on local service are regions' own choices, and consequently they are determined competitively in their nature like many fiscal federalism models, the decision for interregional transportation infrastructure can be either competitive or cooperative. Their decisive structures are considered and their results are compared.

II. The Model

A. Two-Region Setting

Two regions economy with immobile labor is modeled as a general equilibrium system. The general equilibrium model with two regions is often used to analyze the effects of improvement of transportation between the regions (e.g., [1], [2]). This study follows this two-region with one connecting transportation infrastructure setting with some extension and limitation. The extension is the inclusion of decisive determination of transportation service level of the inter-regional transportation infrastructure. The main restriction of the modeling is, on the other hand, the immobility assumption of industry and labor/households between regions.[1]

The system attains equilibrium when the labor market is cleared (full employment) and all good markets are cleared. The model follows the main settings in [2] that analyzes the transportation network improvement effects on the system of regional economy and geography. The detailed setting and basic assumptions are as follows.

There are two regions $(i = 1,2)$ and their locations are exogenously fixed. Transport facilities are used only for inter-regional trade of goods. The population of region i (N_i) is exogenously fixed and therefore they cannot migrate to the other region. The total stock of capital in the economy is fixed and given by K. It is equally owned by all households and each household receives an equal share of the capital rental revenue.

B. Productions

The economy has only two goods of production (and therefore consumption), and each region is assumed to specialize in one (mutually-different) good production, while both goods are 'necessary goods' for all households. This setting leads the necessity of trade between the two regions. Inputs of both productions are labor and capital. The production function of the good produced in the region i (or 'good i' in short hereafter) is specified as the following linear homogenous Cobb-Douglas form,

[1] Industry and labor are assumed immobile as the simplest setting to guarantee productions and consumption in both regions. If both industry and labor are mobile between regions, the region's own welfare maximizing decision coincides with the social welfare maximizing problem [see [6]], and the decentralization of transportation infrastructure management becomes a trivial problem. One possible way to introduce mobility of industry and labor without making the model trivial is to introduce both mobile labor (which is also entrepreneur) and immobile labor, and assume that the regional government maximizes the welfare of the immobile household which can be naturally assumed to be a majority of the region (for this setting, see [7]).

$$y_i = a^i (L_i)^{\alpha^i} (K_i)^{1-\alpha^i} \qquad (i = 1,2)$$

where a^i and α^i are parameters, and y_i , L_i , and K_i are amounts of output, labor, and capital inputs in region i's production, respectively.

The first order condition for each production leads to the following regional demand functions,

$$L_i = \frac{\alpha^i}{w_i} q_i y_i , \qquad K_i = \frac{1-\alpha^i}{r} q_i y_i \qquad (i = 1,2) \tag{1}$$

where q_i , w_i , and r are the f.o.b. (free-on-board) price of good i , wage rate in region i , and the capital rent, respectively. Note that capital rent is same for both regions since capital moves freely within the economy. The wages are, on the other hand, different in regions due to labor immobility assumption between regions.

C. Households

Household in each region has an identical taste and the utility function is specified by

$$u_i = \left(x_i^1\right)^{\beta_i} \left(x_i^2\right)^{1-\beta_i} \qquad (i = 1,2)$$

where x_i^m is the quantity of good m consumed by each household in the region i , and β_i is the parameter representing consumption share for the good 1, and $0 < \beta_i \le 1$.

Income of a household consists of the wage and the share of capital revenue. Expenditure consists of good consumptions, local tax and transfer by the upper authority. The budget constraint for a household in region i is expressed as

$$w_i + s_i + \frac{rK}{N} = \sum_m p_i^m x_i^m + t_i \qquad (i = 1,2)$$

where N is the total population and p_i^m is the c.i.f. (cost, insurance, and freight) price of good m . The two variables, t_i and s_i , are the lump-sum tax by the government of the region i and the income transfer by the upper authority to the region i , respectively.

The demand functions are then derived as the following first order conditions

$$x_i^m = \frac{\beta_i}{p_i^m}\left(w_i + \frac{rK}{N} + s_i - t_i\right) \qquad (i = 1,2, m = 1,2) \tag{2}$$

D. Provision of Transportation Infrastructure

The regionally specialized productions are traded between the regions. Carrier for Trade is provided by the production sectors themselves. There exists cost of trade, and it is assumed to be represented by 'Iceberg type transportation cost' for each product.

This transportation cost is determined by the service level of the transportation infrastructure. Let the level of the infrastructure be represented by the 'trade friction rate', Θ , where lower this value means the higher the service quality. The level of infrastructure service is determined by the governments of both regions. Let the decision on this service by the region i is represented by θ_i. Then the relationship between the overall service level of the transportation infrastructure, Θ, and the decision by each regional government, θ_i, can be expressed as

$$\Theta = \Theta(\theta_1, \theta_2) \tag{3}$$

This function represents the property, institutional, and technological structures of the infrastructure construction. Detailed discussion and specification of this function are given later. This function can be assumed to have the following general property.

$$\partial\Theta(\theta_1,\theta_2)\big/\partial\theta_i \geq 0 \qquad (i = 1,2)$$

Namely, the decision of one regional government to improve the infrastructure service quality always has non-negative effect on resultant infrastructure service. In order to implement the decision on infrastructure, each region needs to input the capital[2].

$$\theta_i = \theta_i(K_i^T), \quad \theta_i \geq 0 \qquad (i = 1,2) \tag{4}$$

where K_i^T is the capital input by the region i. More capital input means better service of infrastructure. The following property is naturally assumed.

$$\partial\theta_i(K_i^T)\big/\partial K_i^T < 0, \quad \partial^2\theta_i(K_i^T)\big/\partial K_i^{T\,2} \geq 0 \qquad (i = 1,2)$$

The regional government levies the purpose specific tax on the households for purchase of capital for infrastructure construction. The tax is specified as a lump-sum type, and is equal across all households in the region.

$$rK_{Ti} = N_i t_i \qquad (i = 1,2) \tag{5}$$

where r is the rent of the capital.

E. Price System

Under the perfectly competitive environment, the mill price of the good i, q_i, and the c.i.f. price of the good m to be traded in the region i, p_i^m, have the following relationship.

$$p_i^m = \begin{cases} q_i & if \quad i = m \\ q_i(1+\kappa^m\Theta) & if \quad i \neq m \end{cases} \qquad (m = 1,2) \; (i = 1,2) \tag{6}$$

where κ^m is the good specific parameter on trade friction.

The average cost of the good, $C(w_i, r)$, can be deduced from the equations (2) and (3).

[2] Some may argue that the capital for infrastructure construction/maintenance must be different from the one for private production input. This claim may be avoided with the cost of introducing another capital which is only for infrastructure construction/maintenance, which however, complicates the model without giving any change in conclusions given later in the paper.

$$q_i = C(w_i, r) = (a^i)^{-1}(\alpha^i)^{-\alpha^i}(1-\alpha^i)^{\alpha^i - 1} w_i^{\alpha^i} r^{1-\alpha^i} \qquad (i = 1,2) \qquad (7)$$

F. Equilibrium Conditions

For each good market, the following good clearance conditions hold.

$$y_1 = L_1 x_1^1 + L_2 x_2^1 (1 + \kappa^1 \Theta) \qquad (8a)$$

$$y_2 = L_1 x_1^2 (1 + \kappa^2 \Theta) + L_2 x_2^2 \qquad (8b)$$

The equilibrium of the capital market is given as

$$\sum_{k=1}^{2} K_k + \sum_{k=1}^{2} K_k^T = K \qquad (9)$$

The labor is immobile and therefore the number of households always equals to the number of labor of the region.

$$L_i = N_i \qquad (i = 1,2) \qquad (10)$$

The equations from (1) to (10) constitute the two region economic system. There are 24 unknown variables of $L_i, K_i, K_i^T, x_i^m, w_i, q_i, p_i^m, y_i, r, \theta_i$, and Θ . The system constitutes the general equilibrium framework. According to Walras's law, the capital rent is set as a numerare, and the equation (9) is dropped from the system.

G. Governments

Each regional government can only determine the purpose-specific lump-sum tax. The decision is totally free from the upper authority. Their purpose is to maximize the utility of their residents. The detailed description on the decision of the regional governments will be given later.

The upper authority's sole role in this model is the redistribution of the wealth between the regions. The authority can determine this redistribution level prior to the regional decisions, and therefore, this transfer between regions is exogenous for the local governments. The following transfer balance should hold.

$$N_1 s_1 + N_2 s_2 = 0 \qquad (11)$$

III. Competition between Regions

A. Basic Case: Property-Based Scheme

The model described in the previous section is a complex system of non-linear equations with many unknown variables. Especially, the effect of infrastructure service level, which is key feature of the analysis, is complex. Since property of the system is difficult to trace analytically, numerical analyses are employed. In order to calculate the system, the functions that determine the 'structure' of infrastructure construction, which is given as a general form in the equations (4) and (5) must be specified.

Before constructing an appropriate function with general characteristics, it is helpful to specify the situation and scheme that the transportation infrastructure is constructed. We now focus on the situation that the decisive property of the transportation infrastructure is clearly divided according to the actual attribution of the space occupied by the infrastructure. While we assume the point economy for inner-regional production and consumption, the intra-regional space is explicitly considered. Fig. 1 depicts the situation. The regions 1 and 2 have their own spatial territories, and they are free on decision on any public service within the territory. Namely, on the transportation infrastructure, the region 1 decides on the service level of its segment (length d_1) and the region 2 does on the segment (d_2).

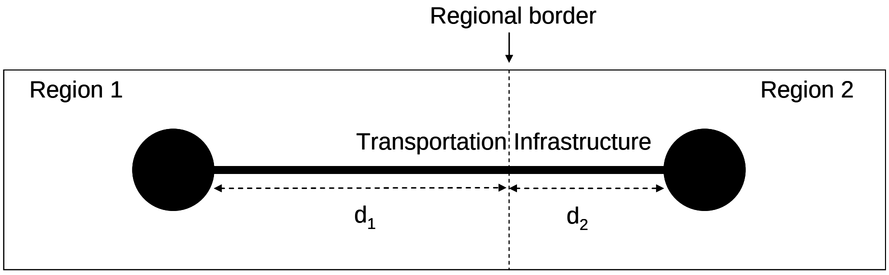

Fig. 1. Regions and transportation infrastructure.

In this case, the decision on level of service by each region can be naturally specified as the par-mile friction of the transportation service of the segment.

$$\theta_i = \theta_i\left(\frac{K_i^T}{d_i}\right) = \phi \cdot \left(\frac{K_i^T}{d_i}\right)^{-\varphi} \qquad \phi, \varphi \geq 0 \qquad (i = 1,2) \tag{4*}$$

Namely, the friction per-mile of the road is a (decreasing) function of per-mile capital investment.

For simplicity, we set $\varphi = 1$. The overall friction of trade between the two regions is then given as follows.

$$\Theta = \Theta(\theta_1, \theta_2) = \left(d_1\theta_1(K_1^T) + d_2\theta_2(K_2^T)\right)/(d_1 + d_2) = \frac{\phi}{d_1 + d_2}\left\{\left(\frac{(d_1)^2}{K_1^T}\right) + \left(\frac{(d_2)^2}{K_2^T}\right)\right\} \tag{3*}$$

The ice-berg cost of each good is then given as $\kappa^m \Theta = \kappa^m (d_1\theta_1 + d_2\theta_2)$. Parameter values for this basic case are set as follows:

$\alpha^1 = \alpha^2 = 0.5$, $\beta_1 = \beta_2 = 0.5$, $\kappa_1 = \kappa_2 = 0.01$, $r = 1$, $\phi = 0.1$, $N_1 = N_2 = 15$, $K = 5$, $d_1 = d_2 = 5$, $s_1 = 0$.

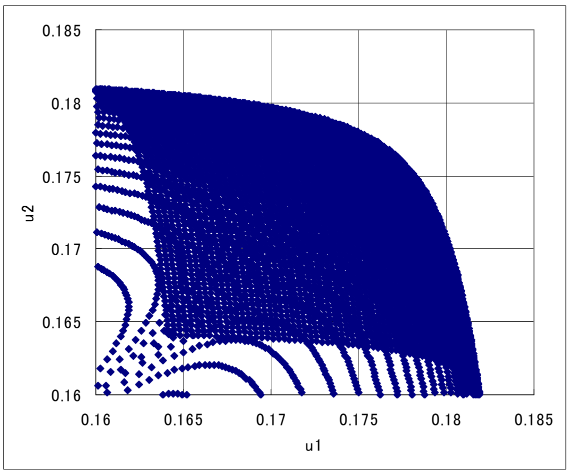

Fig. 2. Utility profile.

Fig. 2 shows the utility profile. The points in the figure show the upper-right part of all depict for each combinations of t_1 and t_2 for their value ranging between 0 and 0.05. The convexity of the utility profile set is recognizable, and the Pareto frontier is continuous. We can see the inherent trade-off on provision of transportation infrastructure between two regions.

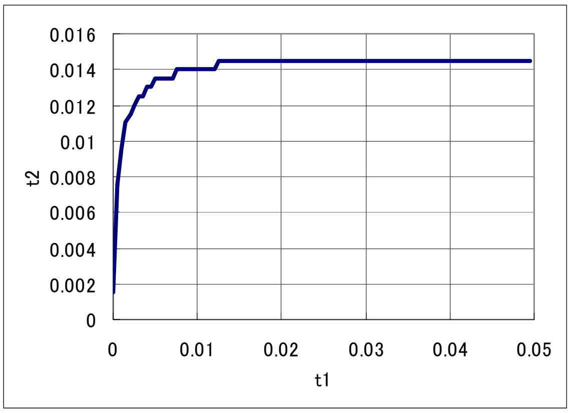

Fig. 3a: best reply correspondence

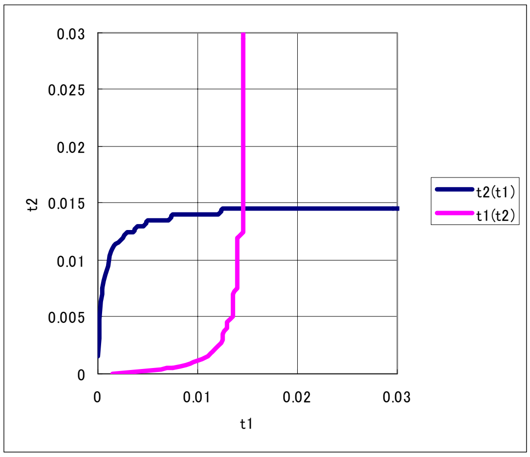

Fig. 3b. Nash equilibrium

Fig. 3a shows the best reply correspondence (BRC) of the region 2. The increase in the tax (and therefore, improvement of the transportation infrastructure) brings about more tax in the region 1. This is because the construction/maintenance of the transportation infrastructure is divided according to the land property, and the overall service level of the infrastructure crucially depends on the service level of the other region. Two regions are therefore *strategic complement*.

Fig. 3b depicts the BRCs for the both regions. Because of the symmetric settings of all parameters, these two BRCs are also symmetric. The crossing point of the two curves is Nash equilibrium[3]. You can easily check that the uniquely depicted equilibrium is stable. Because the tax levels at Nash equilibrium in Fig. 3b is not on the Pareto frontier depicted in Fig. 2, one can see that Nash equilibrium does not bring about Pareto efficient in the Property-based Scheme.

Effects of the parameters, α^i, β^i, κ^m, and N_i on Nash equilibrium are investigated in details. However, due to the space limitation, only effects of asymmetry in population between the regions are mentioned[4]. More asymmetry in population means more wage difference (because of the immobile assumption), and more tax for the infrastructure by less populated region. *Infrastructure service level is maximized when they have asymmetric population structure.*

B. Common-Pool Scheme

In the previous section, the property based construction of infrastructure is modeled and analyzed. Alternatively, one can think a system where the both regions maintain the common infrastructure 'together'. One way of modeling this common construction scheme is to consider the situation that both regions decide their own investment levels, and achieve a common level of transportation service by using these investments together. The

[3] While many numerical calculations that we had performed indicate the existence and also the uniqueness of Nash equilibrium, we cannot guarantee these. While the existence can be guaranteed by explicitly setting the finite strategy space, uniqueness requires checking of single-crossing of the BRCs. In the succeeding analyses, the existence and uniqueness are supposed.

[4] The utility is always higher for the households in the region with smaller population, which may be counterintuitive. This is due to the immobile assumption on labor and households between the regions; under this assumption the wage is always enhanced by the decrease of the labor in the region due to full employment assumption on labor market of each region.

equation of this ‘common pool scheme’ is modeled as follows.

$$\Theta = \Theta(\theta_1, \theta_2) = \eta \left(\frac{K_1^T + K_2^T}{d_1 + d_2} \right)^{-\varphi}, \quad \eta, \varphi > 0 \tag{3**}$$

where all the capital inputs by the both regions, $K_1^T + K_2^T$, are all together used for the construction of whole infrastructure which should be same service level throughout the road. For simplicity, $\eta = 1, \varphi = 1$ are assumed.

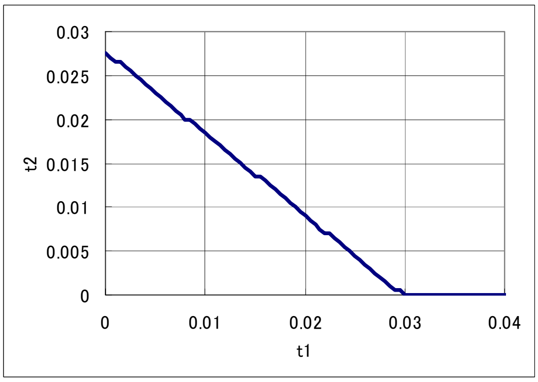

Fig 4a. BRC.

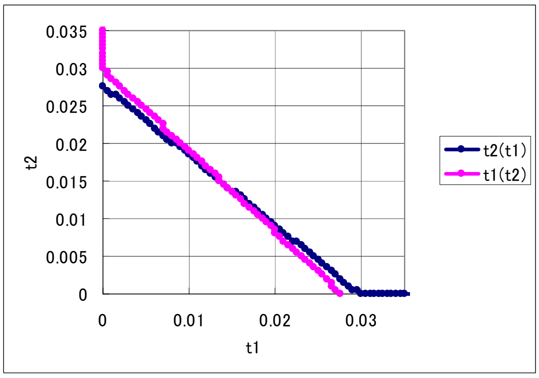

Fig 4b. Nash equilibrium.

Fig. 4a and 4b are the BRCs in the numerical calculation. Parameter settings are the same symmetric one as given in the previous section. The two BRC lines in Fig. 4b have a unique intersection which corresponds to Nash equilibrium. It can be checked that it is a stable equilibrium. Notice that while the BRC of the property-based construction is the increasing function, the BRC of the common pool scheme is the decreasing one. In other words, regions are mutually *strategic substitution*. Obviously, this is because of the perfect substitutability between the region 1’s capital investment into the transportation infrastructure and the region 2’s one in this common-pool scheme.

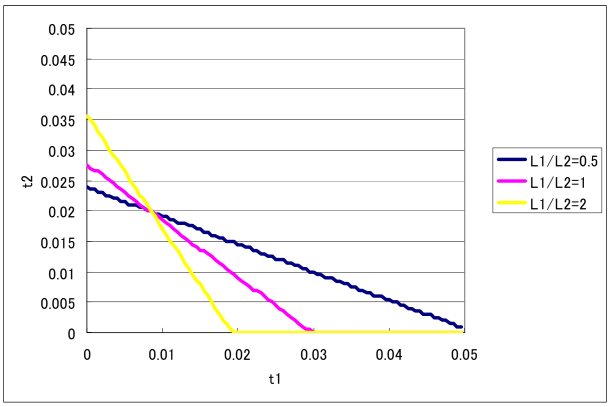

Fig 5a. BRCs (asymmetric pop.).

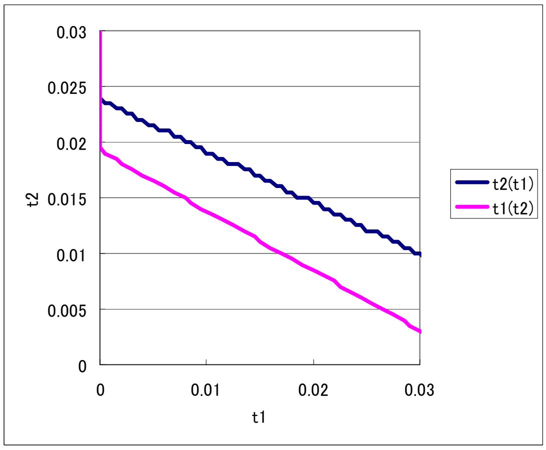

Fig 5b. Nash equilibrium.

The Fig. 5a shows the effects of population asymmetry on the BRC. Less population means steeper BRC curve. In other words, the region with less population tends to be ‘more’ strategic substitution. Fig. 5b depicts an extreme case with $n = N_1 / N = 0.5$ where the Nash equilibrium is that ‘the region 1 (with less population) pays nothing and the region 2 pays all’. In the common-pool scheme, because of this substitutability property, the larger region tends to put more capitals, and sometimes smaller region pays nothing.

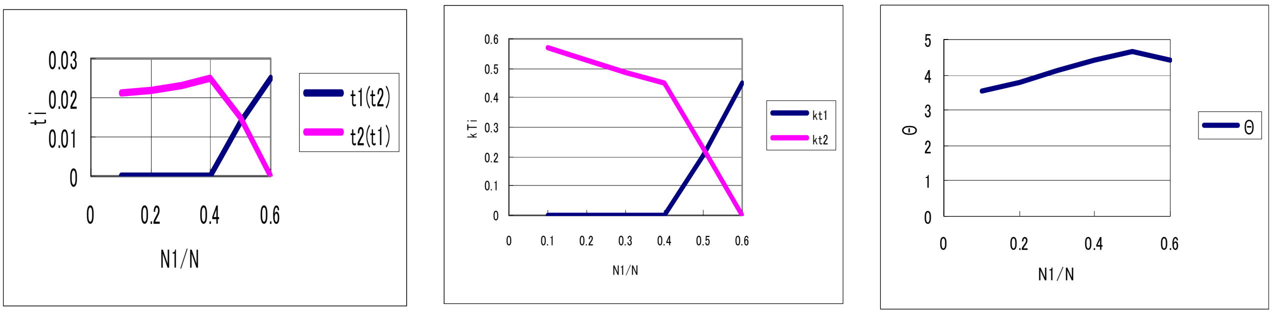

Fig. 6 Population asymmetry and Nash equilibrium
(Tax, capitals, and overall service level; from left to right)

Fig. 6 depicts the population asymmetry and Nash equilibrium under the 'common-pool scheme'. When the population in the region 1 is relatively low (namely, when $N_1 / N \leq 0.4$), the region 1 pays nothing for the transportation infrastructure, expecting for the region 2's enough investment into the service.

The most-right Figure in Fig. 6 depicts the overall infrastructure service level. *It is worst when the regional population is equal*. This is the totally opposite phenomenon to the one obtained in the property-based scheme.

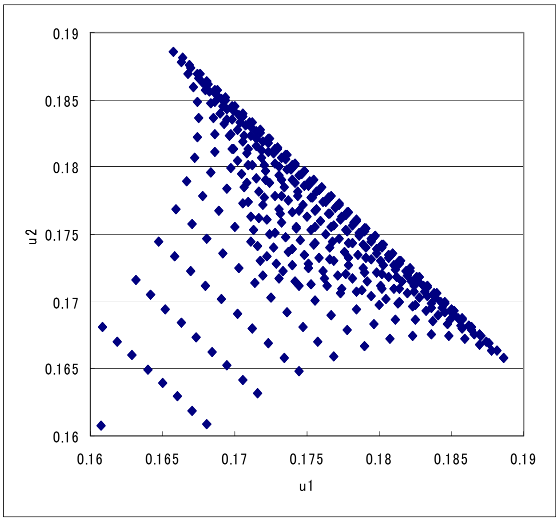

Fig 7. Utility profile for the common-pool system.

Fig. 7 shows the utility profile of the two regions under the common-pool scheme. The Pareto frontier, and therefore, the bargaining set, is rather 'flat', indicating the inherent strategic substitutability of the problem.

The effects of the changes in the parameters are investigated numerically. These effects are similar to the one in the property based scheme except for the following points: the increase in α^1 brings about the increase in the tax in the region 1 *but the decrease in the region 2*. This increase also results in the increase in the capital input to infrastructure in the region 1 and its decrease in the region 2. The overall infrastructure friction decreases same as the one obtained in the property based scheme.

C. *Construction Schemes and Regional Decisions*

So far we have looked at two distinct construction schemes of the 'property based' scheme and 'common-pool' scheme. The scheme is now generalized and its effects on regional decision on the inter-regional transportation infrastructure are analyzed.

The function that represents the generalized construction of the interregional transportation infrastructure is specified as follows.

$$\Theta = \left(\gamma_1 \left(K_1^T\right)^{-\rho} + \gamma_2 \left(K_2^T\right)^{-\rho} \right)^{\frac{1}{\rho}}, \qquad \gamma_1, \gamma_2 > 0 \tag{3***}$$

Notice that this function becomes the simple case of the scheme (3*) with $\varphi = 1$ (the property based scheme) if $\rho = 1$ and $\gamma_i = \phi d_i^{\ 2} / (d_1 + d_2)$. Also, it becomes the scheme (3**) (the simple case of common pool scheme with $\varphi = 1$) if $\rho = -1$ and $\gamma_i = \eta / (d_1 + d_2)$. One key difference in schemes is therefore represented by the difference in values of parameter ρ.

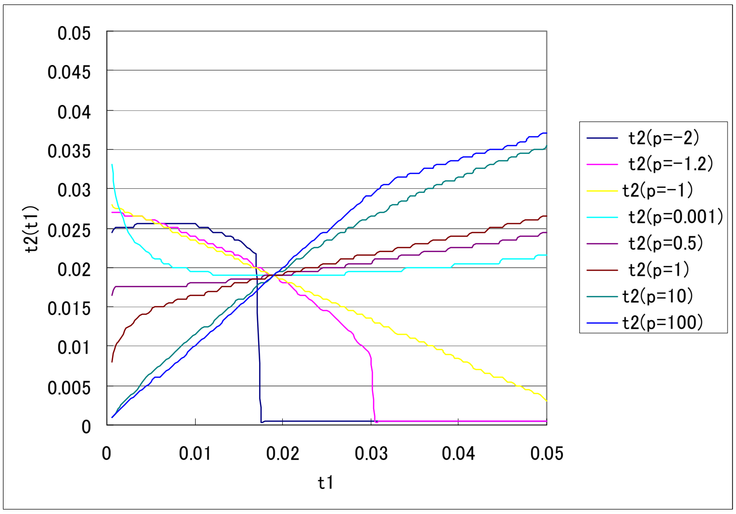

Fig. 8. The best reply correspondences with various ρ.

Fig. 8 shows the relationships between the value of ρ and the BRCs. Generally speaking, higher the value of ρ means more the regional strategy complement and less substitution.

D. *Interregional Transfer and Regional Decisions*

The intervention by inter-regional transfer may change the capital input level of each region. The effects of such intervention are analyzed, again numerically. More precisely, effects of parametric change of s_i are investigated for different value of ρ. The population distribution is set asymmetric as $L_1 / L_2 = 0.55$.

When $\rho = -1$, regional decision is strategic substitution. Increase in the transfer which brings about more asymmetry between the two regions, leads to more input to the infrastructure (by the receiving region).

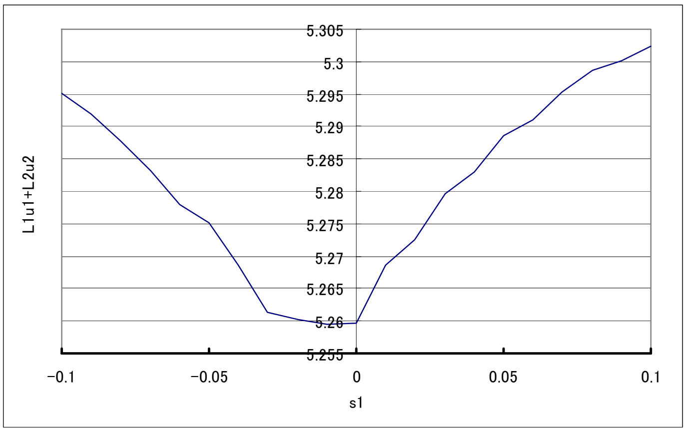

Fig. 9. Social welfare when $\rho = -1$.

Fig. 9 shows the social welfare which is defined as sum of all households' utilities. The social welfare increases according to the increase in the transfer. According to the increase in the transfer to the region 1, the utility of households in the receiving region increases while the one in the sending region decreases.

When $\rho = 0.001$, the regional decision is strategically complement. Increase in the transfer (to the smaller region 2) which brings about more symmetry between the two regions, leads to more overall input to the infrastructure. Fig. 10 shows that the social welfare is maximized when there is a moderate transfer from the larger region (1) to the smaller region (2). However, excessive increase in this transfer that brings about asymmetry between the regions, starts decreasing the overall capital inputs to infrastructure, and therefore, decreases the social welfare.

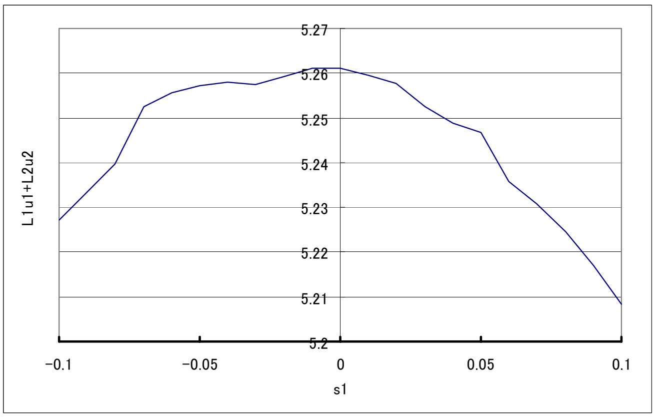

Fig. 10. Social welfare when $\rho = 0.001$.

Transfer is effective to improve the trade-off situation between the regions when they are faced with more strategic substitution situation. In this case the transfer should work as the scheme to introduce the regional asymmetry. On the other hand, when the regions are strategic complement, the transfer should be used to adjust the asymmetry between the regions which enhances the input into the infrastructure.

IV. Conclusion

The effects of improvement on the transportation infrastructure between regions have been analyzed by system of two-region model. To the author's knowledge, while there are many studies on strategic provision of local public goods by multiple local governments, there is no direct research regarding the decisions on ‘transportation infrastructure’ as an endogenous variable.

It is shown that strategic structure of ‘complementarily/substitutability’ plays important role in the regional decisions and resultant equilibrium on the interregional transportation infrastructure level. Accordingly, the intervention by the higher-level authority, namely the regional transfer, plays different roles depending on the strategic structure. The strategic structure depends on physical, technological, and fiscal figures of the targeting transportation. For example, for merchant services (shipping) and airfreights that have ports and airports as the main transportation infrastructures, the infrastructure (port) enhancement of the regions can be regarded as being in mutually complement structure. In such a case, a bigger region tends to invest little to the transportation infrastructure. It therefore stays at suboptimal level.

The model and analyses in this research have some critical limitations. Firstly and most critically, industrial sectors and households in the model never change their location. More general equilibrium setting with free-mobile firms should be examined. Introduction of the New Economic Geography setting with immobile and mobile labor may be useful to analyze the mobile case. Secondly, we only analyze two-region model. In the two-region model setting, only two regions compete over provision of one network (or link) infrastructure. However, if there are more than three regions, each region has much more freedom on ‘with whom they build up a better transportation infrastructure. In such case, each region may start making bargaining over agreements and coalition. In this setting the structure becomes similar to the recent development of the Free Trade Agreement models [8], but with different coalition structures.

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