A MODEL ANANLYSIS OF IMPACTS OF INTERREGIONAL TRANASPORT IMPROVEMNT ON AGGLOMERATION AND DISPERSION OF ACTIVITY LOCATIONS

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INTRODUCTION

The impacts of interregional transport improvement on agglomeration or dispersion of activity locations are now becoming more important than before. In Japan, it has been under a heated debate whether, new Shinkansen lines stimulate the dispersion of agglomerated population and economic activities in metropolitan areas, or result in a higher agglomeration than the present. Also in Europe, the impacts of Channel Tunnel on locations of economic activities are now much focused on, with the background of EC unification.

This paper attempts at the model analysis of location changes caused by interregional transport improvement, to provide the theoretical basis necessary for the above discussion. The analysis will clarify the conditions under which transport improvement results in agglomeration or dispersion.

NAKAMURA and UEDA (1989) analyzed the impacts of Shinkansen, and showed some scenarios of those impacts on regional development. In the scenarios, location changes were described by using the concept of location surplus. The concept and scenarios in their paper, are expressed mathematically to add some new findings in this paper.

1.MODEL

1.1.Outline of the model

Major assumptions in the model are as follows.

1)There are two regions in a nation. Region 1 is larger than Region 2, and a single transport mode connects them.

2)Population or economic activities, called locators in the rest of this paper, are allocated in the two regions according to the attractiveness of each region (See Figure 1).

3)For simplicity in the analysis, a single type of locator will be focused on.

The attractiveness mentioned in assumption 2) is called location surplus, because, it is a key concept dominating location choice behavior and measured in the term of surplus such as consumer surplus or producer surplus (See NAKAMURA and UEDA(1989), UEDA(1991)). Transport improvement affects the level of location surplus in both regions through reduction of generalized transport cost, and then leads to location changes.

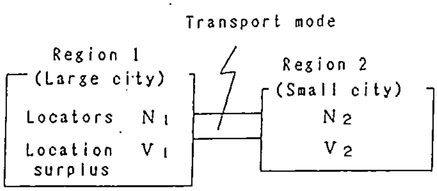

Figure 1 Sketch of spatial structure

1.2.Behavior of locators

1.2.1.Location surplus

A locator consumes(produces) goods so as to maximize its utility(profit) under given generalized prices. Since generalized price reflects transport costs and other regionäl factors, maximized utility(prōfit) depends on location. According to conventional multi-markets equilibrium theory such as Walrasian equilibrium(for instance, Varian(1984)) or spatial price equilibrium theory, exogeneous vector of transport costs, regional factors, and locators distribution determines an unique vector of equilibrium prices, and distribution of location surplus among regions endogenously (UEDA(1991)) .

For simplicity in discussion, the mechanism of market equilibrium will not be considered explicitly in this section. Details concerned to it will be discussed in Section 3. Here, location surplus V is considered to be as a function of a vector of locators distribution $[N_1, N_2]$ and a vector of transport cost t as follows.

$$V_i=V_i(N_i,N_j,t) \quad (i=1,2) \ (i\neq j) \qquad (1)$$

where subscript i and j label regions.

1.2.2.Location choice behavior

Location choice behavior will be represented as binary logit model as follows.

$$P_i=\exp(\theta V_{di})/\Sigma_j \exp(\theta V_{dj}) \ (i=1,2) \ \ (j=1,2) \qquad (2)$$

where, P represents proportion of location choice, subscript d labels deterministic part of location surplus, and θ is parameter of logit model.

1.3.Spatial equilibrium of locators distribution

As above mentioned, the total of locators distributed into two regions, is assumed to be fixed. Which will be represented as follows.

$$N_T = N_1 + N_2 \qquad (3)$$

where subscript T means total.
In spatial equilibrium of locators distribution, the number of locators in each region is expressed by,

$$N_i = N_T \exp(\theta V d_i) / \Sigma_j \exp(\theta V_{dj}) \quad (i=1,2) \quad (j=1,2) \qquad (4)$$

In addition to the above condition, the deterministic parts of location surplus equal to the level represented by (2).

$$V_{di} = V_i(N_i, N_j, t) \quad (i=1,2) \quad (i \neq j) \qquad (5)$$

Locators distribution in equilibrium $[N_{e1}, N_{e2}]$ satisfies (4)and(5), that is, it is a solution of these equations. Here, subscript e means variables in equilibrium state. Solution can be illustrated as a crossing point of curves in Figure 2.

Curves in the figure are drawn with the following formulas.

Curve A:

$$V_A = V_1(N_1, t) - V_2(N_1, t) \qquad (6)$$

Curve B:

$$N_1 = N_T / \{1 + \exp(-\theta V_B)\}, \text{ or } V_B = V_{d1} - V_{d2} \qquad (7)$$

Considering assumption (3), variable N_2 is omitted here in the above formula and in the figure.

Curve A shows that locators distribution N_1, determines the gap of location surplus V_A between two regions. On the contrary, curve B shows that gap of location surplus V_B, determines locators distribution N_1. Needless to say, curve B is a logistic curve. It should be noted that the vector of transport costs t is reflected only in V_A, not in V_B.

Existence of equilibrium can be easily proved by Brouwer', fixed point theorem, because the domain of $[N_1, N_2]$ is a kind of simplex. However, equilibrium is not always unique, as illustrated in Figure 2. Condisering the shapes of curve A, we can illustrate the case that there are a few equilibrium points, as shown in Figure 3.

Next, what should be discussed is stability of equilibrium. The analogy of conventional market equilibrium, where equilibrium price is represented as the crossing point of demand and supply curves, gives the stability condition of the above spatial equilibrium of locators distribution. Then, curve A can be regarded as demand curve, and curve B as supply curve. According to Samuelson's dynamic stability condition, the stability of each equilibrium point illustrated in Figure 2 and Figure 3 can be discriminated as shown in Figure 4 and Figure 5, respectively.

Among equilibrium points illustrated in Figure 5, two of them are stable, and one is unstable. Since it was already assumed that Region 1 is larger than Region 2, the stable point in the right side in Figure 5 should be adopted as the equilibrium point to analyze.

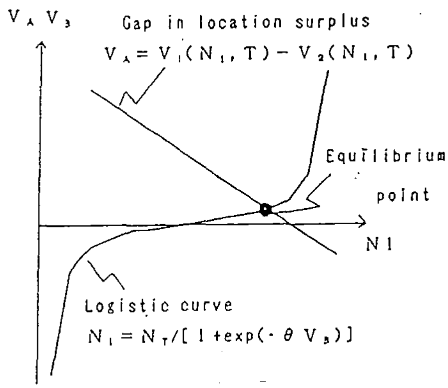

Figure 2 Representation of equilibrium as crossing point (1).

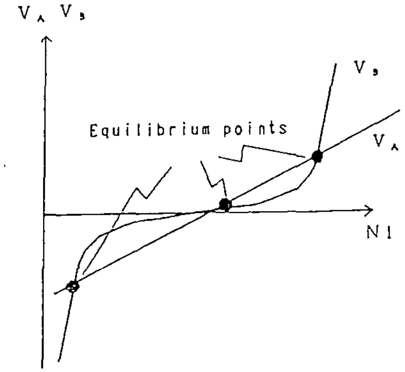

Figure 3 Representation of equilibrium as crossing point (2)

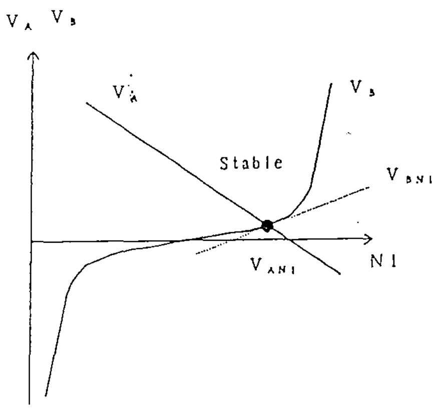

Figure 4

Stability of Equilibrium (1)

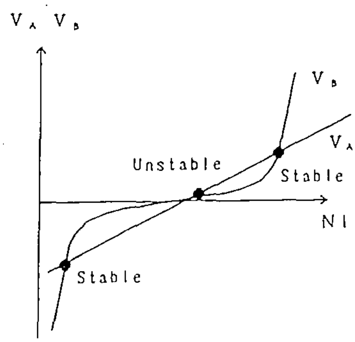

Figure 5

Stability of Equilibrium (2)

2.SKETCH OF IMPACTS OF TRANSPORT IMPROVEMENT ON LOCATION CHANGES

Any pattern of location changes can be described as the movement of stable equilibrium point illustrated in Figure 2 ~ 5, which is caused by shift of curve A and curve B. However, the vector of transport costs is reflected only in curve A. Transport improvement, therefore, causes the shift of only curve A.

So far as stability condition is satisfied, the following relation can be easily understood, as shown in Figure 6. If transport improvement makes curve A to shift upward, then a equilibrium point will move to the right side. On the contrary, if curve B shifts downward then the point will move to the left side. In other words, if the gap of location surplus $V_A = V_1 - V_2$, increases, then the number of locators in Region 1 increases. Thus impacts of transport improvement on activity locations can be known by analyzing shift of curve A.

Here, some interesting example of location changes illustrated from in Figure 7 and Figure 8. In these figures, the number of locators in region 1 is drawn under the assumption that transport improvement makes curve A to shift downward smoothly. Figure 7 shows trajectory of unique equilibrium point, which moves to the right side continuously. This was drawn with the downward shift of curve A. On the contrary, Figure 8 shows that trajectory of stable equilibrium point is discontinuous because of the following reason.

Initially unique and stable equilibrium point appeared, but with more shift of the curve. An unstable equilibrium point and a stable one appeared, and finally initial stable equilibrium point vanished. Therefore, the number of locators in regions 1 decreases discontinuously with jumping.

This change is one kind of catastrophe, which is a remarkable characteristic of non-liner systems. Even depending on initial conditions and magnitude of transport improvement, there is a possible case that transport improvement causes a sudden decline of agglomeration in larger region and then growth of smaller region, on the other hand.

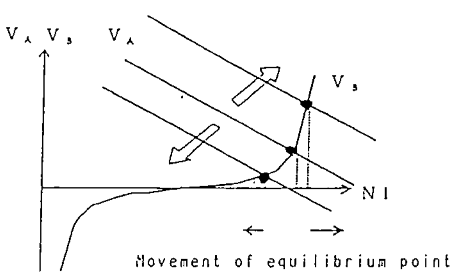

Figure 6 Location changes as the movement of equilibrium point

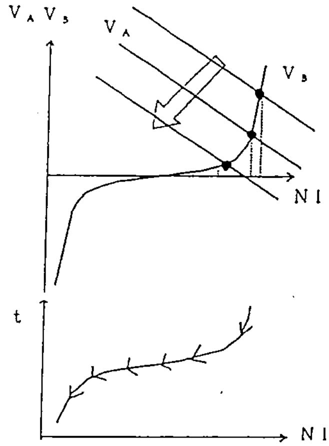

Figure 7 Trajectory of unique equilibrium point with decreasing transport cost

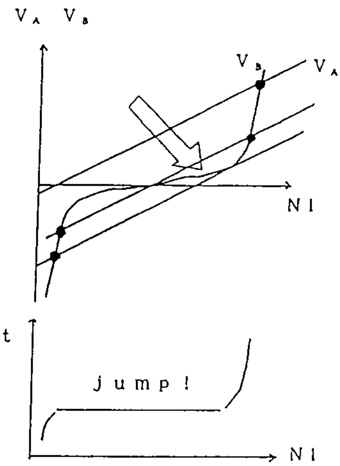

Figure 8 Trajectory of stable equilibrium point with decreasing transport cost

3. LOCATION CHANGES UNDER THE SPECIFIED STRUCTURE OF MARKETS

In the previous section, location surplus was not modeled explicitly. In this section, market structure of non-daily immobile goods will be modeled, so as to analyze location changes of firms with the curves discussed before.

3.1.Outline of the specified model

The model specified in this section focuses on the structure of the market of non-daily immobile goods. Non-daily immobile goods can be supplied only at the place of production and consumed in non-daily frequence. (See NAKAMURA and UEDA (1989)). Each region is assumed to have a market of non-daily immobile goods. Any firm can supply them only at its own region, while consumers must pay passenger transport cost to access such a place. Also assuming that there are two regions connected by a single transport mode, consumers can demand such goods in markets in both regions.

3.2.Firm's behavior and its location surplus

Producer's price in each region is the market price itself, not the generalized price. In this analysis, since enlargement of demand caused by transport improvement is focused on, production technology of firms is modeled as simply as possible. Firm's behavior, therefore, will be represented by a priori supply function which is identical to any firm regardless to its location.

Location surplus of firm is profit, as explained before, which can be formulated as producer's surplus with the assumption of price-taking behavior. Thus, location surplus is expressed as below.

$$V_i = \int_{0-p_i} S\ (p_i)\ dp_i \qquad (8)$$

where p represents market price in region i .

3.3.Consumer's behavior and agglomeration effects on demand side

A consumer can choose the amount of goods and the place of purchase. In such choice behavior, consumer considers market price, necessary passenger transport cost, and other factors such as quality of goods, certainty of purchasing, and so on. These factors affecting demand will be combined into a generalized price as follows.

$$q_{ij} = p_j + t_{ij} - f_j \qquad (9)$$

where, t represents passenger transport cost per unit of goods to consume, and f other demand affecting factors. In addition, subscript i labels where the region where consumer locates, and subscript j, does a purchasing place.

Amount of goods purchased at each region is formulated as independent demand function as follows.

$$c_{ij} = c\ (q_{ij}) \qquad (10)$$

where c_{ij} represents amount of goods purchased.
Fixing the purchasing place, a consumer chooses amount of goods to consume, which is represented as independent demand function. Then, realized level of utility derived from consumption can be measured with consumer's surplus as follows.

$$CS_{ij} = \int_{q-\infty} c\ (q_{ij})\ dq_{ij} \qquad (11)$$

According to the realized level of utility for each region, consumer chooses purchasing place. This choice behavior of purchasing place will be formulated as logit model as follows.

$$R_{ij} = \exp(\alpha CS_{ij}) / \Sigma_{j'} \exp(\alpha CS_{ij'}) \qquad (12)$$

where R is proportion of choice.
Combining independent demand function and proportion of choice in

purchasing places, the aggregate demand of consumers in region i to firms in region j is represented as follows.

$$D_{ij} = n_i R_{ij} c\ (q_{ij}) \qquad (13)$$

where n is the number of consumers in region i.
The above demand function reflects substitution between goods supplied in each region, and then interregional competition of firms in attraction of demand is caused.

In this model, demand affecting factor f, is assumed to reflect agglomeration effect of firms on demand side. It would be natural that quality competition of firms is more severe in firm-agglomerating region than in others, and then lead to supply of better quality of goods. Also it can be easily supposed that consumer can purchase goods more certainly in firm-agglomerating region than in others. Agglomeration of firms, thus, raises up demand, while it makes price competition in interregional market more severely. This effect on demand side will be expressed with assuming that f_j is as increasing function of number of locating firms N_j. According to the definition of generalized price, the increase in f raises up the demand level as well as price reduction.

3.4.Market clearing condition

Market in each region must be cleared, that is, aggregate demand and supply must be balanced as the following equations

$$\Sigma_i n_i R_{ij} c_{ij} = N_j s_j \quad (i=1,2),(j=1,2) \qquad (14)$$

where the left hand represents the aggregate demand at market in region j, and the right hand does the aggregate supply there.

Fixing N_j, eqs.(14) contains only market prices p_1 and p_2, as unknown variables. Solving them, so far solution is unique, market prices are represented as functions of locators distribution $[N_1, N_2]$, and the vector of transport costs. Location surplus of firm can be calculated with such solved prices according to its definition as already shown in (8). Then it leads to be a function with the same form as shown in Section 1, that is, $V_j = V_j(N_i, N_j, t)$.

3.5 Numerical examples of location changes

In this analysis, 4 typical cases will be examined, which are summarized in Table 1. In cases (a) and (b) there is not the agglomeration effect as explained in section 3.3. On the contrary, there it is in cases (c) and (d). Difference between case (a) and case (b), as well as between case (c) and (d), is the distribution of consumers.

Since market clearing conditions have a non-liner structure, it is very difficult to solve them analytically. In this section, some numerical examples will be shown so as to illustrate plausible location changes caused by transport improvement. Examples were calculated with specifying demand and supply functions and with setting parameters as shown in Table 2. Figure 9 shows shift of curve A and curve B, which were drawn with numerical calculation, according to the level of interregional transport costs. As already explained in Section 2, the movement of crossing points represents location changes of firms. Next, each case from (a) to (d) will be examined respectively.

In case (a) the gap of location surplus V_A, represented by curve A, decreases with increasing number of locators, N_1 in Region 1, because, the increase in competitors in Region 1 leads to less profit, while in region 2 it leads to more profit. Any reduction of interregional transport cost makes curve A shift downward in case (a), which causes the movement of crossing point for the left side. Thus, in case (a), transport improvement results in the dispersion of locators from larger region to smaller region.

In case (b) the directions of location changes are same as that in case (a), although magnitudes of changes are different. The difference in setting of case (a) and case (b) is the distribution of consumers, which might causes the different magnitude of impact of transport improvement on location changes. At the intersection of curve A with the horizontal axis, as marked in case (a) and case (b), location surplus in both regions are equal. Proportion of number of locators are equal to that of consumers in those cases.

In cases (c) and (d) gap of location surplus V_A, represented by curve A, firstly increases to a certain extent and then turns to decrease, and finally increases again in accordance with number of locators in region 1. This shape of curve A is due to agglomeration effect on demand side and severe competition in markets, the former of them raises up profit through increase in demand, and the latter decreases through share competition of market. Reduction of interregional transport cost makes curve A to shift downward in the left side and upward in the right side. In case (c) there are crossing points in the downward shifting section of curve A. Thus location changes, represented by the movement of crossing points for the left side, indicates teh dispersion of locators from larger region to smaller one. However, in case (d) the crossing point locates in the section where curve A shifts upward, then it moves to the right side. Therefore, in case (d), transport improvement results in more agglomeration of locators in larger region.

Direction and relative magnitude of location changes examined above are summarized in Table 3. The comparison of cases shows that only in case (d) transport improvement results in more agglomeration of locators because of agglomeration effect on demand side. It is needless to say that outcomes illustrated here can be justified only as far as the specification in numerical simulations is realistic. However, the mechanism of agglomeration and dispersion of locators, as discussed in this paper, is plausibile to a certain extent.

Table 1 Setting of cases in numerical simulation

		Agglomeration effect on demand side	
		Without	With
Proportion in numbers of consumers (n_1/n_2)	Large	Case (a)	Case (c)
	Small	Case (b)	Case (d)

Table 2 Setting of parameters and specification of functions in numerical simulation

	Case (a)	Case (b)	Case (c)	Case (d)
Number of consumers	$n_1=990000$ $n_2=10000$	$n_1=800000$ $n_2=200000$	$n_1=990000$ $n_2=10000$	$n_1=800000$ $n_2=200000$
Demand function	$c_{ij}=8500-10(p_j+t_{ij})$		$c_{ij}=8500-10(p_j+t_{ij}-0.01N_j)$	

	All cases
Parameter in logit model for purchasing places	$\beta=0.0001$
supply function	$s_j=1000p_j$
Total number of firms	$N_T=10000$
Parameter in logit model for location	$\alpha=0.000001$
Transport cost	$t_{12}=t_{21}=250, 200, 150, 100, 50$ $t_{11}=t_{22}=10$

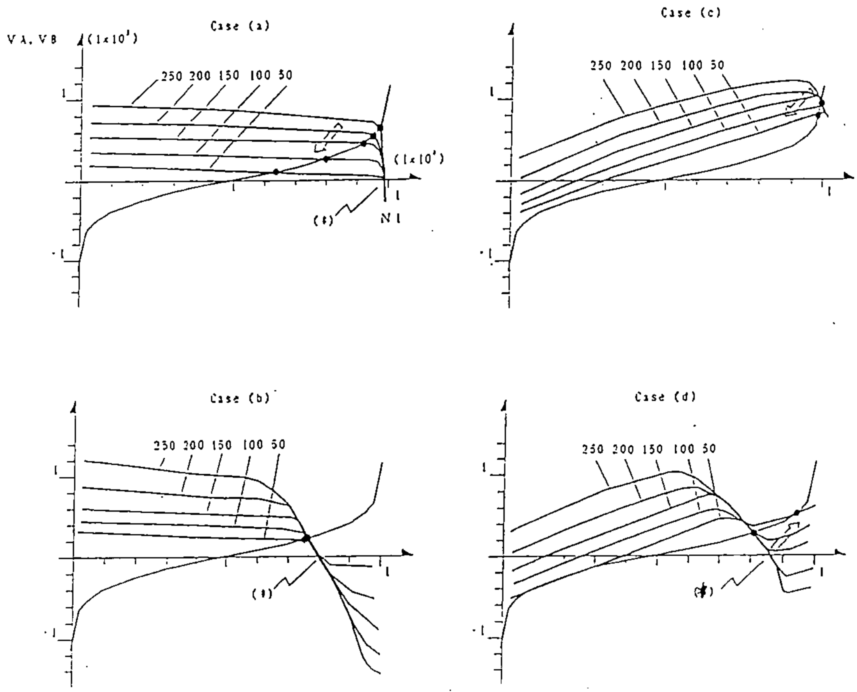

Figure 3 Location changes illustrated with numerical simulation

Table 3 Comparison of location chanegs in each case

		Agglomeration effect on demand side	
		Without	With
Proportion in numbers of consumers (n_1/n_2)	Large	Case (a) N_1 ↘ N_2 ↗	Case (c) N_1 ↘ N_2 ↗
	Small	Case (b) N_1 ↘ N_2 ↗	Case (d) N_1 ↗ N_2 ↘

4.CONCLUSION AND FUTURE OF FUTURE RESEARCH

In this paper, the model analysis on location changes caused by interregional transport improvement was presented by using the concept of location surplus. The conditions of agglomeration or dispersion were examined even though outcomes were illustrated by numerical simulations.

Numerical examples suggested that agglomeration effect on demand side is one of the important conditions, under which transport improvement results in more agglomeration of locators in larger region. Although this suggestion might depend on the range of parameters, this paper succeeded in simulating the so called "backwash effect" or "pump-up effect" of transport improvement.

There still remain many tasks for future research. One of them is finding realistic range of parameters, and the other is the extension of theoretical frame work of the model to deal with multi-types of locators, goods, and regions, that is, general equilibrium in a strict sense.

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