Study on Population Distribution Changes due to Development of Inter-regional Transportation in Japan

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ABSTRACT

The development of inter-regional transportation, such as the *Shinkansen* and the expressway projects, makes possible regional interchanges which could lead to higher growths for both regions. However, there are cases when the agglomerate regions enjoy more benefits than the non-agglomerate ones. This paper attempts to present a population distribution model which can forecast the inter-regional transportation developments, and estimate the population distribution changes due to future *Shinkansen* projects. This project geared towards the possibility of population de-concentration in urban areas, through the development of transportation systems.

1. Introduction

Like any other Asian country, Japan has suffered from over-concentration of population, economic activities and administrative power in its capital, Tokyo. About one fourth of national population is gathered in Tokyo Metropolitan Area and about half of its annual commercial sales is concentrated in there. The over-concentration of population had caused various problems such as high land prices, serious working conditions and wretched commuter situations. For the past 30 years, many policies have been implemented to solve those problems. These policies include inter-regional transportation projects like the *Shinkansen* (super express railway) and the expressways projects. It has been said that they help de-concentrate the population because it can provide transportation convenience for people living in the rural regions[1)]

But recently some people have suggested that there will be more concentration of population in the urban regions when inter-regional transportation facilities between urban and rural region are constucted[2)]. Their study says that transportation development works like a straw and population and economy are absorbed by the urban region.

If that is true, we have to consider the possibility of concentration of population caused by transportation development. Ueda and Nakamura had arranged the relationship between inter-regional transportation development and growth or decline of regions through a demonstrative analysis about the *Tohoku Shinkansen* and the *Jyoetu Shinkansen*[3]. But their study was limited to a qualitative evaluation based on the statistics data. As concerns about population distribution models, various model were constructed by regional scientists such as Ueda and Matsuba[4], Kobayashi and Okumura[5] , Mun[6] and Morisugi, Ueda and Koike[7] . But these studies were limited only to model analysis or numerical tests.

In this study, taking note that about three-fourths of the population change across the region is caused by employment reasons[8], it is supposed that population change is influenced by the variation in located patterns of employee. Based on this supposition, a population distribution model is constructed using the theory of company's behavior when some inter-regional transportation are developed. The parameters of this model are estimated by using past data. After this, an inter-regional transportation in future is constructed and its influence on the population is forecast.

2. Theory of Population Distribution Model

The distribution pattern of employee is expressed in a logit model as below:

$$P_i^k = \frac{\exp(\omega V_i^k)}{\sum_j \exp(\omega V_j^k)} \tag{1}$$

subject to $V_i^k = \alpha_0 + \alpha_1 \ln(r_i) + \alpha_2 \ln(w_i^k) + \alpha_3 \ln(Ma_i) + \alpha_4 \ln(Mb_i)$ (2)

Where :
- P_i^k is a probability of location of region *i*, type of industry *k*
- V_i^k is a function of maximized profit of region *i*, type-of industry *k*
- ω is a distribution parameter of errors attached with V_i^k ($\omega \equiv 1$)
- r_i is a land price of region *i*
- w_i^k is a wage of region *i*, type of industry *k*
- Ma_i is an inter-regional market size of region *i*
- Mb_i is a local regional market size of region *i*
- $\alpha_0, \ldots, \alpha_4$ are unknown parameters

To Give a land supply amount fixed as *Si*, area space of region *i*, the land price function is expressed as below from the market balance[9]:

$$r_i = r_i\left[w_i^k, Ma_i, Mb_i, S_i\right] \tag{3}$$

In a similar way, to give a employee supply amount expressed by a function of population, the wage function is expressed as below from the market balance:

$$w_i^k = w_i^k\left[r_i, Ma_i, Mb_i, N_i\right] \tag{4}$$

Where : N_i is a population in region *i*

The inter-regional market size is assumed to have a relationship with inter-regional transportation development as it expressed below:

$$Mai = \sum_j N_j \exp\left(-\frac{\beta_1 t_{ij}}{N_i^{\beta_2}}\right) \qquad (5)$$

Where: t_{ij} is time-distance between region i and j

β_1, β_2 are unknown parameters

Based on the idea that the population of region j will be counted as a market of region i more and more when the t_{ij} is decreased by inter-regional transportation developments, the equation (5) is a decreasing function of t_{ij}.

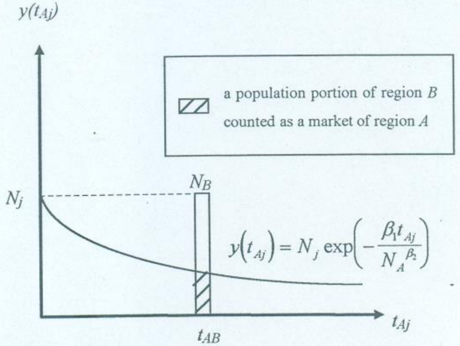

Figure 2-1 Market Size of Region *A*
(Limited to Population of Region *B*)

Fig. 2-1 shows the market size of region A is limited to population portion of region B. The domain with slant lines expresses the population portion of region B counted as a market of region A. We can see that when the t_{AB} is decreased, the square N_B will move to the left side and the space of domain with slant lines will increase. The total market size of region A is calculated by summating up the population portion of every region.

It is also assumed that the location of company has the effect of concentration so that the equation (5) is increasing function of an own population, N_i. The more own population increases, the more market size increases based on the idea that an urban region has the advantage on location as the result of the concentration.

The local region market size is assumed to have a relationship with equipment of urban development as it expressed below:

$$Mb_i = \beta_3 N_i q_i \tag{6}$$

Where: q_i is an equipment degree of urban development of region i
β_3 is an unknown parameter

The population of region i is given by the function of number of employees.

$$N_i = N_i\left[\sum_k Q_i^k\right] \tag{7}$$

$$Q_i^k = P_i^k Q^k \tag{8}$$

Where: Q_i^k is a number of employees of region i, type of industry k

Total population N and total numbers of employee for each type of industries Q^k are estimated by regression analysis from past values.

Setting up these simultaneous equations, we can get population of region i. In this study a group of these simultaneous equations is supposed as a population distribution model.

3. Result of Parameter Estimation of Population Distribution Model

Japanese land is divided to 11 regions (*see Fig. 3-1 & Tab. 3-1*) and the parameters of the population distribution model are estimated by using such data: population of each regions, number of employees for each type of industry, land prices, average wages of each types for industry and time-distances[10] between prefectures in 1975, 1980, 1985 and 1990. As for concerned industries, three types were selected: manufacture, wholesale-retail and service because their employees have been counted about 80% of the total number of workers in all industries. On the traffic mode, time-distances of air plane is not used because in this data their time schedule is not included so there is a possibility of over-evaluating the air plane data.

First, the parameters of equation (1) are estimated (*see Tab. 3-2*). As concerns β_1 and β_2 of equation (5), they are set up to maximize R^2. About β_3 of equation (6), we can consider it including α_0 of equation (2) so that it set up to constant, 1. Next, the parameters of equation (3) are estimated (*see Tab. 3-3*). The equation is applied to logarithm regression, and employee densities of each regions and their observation years are selected as the independent variables. About the parameters of equation (4), the equation is also applied to logarithm regression and number of employees of each regions and their observation years are selected as independent variables (*see Tab. 3-4*). The equation (7) is also applied to logarithm regression and each populations are expressed by the number of employees of per region (*see Tab. 3-5*). About the national population and total number of employees of each type for industry, the equations are applied to liner regression and expressed by observation years (*see Tab. 3-6*). As concerns about equipment degrees of urban development of each region, the equation (6) is applied to logistic regression, and future values are given by their regression.

Above this, each model has sufficient R^2 and t-value, so we can consider this population distribution model statistically sufficient. In addition to this, we can see the comparison between observed values and estimated one in 1975, 1980, 1985 and 1990 (*see Fig.3-1*). Every correlation exceeds 0.95 so that we can consider this model to be estimated accurately.

Figure 3-1 Region Distinctions

Table 3-1 figures of Regions

	Population (*1000:1991)	Habitable Area (Km^2:1990)	Central City (Time-Distance from Tokyo Special Wards: Hours)
Hokkaido	5,644	26,754	Sapporo (10.82)
Tohoku	9,791	20,027	Sendai (1.8)
Tokyo	31,494	8,799	Tokyo special wards (-)
Kita-kanto	6,775	9,057	Utsunomiya (0.88)
Koushin-etsu	5,496	8,789	Nagano (2.5)
Nagoya	14,167	9,671	Nagoya (1.8)
Hokuriku	3,105	4,286	Kanazawa (4.14)
Osaka	20,160	8,293	Osaka (2.8)
Chugoku	7,747	8,286	Hiroshima (4.42)
Shikoku	4,236	4,804	Matsuyama (6.66)
Kyushu	13,301	15,273	Fukuoka (6.04)

Note) Time-Distance are by using data of railways and roads in 1990

Table 3-2 Estimation of Employee Distribution Function

	Constant	Coefficients of each variables (t-value)				R^2	Parameters of Ma Function	
		ln $[r_i]$	ln $[w_i^k]$	ln $[Ma_i]$	ln $[Mb_i]$		β_1	β_2
Manufacture	-0.22	0.04 (0.9)	0.44 (1.8)	0.58 (9.8)	0.49 (8.6)	0.95	20.0	0.25
Wholesale-Retail	0.24	-0.1 (2.6)	-1.0 (4.5)	0.61 (7.6)	0.14 (1.3)	0.97	1.0 $*10^{-14}$	2.0
Service	0.05	-0.1 (0.5)	-0.2 (0.4)	0.64 (5.3)	0.06 (0.4)	0.94	1.5 $*10^{-14}$	2.0

Table 3-3 Estimation of Land Price Function

	Constant	Coefficients of each variables (t-value)		R^2
		ln [Employee Density]	ln [Year]	
	5.00	$1.46*10^{-3}$ (10.0)	0.08 (9.0)	0.83

Note) Year = observed year - 1900

Table 3-4 Estimation of Wage Function

	Constant	Coefficients of each variables (t-value)		R^2
		ln [Number of employees]	ln [year]	
Manufacture	8.17	$3.48*10^{-8}$ (5.7)	0.05 (15.4)	0.88
Wholesale-Retail	9.03	$1.53*10^{-8}$ (3.1)	0.04 (14.8)	0.86
Service	9.20	$1.27*10^{-3}$ (3.6)	0.04 (22.1)	0.93

Note) Year = observed year - 1900

Table 3-5 Estimation of Population Function

Region	Constant	Coefficients of each variables (t-value)		R^2
		ln [number of employees]		
Hokkaido	$-1.48*10^7$	$1.43*10^6$	(4.6)	0.84
Tohoku	$-1.43*10^7$	$1.61*10^6$	(8.4)	0.95
Tokyo	$-2.42*10^8$	$1.68*10^7$	(19.8)	0.98
Kita-kanto	$-2.66*10^7$	$2.26*10^6$	(13.0)	0.97
Koushin-etsu	$-1.24*10^7$	$1.23*10^6$	(8.5)	0.95
Nagoya	$-7.12*10^7$	$5.48*10^6$	(15.1)	0.97
Hokuriku	$-1.14*10^7$	$1.04*10^6$	(7.1)	0.91
Osaka	$-1.35*10^8$	$9.80*10^6$	(16.9)	0.97
Chugoku	$-2.58*10^7$	$2.27*10^6$	(6.4)	0.89
Shikoku	$-8.10*10^6$	$8.80*10^5$	(4.6)	0.84
Kyushu	$-3.92*10^7$	$3.45*10^6$	(8.6)	0.95

Table 3-6 Estimation of Total Population/Number of employees Function

		Constant	Coefficients of each variables (t-value)		R^2
			ln [year]		
Population		$4.01*10^7$	$9.20*10^5$	(26.5)	0.99
	Manufacture	$-1.42*10^6$	$1.71*10^5$	(4.5)	0.91
	Wholesale-Retail	$-1.24*10^7$	$3.28*10^5$	(22.7)	0.98
	Service	$-1.48*10^7$	$3.14*10^5$	(23.4)	0.99

Note) Year = observed year - 1900

Figure 3-1 Observed and Estimated Values (1990)

4. Case Study

In this chapter, as a case study, planning *Shinkansen* projects[11)] in Japan are applied to the population distribution model. The two cases are supposed: with developing planning *Shinkansen* projects and without developing planning *Shinkansen* projects. At *With Projects Case* it is supposed that the constructions of the planning *Shinkansen* will finish in 2015. On the other hand, at *Without Projects Case* it is supposed that the development of *Shinkansen* will be same as existing condition (*see Fig. 4-1*).

Population distribution changes of each region are estimated at this two case. Taking for example the result of population distribution change of *Kyushu* region is shown in *Fig.*

4-2. It is shown by percentage for national population. In this case, without depending on projects, the population ratio of *Kyushu* region will decrease. The population outflow, however, relatively will be lessen by these projects. We can see the result of estimated population distribution change of *Without Projects Case* at *Fig. 4-3*. This figure shows the degree of changes of population ratios between 1995 and 2025 by four categories. According to this, the population ratios of *Tokyo*, *Osaka* and *Nagoya* regions will increase.

We can see the result of estimated population distribution difference between *With Projects Case* and *Without Projects Case* at *Fig 4-4*. This figure shows the degree of difference of population ratios between *With Projects Case* and *Without Projects Case* by four categories. At *With Projects Case* the population ratios of *Koushin-etsu* , *Tohoku* and *Kyushu* regions under *Shinkansen* projects will become larger than those *Without Projects Case*. But The ratios of *Hokkaido* and *Hokuriku* regions also under planing will decrease. One the other hand, the ratios of *Tokyo* and *Osaka* regions will decrease so that we can consider the de-concentration of population in agglomerate areas as affected by the projects. The result of estimated population distribution change depends on the change of employees distribution changes for each industries so that we have to see the results about number of employees change for each industries. The ways to express each figures are the same as that of *Fig. 4-4*.

At First, about the manufacture industry (*see Fig. 4-5*), the trend of de-concentration will become stronger by the projects. Especially, ratios of *Hokkaido* and *Kyushu* regions will become much larger by the project. Next, about the wholesale-retail industry (*see Fig. 4-6*), its condition is similar to the population change: ratios of *Tohoku* , *Koushin-etsu* and *Kyushu* regions will become larger, but ones of *Hokkaido* and *Hokuriku* regions will become smaller though all those regions are under the *Shinkansen* projects. Lastly, about the service industry, ratios of *Tokyo*, *Osaka* and *Kyushu* regions will become larger with the projects. As far as service industry, the concentration to agglomerate regions will occur.

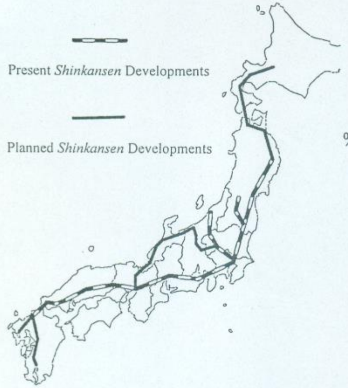

Figure 4-1 *Shinkansen* development

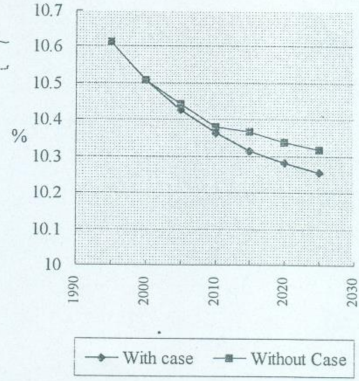

Figure 4-2 Population distribution change (*Kyushu* region)

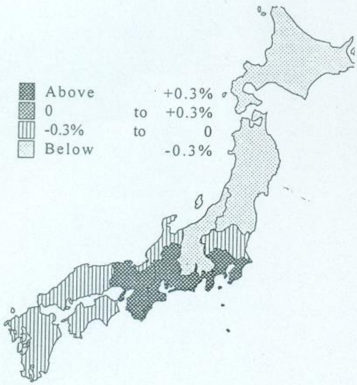

Figure 4-3 Estimation of Population Distribution Change (1995 - 2025: *With Project Case*)

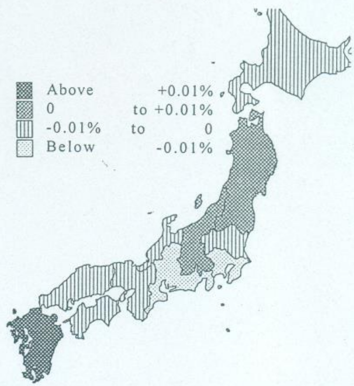

Figure 4-4 Estimation of Population Distribution Change (2025: *With* and *Without case*)

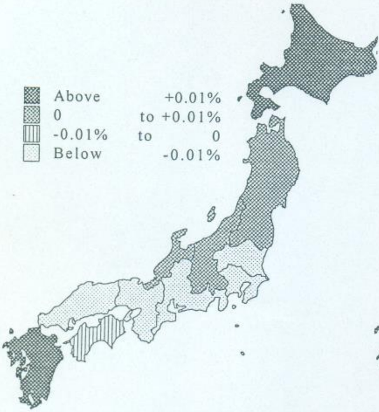

Figure 4-3 Estimation of Number of employees Distribution Change: Manufacture (2025:*With* and *Without Case*)

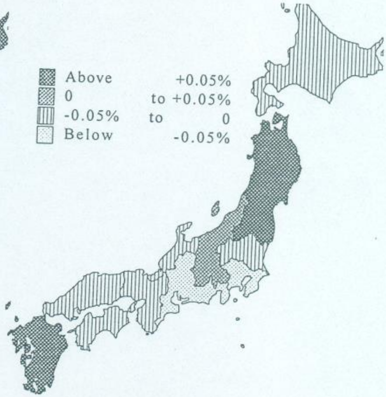

Figure 4-4 Estimation of Number of employees Distribution Change: Wholesale-Retail (2025:*With* and *Without case*)

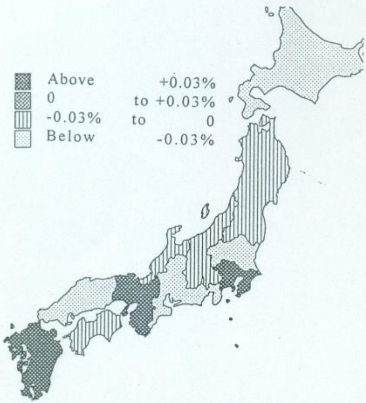

Figure 4-3 Estimation of Number of employees Distribution Change: Service (2025:*With* and *Without Case*)

5. Conclusion

We find the probability of de-concentration of population by the planned *Shinkansen* development in this study. Noticing the employees distribution changes of each type of industry, about those of the manufacturing, the de-concentration of employees on agglomerate areas will become strong while employees of the service will concentrate on the agglomerate areas by this *Shinkansen* plan. Therefore, we can assume that the de-concentration will be promoted while regional specialization of industry will be promoted by the project.

This population distribution model has problems that we have to improve. First, in this study we assumed that population changes across regions are caused by employee reasons. We should consider another reasons. And as inter-regional transportation, we analyzed only railway so that we need think about another mode.

If we think applying this model to the Philippines, first we should consider two points: One, about industry of informal section. As you know, there are many people who migrated to city area, particularly in Metro Manila, and worked on informal sector. Generally, these people have come on the premise of finding good jobs and living better in the city, thus, leaving their previous jobs or occupation behind. So if we apply this population model to the Philippines, we may under-estimate the concentration in the agglomerate region. Two, in the Philippines the most important regional transportation mode is not railway but airplane. However, it is difficult to evaluate the time-distance by airplane because we need to calculate not only the travel but also the waiting time and the possibilities of delay. Thus, before we think of applying this model, then we should first find a way to cope with the time-distance by airplane.

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