# The Relationship between Migration and Distance in Japan

# The Relationship between Migration and Distance in Japan

**Takashi ABE***

## 1 Gravity model

Distance is much influential to migration as intervening barrier. It is an important factor to control the accuracy of information about the destinations. Many researchers accordingly have tried to specify the relationship between migration and distance, mostly with the introduction of "Gravity model".

At first, Ravenstein (1885) suggested that "Gravity model" should be applied to the relationship between migration and distance. Expression and evaluation of this model were given by Young (1924), Isard (1960) and others. The common structure of their expressions are represented as the next equation,

$$F_{ij} = f(M_i, M_j, D_{ij}) \tag{1}$$

$F_{ij}$=number of migrants from region $I$ to region $J$.

$M_i, M_j$=sizes of region $I$ or region $J$ which are shown by population, numbers of out-migrants or in-migrants, $\cdots$ etc.

$D_{ij}$=distance between regions $I$ and $J$.

In this paper, the author introduces the "Gravity model" which was given by Isard and Smith (1949) and expressed by the next equation.

$$F_{ij} = k \frac{F_{i\cdot} \times F_{\cdot j}}{F_{\cdot\cdot} \times D_{ij}^{\alpha}} \tag{2}$$

$F_{ij}$=number of migrants from region $I$ to region $J$

$F_{i\cdot}$=the total number of out-migrants from region $I$

$F_{\cdot j}$=the total number of in-migrants to region $J$

$F_{\cdot\cdot}$=the total number of internal migrants in Japan

$D_{ij}$=distance between region $I$ and region $J$

$\alpha, k$=parameters.

The fitness of this model is not particularly discussed here.

Equation (3) is derived from equation (2) by logarithmic transformation

$$\log(F_{ij}) = \log\left(k \frac{F_{i\cdot} \times F_{\cdot j}}{F_{\cdot\cdot}}\right) - \alpha \log(D_{ij}) . \tag{3}$$

Linear regressive functions includung number of out-migrants or in-migrants

* Miyagi Gakuin Women's College, Sendai

as functions of distance are derived from statistics regarding the inter-prefectural migration as follows,

On out-migrants from region $I$ to region $J$,

$$\log\left(\frac{F_{ij}}{F_{.j}}\right)=\beta-\alpha\log(D_{ij}) \tag{4}$$

where $\beta$=constant, so that $(F_{.i}/F_{..})$=constant for region $I$.
On in-migrants to region $I$ from region $J$,

$$\log\left(\frac{F_{ji}}{F_{j.}}\right)=\beta-\alpha\log(D_{ij}) \tag{5}$$

where $\beta$=constant, as the above.

Regression parameters-$\alpha$ and $\beta$ are derived by least squares method for each prefecture.[1] And regional differentiation of their values are used to clarify the relationship between migration and distance for each prefecture.

In the following statements about the model, the great circle distance between the centroids by population in each prefectures are taked for $D_{ij}$, where $D_{ij}$ is derived as follows,

$$D_{ij}=R\times\omega \tag{6}$$

whece

$$\omega=\arctan\frac{\sin\omega}{\cos\omega},\quad \sin\omega=\sqrt{1-(\cos\omega)^2},\quad \cos\omega=\cos(|\alpha-\gamma|)\times\cos(|\beta-\delta|)$$

$\alpha$=longitude of centroid by population in region $I$
$\beta$=latitude of centroid by population in region $I$
$\gamma$=longitude of centroid by population in region $J$
$\delta$=latitude of centroid by population in region $J$
} (in radian angle)

$R$=6367 km, which is a mean value of the radius of the earth.

These centroids are calculated from Population Census in 1960 by the Bureau of Statistics.

Other measurements for $D_{ij}$ are possible, for example, the adoption of distances along the railway among prefectural capitals seems to be valid. In this case, however, the correlation coefficients between migration and distance change little or become rather lower by the adoption of the railway distances.

Therefore the above measurements are acceptable in this paper.

## 2 Effect of distance on migration and its regional variations

The regression parameters calculated for the year 1975 are shown in Table 1. The null hypotheses $H_0(r=0.000)$ are rejected in every prefectures (in 95% confidence level).

1) Number of sample is 45 because $F_{ii}=0$ and $D_{ii}=0$.

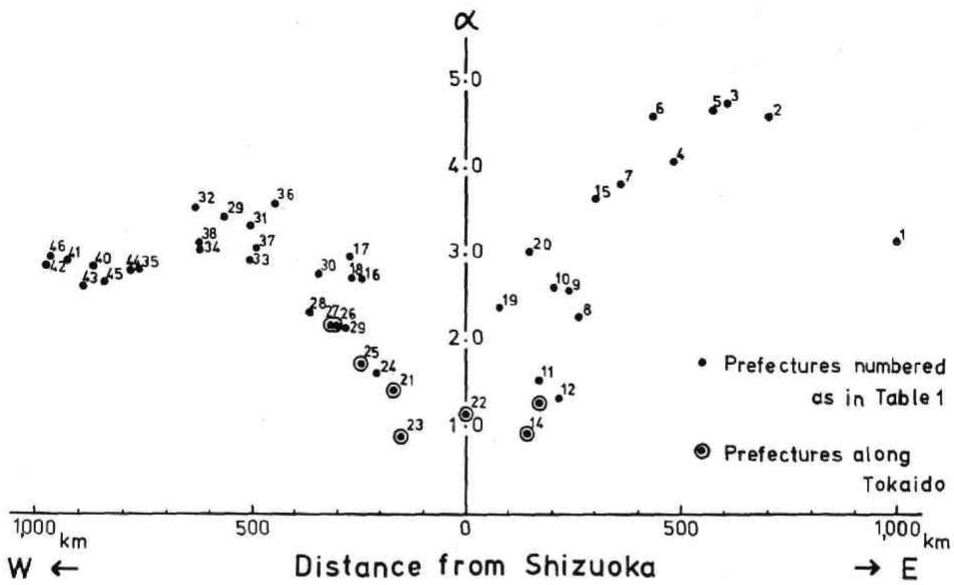


Fig. 1 Regression parameter-$\alpha$ and distance from Shizuoka (center of Tokaido)

The regression parameters-$\alpha$ for prefectures seem to vary in zonal pattern i.e. the values of $\alpha$ are correlated with distance from Tokaido (Fig. 1). Some traits of the zonal pattern are as follows,

1. The prefectures along Tokaido form the lowest zone.
2. The prefectures in Tohoku District form the highest zone.
3. The values of $\alpha$ vary gradually between the lowest zone and highest zone.
4. The values of $\alpha$ are higher in East Japan than in West Japan in general.

For the concentric pattern of the regression parameter-$\alpha$, some reasons are considered on the basis of previous researches.

1) Spatial auto-correlation

The extreme difficulties, King (1969) suggested in trying to interpret and compare parameter values of gravity model, are in spatial auto-correlation (Gould, 1975).

Japanese population has concentric distribution pattern. The total numbers of in-migrants to each prefecture-$F._j$ are distributed similarly in concentric pattern. Now, for the regression analysis to ascertain the relationship between the values of $F._j$ and distance from Shizuoka, a prefecture in center of Tokaido, the following regression equation is used,

$$\log (F._j)^* = \beta - \alpha \log (D._j)^* . \qquad (7)$$

where, $D._j$=distance from Shizuoka

* excluding Shizuoka

Table 1 Correlation coefficient-r and regression parameters-$\alpha$, $\beta$, 1975 out-migrants

| No. | Prefectures | r | $\alpha$ | $\beta$ |
|---|---|---|---|---|
| 1 | Hokkaido | −0.859 | 3.151 | 9.108 |
| 2 | Aomori | −0.893 | 4.584 | 12.143 |
| 3 | Iwate | −0.928 | 4.708 | 12.000 |
| 4 | Miyagi | −0.920 | 4.065 | 10.265 |
| 5 | Akita | −0.941 | 4.666 | 11.902 |
| 6 | Yamagata | −0.930 | 4.596 | 11.188 |
| 7 | Fukushima | −0.923 | 3.820 | 9.094 |
| 8 | Ibaraki | −0.880 | 2.283 | 5.178 |
| 9 | Tochigi | −0.855 | 2.557 | 5.732 |
| 10 | Gunma | −0.858 | 2.592 | 5.807 |
| 11 | Saitama | −0.718 | 1.536 | 3.416 |
| 12 | Chiba | −0.689 | 1.303 | 2.961 |
| 13 | Tokyo | −0.709 | 1.286 | 2.967 |
| 14 | Kanagawa | −0.511 | 0.903 | 2.072 |
| 15 | Niigata | −0.889 | 3.662 | 8.852 |
| 16 | Toyama | −0.734 | 2.734 | 6.550 |
| 17 | Ishikawa | −0.806 | 2.965 | 7.242 |
| 18 | Fukui | −0.808 | 2.716 | 6.490 |
| 19 | Yamanashi | −0.830 | 2.382 | 5.096 |
| 20 | Nagano | −0.871 | 3.024 | 6.940 |
| 21 | Gifu | −0.527 | 1.405 | 3.165 |
| 22 | Shizuoka | −0.554 | 1.140 | 2.632 |
| 23 | Aichi | −0.367 | 0.893 | 2.207 |
| 24 | Mie | −0.685 | 1.621 | 3.764 |
| 25 | Shiga | −0.650 | 1.732 | 3.993 |
| 26 | Kyoto | −0.751 | 2.200 | 5.274 |
| 27 | Osaka | −0.700 | 2.176 | 5.284 |
| 28 | Hyogo | −0.758 | 2.313 | 5.477 |
| 29 | Nara | −0.757 | 2.178 | 4.966 |
| 30 | Wakayama | −0.804 | 2.768 | 6.383 |
| 31 | Tottori | −0.808 | 3.314 | 7.936 |
| 32 | Shimane | −0.802 | 3.511 | 8.495 |
| 33 | Okayama | −0.887 | 2.944 | 7.103 |
| 34 | Hiroshima | −0.889 | 3.045 | 7.564 |
| 35 | Yamaguchi | −0.805 | 2.817 | 6.976 |
| 36 | Tokushima | −0.874 | 3.560 | 8.335 |
| 37 | Kagawa | −0.838 | 3.054 | 7.149 |
| 38 | Ehime | −0.849 | 3.251 | 7.899 |
| 39 | Kochi | −0.852 | 3.411 | 8.262 |
| 40 | Fukuoka | −0.899 | 2.852 | 7.308 |
| 41 | Saga | −0.776 | 2.938 | 6.960 |
| 42 | Nagasaki | −0.777 | 2.865 | 7.166 |
| 43 | Kumamoto | −0.775 | 2.621 | 6.415 |
| 44 | Oita | −0.813 | 2.803 | 6.793 |
| 45 | Miyazaki | −0.750 | 2.678 | 6.681 |
| 46 | Kagoshima | −0.698 | 2.994 | 7.644 |

Table 2 Correlation coefficient-r and regression parameters-$\alpha$, $\beta$, 1975 in-migrants

| No. | Prefectures | r | $\alpha$ | $\beta$ | |
|---|---|---|---|---|---|
| 1 | Hokkaido | −0.823 | 3.218 | 9.331 | |
| 2 | Aomori | −0.890 | 4.564 | 12.103 | |
| 3 | Iwate | −0.922 | 4.689 | 12.019 | |
| 4 | Miyagi | −0.918 | 3.980 | 10.068 | |
| 5 | Akita | −0.909 | 4.745 | 12.163 | |
| 6 | Yamagata | −0.915 | 4.632 | 11.364 | |
| 7 | Fukushima | −0.929 | 3.797 | 9.139 | |
| 8 | Iabaraki | −0.839 | 2.217 | 4.999 | |
| 9 | Tochigi | −0.901 | 2.660 | 6.031 | |
| 10 | Gunma | −0.895 | 2.838 | 6.450 | |
| 11 | Saitama | −0.766 | 1.648 | 3.422 | Tokyo' M.a. |
| 12 | Chiba | −0.762 | 1.337 | 2.905 | |
| 13 | Tokyo | −0.681 | 1.084 | 2.733 | |
| 14 | Kanagawa | −0.533 | 0.854 | 1.911 | |
| 15 | Niigata | −0.906 | 3.645 | 8.926 | |
| 16 | Toyama | −0.799 | 3.053 | 7.343 | |
| 17 | Ishikawa | −0.831 | 3.018 | 7.381 | |
| 18 | Fukui | −0.843 | 3.125 | 7.428 | |
| 19 | Yamanashi | −0.838 | 2.290 | 4.970 | |
| 20 | Nagano | −0.894 | 3.155 | 7.303 | |
| 21 | Gifu | −0.594 | 1.595 | 3.536 | |
| 22 | Shizuoka | −0.609 | 1.223 | 2.868 | |
| 23 | Aichi | −0.421 | 1.018 | 2.535 | |
| 24 | Mie | −0.721 | 1.798 | 4.173 | |
| 25 | Shiga | −0.698 | 2.056 | 4.576 | |
| 26 | Kyoto | −0.764 | 2.188 | 5.252 | Osaka' M.a. |
| 27 | Osaka | −0.693 | 2.170 | 5.275 | |
| 28 | Hyogo | −0.740 | 2.378 | 5.625 | |
| 29 | Nara | −0.779 | 2.273 | 4.965 | |
| 30 | Wakayama | −0.851 | 2.875 | 6.662 | |
| 31 | Tottori | −0.808 | 3.634 | 8.648 | |
| 32 | Shimane | −0.785 | 3.690 | 8.870 | |
| 33 | Okayama | −0.897 | 3.014 | 7.270 | |
| 34 | Hiroshima | −0.889 | 3.144 | 7.794 | |
| 35 | Yamaguchi | −0.848 | 2.984 | 7.464 | |
| 36 | Tokushima | −0.881 | 3.491 | 8.189 | |
| 37 | Kagawa | −0.862 | 3.352 | 7.862 | |
| 38 | Ehime | −0.845 | 3.233 | 7.855 | |
| 39 | Kochi | −0.836 | 3.290 | 7.965 | |
| 40 | Fukuoka | −0.872 | 3.037 | 7.705 | |
| 41 | Saga | −0.802 | 2.503 | 6.008 | |
| 42 | Nagasaki | −0.777 | 2.828 | 7.141 | |
| 43 | Kumamoto | −0.710 | 2.372 | 5.817 | |
| 44 | Oita | −0.818 | 2.795 | 6.835 | |
| 45 | Miyazaki | −0.735 | 2.651 | 6.588 | |
| 46 | Kagoshima | −0.708 | 2.927 | 7.527 | |

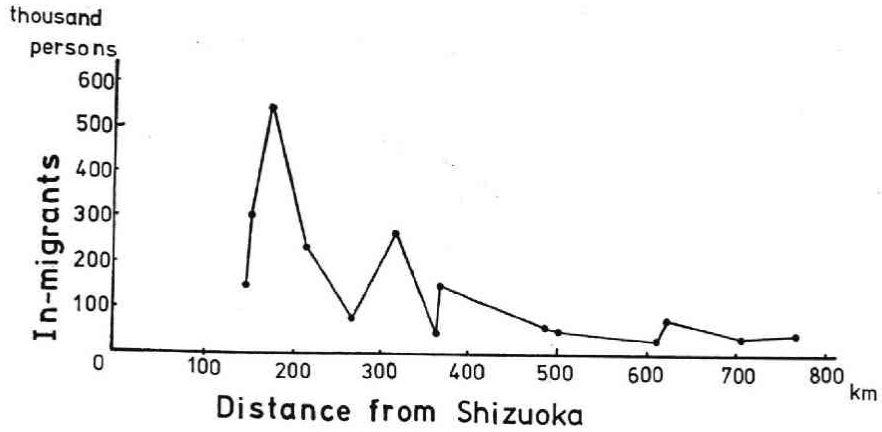


Fig. 2 The total number of In-migrant and distance from Shizuoka

The resulted relationship between the above two variables is not of the significant correlation on the 95% level (r=–0.209).

On the other hand, at the test of 14 prefectures along Pacific Coast and Setonaikai in Honshu, excluding Mie and Wakayama in Kii Peninsula, the total number of in-migrants to these prefectures and distance from Shizuoka are plotted as a damped oscillation curve on the graph (Fig. 2).

We accordingly can infer that the distribution of $F_{\cdot j}$ is autoregressive scheme. And the reason why regression parameters distribute in concentric pattern may be reduced to this fact.

2) Large gravity of Tokyo Meterpolitan area

Inter-prefectural migrants into Tokyo (541, 685 persons in 1975) is the largest in East Japan, and Tokyo Metropolitan area is growing up continuously. For example, the commuting area to Tokyo involves some adjoining prefectures, Saitama, Chiba and Kanagawa.

It is reasonable, therefore, to treat in-migrants to Tokyo Metropolitan area including four prefectures (1,141,894 persons in 1975, 30.9% of the total inter-prefectural migrants in Japan).

On the same reason, it is reasonable to treat in-migrants to Osaka Metropolitan area including Osaka, Hyogo and Kyoto Prefectures in West Japan in the gross (504,706 persons in 1975, 13.6% of the total).

Two metropolitan areas form double poles of internal migration in Japan. But there is a clear difference between both areas, i.e. the gravity of Tokyo Metropolitan area covers all over Japan, and that of Osaka covers only over West Japan. Some evidences thereon are given as follows.

Miyagi and Hiroshima have regional capitals in East and West Japan. The distance between Miyagi and Osaka (737.6 km) is not so different from that between Hiroshima and Tokyo (781.3 km).

If the width of areas in which two poles mostly attract in-migrants changes in proportion to their in-migrants in total, so large difference is not expected between the number of migrants from Miyagi to Osaka Metropolitan area and the number of migrants from Hiroshima to Tokyo Metropolitan area. But the latter (15,911) is about nine times larger than the former (1,891) in 1975.

More saying for another example, the regression parameters-$\alpha$ regarding in-migrants to each prefecture in Tokyo Metropolitan area from other prefectures are distinctly lower than those regarding each prefecture in Osaka Metropolitan area (Table 2).

Such a large gravity of Tokyo Metropolitan area lowers the regression parameters-$\alpha$ regarding out-migrants from West Japan than those in East Japan.

## 3 Change of relationship between migration and distance from 1955 to 1975

The effect of distance on migration is smaller in 1975 than in 1955 (Table 3), and it seems to have changed under distinct regional differentiation (Table 4), i.e. the regression parameters-$\alpha$ and their change from 1955 to 1975 for prefectures show the following traits.

1. Regression parameters-$\alpha$ decreased in central Japan (Kanto, Tokai and Koshin-etsu-Hokuriku districts) and in marginal Japan (Hokkaido and Kyushu districts).
2. They have been stable in transitional Japan (Tohoku, Kinki, Chugoku and Shikoku districts)
3. They have been nearly stable at Tokyo and Osaka.

The above regional differentiation might be caused by following factors.

1) Growth of Tokaido Megalopolis

The population has much increased in the so-called Tokaido Megalopolis, which contain Tokyo, Osaka and Nagoya Metropolitan areas[2]. The national share of the population in Tokaido Megalopolis was 38.4% in 1955 and it rose up to

Table 3 Correlation coefficient-r and regression parameters-$\alpha$, $\beta$, for all inter-prefectural migrants in Japan, 1955 to 1975

| Year | r | $\alpha$ | $\beta$ |
|---|---|---|---|
| 1955 | −0.762 | 2.917 | 6.777 |
| 1965 | −0.720 | 2.642 | 6.182 |
| 1975 | −0.751 | 2.494 | 5.929 |

Table 4 Regression parameter-$\alpha$ for 1955 and its change between 1955 and 1975, out-migrants

| District | No. | Prefectures | $\alpha$ | Increase 1955 to 1975 | |
|---|---|---|---|---|---|
| Hokkaido | 1 | Hokkaido | 5.313 | −2.162 | |
| Tohoku | 2 | Aomori | 5.048 | −0.464 | |
| | 3 | Iwate | 4.548 | 0.160 | |
| | 4 | Miyagi | 3.990 | 0.075 | |
| | 5 | Akita | 4.845 | −0.178 | |
| | 6 | Yamagata | 4.498 | 0.098 | |
| | 7 | Fukushima | 4.499 | −0.679 | |
| Kanto | 8 | Ibaraki | 3.276 | −0.993 | |
| | 9 | Tochigi | 3.898 | −1.341 | |
| | 10 | Gunma | 3.856 | −1.264 | |
| | 11 | Saitama* | 2.533 | −0.997 | —Tokyo M.a. |
| | 12 | Chiba* | 2.234 | −0.931 | |
| | 13 | Tokyo* | 1.722 | −0.436 | |
| | 14 | Kanagawa* | 1.672 | −0.768 | |
| Ko-shin-etsu-Hokuriku | 15 | Niigata | 4.236 | −0.574 | |
| | 16 | Toyama | 3.263 | −0.528 | |
| | 17 | Ishikawa | 3.359 | −0.394 | |
| | 18 | Fukui | 3.258 | −0.542 | |
| | 19 | Yamanashi | 3.411 | −1.029 | |
| | 20 | Nagano | 3.710 | −0.686 | |
| Tokai | 21 | Gifu* | 2.619 | −1.214 | —NagoyaM.a. |
| | 22 | Shizuoka* | 2.035 | −0.895 | |
| | 23 | Aichi* | 2.077 | −1.184 | |
| | 24 | Mie* | 2.517 | −0.896 | |
| Kinki | 25 | Shiga | 2.822 | −1.090 | |
| | 26 | Kyoto* | 2.543 | −0.343 | —Osaka M.a. |
| | 27 | Osaka* | 2.661 | −0.485 | |
| | 28 | Hyogo* | 2.667 | −0.354 | |
| | 29 | Nara | 2.168 | 0.010 | |
| | 30 | Wakayama | 2.643 | 0.125 | |
| Chugoku | 31 | Tottori | 3.585 | −0.271 | |
| | 32 | Shimane | 3.972 | −0.460 | |
| | 33 | Okayama | 3.416 | −0.472 | |
| | 34 | Hiroshima | 3.232 | −0.188 | |
| | 35 | Yamaguchi | 3.208 | −0.391 | |
| Shikoku | 36 | Tokushima | 3.766 | −0.207 | |
| | 37 | Kagawa | 3.610 | −0.556 | |
| | 38 | Ehime | 3.378 | −0.126 | |
| | 39 | Kochi | 3.318 | 0.092 | |
| Kyushu | 40 | Fukuoka | 3.495 | −0.643 | |
| | 41 | Saga | 3.324 | −0.386 | |
| | 42 | Nagasaki | 3.484 | −0.620 | |
| | 43 | Kumamoto | 3.124 | −0.503 | |
| | 44 | Oita | 3.224 | −0.421 | |
| | 45 | Miyazaki | 3.816 | −1.138 | |
| | 46 | Kagoshima | 3.289 | −0.295 | |

* Prefectures in Tokaido Megalopolis

49.5% in 1975. Such a growth of population in this region caused, consequently, further spatial auto-correlation of population distribution in Japan. Thus the regression parameters-$\alpha$ decrease in central Japan.

2) Enlargement of three metropolitan areas

The growth of Tokaido Megalopolis resulted not only in the concentration of population, but also in the enlargement of three metropolitan areas, i.e. the housing and industrialization has proceeded in the adjoining prefectures, such as Ibaraki, Tochigi and Gunma around Tokyo M.A., Shiga and Nara around Osaka M.A. and Nagoya, M.A., where the regression parameters-$\alpha$ dropped excluding Nara.

3) Reduction of gravity for internal migration in marginal Japan

Hokkaido and Kyushu were main Japanese coal producing areas in 1955, but the coal mining industry has depressed since last two decades, and other sections of industry have also depressed in Hokkaido and Kyushu. And the developmental program in Hokkaido has paused because the growth rate of Japanese population had rapidly diminished since 1955.[3)]

Such a depression in industry resulted in the relative decrease of local economic powers in Hokkaido and Kyushu, and the out-migrants from Hokkaido and Kyushu have been destined for further prefecturs than before (Table 5) and regression parameters-$\alpha$ decreased.

Table 5 Number and percentage of out-migrants from Hokkaido and Kyushu by destination

| | Year | Number | Ratio to total out-migrants |
|---|---|---|---|
| Out-migrants for Tohoku from **Hokkaido** | 1955 | 13,099 | 20.3% |
| | 1975 | 12,533 | 13.9 |
| Intra-district migrants within **Kyushu** | 1955 | 182,792 | 53.5 |
| | 1975 | 161,609 | 38.4 |

## 4 Conclusion

Inter-prefecturs1 migrants increased from 1955 to 1975, and they have been destined for further prefectures than before, i.e. the resistance of distance has been reduced. But, this trend in internal migration might change in the future, because inter-prefectural migrants rapidly decreased in number and in rate from 1973 (Fig. 3), when the Oil Crisis happened in Japan.

2) Tokaido Megalopolis=Tokyo M.a. (Tokyo, Saitama, Chiba, Kanagawa)+Osaka M.A. (Osaka, Kyoto, Hyogo)+Nagoya M.a. (Aichi, Gifu, Mie)+Shizuoka.

3) Until 1950, the crude birth rate was above 2.0% in Japan, but it has continued below 2.0% since 1955.

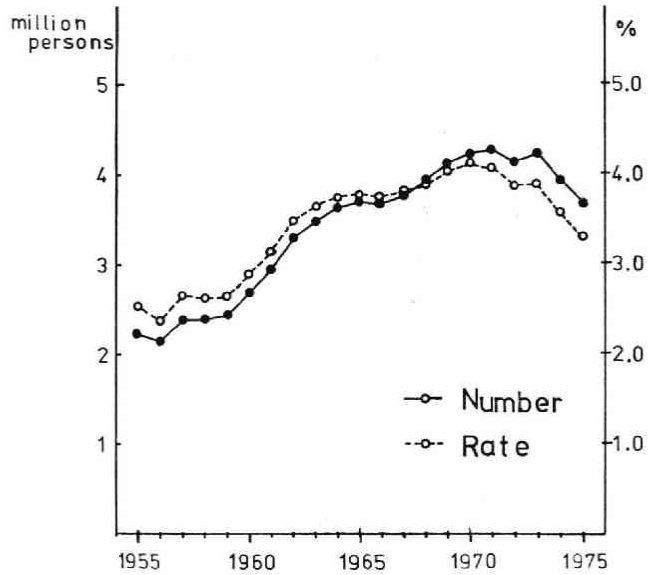


Fig. 3 Inter-prefectural migrants in Japan, 1955 to 1975
Rate is the number of inter-prefectural migrants by 100 persons in population.

While migrants decreased in number, the resistance of distance seems to increase. Both the ratio of out-migrants for Tohoku from Hokkaido to total out-migrants from Hokkaido (11.1%, 1973) and the ratio of intra-district migrants for Kyushu to total out-migrants from prefectures in Kyushu (33.7%, 1973) increased noticeably since 1973 (Table 5).

The effect of distance on migration will be clearer in the future than before. Probably new poles of internal migration will grow up, such as Hokkaido, Miyagi, Hiroshima and Fukuoka whose capital cities are qualified as regional centers.

The writer would like to express his gratitude to Prof. Kasuke Nishimura of Tohoku Univ. for continuous guidance and encouragement. The calculations in this paper are performed with ACOS NEAC 700 in Computer Center, Tohoku Univ..

**References** (*in Japanese, **in Japanese with English abstract)

**Bureau of Statistics, Office of the Prime Minister** (1973): *Internal Migration in Japan*, **1954-1971****

——— (1976): *Annual Report on the Internal Migration in Japan, Derived from the Basic Resident Registers*, **1975****

——— (1977a): *Report on the Internal Migration in Japan, Derived from the Basic Resident Resisters, for Shi-Ku-Cho-Son*, **1966-1975***

——— (1977b): *Popuplation of Japan, 1975 Population Census of Japan Abridged Report Series* **No. 1****

**Gould, P.** (1975): *Acquiring Spatial Information. Econ. Geogr.*, **51** 87–99

**Isard, W.** (1960): *Method of Regional Analysis: An Introduction to Regional Science,* New York: John Wiley & Sons, Inc.

**Ishimizu, T. and Okuno, T.** (1973): *Quantitative Geography.* Tokyo: Kyoritsu Shuppan, Inc.*

**Kawabe, H.** (1963): The Migration and Distance in the Case of Internal Migration in Japan. *Annals of the Tohoku Geographical Association,* **15** 47–53**

**King, L.J.** (1969): Statistical Analysis in Geography. *Englewood Cliffs, N.J.*: Prentice-Hall, Inc.

**Olsson, G.** (1965): Distance and Human Interaction. A Migration Study. *Geografiska Annaler,* **47** 3–43

**Tachi, M.** (1961): *Internal Migration in Japan.* Tokyo: Kokon-Shoin, Inc.*