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The Structure of Interregional Migration in Japanese Regions : An Application of Multidimensional Scaling

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SYNOPSIS

Multidimensional scaling (MDS) has been used in a wide variety of research fields; psychology, political science, anthropology, marketing research, urban and regional planning, and so on. In practical terms, MDS is a statistical method to make a picture of the information in the data. It enables us to examine the "hidden structure" of a set of data. When the set of data is large, MDS is extremely useful, since it is easier and more informative to look at a picture than the data themselves. In this paper, MDS is applied to the interregional migration data of Japanese regions for the years 1960-85. Findings show that the two-dimensional configuration of regions estimated by MDS generally corresponds with the geographical locations of regions, and the structure of interregional migration was very stable over the study years 1960-85. It is also suggested that MDS is a useful tool to identify the relationships between regions using the spatial interaction data.

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1. INTRODUCTION

In the first stage of the urban and regional planning, it is often necessary to examine the relationships between cities or regions using demographic, fiscal, and economic factors. Various methods of multivariate analysis, such as the multiple regression analysis, the principal component analysis, and the cluster analysis, have been widely used for this purpose.[1][2][3]

In this study, the multidimensional scaling (MDS) is applied to the interregional migration data of Japanese regions. MDS is a statistical method which enables us to uncover the structure of a set of data. The information in the migration data is briefly presented in a reduced space configuration of regions by using MDS. This paper aims to examine the characteristics of interregional migration pattern in Japanese regions as well as the practical value of MDS as an analytical tool for urban and regional planning.

2. METHODOLOGY

Multidimensional Scaling (MDS) is a statistical tool to estimate the configuration of objects in a given dimensional space using distance data between objects.[4] In urban and regional research, MDS is useful to identify the similarities and dissimilarities of various cities or regions using data on demographic, fiscal, and economic factors. In this paper MDS is applied to examine the structure of interregional migration in Japanese regions.

MDS is broadly classified into two models; the simple Euclidian model and the weighted Euclidian model. The simple Euclidian model defines the distance between objects i and j by the following equations:

$$d_{ij} = \sqrt{\sum_{r=1}^{t} (x_{ir}-x_{jr})^2} \qquad (1)$$

where,

d_{ij}: distance between objects i and j

x_{ir}: coordinate of object i on dimension r

t: the number of dimensions

Equation (1) represents the definition of the Euclidian distance between objects i and j in a t-dimensional space. The sum of the squared deviations between the actual (or observed) distance D_{ij} and the estimated distance d_{ij} is minimized to determine the coordinates of objects in the t-dimensional space.

While the simple Euclidian model estimates the coordinates of objects using a single distance matrix, the weighted Euclidian model requires several distance matrices for input data and generates a configuration of objects in a t-dimensional space and weights of distance matrices on each dimension. The weighted Euclidian distance is defined as follows:

$$d_{ijk} = \sqrt{\sum_{r=1}^{t} w_{kr}(x_{ir}-x_{jr})^2} \qquad (2)$$

where,

d_{ijk}: distance between objects i and j for distance matrix k
w_{kr}: weight of distance matrix k on dimension r
x_{ir}: coordinate of object i on dimension r

Equation (2) implies that the weight on each dimension is unique to each distance matrix, while the coordinates of objects are common to all of the distance matrices.

Fig.2 shows the outline of the analysis. Firstly, the simple Euclidian model is applied in order to estimate the distance matrix for each year. Assume the gravity model for the interregional migration:

$$M_{ijk} = (\sum_{i} M_{ijk})*(\sum_{j} M_{ijk})/D_{ijk}^{\alpha_k} \qquad (3)$$

where,

M_{ijk}: the number of migrants between regions i and j for year k
D_{ijk}: distance between regions i and j for year k
α_k: distance-decay parameter for year k

The equation (3) can be expressed as follows:

$$D_{ijk} = \{(\sum_{i} M_{ijk})*(\sum_{j} M_{ijk})/M_{ijk}\}^{1/\alpha_k} \qquad (4)$$

As MDS requires a symmetric distance matrix for its input data, the distance matrix is symmetrized by the equation (5).

$$D_{ijk}' = (D_{ijk}+D_{jik})/2 \qquad (5)$$

where,

D_{ijk}' : element of the symmetrized distance matrix

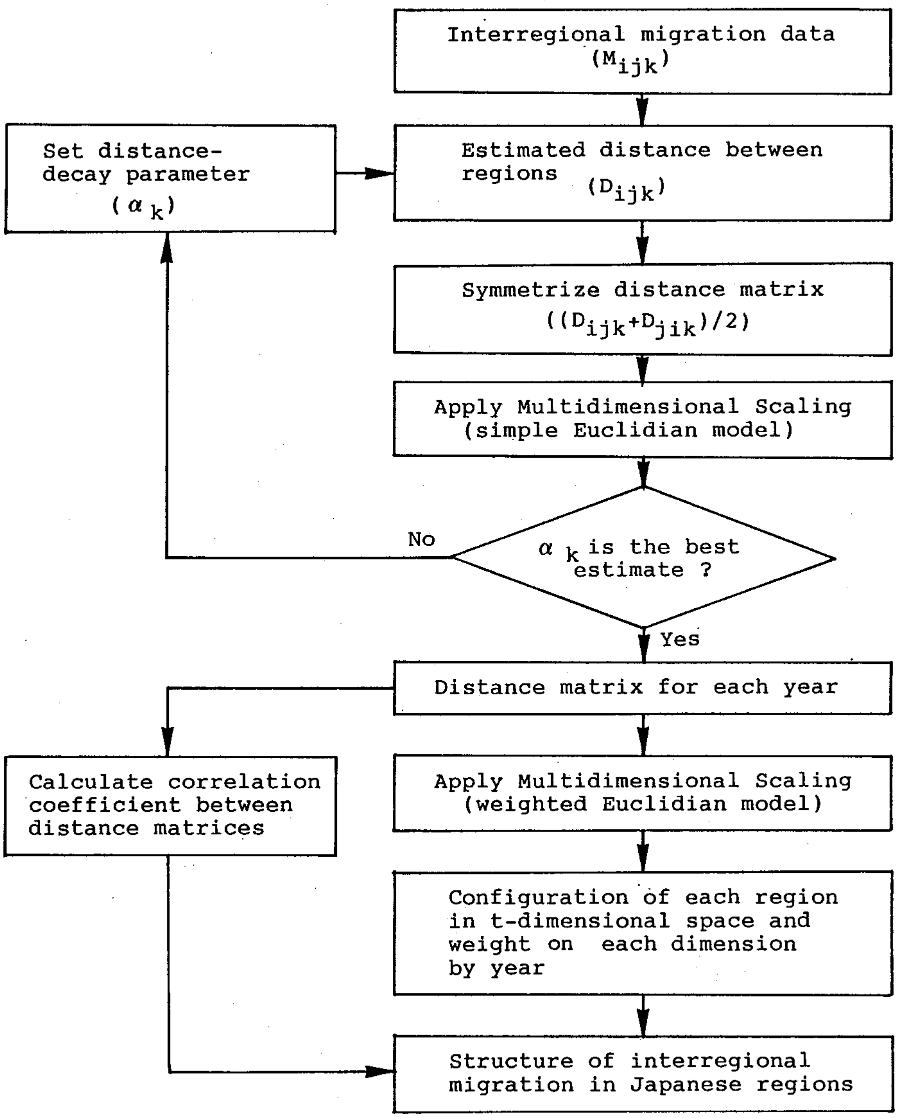

Fig.2 Outline of the analysis

The equation (4) represents that the distance-decay parameter α_k should be determined in advance in order to estimate the distance D_{ijk}. In this study, assuming various values of α_k, the simple Euclidian model is applied repeatedly until the 'best' parameter value is obtained, where the simple Euclidian model shows the best fit for the observed distances D_{ijk}. The goodness-of-fit is evaluated by the equation (6), which implies the relative deviation between the observed and the estimated distances.

$$\phi = \sqrt{tr(\hat{P}_k - P_k)^2 / tr\hat{P}_k^{\,2}} \qquad (6)$$

where,

$\hat{P}_k$: matrix of scalar products calculated from the distance data for year k

P_k: matrix of scalar products calculated from the estimated distance by the simple Euclidian model

tr( ): trace of the matrix

The smaller value of ϕ means the higher goodness-of-fit of the simple Euclidian model.

Secondly, the structure of interregional migration is examined by two analyses using the estimated distance matrices; the analysis of correlation coefficient and the application of MDS basing on the weighted Euclidian model. The former analysis investigates the similarities between distance matrices. The higher value of a correlation coefficient means the closer similarity between the migration patterns, which are represented by the distance matrices.

The latter analysis estimates the configuration of regions which is common to the distance matrices, and the weight for each dimension which is unique to each distance matrix. The configuration of regions shows the relationships between regions in the interregional migration, and the weights represent changes in the structure of interregional migration over the study years.

3. STUDY REGION AND DATA FOR THE ANALYSIS

The definition of regions in this study is based on the one by the Economic Planning Agency of the Japanese Government, in which the fourty-six prefectures are aggregated to fourteen regions, shown in Fig.1 and Table 1.

The interregional migration data for the analysis come from the Annual Report of Population Registers during 1960-85. The report records the number of people, who changed their dwelling locations from one prefecture to another during a calendar year. The number of migrants between prefectures is summarized in a origin-destination table for each calendar year. For the purpose of the analysis, the prefectural migration data are aggregated to the data by region.

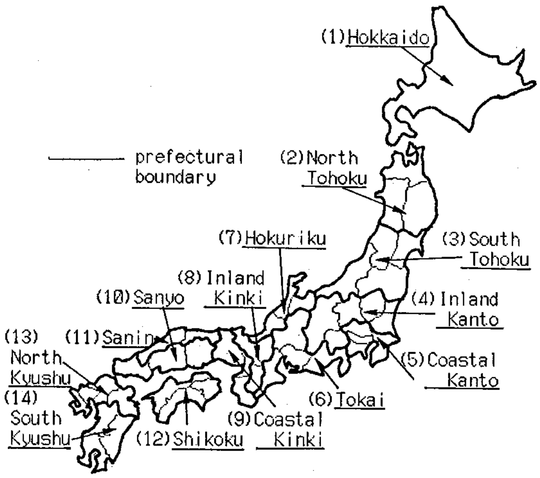

Fig.1 Locations of 14 regions

Table 1 Relationships between 14 regions and 46 prefectures

Region	Prefecture
(1) Hokkaido	Hokkaido
(2) North Tohoku	Aomori, Iwate, Akita
(3) South Tohoku	Miyagi, Yamagata, Fukushima, Niigata
(4) Inland Kanto	Ibaraki, Tochigi, Gunma, Yamanashi, Nagano
(5) Coastal Kanto	Saitama, Chiba, Tokyo, Kanagawa
(6) Tokai	Gifu, Shizuoka, Aichi, Mie
(7) Hokuriku	Toyama, Ishikawa, Fukui
(8) Inland Kinki	Shiga, Kyoto, Nara
(9) Coastal Kinki	Osaka, Hyogo, Wakayama
(10) Sanyo	Tottori, Shimane
(11) Sanin	Okayama, Hiroshima, Yamaguchi
(12) Shikoku	Tokushima, Kagawa, Ehime, Kochi
(13) North Kyushu	Fukuoka, Saga, Nagasaki, Oita
(14) South Kyushu	Kumamoto, Miyazaki, Kagoshima

The MDS computer programs, ADDSCAL(the simple Euclidian model) and SUMSCAL(the weighted Euclidian model), which have been developed by Takane, are used in the study.[5)]

4. RESULTS OF THE ANALYSIS

The simple Euclidian model is applied assuming various values of the distance-decay parameter α_k, and the relationship between the distance-decay parameter and the fit of the simple Euclidian model is examined. Fig.3 shows the result for each year. The best parameter value for each year, which maximize the goodness-of-fit of the simple Euclidian model, is identified as shown in Table 2. The values of α_k in Table 2 varies between 2.37 to 3.10. The fact corresponds with the empirical results of the existing studies on the spatial interaction model.

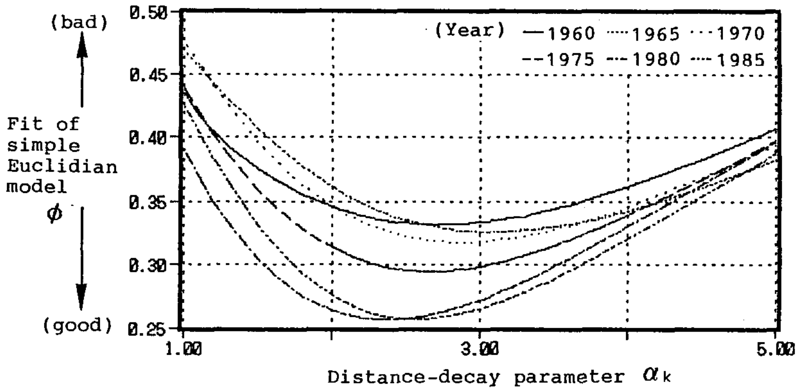

Fig.3 Relationships between fit of simple Euclidian model and distance-decay parameter

Table 2 The Estimated distance-decay parameter for years 1960-1985

Year	Fit of simple Euclidian model	Estimated distance-decay parameter
1960	0.312	2.70
1965	0.326	3.10
1970	0.318	2.87
1975	0.295	2.67
1980	0.257	2.37
1985	0.258	2.57

The distance matrix for each year is then calculated by using the equation (4). The validity of the estimated parameters is also examined by comparing the actual migration with the estimate. Table 3 shows the result of validation for each year. The high values of the correlation coefficients and the low values of the mean average percent errors (MAPE) reveal that the estimated values of α_k are extremely satisfactory.

Table 3 Relationships between actual and predicted migration

Year	Correlation coefficient	Mean absolute percent error
1960	0.986	8.47 %
1965	0.991	3.68 %
1970	0.994	2.05 %
1975	0.999	0.34 %
1980	0.999	0.33 %
1985	0.998	0.43 %

The structure of interregional migration is examined by the two methods; the analysis of correlation coefficients and the application of MDS basing on the weighted Euclidian model.

Table 4 shows the correlation coefficients between distance matrices for the study years. The high values of the coefficients indicate that there were no significant changes in the structure of interregional migration during the study years 1960-85.

Fig.4 and Fig.5 are the configuration of regions in a two-dimensional space and the weights of the study years on each dimension, which are derived by the weighted Euclidian model. As explained in Chapter 3, the configuration of regions in Fig.4 is common to the distance matrices (i.e. the study years), and the changes in the configuration are reflected by the weights in Fig.5.

Table 4 Relationships between estimated distance matrices

	Year				
Year	1965	1970	1975	1980	1985
1960	0.973	0.958	0.960	0.951	0.941
1965	-	0.992	0.989	0.979	0.973
1970	-	-	0.996	0.985	0.983
1975	-	-	-	0.993	0.990
1980	-	-	-	-	0.995

Dimension I in Fig.4 appears to separate the eastern and the western regions of Japan, whereas Dimension II seems to separate the southern and the northern regions of Japan. Therefore, the configuration of regions shown in Fig.4 generally corresponds with the geographical locations of Japanese regions. However, the locations of Hokkaido, North Kyushu and South Kyushu in Fig.4 are closer to Inland Kanto than their actual locations on a map. The fact represents the close relationships between these regions in the interregional migration.

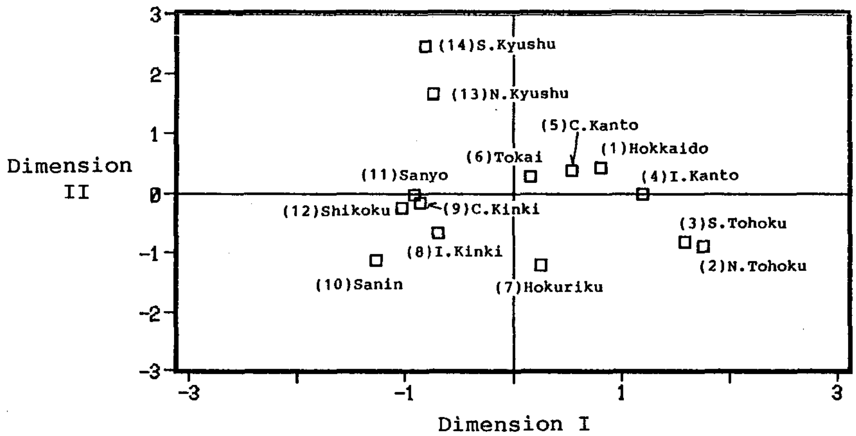

Fig.4 Configuration of regions in 2-dimensional space

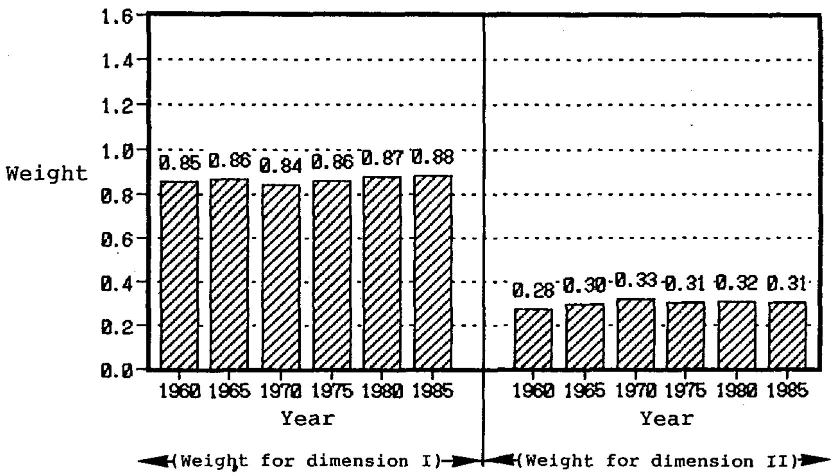

Fig.5 Changes in weight on each dimension

The weights on each dimension vary 0.84-0.88 for Dimension I and 0.28-0.33 for Dimension II. It means that there are no significant changes in the configuration of regions over the study years, and the structure of interregional migration in Japan was stable during 1960-85.

5. CONCLUSIONS

Multidimensional scaling (MDS) has been used in urban and regional planning to examine the similarities and dissimilarities of various cities or regions using data on demographic, fiscal, and economic factors.

In this paper, MDS has been applied to the interregional migration in Japanese regions, and the regional structure of migration has been examined. The results of the study have demonstrated that MDS is a useful tool to identify the structure of interregional migration. The major fact-findings show that the configuration of regions in a two-dimensional space generally corresponds with the geographical locations of the regions, while the close relationships have been identified between Inland Kanto and a few local regions; Hokkaido, North Kyushu, and South Kyushu. The relationships between regions estimated with the interregional migration data were stable over the study years 1960-85.

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