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An economic geographical analysis of relevancies between the city systems

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1 Introduction

Cities are places where production and consumption activities are linked and realized in region. And these economic activities are conducted by people who live in city and city areas. It is said that the cities are places that represent the human economic activities in region. Thus, the cities are gaining attention and have been analyzed in many academic disciplines. Economic geography is one of a leading academic field in the analyses and it has been studied the cities for the past two centuries.

From the viewpoint of economic geography, the changes in economic activities of the cities is outlined as follows. At the stage of early economic development where economic activity in general is substantially limited within a territory of the country, the formation of the individual cities, their industrial composition, and the optimal population size of the cities are analyzed. As the relationships and cooperativeness between the cities are gradually formed, and a concept of city system in a region is established. The structure of city system attracts attention of the scholars in the regional economics. In the analysis of city system, the market areas of retailers are analyzed in detail since the market areas are the basis of building city system.

In the following stage of economic development, through the progress of the various kinds of technologies the economic globalization advances. The globalized economy generates a harsher price competition in the manufacturing industry in the industrial countries. Especially, the manufacturing firms in existing industrial areas are exposed to the price competition which is followed by a cost cutting competition. In order to cope with the cost cutting competition, many manufacturing firms fragment production processes to reduce production costs. Some fragmented processes are scattered to other local cities where the factories produce goods with the lower costs. In addition to this, production activities of the manufacturing firms are supervised by the management functions which are organized through the interconnected cities and the city systems. The relationships between the city systems, therefore, are deepen through the firms' managements The importance of the coordination between the cities increases in firms' production and sales activities. In the era when the economic activity is globalized, the relevancies between the city systems inevitably expands and deepens. Fragmentation of firms' production processes and the spatial diffusion of the fragmented processes change the economic role of the cities and vary the spatial economic structure of city systems.

Tracing the transition of the cities, it seems that establishing a broad framework to analyze the city

systems is required in the field of Economic geography[1]. Ishikawa (2016) examines the theories of construction of city systems which have been basic economic unit in the globalization economy. And he proposes construction method that can make the existing analysis framework of city system diversified and increases their applicability. This paper focuses on the relevancies between city systems from the view point of the empirical analysis. And the present paper, applying the network analysis and graphical modeling method, analyze how the relevancies between the city systems are formed by using industrial data in Japan.

The paper is organized as follows. In the next section, a method to quantify the characteristics of city system is explained by using a case study of the city system in Yamagata prefecture in Japan. Section 2 analyzes the level of relevancies between the city systems by the data of the passenger flow amounts of the prefectures in Japan. Subsequently, Section 3 the relevancies between the city systems is examined by using location data of the branch factories and business/sales offices of companies in manufacturing industry. By combining the indicator showing the characteristics of the city system and three indicators indicating relevancies of the prefecture, the followings will be found out: 47 prefectures in Japan are divided into 16 groups and there is a possibility that their economic geographical characteristics can be explained successfully from the relevancies between prefectures . Section 4 summarizes the results obtained in this paper.

2 Qualification of city system

2.1 City system in Yamagata prefecture

Let us select the city system in Yamagata prefecture in Japan to describe a city system in a region. Fig.1 depicts the distribution of city population in Yamagata Prefecture in 1969, ranking the cities according to population size. Fig.1 shows the regularity in the distribution; the distribution of city population is formed by three stratums and the series of the number of cities in each stratum is 1-3-9. These regularities are successfully explained by the concept of the city system according to Christaller's theory (1933) using the market areas of the retailers under the pseudo-monopoly.

Fig.2 shows the city population distribution in Yamagata prefecture in japan in 2015. The distribution of city population is polarized; one large city and many small cities. As indicated by the comparison between Fig.1 and Fig.2, the second stratum of the city population distribution collapses in 2015, and the city population distribution has become more concentrated. It seems to be difficult to explain and interpret such the change of the city system by the traditional city system theories based on Christaller and Lösch (1942). Ishikawa (2016) proposes the concept of Flexible Market Area Theory which deals with this change of the city system.

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[1] A lot of theoretical studies on city systems have been accumulated so far. Useful in consideration here are as follows. Beckmann-McPherson (1970), Capello (2004), Hoover (1970). Parr (1988), and Tinbergen (1968).

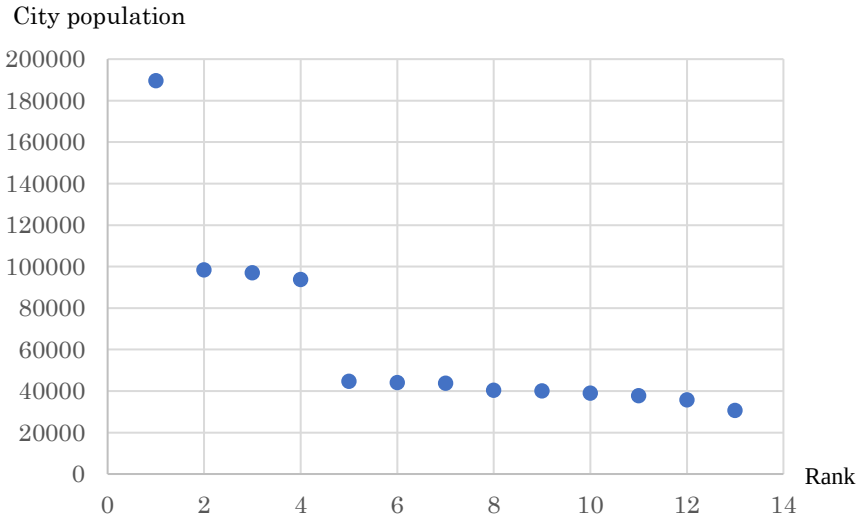

Fig.1　City population distribution in Yamagata prefectute,1969

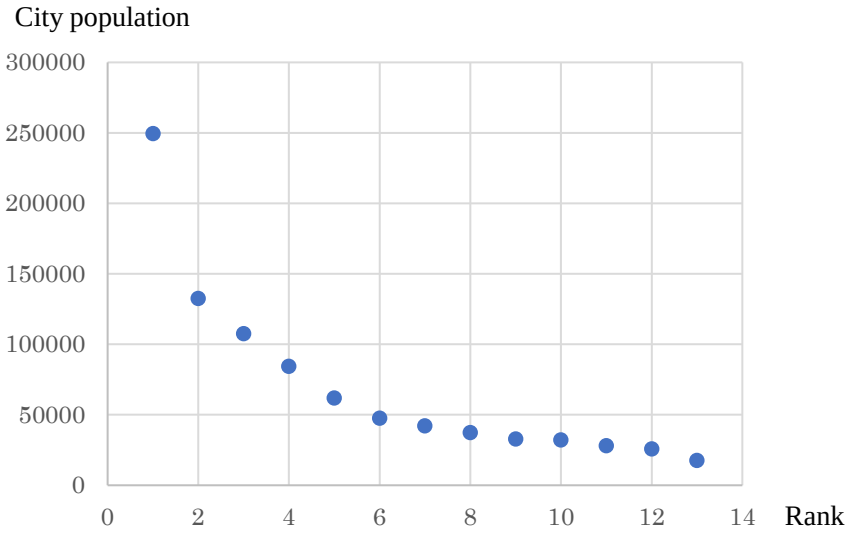

Fig.2　Population distribution of cities in Yamagata prefectute,2015

2.2 Derivation of an index to describe city system

As shown in the previous subsection, over time the city system changes and shows different aspects. And it could be said that city system established in regions show various characteristics. Since the city system is formed on the basis of people's economic activities, economic principles should play a major role in the formation of city systems and their characteristics. Therefore, it is inferred that differences in structures of the city systems are related to the industrial characteristics of the region.

For the purpose of verifying the relationships between city system and regional industrial characteristics from empirical analysis, an index to describe city system is needed. Thus, the City

System Index is devised as an indicator to show the characteristics of city systems. The City System Index captures a city system from two points of view, the distribution of city population and the density of cities in a region. In this subsection, after explanation of method of derivation of the City System Index, the City System Index is concretely derived using Japanese data and the index is used to show characteristics of the city systems in Japan.

2.3. Derivation of City System Index

2.3.1 Divergence of city population distribution to the largest city

In order to describe the divergence toward the primary city of the population distribution of the cities which form a city system, the coefficient of the divergence is used. Based on the framework shown by Sheppard (1982), the coefficient of the divergence, CD, is derived as follows (Sheppard, 1982).

Suppose that there are N cities in a region. Term of p_r denotes the population share of a city for all cities' population in the region. The value of CD obtained by equation (1) is considered as the coefficient of divergence of the population distribution to the primary city in the region.

$$CD = (1/N)\sum_{r=1}^{N} p_r L_N(r) \qquad (1)$$

where r is rank of city by population share order.

CD is used as the index that indicates the characteristic of the distribution of cities' population in a city system. As the distribution of cities' population becomes to diverge toward the largest city of the city system, the value of CD lowers.

2.3.2 Spatial convergence of city distribution in a region

A city system is captured from the viewpoint of the locations of the cities within a city system; the spatial convergence of the cities' locations in a region. The spatial convergence of the cities' locations, SC, in a region is derived by using Poisson distribution. Assume that there are N_i (i=1, 2, 3…N) cities in a region of which land area is *M*. The distance from a city N_1 to the nearest city is denoted as d_1. This distance is named as the least distance of the city N_1. The least distance is obtained for each of cities N_i (i=1, 2, 3…N), the average least distance, AD, of cities is derived as equation (2),

$$AD = (1/N)\sum_{i=1}^{N} d_i \qquad (2)$$

The spatial convergence of cities distribution in region, SC, is expressed by equation (3),

$$SC=AD/(1/(2\ (N/M)^{0.5}\ )\ ) \qquad (3)$$

As the cities locate more closely each other, SC becomes smaller. The SC's value is used to specify a spatial characteristic of a city system.

2.3.3 Derivation of the City System Index for 47 prefectures in Japan

The values of both CD and SC become smaller as the divergence of the distribution of cities' population to the largest city progresses and the spatial convergence of cities distribution is higher. Hence, combining these two values, an index can be built to reveal the characteristics of city systems, City System Index, CSI. The City System Index is derived by equation (4),

$$CSI = ((\alpha CD)^2 + (\beta SC)^2)^{0.5} \quad (4)$$

where α and β are positive parameters. When the value of the CSI is lower, it means that the structure of the city system has concentrating characteristics in terms of the cities' population distribution and the location of cities. On the other hand, the high value of the CSI means that the structure of the city system has leveling characteristics. In the rest of this chapter, CSI is used as an index that indicates the characteristics of city systems.

Let us derive the CSIs of the city system in Yamagata prefecture in 1964 and 2015. The parameters in the equation (4) are assumed as $\alpha = 20$ and $\beta = 1$. The CSI in 1964 can be derived as 2.52 and that of 2015 is 2.32. As shown by comparison of Fig.1 and Fig.2, City system in Yamagata prefecture in 2015 becomes concentrating more than that in 1964 since the divergence of the population distribution to the primary city becomes higher in the period between 1964 and 2015.

City System Indices of 47 city systems in 47 prefectures in Japan in 2012 are shown in Table 1. In Table 1 the standardized CSI of each city system is also shown to derive the relative differences in the city systems of 47 prefectures. And locations of 47 prefectures are indicated by the number assigned to each of all prefectures in Fig.3

Table 1 City system Indices of 47 prefectures in Japan,2012

Prefecture	No.	CSI	Standardized CSI		Prefecture	No.	CSI	Standardized CSI
Hokkaido	1	1.5325	-1.4569		Mie	24	2.7643	0.1934
Aomori	2	3.0892	0.6341		Shiga	25	2.6756	-0.0702
Iwate	3	3.2298	0.8076		Kiyoto	26	2.2535	-0.5842
Miyagi	4	2.3012	-0.4266		Osaka	27	1.2892	-1.5093
Akita	5	3.151	0.7066		Hiyogo	28	2.2265	-0.5194
Yamagata	6	2.3449	-0.3772		Nara	29	2.2103	-0.5562
Fukushima	7	2.7192	0.1399		Wakayama	30	4.3667	2.3597
Ibaragi	8	1.9486	-0.9003		Tottori	31	4.2606	2.1984
Tochigi	9	2.1339	-0.6218		Shimane	32	3.7509	1.4544
Gunma	10	2.5702	-0.0725		Okayama	33	2.7574	0.1745
Saitama	11	1.6851	-1.3954		Hiroshima	34	2.5905	-0.0383

Chiba	12	2.1704	-0.7022		Yamanashi	35	3.646	1.3784
Tokyo	13	1.2008	-1.9211		Tokushima	36	4.1194	1.9851
Kanagawa	14	1.8164	-1.0735		Kagawa	37	2.3134	-0.4295
Niigata	15	2.143	-0.6464		Ehime	38	2.536	-0.1298
Toyama	16	1.9671	-0.8928		Kochi	39	3.7353	1.4916
Ishikawa	17	3.5271	1.1968		Fukuoka	40	1.7398	-1.1872
Fukui	18	3.0731	0.6040		Saga	41	3.039	0.5613
Yamanashi	19	2.3523	-0.3783		Nagasaki	42	2.8465	0.2978
Nagano	20	2.139	-0.4033		Kumamoto	43	3.045	0.4914
Gifu	21	2.2844	-0.3387		Oita	44	3.2104	0.7793
Shizuoka	22	2.4623	-0.4783		Miyasaki	45	3.344	0.9625
Aichi	23	1.5726	-1.4110		Kagoshima	46	2.8953	0.3633
					Okinawa	47	2.4394	-0.2575

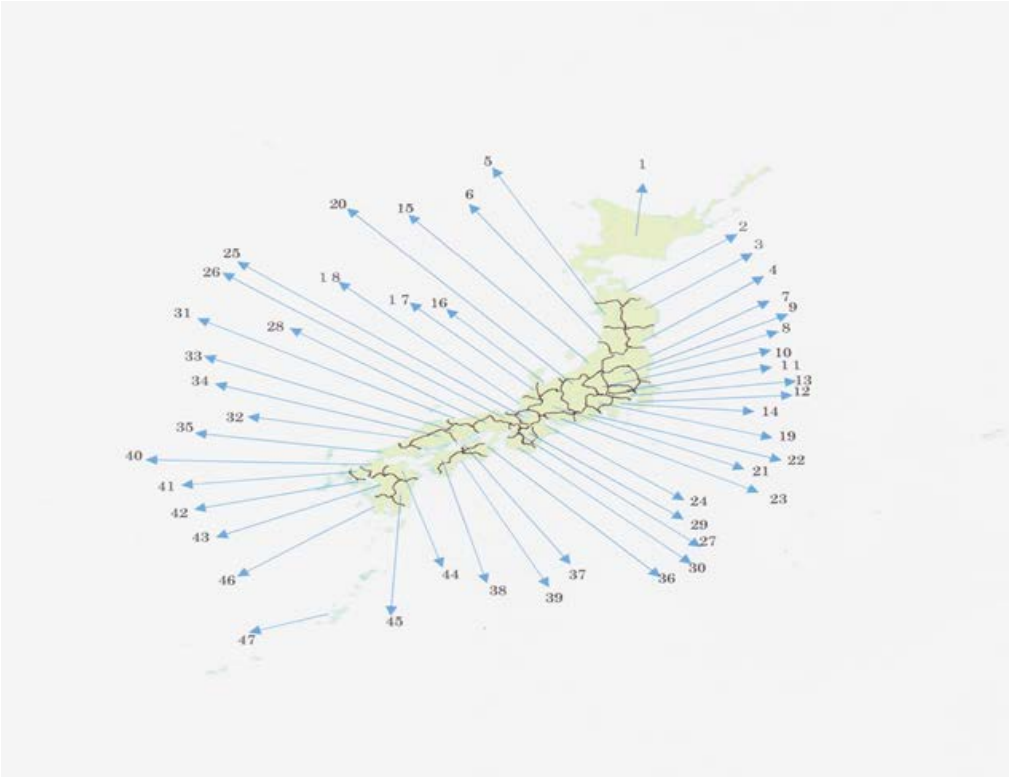

Fig.3 Locations of 47 prefectures in Japan

3 Analysis on the relevance of a city system with other city systems

3.1 Framework of the analysis of relevancies between city systems

As mentioned in the above section, people's consumption activity and production activity are

embodied in cities. Each city is rarely isolated and usually belongs to a city system. As economic activities expand to cover whole the world, the export and import of products among these city systems increase and the movements of various kinds of intermediate goods such as machinery parts also sharply increase. As a result, economic relations among city systems are greatly deepened.

It could be said in Japan that a city system is formed in a prefecture, centering on the city of the prefecture's government. Export and import of goods between the city systems can be regarded as movements of goods between the prefectures. This section, based on the data of the prefectural economic activities in Japan, analyzes the relevancies between city systems.

This section is organized by three stages. The first stage focuses on amount of passenger flow between the prefectures. Based on the distribution of the passenger flow amounts between the prefectures, the relations between the prefectures are processed to be represented by 1 and 0. A network analysis derives relevance index, NIf, through passenger flow amounts. NIf shows the prefecture's relevance to other prefectures based on the amounts of passenger flow. This NIf is considered as an index that indicates how much a city system in a prefecture has relevance with the city systems in other prefectures. And then, the relationship between NIf and CSI is analyzed for each city system.

The second stage proceeds as follows. First, it picks up the locations of the branch factories and sales offices of companies, which are fixed facilities of the companies. Specifically, it investigates how branch factories and business/sales offices of 152 companies in the machine assembly industry are distributed among 47 prefectures in Japan. Using the number of locations of branch factories of companies in each prefecture, correlation matrix and partial correlation matrix are created. And making use of the graphical modeling method, relativity between prefectures is represented by 1 and 0. Then, summing the relativities of each prefecture to other 46 prefectures provides an index of the relevance index through the locations of the branch factories, NIp. The NIp represents the extent to which a city system in a prefecture has cooperation with other city systems through the location of branch factories of the companies. In the same way, an index of relevance index, NIm, based on business/sales offices is obtained. The NIm shows the extent to which a city system has cooperation with city systems in other prefectures though the locations of the company's business/sales offices.

In the third stage, the results obtained in the second stage are illustrated in relation with the results obtained in the first stage. The obtained results are interpreted from the viewpoint of economic geography. From these three-stage analyses, it is clarified what kind of features the 47 city systems in Japan have and how they are related to other city systems[2].

[2] The passenger flow amounts between the 47 prefectures in Japan are provided by Data Books by Toyo Keizai Shinposha (2016). And Toyo Keizai Shinposha (2017) shows information of firms' branch factories and sales/business offices.

3.2 Relevance between city systems based on passenger flow amount between prefectures

This subsection estimates the relevancies between prefectures based on passenger flow amounts between prefectures. The estimation procedure of the relevancies is as follows. Passenger flow amounts between 47 prefectures in Japan are obtained from the data of 2017 and they are displayed by ratio in matrix formed by 47 prefectures[3]. There are large differences among the values of the ratios of the prefectures' passenger flow amounts. Thus, considerably lower ratios near to 0 are positively set to 0 in the matrix, while large ratios are set to 1. The prefectures which are set 1 by a prefecture are judged that they have relevance each other; they are connected through the prefecture, while the prefectures which are set 0 are supposed that they do not have relevance each other.

In addition to prefectures, the following four ratios are incorporated as a criterion for determining the relevance between prefectures. 1) ratio of [passenger flow amount *outside* the prefecture / passenger flow amount *in* the prefecture], 2) ratio of [passenger flow amount outside the prefecture / total passenger flow amount in Japan], 3) ratio of [passenger flow amount outside the prefecture / goods flow amount of the prefecture] , 4) ratio of [GRP of the prefecture / GDP in Japan]. In each criterion, considerably lower ratios near to 0 are positively set to 0, while large ratios are set to 1. And it is judged that the prefectures with the value of 1 in a criterion are connected through the criterion. A value of 0 or 1 is assigned to individual 47 prefectures based on 51 criteria. This creates a matrix X by rowing 51 criteria items and associating 47 prefectures with columns.

This subsection derives connectivity among the prefectures using the basic concept of network analysis theory. According to a theory of network analysis[4], multiplying the matrix X by its transposed matrix X′ forms the matrix X X' which shows the relevancies between the 47 prefectures. The relevance that each prefecture has with each of the other prefectures is indicated by the X X' matrix.

By summing up the numerical values in each row, Network Index based on based on passenger flow amounts, NIf, that indicates the level of relevance of a prefecture to outside city systems is obtained. It is considered that the value of NIf of the prefecture is used as a relevance index of the city system that shows the level of connected with other city systems. Table 2 shows the numerical values of NIf of 47 prefectures which is standardized using the data of the passenger flow amounts in Japan 2016.

Table 2 Relevance indices, NIf, of 47 prefectures in Japan,2016

Prefecture	No.	Standardized NIf		Prefecture	No.	Standardized NIf
Hokkaido	1	-0.0192		Mie	24	-0.8846
Aomori	2	0.4135		Shiga	25	-0.3557

[3] Data Books published by Toyo Keizai Shinposha (2017).

[4] There are many studies on Network analysis. For example, see works shown in Book by Von Wouter et al (2005).

Iwate	3	0.6635	Kiyoto	26	1.0384
Miyagi	4	1.2596	Osaka	27	1.375
Akita	5	-0.7885	Hiyogo	28	-0.6346
Yamagata	6	0.0385	Nara	29	-0.8173
Fukushima	7	-0.2596	Wakayama	30	-2.2884
Ibaragi	8	-0.9712	Tottori	31	-1.7307
Tochigi	9	-0.7596	Shimane	32	0.0576
Gunma	10	-0.5385	Okayama	33	0.1826
Saitama	11	-1.3654	Hiroshima	34	1.6538
Chiba	12	-1.3654	Yamanashi	35	-1.8942
Tokyo	13	1.6635	Tokushima	36	-1.0384
Kanagawa	14	-0.5288	Kagawa	37	0.1153
Niigata	15	1.3269	Ehime	38	-0.3653
Toyama	16	0.3462	Kochi	39	-0.0769
Ishikawa	17	1.7692	Fukuoka	40	0.8846
Fukui	18	0.6827	Saga	41	-1.0192
Yamanashi	19	-0.2115	Nagasaki	42	0.0288
Nagano	20	0.9038	Kumamoto	43	0.3365
Gifu	21	0.2596	Oita	44	-0.2692
Shizuoka	22	0.9038	Miyasaki	45	-0.5865
Aichi	23	1.4712	Kagoshima	46	0.6634
			Okinawa	47	0.7211

3.3 Analysis of the relationships between city system index and relevance index

This subsection examines the relationships between city system index (CSI) and relevance index (NIf). Fig.6 shows the city system index CSI, which is standardized, on the horizontal axis and the relevance index through the passenger flow amounts, NIf, which is standardized, on the vertical axis. These values of each of 47 prefectures are indicated by coordinate points. Fig.6 is divided into the four quadrants, A, B, C and D which are assigned in the counterclockwise direction from the upper left of the figure. The characteristics of the prefectures in each quadrant can be inferred from the economic geographical viewpoint.

(1)The city systems in the prefectures belonging into the quadrant A are intensive and they have high relevancies with the city systems in other prefectures. The prefectures that play important social and economic roles in Japan such as Tokyo (No.13), Aichi (No.23), Osaka (No.27) are located in the North-West part in the quadrant A. And the prefectures that play social and economic roles in a regional

level are also placed in the quadrant A; Miyagi (4), Niigata (15), Kyoto (26), Hiroshima (34), Fukuoka (40), Okinawa (47) are also in this quadrant. It is clear that the prefectures that play social and economic roles in the whole country or in the regional areas are placed on this quadrant: And the structure of city systems in these prefectures are intensive and based on the passenger flow amounts, they have high relevancies with other city systems.

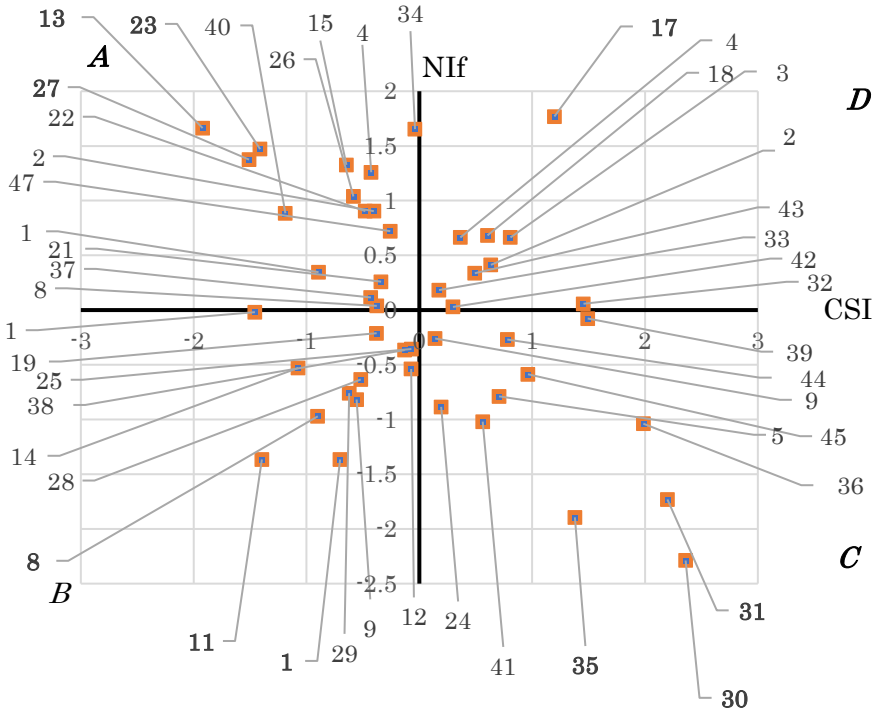

Fig.4 Relationship between CSI and NIf of 47prefectures in Japan

(2)The city systems of the prefectures in the quadrant B are intensive and they have low relevancies with the city systems of other prefectures. Prefectures in the quadrant B are Saitama (11), Chiba (12), Ibaraki (8), Tochigi (9), Gunma (10), Kanagawa (14), Hyogo (28), Nara (29), Shiga (25), and Yamanashi (19). These prefectures are located around the regions which play large social-economic roles in Japan. The economic scale of these prefectures is large, but, the values of NIf of them are low since their connectivity of these prefectures is considered to be biased toward Tokyo or Osaka region. Therefore, it can be said that based on the passenger flow amounts, in prefectures adjacent to the regions that play huge social-economic roles, their city systems have intensive structure and have low relevance index . It is clear that in the quadrant B the geographical location of the prefecture decisively influences the spatial economic characteristics of its city system.

(3)The prefectures in the quadrant C and D are located relatively departed from the regions which

play central role in social-economic activity and their city system are leveled. And almost prefectures in this quadrant have low relevancies with the other prefectures.

A typical characteristic of the prefectures in the quadrant C may be successfully explained by the industrial composition and geographical situation of the two prefectures, Wakayama (30) and Yamaguchi (35). They are located in the lower right part of the quadrant C. They have a large proportion of heavy chemical industry in its industrial composition[5]. It could be considered that because dominant parts of production activity are carried out by many equipment machines, their relevance index based on passenger flow amounts is low. In addition to this, Yamaguchi Prefecture is sandwiched between Hiroshima and Fukuoka prefecture, which possess large economic scale. Thus, large city is hard to be formed in Yamaguchi prefecture and its city system is thought to be leveled. And although Wakayama prefecture is adjacent to Osaka, its geographical shape is complicated and quite long, so its city system becomes level. While, Tottori (31) is explained from rather different viewpoint. It is departed far from Osaka in time and the economic scale is quite small: Since Tottori is rather isolated from other prefectures, its city system is leveled and the relevance through the passenger flow amounts is low. In sum, it could be considered that the city systems of prefectures in which the economic scale is rather small and the ration of heavy industries in the industrial composition is high, tend to be leveled and to have low relevance index based on passenger flow amounts.

(4)The city systems of the prefectures in the quadrant D are level and they have relatively high relevance with the city systems of other prefectures. Typical characteristics of the prefecture belonging to this quadrant are shown in Ishikawa Prefecture (17). Ishikawa Prefecture is relatively far from Tokyo and Osaka and faces the Sea of Japan. Although the economic scale is not so high, the production value of the production equipment is considerably high, and the production machine occupies the first rank in its industrial composition. Prefecture is not in Japan other than Ishikawa prefecture where production machine occupies the top position in the industrial composition. It could be said that in the prefectures, in which economic scale is small and the non-equipment industry is popular in industrial composition, the city systems are leveled and have high relevance index based on passenger flow amounts.

In order to show typical characteristics of the four quadrants, let us expand slightly the scope of analysis: First, select three prefectures from each of the four quadrants, and choose the following items as criterion; ratios of population and GRP of each prefecture in Japan, and the top three industries that account for the high proportion of each prefecture's industrial composition. By these simple

[5] The analysis here does not focus on heavy chemical industry. The analysis of this paper covers companies belonging to industries with relatively many factories and branches. Nevertheless, Considering the characters that fundamental industries may have, the result derived here may be judged to be valid.

procedures a fundamental characteristic of the four quadrants is derived. Table 3 shows a characteristic of the three prefectures in each quadrant from the three criteria. Table 3 may describe successfully a typical characteristic of the prefectures in each quadrant in Fig.4.

Table 3 Characteristics of representative 3 prefectures in each dimension,2012

Pref.	**pop.**	**GRP**	**business type**	**shipment value**	**business type**	**shipment value**	**business type**	**shipment value**
No.	**%**	**%**	**rank 1**	**(1million yen)**	**rank 2**	**(1million yen)**	**rank 3**	**(1million yen)**
A 13	10	18.3	transportation	1,473,415	printing	1,014,133	IT equipment	832,955
A 23	5.73	12.8	transportation	23,091,312	steel	2,437,217	electric equipment	1,894,771
A 27	6.85	13.1	chemistry	1,987,514	oil-coal products	1,660,105	metal product	1,354,280
B 8	2.34	4.36	chemistry	1,511,568	groceries	1,164,414	product equipment	1,031,433
B 11	5.64	8.1	transportation	1,820,269	chemistry	1,636,801	groceries	1,507,802
B 12	4.85	7.71	oil-coal products	3,062,973	chemistry	3,016,494	steel	1,697,053
C 29	0.8	1.34	**steel**	846,093	oil-coal products	825,772	chemistry	323,057
C 31	0.46	0.68	device	139,067	groceries	131,312	pulp-paper	91,465
C 35	1.14	2.11	**oil-coal product**s	1,95,9488	chemistry	1,610,271	transportation	1,015,623
D 3	1.04	1.63	transportation	669,404	groceries	320,842	device	211,958
D 17	0.91	1.66	**product equipment**	593,255	device	313,773	fabric	192,991
D 18	0.63	1.15	**chemistry**	289,475	device	257,038	fabric	234,708

3.4 Relevance Indices based on branch factories and business/sales offices

This subsection focuses on manufacturing companies have some branch factories and business/sales offices. And 152 manufacturing companies are arbitrarily extracted. Then, using the numbers of locations of branch factories and business/sales office in every prefecture, the two kinds of indices of relevance of every prefecture with other prefectures in Japan are derived. The obtained relevance indices of prefecture are used as those of the city system within the prefecture.

3.4.1 Relevance index of city system through locations of branch factories

Procedure for deriving the relevance index of a city system through companies' branch factory locations is as follows. First, 152 companies are extracted from the industry data of 2016. The headquarters, which is handled as one factory, and locations of the branch factories of each company in every prefecture are examined. Then, the number of the factories is assigned to the 47 prefectures. 0 is assign to prefectures where branch factory is not located. The latter two steps are carried out for every company. As a result, a correlation matrix of 47 rows and 47 columns is derived based on the locations of the factories of the 152 companies. Each element of this matrix reveals the level of

relevance between the prefectures through the branch factory. From the correlation matrix, a partial correlation matrix is derived. An element close to zero in the partial correlation matrix is positively set to 0, and from this matrix a correlation matrix is estimated. The same procedure is carried out iteratively until the simplest correlation matrix is obtained. In the resulted correlation matrix, 1 is assigned to nonzero elements. This creates the matrix of 47 rows and 47 columns consisting of 1s and 0s. The prefectures assigned 1 in an element of the matrix have a connectivity each other through the location of the branch factory of a company. And the value obtained by summing up elements of each prefecture is considered as the degree of the relevance to others, which is denoted by NIp. This NIp is used as the level of relevance of a city system in a prefecture to other city systems. Table 4 shows the values of standardized NIp of 47 prefectures in Japan.

Table 4　Relevance Index, NIp, of 47 prefectures in Japan,2016

Prefecture	No.	Standardized NIp		Prefecture	No.	Standardized NIp
Hokkaido	1	0.4519		Mie	24	0.5916
Aomori	2	0.0188		Shiga	25	-1.0197
Iwate	3	-1.7135		Kiyoto	26	0.4125
Miyagi	4	0.0188		Osaka	27	-1.1988
Akita	5	0.4519		Hiyogo	28	-0.4826
Yamagata	6	0.0188		Nara	29	-2.2730
Fukushima	7	0.4519		Wakayama	30	0.2335
Ibaragi	8	-0.8473		Tottori	31	1.6658
Tochigi	9	-0.8473		Shimane	32	1.4868
Gunma	10	0.4519		Okayama	33	-0.1245
Saitama	11	0.4519		Hiroshima	34	-1.0197
Chiba	12	-0.8473		Yamanashi	35	-0.1245
Tokyo	13	1.7511		Tokushima	36	1.4868
Kanagawa	14	1.3181		Kagawa	37	0.4125
Niigata	15	1.3181		Ehime	38	-0.3036
Toyama	16	2.1842		Kochi	39	-1.9150
Ishikawa	17	-1.7135		Fukuoka	40	-1.0197
Fukui	18	0.0188		Saga	41	0.2335
Yamanashi	19	-0.4142		Nagasaki	42	0.7706
Nagano	20	-1.2804		Kumamoto	43	0.9497
Gifu	21	0.0188		Oita	44	1.6658

Shizuoka	22	-0.4142		Miyasaki	45	0.2335
Aichi	23	0.8850		Kagoshima	46	2.0239
				Okinawa	47	-1.0197

3.4.2 Derivation of relevance index based on the locations of business/sales offices

This subsection inquires the locations of the business/sales offices of manufacturing companies. And 152 companies are extracted from the data of 2017, and then, the locations of headquarters and business /sales offices of each company are examined. The headquarters is treated as one business/ sales office and the number of locations of business/sales offices in prefecture is assigned to the prefecture. While, prefectures where the office is not located are assigned 0. The same procedure is carried out for the 152 companies. The procedure for deriving relevance index of the city system through the location of the business/sales offices is the same as the index through the branch factories mentioned above. The prefectures assigned 1 in an element of the matrix have a relevance each other through the location of the business/sales offices. The value obtained by summing up the elements of each prefecture is considered as the degree of the relevance to other prefectures, which is denoted by NIm. This NIm is used as the level of relevance of a city system in a prefecture to other city systems in other prefectures through the location of the business/sales offices. Table 5 shows the values of standardized NIm of 47 prefectures in Japan.

Table 5 Relevance Index, NIm, of 47 prefectures in Japan,2016

Prefecture	**No.**	**Standardized NIm**		**Prefecture**	**No.**	**Standardized NIm**
Hokkaido	1	-0.6617		Mie	24	-0.4142
Aomori	2	0.0544		Shiga	25	-0.8473
Iwate	3	-0.6617		Kiyoto	26	-0.8473
Miyagi	4	-0.8407		Osaka	27	1.3181
Akita	5	0.2335		Hiyogo	28	2.6173
Yamagata	6	1.1287		Nara	29	0.0188
Fukushima	7	1.1287		Wakayama	30	-0.8473
Ibaragi	8	-0.1245		Tottori	31	0.0188
Tochigi	9	-0.1245		Shimane	32	-0.8473
Gunma	10	-0.1245		Okayama	33	-0.8473
Saitama	11	-0.8407		Hiroshima	34	0.4519
Chiba	12	0.0544		Yamanashi	35	1.7511
Tokyo	13	-0.6617		Tokushima	36	0.4519

Kanagawa	14	-1.0197	Kagawa	37	0.4519
Niigata	15	-0.3036	Ehime	38	-1.2804
Toyama	16	1.3077	Kochi	39	-0.8473
Ishikawa	17	-1.0197	Fukuoka	40	0.0188
Fukui	18	0.4125	Saga	41	-0.4142
Yamanashi	19	-0.8407	Nagasaki	42	1.3181
Nagano	20	-0.1245	Kumamoto	43	-0.8473
Gifu	21	1.8449	Oita	44	-0.4142
Shizuoka	22	-0.6617	Miyasaki	45	-0.4142
Aichi	23	-0.4826	Kagoshima	46	-0.8473
			Okinawa	47	0.0188

3.4.3 Characteristics of relevancies between city systems from economic geographical view

Let's combine two kinds of the relevance indices which are derived the above two subsections for each of prefectures placed in each quadrant of A, B, C, D: By the examination of these combinations this subsection observes characteristics of relevancies between the city systems in these four quadrants from an economic geographical view.

(1)In Fig.5 NIp is measured on the horizontal axis and NIm is indicated by the vertical axis. The diamond marks of the figure show the combination of the two relevance indices of each prefecture in the quadrant A. From Fig.5 the followings are indicated. Of 14 prefectures 11 ones in the quadrant A have relatively high relevance with others through the branch factories in manufacturing industry. It is said that the city system of the prefectures which play central roles in social and economic activities in the country have intensive structure and they have high relevancies in NIf and NIp and low relevance in NIm: The networks of the prefectures through branch factories are rather wide, while the networks through business/sales offices tend to be narrow.

(2)Fig.6 shows the combination of the two relevance indices in each prefecture belonging to the quadrant B. The number of prefectures in the quadrant B is 12. The city systems of these prefectures have intensive structure. And almost all prefectures located in the vicinity of the prefectures with huge social and economic activities are placed in the South area of Fig.6. That is, 11prefectures of 12 ones in the quadrant B have relatively low relevance indicated though the business/sales offices. Only one, Chiba Prefecture (12), is slightly away from the South area. As can be easily expected, these prefectures are thought to have a great influence on proximity to regions with huge economic activity

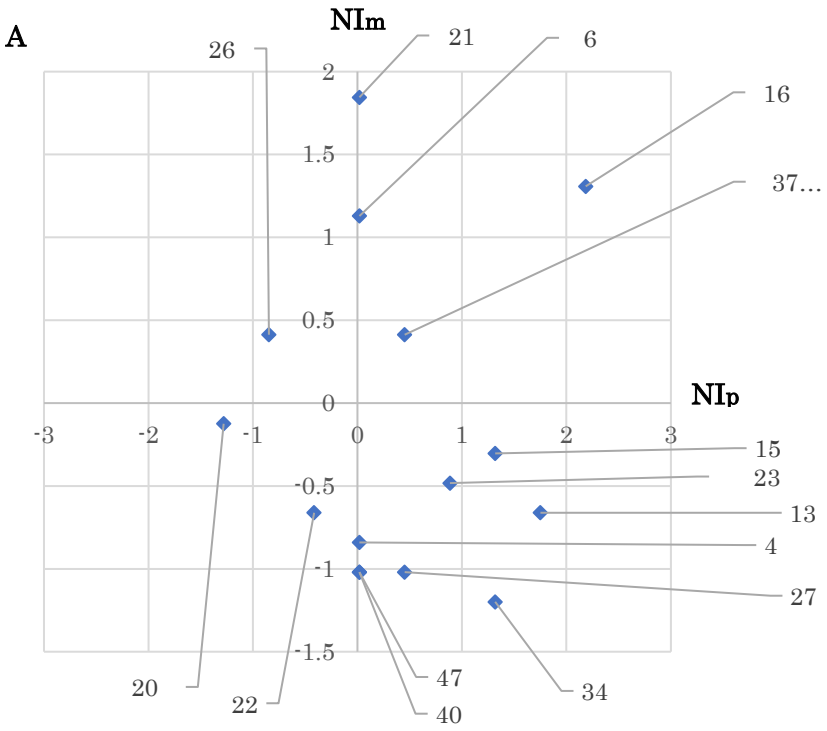

Fig.5 Combination of two relevance indices in quadrant A

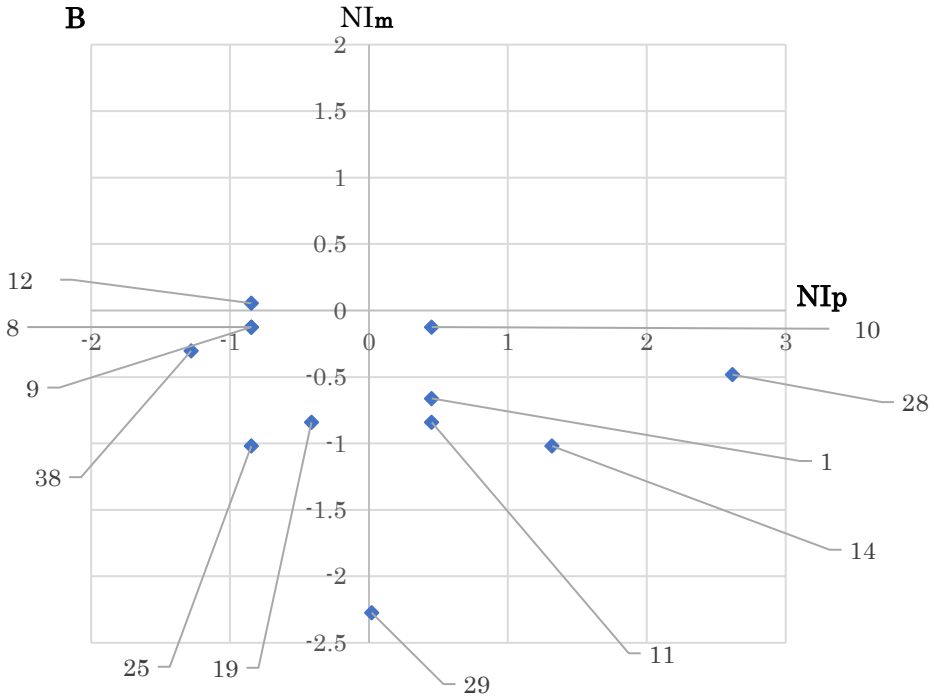

Fig.6 Combination of two relevance indices in quadrant B

(3)Fig.7 shows the combination of the two relevance indices NIp and NIm of each prefecture belonging to the quadrant C. The number of prefectures belonging to the quadrant C is 11. The city systems of these prefectures have level structure. And the prefectures in this quadrant are relatively far from the prefectures with large social and economic activities. And 82 percent of the prefectures in this quadrant belong to the North area of Fig.7. That is, their relevancy index based on NIm is high. Only two prefectures of Kochi (39) and Yamaguchi (35) enter into the South area of Fig.7. Many prefectures in this group are considered to substitute for the passenger flow amounts with the locations of the business/sales offices. Kochi (39) prefecture seem to have different economic geographical characters from others.

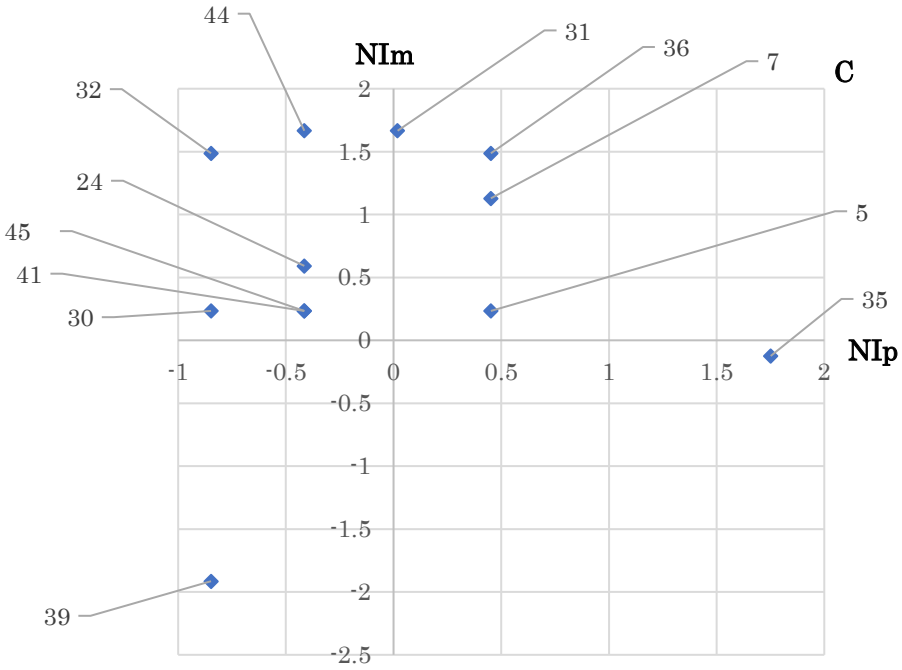

Fig.7 Combination of two relevance indices in quadrant C

(4)Fig.8 shows the combination of the two relevance indices of each prefecture in the quadrant D. The number of prefectures in the quadrant D is 9. The city systems of these prefectures have level structure. The prefectures that in this area are relatively far from the prefectures that play central roles in social and economic fields. And 67 percent of the prefectures in the quadrant D belongs to the West area of Fig.8 where relevance based on NIp is relatively low. Similarly , 67 percent of the prefectures in the quadrant D belongs to the North area of Fig.10 where relevance based on NIm is relatively high. While, there is no prefecture in the East-South area in Fig.8.

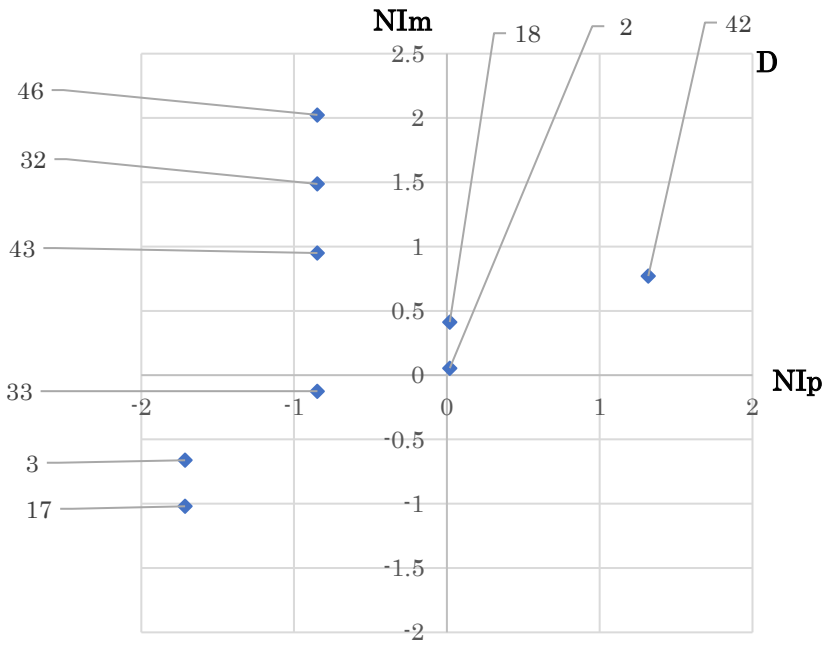

Fig.8 Combination of two relevance indices in quadrant D

3.4.4 Economic geographical consideration on relevancies of prefectures

Considering the results observed in the previous analyses from the view point of economic geography, the relevancies of the city systems of prefectures are summarized into the following four groups.

1)The structure of the city systems in the prefectures that play central roles in social and economic activities tends to be concentrative. And the city systems have high relevancies other city systems through the passenger flow amounts, NIf, and the locations of the branch factories of manufacturing companies, NIp. While they have low relevancy through the locations of the business/sales offices of manufacturing companies. Considering large passenger flow amounts due to huge economic activities, it is inferred that they have high NIf and low NIm.

Prefecture that has an intensive city system and the three relevancy indicators are high is only Toyama prefecture.

2) The prefectures located in the vicinity of the regions with large economic scale have large economic activity. Thus, their city system are concentrative structure. These prefectures have relatively high coopetition with the regions carrying out large social and economic activities. While, they have relatively low connectivity with regions in rural area. Thus, the relevancies of the city systems through the passenger flow amounts and the locations of the business/sales offices of manufacturing companies are low. On the other hand, the extent to which they have the relevancy through the branch factories may depend on their industrial composition.

There is almost no prefecture that has an intensive city system and the high relevancy indicator

based on business/sales offices.

3) The city systems of the prefectures that depart from the economically active regions tend to be leveled. Some of these prefectures tend to have low relevance in passenger flow amount. The cause of this tendency may be considered as follows: since they have the heavy chemical industry in their industrial composition, they do not need to large passenger flow amounts. And It is considered that these prefectures may substitute for the passenger flow amounts with the locations of the business/sales offices in manufacturing industry: The manufactured goods of industries in these prefectures may need to secure a wide range of sales destinations, thus the relevancy through NIm becomes high. The extent to which they have the relevancy through the branch factories may depend on their industrial composition. It is noteworthy that as shown by Kochi(39) prefecture, when a prefecture has a small economic scale and its location is departed from economically active region, the relevancies of the city system based on the passenger flow amounts is not so low, the relevancies through branch factories and business/sales offices of manufacturing companies are small. It seems to be rather isolated city system. In the prefecture entering this group, there are few prefectures that there are not many prefectures that have high relevancy through NIp and low relevancy through NIm.

4) Like the prefectures of 3) above, the city systems in the prefectures that are departed from the economically representative regions tend to be leveled. But others of these prefectures tend to have relatively high relevance in passenger flow amount. Furthermore, there is prefecture that has very high relevancy. The extent to which they have the relevancy through the branch factories may depend on their industrial composition.

There is almost no prefecture that has a leveled city system and the high relevancy indicator based on the branch factories of manufacturing industries.

Meanwhile, considering the relevancies of Ishikawa prefecture may give an insight in planning city system: the city system of Ishikawa prefecture that has low CSI, which means that the city system is level and its economic activity is not concentrated in the largest city. And this prefecture has high relevancy based on passenger flow amount, which may mean that the prefecture is opened to other regional economies. And it has low relevancies through NIp and NIm, this may indicate that this prefecture has established an industrial and economic foundation locally in its own region. This prefecture would provide a good model which some prefectures in rural area should refer for vitalizing regional economy: In order to autonomously revitalize local economic activities, it is necessary to develop a local production organization. On the other hand, to maintain the organization, it is necessary to capture large external demand, for which cooperation with the outside is indispensable. In addition, in order to further maintain social soundness, a level urban system is desirable. Ishikawa Prefecture seems to have the possibility of meeting these requirements.

4 Conclusions

Cities are places where people's consumption activities and production activities are specifically realized. The economic activities in a city are not carried out isolatedly, but in cooperation with many other cities. For this reason, many of the economic roles and characteristics of individual cities are set in the framework of a city system. This city system is usually formed in an administrative area having a certain geographical range. Therefore, the regional economy and the city system are interdependent each other, and the scale and characteristics of economic activities in a region are represented in the structure of the city system. Furthermore, as economic activity in general expands wider, the movement of goods expands on a global scale. In response to this globalization, an economic cooperation is deepened among the city systems in many countries.

This paper examines the relevancies between the city systems by using three kinds of connection indices: These indices are obtained by analyzing the passenger flow amounts(NIf), the locations of the branch factories(NIp), and the locations and business/sales offices(NIm) of the companies in manufacturing industry in 47 prefectures. The analysis of this paper shows the following things. Prefectures that play a central social and economic function in the country and regions have high relevancies with other areas in the indicators of NIf and NIp. Prefectures adjacent to areas playing a central role have low relevancies through NIf and NIm. Many prefectures located far from areas playing a central role have low relevancy through NIf. And the prefectures away from area with large economic activities that have high relevancy through NIm. And among these prefectures, there are few prefectures have low relevancy through NIm and high relevancy through NIp. It is shown in this consideration that even in prefectures located far away from areas with large economic activities, there is prefecture that shows the possibility of maintaining autonomous economic activities by establishing production organization in its area and through many human interactions with other areas .

Since the economic activities in each prefecture are revealed on the city system, the relevancies among the city systems are examined by using prefectural materials in this analysis and the data of the companies in manufacturing industry. As shown in this paper, the relevancy between the city systems changes greatly depending on the index. In order to clarify cooperation of the city system in more detail. It is needed to conduct more refined analysis from more materials. The results derived in this analysis are expected to be a kind of a clue for the future researches.

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