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An Analysis of Regional Production Activity Using Regional Connection Indexes

Toshiharu ISHIKAWA

This paper examines the relation between connection economy and economic activity of a region. There are two types of connection economy : the city system economy and the reginal connection economy. The paper indirectly estimates the effects of the connection economies on the regional economic activity because it is difficult to directly measure influence of these economies on economic activity. First, it divides the 47 prefectures of Japan into 4 categories. And it classifies the prefectures belonging to each of the 4 categories into 4 groups using the regional connection indexes created on the basis on branch factories and sales offices. And then, the paper estimates the effects of the connection economies on regional economic activity. The estimation suggests the followings. The economic activities of the prefectures that play a major socio-economic role in Japan have low regional connection based on sales offices and have high regional connection based on branch factories. On the other hand, the economic activities of the prefectures that do not enjoy abundantly the city system economy and the connection economy based on people flow amount have high the regional connection based on sales offices. Those of the prefectures adjacent to the Tokyo and Osaka prefecture have low regional connection based on sales offices.

1. Introduction

Since the Industrial Revolution, the agglomeration economy has had decisive influence on the factory locations. The influence of the agglomeration economy that sticks to a place has power to attract the factories to a place. The factories enjoy the agglomeration economy at a place and produce goods with low production costs. As economic activity in general becomes wider globally, firms' activities expand. The expansion stimulates innovation in information and communication technology ICT. It significantly changes firms' activities. And the change modifies the production system in agglomeration and restructures spatial formation of the agglomerations : The innovation of the ICT greatly contributes to the regional connection economy created by connections among regions. And the regional connection economy that works on the basis of the agglomeration economy sticked to a place changes functions and production organization of both of the firms and

the agglomerations. It can be said that in addition to the economy of the existing agglomeration, the economy of regional connection created among the regions has been influencing production activity.

From around 1900, the locational effects of agglomeration have widely recognized in the academic realm, and its analysis has greatly progressed.[1] Spatial economics begins to pay attention on the regional connection economy. The progress of the analysis, however, is slow and it is in its starting stage due to the complex of social functions of connections among economic agents. For the purpose of advancing progress of the analysis as much as possible, this paper inquires the connection economy in cooperation with the well-known agglomeration economy.[2] Using the indexes that may represent the degree of economic effect of the connection among regions, it analyzes the influence of the connection among the regions on regional production activity.

The structure of this paper is as follows. In the section 2, the results of the existing research using city system index and regional connection index that may represent the connection economies are introduced. And the research results are used as the basis for the analysis of this paper. Section 3 devises regional connection indexes by using data of the Japanese manufacturing firms, and it proposes two new types of the regional connection indexes. And it is considered how regional connections influence regional economic activity. Section 4 examines the regional industrial economy in Japan. The prefectures that show typical industrial characteristics in 47 prefectures in Japan are selected and it examines their industrial economy. This examination clarifies how the regional connection influences the regional industrial structure. Section 5 summarizes and concludes the discussion in this paper.

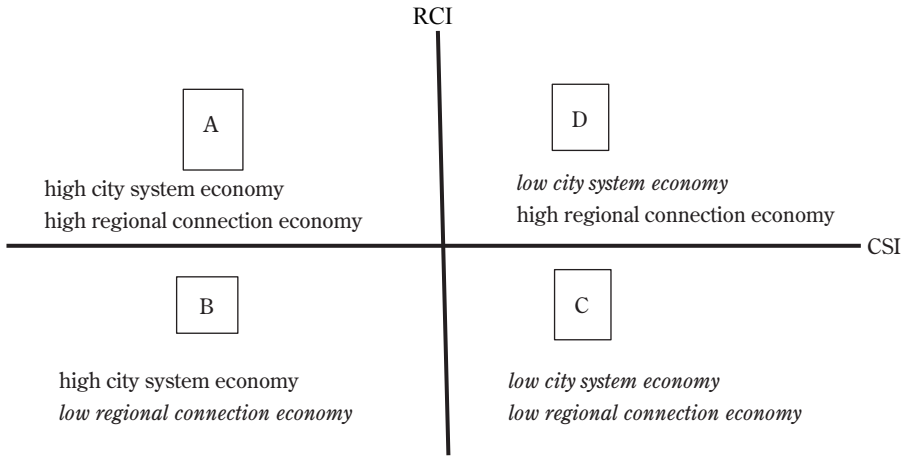
2. Classification of regional production activity by two indexes of connection economy

This section introduces the city system index CSI and the regional connection index RCI and explains their role in analysis of industrial economy in a region. These two indexes are considered to indirectly reveal how much city system economy and regional connection economy influence production activity of factory and region (Ishikawa, 2019, 2021). Using the two indexes, regional production activity can be classified into four groups as shown in the A, B, C, and D quadrants of Figure 1 : The quadrant A in Figure 1

1) From a location theory perspective, Weber (1909) made the first systematic analysis of agglomeration.

2) See Capello (2000) Meeteren, Neal and Derudder (2016) for the connection economy in this analysis which is dealt with as part of network economy.

Figure 1 Classification of regions by indexes of city system and regional connection



includes the regions that relatively abundantly enjoy the two economies of the city system and the regional connection. On the other hand, the quadrant C includes the regions that do not enjoy these two economies relatively much. The quadrant B contains the regions that enjoy much the city system economy but that do not enjoy the regional connection economy relatively much. The quadrant D contains the regions that enjoy much regional connection economy but that do not enjoy the city system economy very much.

Let us reexamine economic characteristics of the 47 prefectures in Japan classified into four quadrants by using the two indexes that are derived based on the Japanese data. Based on the Japanese economic data,[3] Ishikawa (2019, 2021) classified the 47 prefectures into the four quadrants as shown in Table 1 and Figure 2. The quadrant A includes all prefectures that play a major socio-economic role in Japan as a whole or in local area. The quadrant B contains the prefectures adjacent to the above socio-economically large prefectures, Tokyo and Osaka. The quadrant C includes the prefectures located on the outer periphery of a wide economic zone of Tokyo and Osaka. Lastly, the prefectures that are economic geographically departed from Tokyo and Osaka belong to the quadrant D. It can be said, therefore, that the prefectures with a major socio-economic role are in the quadrant A ; and depending on the degree to which the location of the prefecture deviates from the prefecture with a large socio-economic scale, the prefectures are distributed in the order of the quadrant B, the quadrant C, and the quadrant D.

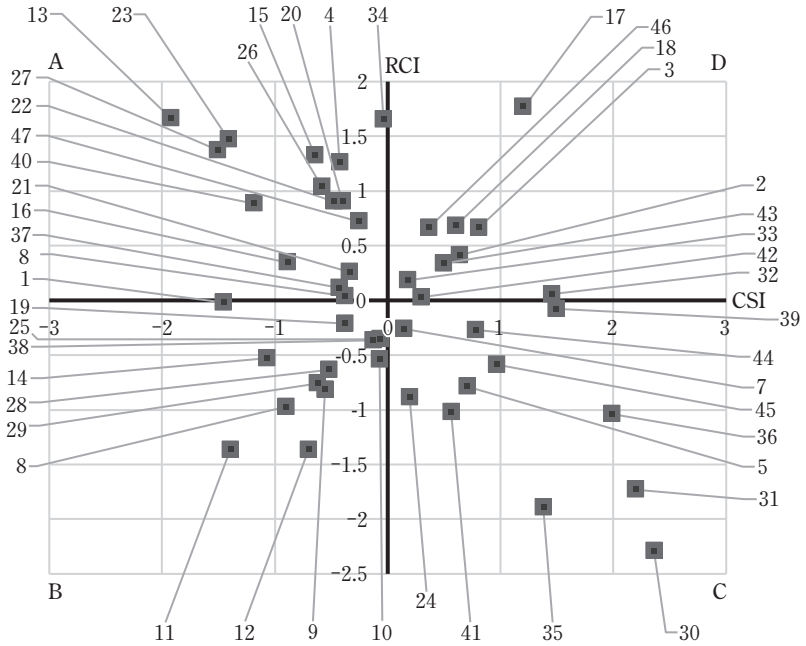
3) *Chiiki-Keizai-Soran* (Data book, 2019, in Japanese).

Table 1 Classification of 47 prefectures into 4 quadrants

A	B	C	D
Miyagi (4)	Hokkaido (1)	Akita (5)	Aomori (2)
Yamagata (6)	Ibaraki (8)	Fukushima (7)	Iwate (3)
Tokyo (13)	Tochigi (9)	Wakayama (30)	Ishikawa (17)
Niigata (15)	Gunma (10	Tottori (31)	Fukui (18)
Toyama (16)	Saitama (11)	Mie (24)	Shimane (32)
Nagano (20)	Chiba (12)	Yamaguchi (35)	Okayama (33)
Shizuoka (22)	Kanagawa (14)	Tokushima (36)	Nagasaki (42)
Gifu (21)	Yamanashi (19)	Kochi (39)	Kumamoto (43)
Aichi (23)	Shiga (25)	Saga (41)	Kagoshima (46)
Kyoto (26)	Nara (29)	Oita (44)	
Osaka (27)	Hyogo (28)	Miyazaki (45)	
Hiroshima (34)	Ehime (38)		
Kagawa (37)			
Fukuoka (40)			
Okinawa (47)			

(Note) The number in parentheses indicates the prefecture.
(Source) Ishikawa (2019)

Figure 2 Classification of 47 prefectures into 4 categories



(Source) Ishikawa (2019)

3. Classification of prefectures in each quadrant by new regional connection indexes

Classification of the 47 prefectures in Figure 2 is made by the city system index of prefecture and the regional connection index derived from the passenger flow amount of each prefecture. These two indexes are constructed from the data for each prefecture and they are effective in dividing the characteristics of production activity of each prefecture into the four groups (Ishikawa, 2021).

This section deepens the examination made above regarding the production activity of each prefecture : In this section, the two new regional connection indexes are derived based on a firm-level perspective. And this section uses these new indexes to classify the prefectures into four groups in each of the four quadrants. One of the new regional connection index is the Production Connection Index PCI. This index is based on the locations of the branch factories owned by the firms. The other is the Sales Connection Index SCI. This index is based on the locations of the sales offices of the firms. These two indexes PCI and SCI are also useful to indirectly reveal how much the regional connection among the regions influence production and sales activity of factory and region. Methods for devising these indexes is explained in the next subsection.

3.1 Derivation of regional connection indexes based on branch factories and sales offices

Index PCI is derived using the Japanese case as follows. First, 152 firms belonging to the machine industry in Japan are arbitrarily selected.[4] And the number of the branch factories of each firm and the prefecture where they are located are derived.[5] Then, assign the number of the branch factories to the prefecture where the firm has branch factory, and then, give value of 0 to the prefecture where the firm has no branch factory. Conduct the same procedures for the selected 151 firms. As a result, a matrix X of 152 rows and 47 columns is created and it is shown by matrix (1).

4) The material is based on *Kaisya-Shikiho* (Data book on stock listed companies, 2017, in Japanese). The machinery industry is a leading industry in Japan. Thus, the indexes based on the branch factories and the sales offices of the machinery 152 firms may be considered to be a useful standard for estimating the degree of connections among the prefectures.

5) The main factory of a firm is also counted as a branch factory.

$$X = \begin{bmatrix} A_{1,1} & A_{1,j} & A_{1,47} \\ \cdots & \cdots & \cdots \\ \cdots & A_{i,j} & \cdots \\ \cdots & \cdots & \cdots \\ A_{152,1} & A_{152,j} & A_{152,47} \end{bmatrix} \quad (1)$$
$$i = 1, \ldots 152, j = 1, \ldots 47$$

$A_{i,j}$ is the number of the branch factories of firm i in j prefecture. Correlation analysis between the 47 prefectures is conducted based on this matrix, and a correlation matrix X_C of 47 rows and 47 columns is obtained. This correlation matrix is shown in matrix (2), and each element $C_{i,j}$ (i, j = 1, . . . 47) shown in matrix (2) indicates the correlation coefficient between the prefectures.

$$Xc = \begin{bmatrix} C_{1,1} & C_{1,j} & C_{1,47} \\ \cdots & \cdots & \cdots \\ \cdots & C_{i,j} & \cdots \\ \cdots & \cdots & \cdots \\ C_{47,1} & C_{47,j} & C_{47,47} \end{bmatrix} \quad (2)$$
$$i = 1, \ldots 47, j = 1, \ldots 47$$

A partial correlation matrix is derived from the correlation matrix represented by the matrix (2). A value of 0 is positively given to the element having an extremely low value in this partial correlation matrix. Based on the derived partial correlation matrix, the second correlation matrix between the 47 prefectures is estimated. Then, the second partial correlation matrix is derived from the new correlation matrix. Repeat this procedure to find the correlation matrix with the maximum number of the blank elements. And then, replace the non-zero value of the elements of this correlation matrix with 1, by this procedure the values of all the elements are set to 1 or 0. As a result, a matrix X_L composed of elements $L_{i,j}$ (i, j = 1, ... 47) having a value of 1 or 0 is obtained. This matrix is shown by matrix (3).

$$X_L = \begin{bmatrix} L_{1,1} & L_{1,j} & L_{1,47} \\ \cdots & \cdots & \cdots \\ \cdots & L_{i,j} & \cdots \\ \cdots & \cdots & \cdots \\ L_{47,1} & L_{47,j} & L_{47,47} \end{bmatrix} \quad (3)$$
$$i = 1, \ldots 47, j = 1, \ldots 47$$

Finally, the elements L_j having a value of 1 are added for each prefecture i, and the total value added is represented by equation (4).The total value shows the Production Connection Index PCI.

$$PCI_i = \sum_{j=1}^{j=47} L_{i,j} \quad (4)$$

Secondly, let us obtain the index SCI based on the locations of the sales offices owned by firm by using Japanese case. It is devised as follows. First,152 firms belonging to the

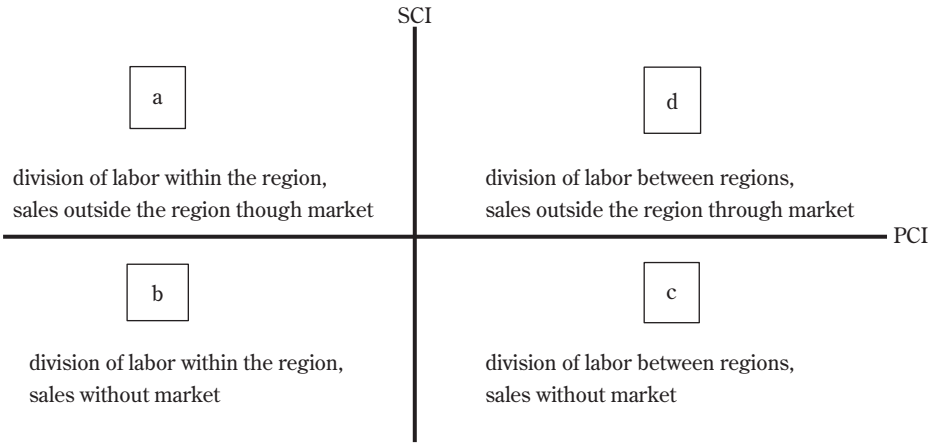
machine industry are again arbitrarily extracted. The number of the sales offices of each firm and the prefecture where they locate are derived.[6] Then, the number of the sales offices is assigned to the prefecture where the firm has the office, and 0 is given to the prefecture that does not have sales office. And conduct the same procedures for the 151 firms. The following derivation procedures are the same as those of PCI. The regional connection index SCI is derived based on the sales offices of the firms for each prefecture.

3.2. Conceptual classification of regional economic activity by new two regional connection indexes

Production and sales activity of firms in the regions in each of the quadrants A, B, C and D are influenced by regional economic environment. And even if firms in the regions belong to the same quadrant, there are some differences in their production and sales activity. By using the new two indexes PCI and SCI, the regional production and sales activity of prefecture are classified into the four groups a, b, c, and d. This classification is useful to deepen the analysis of regional industrial economy.

A conceptual classification of the production and sales activity is suggested as a, b, c, and d in Figure 3. The concrete characteristics of production and sales activity of the prefectures in Japan is analyzed in the next subsection.

Figure 3 Grouping production and sales activity by PCI and SCI



6) The head office of the firm is also included in the number of the sales office.

3.3. Classification of prefectures by new two regional connection indexes

The regional connection indexes PCI and SCI of the 47 prefectures in Japan are obtained by using data of the machine industry according to the methods introduced in the previous subsection. Values of PCI and SCI of the 47 prefectures and their standardized values are shown in Table 2.

Let us classify the prefectures in each of the quadrants A, B, C, and D into the four

Table 2 Regional connection indexes based on branch factories and sales offices (2017)

Prefecture	PCI	Standardized PCI	SCI	Standardized SCI
Hokkaido	5	0.4519	9	−0.6616
Aomori	4	0.0188	13	0.0544
Iwate	0	−1.7135	9	−0.6616
Miyagi	4	0.0188	8	−0.8407
Akita	5	0.4519	14	0.2335
Yamagata	4	0.0188	19	1.1287
Fukushima	5	0.4519	19	1.1287
Ibaraki	2	−0.8473	12	−0.1245
Tochigi	2	−0.8473	12	−0.1245
Gunma	5	0.4519	12	−0.1245
Saitama	5	0.4519	8	−0.8407
Chiba	2	−0.8473	13	0.0544
Tokyo	8	1.7511	9	−0.6616
Kanagawa	7	1.3181	7	−1.0197
Niigata	7	1.3181	11	−0.3036
Toyama	9	2.1843	20	1.3077
Ishikawa	0	−1.7135	7	−1.0197
Fukui	4	0.0188	15	0.4125
Yamanashi	3	−0.4142	8	−0.8407
Nagano	1	−1.2804	12	−0.1245
Gifu	4	0.0188	23	1.8449
Shizuoka	3	−0.4142	9	−0.6616
Aichi	6	0.8850	10	−0.4826
Mie	3	−0.4142	16	0.5916
Shiga	2	−0.8473	7	−1.0197
Kyoto	2	−0.8473	15	0.4125
Osaka	7	1.3181	6	−1.1988
Hyogo	10	2.6173	10	−0.4826
Nara	4	0.0188	0	−2.2730
Wakayama	2	−0.8473	14	0.2335

Tottori	4	0.0188	22	1.6658
Shimane	2	−0.8473	21	1.4868
Okayama	2	−0.8473	12	−0.1245
Hiroshima	5	0.4519	7	−1.0197
Yamaguchi	8	1.7512	12	−0.1245
Tokushima	5	1.7511	21	1.4868
Kagawa	5	0.4519	15	0.4125
Ehime	1	−1.2804	11	−0.3036
Kochi	2	−0.8473	2	−1.9150
Fukuoka	4	0.0188	7	−1.0197
Saga	3	−0.4142	14	0.2335
Nagasaki	7	1.3181	17	0.7706
Kumamoto	2	−0.8473	18	0.9497
Oita	3	−0.4142	22	1.6658
Miyazaki	3	−0.4142	14	0.2335
Kagoshima	2	−0.4142	24	2.0239
Okinawa	4	0.0188	7	−1.0197

(Data) Kaisya-Shikiho (2017)

Figure 4 Four classification of prefectures in quadrant A

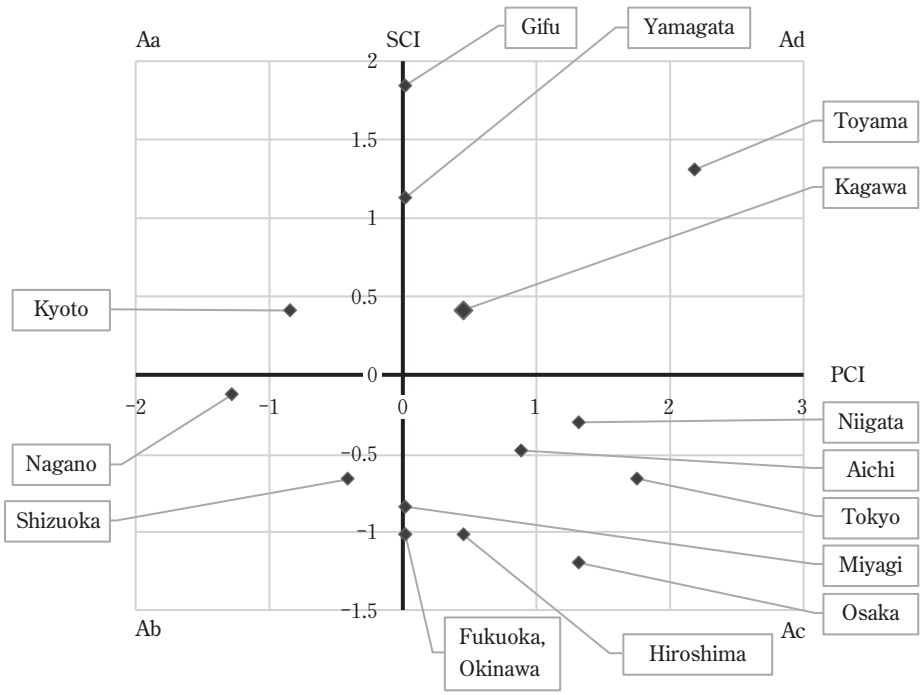


Figure 5 Four classification of prefectures in quadrant B

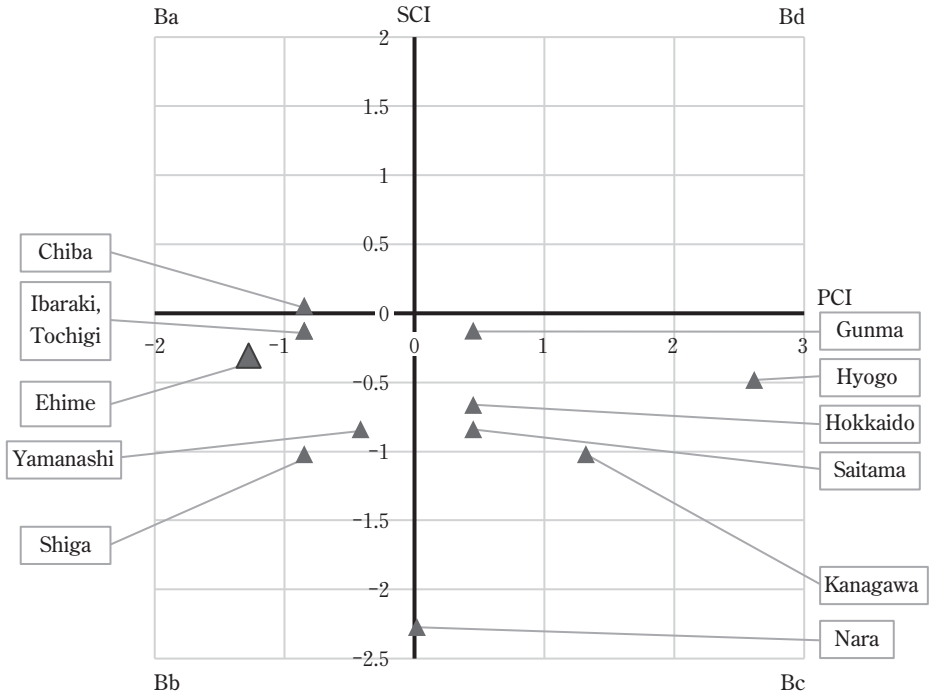


Figure 6 Four classification of prefectures in quadrant C

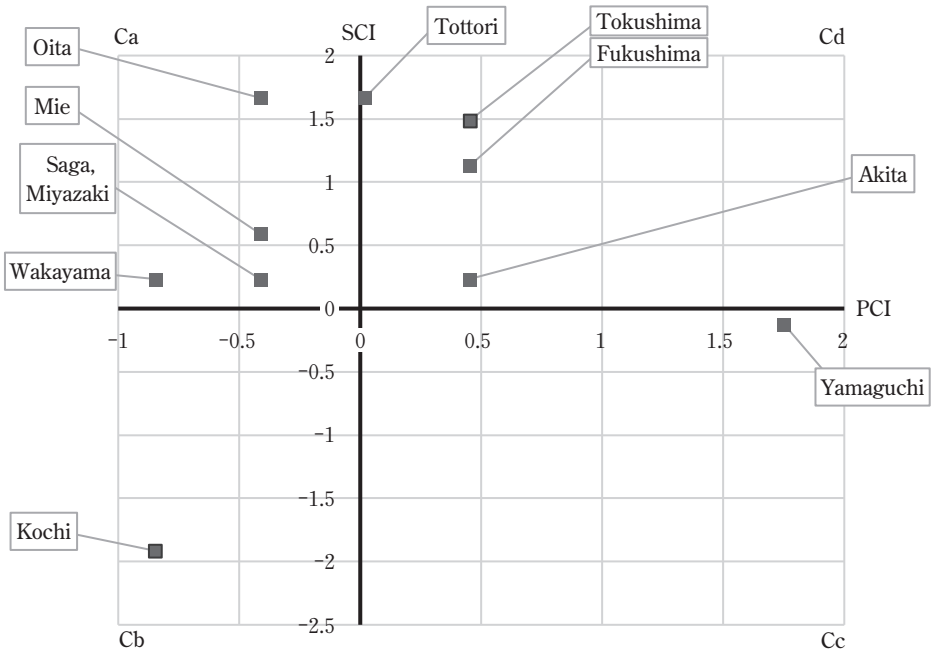


Figure 7 Four classification of prefectures in quadrant D

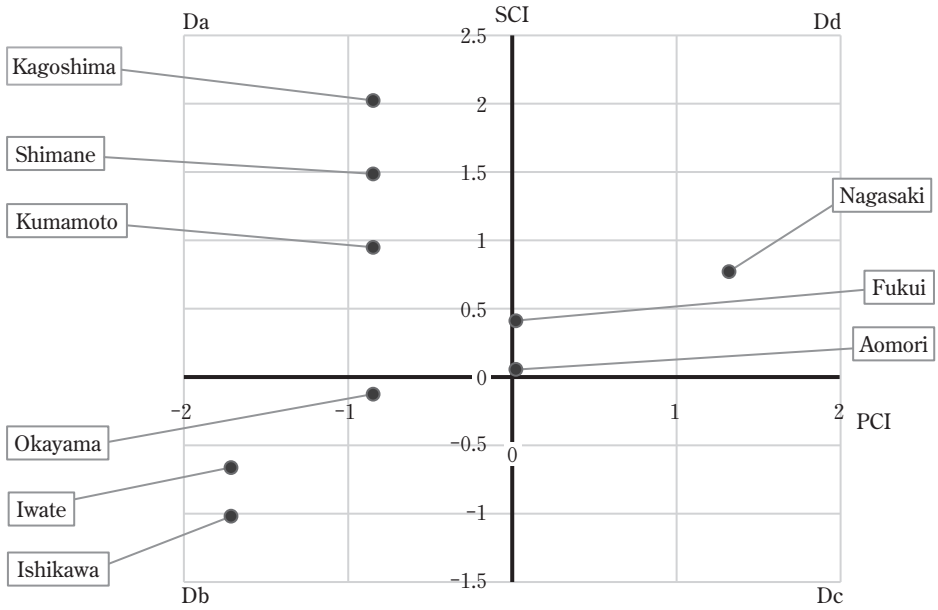


Table 3 The distribution ratios of number of prefectures in each quadrant

A	%	B	%	C	%	D	%
Aa	6.7	Ba	8.3	Ca	45.5	Da	33.3
Ab	13.3	Bb	41.7	Cb	9.1	Db	33.3
Ac	53.3	Bc	50.0	Cc	9.1	Dc	0
Ad	26.7	Bd	0	Cd	36.4	Dd	33.3

groups a, b, c, d by the standardized values of PCI and SCI shown in Table 2. Figure 4 classifies 15 prefectures in the A quadrant into Aa, Ab, Ac, and Ad. Similarly, Figures 5, 6 and 7 show the classification of the prefectures in each of the B, C and D quadrants, respectively. Table 3 shows the distribution percentage of the prefectures into each of 16 quadrants.

4. Characteristics of economic activity in each quadrant

This section examines economic activity of the prefectures in teach of the 16 quadrants by the following four items. Gross Regional Product (GRP), Shipment Value of manufactured product per person (S), Gross Value added of manufactured product per person (V), Ratio of (V / S). The value of each item in each prefecture are shown in Table 4.

Table 4 Values of basic economic indicators of prefectures

Prefecture	GRP gross regional product (100 million yen)	V gross value added per person in manufacturing industry (10,000 yen)	S manufactured product shipment value per person (10,000 yen)	(V/S) ratio
Hokkaido	198,106	1,130	3,842	0.2941
Aomori	46,589	1,252	3,088	0.4054
Iwate	48,560	853	2,800	0.3046
Miyagi	95,940	1,204	3,607	0.3337
Akita	38,437	869	2,056	0.4226
Yamagata	44,145	951	2,644	0.3596
Fukushima	80,129	1,169	3,272	0.3572
Ibaraki	124,261	1,555	4,599	0.3381
Tochigi	89,004	1,598	4,463	0.358
Gunma	86,746	1,747	4,415	0.39563
Saitama	230,961	1,256	3,318	0.3785
Chiba	224,763	1,485	6,160	0.2411
Tokyo	1,029,458	1,261	3,111	0.4053
Kanagawa	431,760	1,545	4,982	0.3101
Niigata	91,408	1,063	2,642	0.4023
Toyama	47,826	1,235	3,149	0.3921
Ishikawa	50,821	1,200	2,940	0.4081
Fukui	32,869	1,205	2,814	0.4282
Yamanashi	32,759	1,433	3,479	0.4118
Nagano	85,827	1,197	3,115	0.3842
Gifu	78,182	1,059	2,752	0.3848
Shizuoka	168,206	1,551	4,130	0.3755
Aichi	3,765,560	1,811	5,583	0.3243
Mie	76,948	1,707	5,673	0.3008
Shiga	64,549	1,621	4,589	0.3532
Kyoto	111,451	1,574	3,840	0.4098
Osaka	372,902	1,273	3,782	0.3365
Hyogo	216,295	1,520	4,437	0.3425
Nara	40,150	1,150	3,172	0.3625
Wakayama	37,380	1,550	5,037	0.3077
Tottori	19,844	834	2,249	0.3708
Shimane	24,755	1,109	2,825	0.3925
Okayama	79,548	1,507	5,484	0.2747

Hiroshima	120,948	1,626	4,881	0.3331
Yamaguchi	62,403	1,945	6,734	0.2888
Tokushima	31,439	1,985	3,767	0.5269
Kagawa	40,107	1,231	3,715	0.3313
Ehime	50,799	1,421	5,391	0.2635
Kochi	25,359	838	2,278	0.3678
Fukuoka	192,370	1,253	4,238	0.2956
Saga	27,548	1,207	3,145	0.3837
Nagasaki	46,663	1,017	2,827	0.3597
Kumamoto	59,841	1,185	3,079	0.3848
Oita	43,865	1,625	6,803	0.2388
Miyazaki	39,191	1,113	2,957	0.3763
Kagoshima	58,003	1,019	2,955	0.3448
Okinawa	58,003	806	2,310	0.3489

(Data) Chiiki keizai soran (2019)

4.1. Characterization of each quadrant by Gross Regional Product

Let us examine the average Gross Regional Product GRP in each of the 16 quadrants.[7] GRP reflects the scale of economic activity in a prefecture, and the economic scale may be successfully revealed by the city system index.[8] The average value of GRPs of the prefectures belonged to each quadrant and the ranking of the prefectures based on it are shown in Table 5 (the value in parentheses indicates the rank of each of 16 quadrants). The following points can be seen from Table 5. GRP is high in the quadrants Ac, Bb and Bc, where city system economy can be fully enjoyed : GRP is high in the Ac quadrant to which all prefectures with a large socio-economic role in Japan. However, the Ad quadrant is slightly spatially divergent from the prefectures of the Ac quadrant, and the Ad quadrant is a slightly heterogeneous in the A quadrant. On the other hand, GRP is low in the C and D quadrants where the enjoyment of city system economy is relatively low. GRP in the Db and Cc quadrants, however, are relatively high and exceed that of the Ad quadrant, and it is considered that there may be interesting industrial structure for these quadrants.

Because the size of the economic scale is reflected in the city system index, the quadrant A and B with *low* city system index have high GRP. This point is reflected in Table 5. And it is also interesting that Db quadrant with *high* city system index has relatively high GRP.

7) The material is based on Chiiki-Keizai-Soran (Data book, 2019).
8) See Ishikawa (2019).

Table 5 Average GRP of 16 quadrants and their ranking (10million Yen)

Aa	76,805 (5)	Ba	181,681 (2)	Ca	33,428 (11)	Da	33,739 (10)
Ab	92,065 (4)	Bb	65,024 (6)	Cb	18,440 (14)	Db	40,697 (7)
Ac	208,703 (1)	Bc	146,109 (3)	Cc	38,965 (8)	Dc	–
Ad	37,648 (9)	Bd	–	Cd	29,008 (13)	Dd	30,078 (12)

4.2. Characterization of each quadrant by economic indicators

This subsection surveys the shipment value of products per person in the prefectures in each quadrant. Table 6 shows the average manufactured product shipment value per person in the quadrants and their ranking of it. The shipment value per person suggests a part of characteristics of production activity such as productivity in each quadrant : The Cc quadrant ranks first in terms of the shipment value of product per person. Only Yamaguchi Prefecture belongs to this quadrant and this prefecture has the chemical industry accounts for about 30% of the shipment value in the industry in this prefecture. The chemical industry is considered to be highly productive. The shipment value of product per person in Oita Prefecture in Ca quadrant exceeds that of Yamaguchi prefecture, and its production composition is occupied by the chemical, steel, petroleum coal and the transportation machinery industry. These two prefectures have the industries that tend to be more productive. The production environment in the quadrant C is revealed by the equipment industry.

Next, let us surveys the ratio V / S of the gross value added of product to the shipment value of product. This ratio partly reflects the cost of raw materials and it varies depending on how the raw materials are obtained. Table 7 shows the ratio of each of the quadrants and their ranking of it. The Cc and Ba quadrant are placed on the 13th and 14th place in the V / S ratio, respectively. They occupy the 1st and 2nd place in the shipment value of

Table 6 Average Shipment value per person of 16 quadrants and their ranking (10,000 Yen)

Aa	3,840 (6)	Ba	6,160 (2)	Ca	4,723 (3)	Da	2,953 (11)
Ab	3,623 (9)	Bb	4,504 (4)	Cb	2,278 (14)	Db	3,741 (8)
Ac	3,769 (8)	Bc	4,028 (5)	Cc	6,734 (1)	Dc	–
Ad	3,065 (10)	Bd	–	Cd	2,836 (13)	Dd	2,910 (12)

Table 7 Average Ratio of (V/S) of 16 quadrants and their ranking

Aa	0.4098 (3)	Ba	0.2411 (14)	Ca	0.3214 (12)	Da	0.3741 (5)
Ab	0.3799 (4)	Bb	0.3654 (7)	Cb	0.3677 (6)	Db	0.3292 (11)
Ac	0.3475 (9)	Bc	0.3472 (10)	Cc	0.2888 (13)	Dc	–
Ad	0.3636 (8)	Bd	–	Cd	0.4188 (2)	Dd	0.4224 (1)

product per person.

Conversely, the Dd and Cd quadrant are placed on the 1st and 2nd place in the V / S ratio, respectively. They occupy the 12th and 13th place in the shipment value of product per person, respectively, An interesting phenomenon is shown by the change in the ranking.[9)]

4.3. Industrial characteristics of 4 prefectures in Shikoku area

The comparison of the industrial characteristics of the quadrants is useful to clarify effects of production environment on production activity in the prefectures. This subsection compares production activities of the four prefectures in Shikoku area, Kagawa, Ehime, Kochi, and Tokushima. They belong to the quadrants Ad, Bb, Cb, Cd and their production environment is different each other. The production characteristics of each prefecture are extracted by the comparative consideration of their basic economic conditions. It may contribute to expands the analysis of the production influences of regional connections.

Table 8 shows the cargo movement of each of the four prefectures. Table 8 points out in the row 4 and 5 that the largest export destination prefecture of each prefecture and its export volume : 73,872 tons of cargo are transferred from Tokushima prefecture to Kagawa prefecture, 86,781 tons are transferred from Kagawa prefecture to Ehime prefecture, and 31,757 tons are transferred from Ehime prefecture to Tokushima prefecture. Each volume accounts for 70% of the total transfer volume of each prefecture. Next, let us survey the largest amount of imports of these three prefectures. The largest cargo import amount in each of the three prefectures is the same as in the export, and its destination of movement is opposite to that in the export. The rates of cargo transfer within the prefecture itself to total cargo movement in the three prefectures are low, ranging from 6.6% to 4.9%. It seems that a production system in the process of manufacturing goods has been established between these three prefectures.

While. the state of cargo transfer in Kochi prefecture is different from the above three prefectures. In Kochi prefecture, cargo transportation within the prefecture itself accounts for 63.2%. The largest amount of export to the outside of the prefecture is 4,142 tons, accounting for 9.7% of the total amount of export, and the largest export destination prefecture is Chiba prefecture. The largest cargo import amount is 4,876 tons, which is 12.3% of the total import amount, and the largest import destination prefecture is Kagawa prefecture. Kochi Prefecture is different from the other three prefectures in the production system.

9) A more detailed analysis of the industrial composition of the prefectures that make up each quadrant and their production activities will be an issue for future analysis.

Table 8 Freight transfer of each of four prefectures in Shikoku area

	Tokushima	Kagawa	Ehime	Kochi
Total export volume	105,573	123,421	46,046	42,771
Export volume within the prefecture (%)	5,131 (4.9%)	6,426 (5.2%)	3,040 (6.6%)	27,045 (63.2%)
Largest export destination	Kagawa	Ehime	Tokushima	Chiba
Largest export volume (%)	73,872 (70%)	86,781 (70.3%)	31,757 (69%)	4,142 (9.7%)
Total import volume	46,898	104,740	120,681	39,569
Largest import destination	Ehime	Tokushima	Kagawa	Kagawa
Largest import volume (%)	31,757 (68%)	73,872 (71%)	86,781 (72%)	4,876 (12.3%)

(Note) The unit of transportation : 1,000 tons.
(Data) Chiiki-Keizai-Soran(2019)

From the freight transfer between Tokushima, Kagawa and Ehime prefectures in the Shikoku area, it may be considered that there is a strong relationship in production activity between these three prefectures. Thus,let us derive degree of the connection between the two prefectures that are thought to have a strong relationship in the freight transfer, Tokushima and Kagawa, Kagawa and Ehime, and Ehime and Tokushima, including the case of Kochi and Chiba. The degree of the connection between the two prefectures is measured by the Connection Index CI. The CI is derived from the following equation (5) based on the transfer volume of Japan as a whole and on the relationship between the export volume and the import volume between the two prefectures.[10] If CI value exceeds 1, the degree of the connection between the two prefectures is relatively high on the basis of the transfer relationship in Japan.

$$CI_{ij} = (E_{i,j} / E_i) / (M_j / (M - M_i)) \quad (5)$$

where

$E_{i,j}$: freight export transfer amount from *i* prefecture to *j* prefecture ,

E_i : freight export transfer amount from *i* prefecture to the 47prefectures,

M_j : freight import transfer amount from the 47 prefectures to *j* prefecture,

M : total freight import transfer amount in Japan, 4,911,845 (1,000 tons),

M_i : freight import transfer from 47 prefectures to *i* prefecture

10) Equation (5) is a method commonly used in international trade theory (Brown, 1947). The largest exports and the largest imports of the three prefectures in Table 8 stand out. The next analysis needs to scrutinize shipments between the prefectures, including shipment volumes of individual items.

Table 9 Connection index by freight transfer amount

Export i	Tokushima	Kagawa	Ehime	Kochi
Import j	Kagawa	Ehime	Tokushima	Chiba
$CI_{i,j}$	32.5	28.0	70.46	2.37

Degree of the connection between each of the two prefectures is shown in Table 9. As shown in Table 9, CI value between each of the two prefectures is high. In particular, the connection between Ehime and Tokushima prefecture is extremely high. The degree of the connection between Kochi and Chiba prefecture is higher than the standard value of 1, but in comparison with the other three prefectures, the value is considerably lower.

Then, let us look at the four prefectures in the Shikoku area from the perspective of industrial economy and re-examine the major characteristics of the production activity of each prefecture. Table 10 shows the major industries of each prefecture. As the city system index CSI suggests, Kagawa and Ehime prefecture have relatively large economic scale. On the other hand, Tokushima and Kochi prefecture have relatively low economic scale.

The chemical and the electronic component industry are thriving in Tokushima prefecture, and the gross value added per person in manufacturing industry and the V / S ratio are high due to the characteristics of these industries. And in Tokushima prefecture the degree of diversification of the industrial composition of this prefecture is low.[11] And there are large products movements between Tokushima, Kagawa and Ehime prefecture. Hence a kind of division of labor is established between these three prefectures. Considering these facts, it is inferred that Tokushima Prefecture has high CSI and low RCI. Hence, in this prefecture enjoyment of the internal economy is high and the exchange of few people between prefectures is low. Due to the dense production relationship by the branch factories and the sales offices, the production connection with other prefectures is strong ; the regional connection indexes PCI and SCI are high. In particular, the regional connection index SCI based on sales offices is quite high.

Kagawa Prefecture is relatively close to prefectures with a large economic scale outside Shikoku area, thus, CSI is relatively low and RCI is relatively high. Its industrial composition is evenly composed of non-ferrous metals, transportation machinery, and chemistry, and the degree of diversification in production activities is high.[12] Production activity by using the branch factories is active, and the produced goods tend to be sold through sales offices. Therefore, the regional connection indexes PCI and SCI are high. And Kagawa Prefecture is located in the middle of Tokushima Prefecture and Ehime Prefecture, and

11) See Shear (1965) for derivation of the degree of diversification of the industrial composition.
12) This verification will be done in future research.

Table 10 Economic performance of 4 prefectures in Shikoku area

Prefecture (Quadrant)	Tokushima (Cd)	Kagawa (Ad)	Ehime (Bb)	Kochi (Cb)
PCI	0.4519	0.4519	−1.2804	−0.8473
SCI	1.4868	0.4126	−0.3036	−1.915
1st place industry in industrial composition (%)	chemistry (31%)	non-ferrous / machinery (15%)	non-ferrous / machinery (15.7%)	food (16.7%)
2nd place	electronic components	food	pulp / paper	pulp / paper
3rd place	food	transport machinery	petroleum and coal products	ceramics / earth and stone
4th place	pulp / paper	chemistry	transport machinery	production machine
Diversity degree in industrial composition	4.55	6.52	6.47	7.63

(Data) Chiiki-Keizai-Soran (2019)

the volume of cargo transferred between these two prefectures is large, and the direction of movement is one-sided. It may be considered that a division of labor relationship is established between these three prefectures, and Kagawa Prefecture is in charge of the intermediate stage in the vertical division of labor and various intermediate materials are produced and sold.

Ehime Prefecture has the largest economic scale in the Shikoku area, and the Gross Regional Product GRP in the prefecture is high. Ehime Prefecture belongs to the B quadrant. On the other hand, in Ehime Prefecture, the regional connection index RCI based on passenger flow, the index PCI based on branch factory, and the index SCI based on sales offices are relatively low. Especially, PCI is fairly low. Ehime Prefecture imports raw and intermediate materials from Kagawa Prefecture, and manufacturing activity is carried out mainly within the prefecture. And manufactured products are less likely to be sold through the market.

Kochi Prefecture has low the Gross Regional Product that is the smallest in the Shikoku area. In terms of industrial composition, the food, pulp and paper industries, the ceramics and earth and stone industries occupy the top three positions, and the production machinery industry is ranked the fourth position. Due to its industrial structure, the regional connection index RCI based on the amount of passenger flow is relatively high, but the regional connection PCI and SCI based on branch factories and sales offices are low. Thus, its manufacturing activity tends to be carried out mainly within the prefecture itself. And the produced goods tend to be sold without going through the market. Since

Kochi Prefecture carries out isolated production activity, the degree of industrial diversification is high. The comparison of these four prefectures clearly shows that there is a great relationship between the production environment and the industrial composition.

5. Summary and conclusions

As the sources of creating connection economies, there are a city system composed of cities located in the area within the system and a regional connection between the regions. And degree of the economy generated by these connections is revealed by the city system economic index CSI and the regional connection economic index RCI. In addition to these indexes, this paper introduces new two regional connection indexes, PCI and SCI. Using these four connection indexes, the regional economy can be classified into 16 quadrants, and the theoretical characteristics of the regional economy can be examined

On the basis of the above constructed conceptual framework, this paper classifies the 47 prefectures of Japan into 16 quadrants and examines the industrial economy in each quadrant. As a result, the following spatial characteristics of production are emerged in each quadrant. The prefectures that play a major socio-economic role in Japan have low city system index CSI and low the regional connection index SCI. While, they have high regional connection indexes RCI and PCI. And in the prefectures in which production activity is carried out mainly within a prefecture, the city system index CSI is high, and the regional connection indexes PCI, and SCI are all low. In most prefectures near prefectures with large economic scale, the SCI of regional connection index is low. Conversely, most prefectures on the outskirts of the sphere of the large-scale economic prefectures have high SCI and low RCI. In the last part of this paper, in order to deepen the consideration, the analysis takes up the four prefectures that make up the Shikoku area and considers the cargo flow and industrial composition of each prefecture. This analysis shows that there is a certain relationship between the production environment and the industrial composition in the prefecture.

This paper classifies the regional economy into 16 quadrants by the four indexes and grasp the state of production activity in each region. The paper may have a certain effectiveness in spatial production economics : It may contribute to find out the entrance of an economic analysis of how and to what extent the connection economy affects regional production activity.

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