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REGIONAL VITALITY VIA INTERACTION STRUCTURE

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Introduction

There is little doubt that interaction between regions is a function of their population and the distance between them. In 1946 Zipf presented the gravity model which stated that the interaction between two places would be a direct function of the product of their population and an inverse function of the distance between them. (Zipf, 1946) The hypothesis of interactance was proposed by Dodd in 1955, which predicted the number of interactions among people from their basic dimensions of time, space, population and per capita activity. (Dodd, 1955) Since then geologists, regional scientists and sociologists have pointed out the importance of the relative location concept and spatial interaction making effort to sophisticate the gravity model. Zipf's Minimum Effort Model (Zipf, 1946), Dodd's interactance hypothesis (Dodd, 1955), Stouffer's Intervening Opportunity Hypothesis Model (Stouffer, 1960) are the major works of this line.

All of the works cited above have been concerned with developing models which predict the quantity of interaction by spatial structure and other attributes of regions. Although works based on gravity models have produced fruitful results for more than 40 years, the scheme fails to shed light on the huge regional attributes differential. By employing regional vitality attributes such as per capita activity and gross regional products as independent variables, formula of the gravity models take them as given factors to explain regional interaction, not as the phenomena to be analyzed and explained.

Considering the present huge differential of regional vitality existing in Japan, what needs to be explained is not the quantity of interaction but the regional attribute itself, especially the vitality differences among regions. Recent work of Irwin and Kasarda (1991) examines the structure of the airline network and its effect on employment growth in American metropolitan areas. The work is of great significance, as it indicates what underlying the metropolitan division of labor is the structure of intercity linkages.

In this paper, I will depict the spatial and interaction structures within Japan, and see their associations with regional vitality. I do this by comparing the spatial and interaction structures of 47 regions of Japan and by examining their relations to local vitality. Given the association between interaction and local vitality, I will examine the elasticity of interaction to the space, cost and population of regions.

The Hypothesis

From structural sociology's axiom that social structure affects the behavior, norm and beliefs of actors within the structure, it is possible to deduce a hypothesis that regional vitality is associated with the region's position within the structure. I speculate that behind the huge regional vitality differential, there exists an interaction structure which makes it inevitable. In order to examine the hypothesis, first I detect two regional structures of interest. One is the spatial structure of regions which is determined by purely spatial and geographical distances among regions. The other is the interaction structure of regions which is determined by the interaction patterns of people of regions, which I suspect is different from the spatial structure.

People do interact with each other depending on their physical and social distance. (Dodd, 1957) (Blau, 1977) Physical distance, however, is not the only factor which determines the degree of interaction. In reality, regions themselves possess pull factors such as existence of convenient transportation systems or public institutes, to attract people and promote interaction between their residence and others. As the gravity-model studies have taken the regional attributes into consideration, such regional attributes are found to be greatly related to the degree of interaction. In reality, under present regional differences, people do not simply interact only with those who are spatially close. By interacting with the people of different regions, people develop the subjective distance between these places. The relative distance is the concept which explains that people's subjective distance between places is not necessarily the same as the spatial distance between places. What shapes people's relative distance is the interaction structure which consists of bonds of interaction among peoples of different places. Thus the distance among regions within the interaction structure should be the relative distance. And the interaction structure should not be the same as the spatial structure.

Second, I examine the relations between spatial structure, interaction structure and regional vitality. The point is whether or not positions the regions occupy in spatial and interaction structures are related to their vitality. I suspect those regions which occupy similar positions in interaction structures show the similar degree of regional vitality, rather than those which occupy similar positions in spatial structure.

The reason for this is that since isolation generates no vitalities, as more people in a region interact with those in other regions, the vitality of the region is enhanced. The underlying reason is that regional vitality must be highly dependent upon the efficiency and speed by which information and impulses are relayed to regions. The most basic social interaction is a dyad and in the present society telephone is the most common means for a physically distant dyad to interact. What intervenes the information flow, in the present days of technology, should no longer be space. Therefore which position a region occupies in the interaction structure should be more strongly associated with the degree of regional vitality than that in the spatial structure. What matters is not where a region is spatially located but how and with whom the region interact.

Data and Variables

The unit of analysis is the region, of which there are 47 administrative districts covering all parts of Japan. The degree of interaction among regions is measured by the number of telephone calls made and received in each of the 47 regions in Japan. Prior to 1989, data on telephoning among regions were generally unavailable, but the data of "Inter-District Telephone Call Data" are published by Nippon Telephone and Telegram Co.(NTT, 1991) which has more than 98 percent share of the domestic telephone market. The data contain the numbers and length of telephone calls made and received within and across the 47 districts for the year of 1989. In this analysis, only the number of calls are considered. The distance between districts are shown by a linear distance in kilometers between regions. As parameter of regional vitality, the gross regional products for the year of 1988 is introduced.

In order to grasp the structural characteristics of regions, five network parameters are used. They are structural equivalence 1, centrality 2, aggregate centrality 3, concentration of strong ties in distant networks 4 and network density 5.

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1 Here structural equivalence is the Euclidean distance measuring the dissimilarity between i's relations and j's relations in each network with other regions. It is calculated as $Dij=[\Sigma q(Ziq-Zjq)^2+\Sigma q(Zqj-Zqi)]^{1/2}$, where summation is across all regions 1 within network. When i and j have identical relations with others, the distance between them is zero. It increases to large postitive values as i and j have increasingly different relations with others. For the details of measurements of network parameters, see (Burt, 1982). All the computation was done by the general network analysis program STRUCTURE version 4.1.

2 Centrality measures the proportion of the observed relations that involve region j, which is $Cj=(\Sigma i[Zij+Zji]/(\Sigma i\Sigma jZij), i\neq j$.

3 Aggregate centrality is the left hand eigenvector extracted from the matrix of relations aggregated across networks, which calculated as $ACj=(1/g)(\Sigma iZijCi)$, where g is a constant for all regions j. It increases as the region is the object of strong relations from central region (Ci).

4 Concentration of strong ties in distant networks is a measure which varies from 0 to 1 as the extent to which the information that region i could provide to region j is likely to be redundant with the information

available from the other 46 regions in region j's network. It is expressed as $\Sigma Zji[\Sigma(pjqZqi)]$.

5 The higher the density of relations among other regions in a region's network, the lower the diversity of other regions and so are the range of the region's relations.

$Dj = \Sigma Zji[1 - \Sigma(PjqZqi)]/[\Sigma Zji]$.

Structural equivalence distinguishes the positions of actors within a structure and aggregates actors into those who occupy similar positions in the structure. Centrality is an index of the extent to which a region occupies a central position in the structure, while aggregated centrality measures the centrality of regions considering the relations to a central region weigh more than relations to peripheral regions. Network density as well as concentration of strong ties in a distant network measure the degree of redundant relationships and diversity of ego's network.

Analysis

(1) Interaction, Spatial Distance and Regional Vitality

For the year 1989, the total numbers of calls made in all of Japan through NTT was about 7.18 billion. The region which made calls most frequently was Tokyo whose total number of calls made for the year was about 1.14 billion. The region which contributed the least to the phone company was Tottori, of which number of calls made was about 30 million. Tokyo and Tottori show 38 to 1 ratio of telephoning activity. The fluctuation coefficient (standard deviation divided by the mean) for interaction is 8.85.

The mean spatial distance between regions is about 544 kilometers, and the fluctuation coefficient for distance is 0.84. The average population of a region is 2.623 million, and the fluctuation coefficient is 0.917. The mean gross regional products of regions for 1988 was 7.87 trillion yen, and the fluctuation coefficient is 1.43. Tokyo had the highest gross regional products, and Tottori had the lowest. They were 69 trillion and 1.5 trillion yen respectively. Among these parameters, interaction reveals the remarkably large fluctuation coefficient.

(2) Interaction Structure and Spatial Structure

First, I show the mismatch between interaction structure and spatial structure. Converting interaction data and spatial distance data into two 47 by 47 matrixes X and Z in which Xij represents the number of telephone calls made from region i to region j, and Zij represents the distance between region i and region j. The calculated correlation between matrixes X and Z was -0.32. Although the direction of sign is as expected by the gravity model, it was not significant. It suggests that the spatial structure and interaction structure of regions are not the same. It also indicates that the relation between spatial distance and interaction distance is not simply inverse.

The second task is to aggregate regions into those occupying similar positions in each structure. Aggregation of regions are conventionally done by geographical proximity, but here I would perform cluster analysis to aggregate regions into groups using structural equivalence. Table 1 presents the groups of structurally equivalent regions in spatial structure, while Table 2 shows the groups of structurally equivalent regions in the interaction structure.

Table 1 Structurally Equivalent Regions within the Spatial Structure

Groups	Regions
1	Okinawa, Hokkaido
2	Iwate, Fukushima
3	Aomori, Akita, Yamagata, Miyagi, Ibaragi
4	Tokyo, Gunmma, Kanagawa, Saitama, Chiba, Niigata, Tochigi
5	Yamanashi, Toyama, Nagano, Shizuoka, Fukui, Gifu, Aichi, Ishikawa, Hyogo
6	Mie, Shiga, Osaka, Kyoto, Nara, Wakayama, Tottori Ehime, Okayama, Tokushima, Kagawa, Yamaguchi, Hiroshima, Kouchi, Shimane
7	Fukuoka, Saga, Nagasaki, Oita, Kumamoto, Miyazaki, Kagoshima

Table 2 Structurally Equivalent Regions within the Interaction Structure

Groups	Regions
1	Tokyo
2	Osaka
3	Aichi, Gifu
4	Kanagawa, Saitama, Chiba, Shizuoka, Hyogo, Fukuoka, Hokkaido
5	Kyoto, Ibaragi, Niigata, Miyagi, Okayama, Fukushima, Nagano
6	Hiroshima, Gunmma, Kumamoto, Kagoshima
7	Tochigi, Mie, Ehime, Yamaguchi, Nagasaki
8	Okinawa, Oita, Aomori, Ishikawa
9	Miyazaki, Wakayama, Toyama, Nara, Yamanashi Kagawa, Kouchi, Fukui, Shiga, Tokushima, Tottori, Shimane, Saga
10	Akita, Iwate, Yamagata

In the spatial structure, Japan consists of 7 clusters of structurally equivalent regions, while in the interaction structure Japan is composed of 10 clusters. Clusters generated from spatial structure include regions which are only similar to each other in terms of physical position. In the spatial structure, regions located in the northern and southern ends of Japan are aggregated into group 1, and regions which are located similar distances relatively to other regions are aggregated into groups 2 to 7.

Clusters generated from interaction structure, however, contain regions of not only similar interaction patterns but of similar degree of local vitality. Tokyo and Osaka occupy distinctively unique positions 1 and 2, and Aichi and Gifu together occupy position 3. It indicates that four regions form three uniquely independent interaction networks around themselves. Tokyo and Osaka surely hold the two highest gross regional products, and Aichi scores the third. Each of groups 4 to 7 consists of industrialized regions of medium local vitality, while groups 8, 9 and 10 are composed of less developed regions with low local vitality.

Notice that in Table 2, each group is not composed of regions which are spatially proximate, but composed of regions that are similarly industrialized. Of course, groups 4 to 10 contain spatially adjacent regions. It is only group 10 which consists of solely spatially adjacent regions. Thus the spatial and interaction structures are two independent structures within which the 47 regions are connected to each other in two distinctive ways.

Third, in terms of centrality, regions also reveal differences in the spatial structure and in the interaction structure. Table 3 shows the five most central regions, and the five most central regions in terms of aggregate centrality in interaction structure.

Table 3 Centrality of Regions in the Interaction Structure

Centrality		Aggregate Centrality	
Tokyo	0.443	Tokyo	1.000
Osaka	0.186	Kanagawa	0.711
Kanagawa	0.166	Saitama	0.562
Saitama	0.135	Chiba	0.459
Chiba	0.108	Osaka	0.177

Although the order of two measures of centrality are slightly different, Tokyo, Osaka, Kanagawa, Chiba and Saitama are the most central regions in interaction structure. Those regions are located relatively far away from the regions which occupy the central part of Japan, which are Aichi, Fukui and Gifu. Thus we found null relations between spatially central regions and central regions of interaction. So far I have presented the differences between the spatial structure and interaction structure of the 47 regions in Japan, using network parameters. The next task is to examine which structure is related more to the regional vitality.

(3) Two Structures and Regional Vitality

Table 4 presents the correlations among the variables of network parameters of regions and regional vitality in the spatial structure, while Table 5 shows those in the interaction structure.

Table 4 Correlation Matrix of Network Parameters of Spatial Structure and Local Vitality

	Network Density	Concentration of Strong Ties	Gross Regional Products
Concentration of Strong Ties	-.573**	1.000	
Gross Regional Products	.375	-.002	1.000
Population	.077	-.497	.907**

* p<.1
** p<.01

Table 5 Correlation Matrix of Network Parameters of Interaction Structure and Local Vitality

	Network Density	Concentration of Strong Ties	Gross Regional Products
Concentration of Strong Ties	-.583**	1.000	
Gross Regional Products	-.804**	.610**	1.000
Population	-.735**	.478**	.907**

* p<.1
** p<.01

The most striking feature of the tables is that there are no significant associations observed between network parameters and regional vitality within the spatial structure but that there are strong significant relations between them in interaction structure. Within the interaction structure, both concentration of strong ties in distant networks and network density are significantly correlated with regional vitality. Network density shows strongly negative association with gross regional products. Concentration of strong ties in distant network correlates positively with the gross regional products. The results are consistent with the hypothesis proposed that interaction structure should be more directly related to the regional vitality than spatial structure should. Then the next task is to look into the effect of these parameters and regional vitality.

(4) Concentration of Strong Ties in Distant Networks, Network Density and Regional Vitality

Employing gross regional products as a dependent variable, concentration of strong ties in distant networks and network density as independent variables and controlling for the population, regression (ordinary least square) was performed and the results are presented in the Table 6.

Table 6 Effects of Interaction Structure of Regions on Their Vitality

	Equation 1	Equation 2	Equation 3	Equation 4
Concentration of Strong ties	8081448.4**	10600293.9**		
Network Density	-10056189.1**	-31556450.9***	-13887345.3*	-37386361.5***
Population	31.3***		32.1**	
Constant	704397.5**	2121523.4***	988448.4*	2754583.9***
R square	0.880	0.676	0.863	0.646

* p<.1
** p<.05
*** p<.01
One-tailed test

The endogenous variable for all equations is the gross regional products, and its unit is 1 trillion yen. The coefficients for network density were significantly negative for all equations 1 to 4. The coefficients for concentration of strong ties in distant networks were positively significant in equations 1 and 2. R squares were generally fairly high. For equations 1 and 3, which control for the population, R squares are 0.880 and 0.863 respectively. They are quite similar and so are the R squares for equations 2 and 4, that 0.676 and 0.646

respectively. Thus even without the variable of concentration of strong ties in distant networks more than 60 percent of the variance of GRP can be explained by the variable, network density.

(5) Distance and Cost Elasticity of Interaction

Given that interaction structure is strongly associated with regional vitality, I should speculate the elasticity of interaction to various factors. Major factors which affect the interaction structures are the population, distance, cost and existing regional attribute.

According to the gravity model, the interaction between two regions are positively related to their population and negatively related to the distance between them. A simple gravity model with no weight of regional attribute could be expressed as follows;

$$Iij = aPiPi/Dij^{b}$$

where Iij is the amount of interaction between regions i and j, Pi and Pj are the population of region i and j, and Dij represents the distance between them. Following form expresses the gravity model with weight, taking the regional attribute as factors influencing the degree of interaction.

$$Iij = a(PiWi)(PjWj)/Dij^{b}$$

Wi and Wj represent regions' attribute. In order to estimate and compare the magnitude of the distance, cost and population elasticity of interaction, log-linear regression of following form was performed.

$$Ln(Iij) = b1Ln(Dij) + b2Ln(Pi) + b3Ln(Pj) + b4Ln(Wi) + b5Ln(Wj) + a$$

Dij, as the factor to intervene interaction, is measured in terms of spatial distance and cost. Regional attribute, as a factor to promote interaction, is the gross regional product. Thus the coefficient bl is expected to be negative, and coefficients b2, b3, b4 and b5 are to be positive. The results are reported in Table 7.

Although the terms population i and j show inconsistent signs and significance, all other terms are significant and their signs are expected direction. I speculate the reason for this in consistency of signs and magnitude of population terms as the problem of multicollinearity of population and gross regional products. Terms of gross regional products are stable in their signs as well as magnitude. The intervening factors show significant effects in interaction. In Table 7, equation 1 shows distant elasticity of −1.30, which means that by decreasing 1 percent of spatial distance between regions, interaction is expected to increase by 1.3 percent. Equation 2 shows price elasticity of −2.97 indicating that decreasing 1 percent of cost would increase the interaction by 2.97 percent. Taking both spatial distance and cost into consideration, equation 3 in Table 7 states distance elasticity and cost elasticity are −0.45 and −1.15 respectively. All three equations are significant and their R squares are reasonably high.

Table 7 Effects of Interaction Structure of Regions on Their Vitality

	Equation 1	Equation 2	Equation 3
Constant	-5.768439***	-14.765923***	-6.747040***
Distance	-1.300359***		-.453765***
Cost		-2.965921***	-1.151134***
Population i	.064305	.224889**	.08268
Population j	-.208756***	-.62397*	-.205109***
Gross Regional Products i	1.302011***	1.090653***	1.275843***
Gross Regional Products j	1.333538***	1.092510***	1.315602***
R square	.859	.791	.861
F probability	.000	.000	.000

* p<.1
** p<.05
*** p<.01
One-tailed test

Discussion

It was found that there are clear differences between spatial and interaction structures and that there is also a strong association between regions' interaction patterns and their vitality. Given the regional vitality differences and their relations to interaction structure, it is reasonable to expect that change in interaction structure should foster change in regional vitality. Thus the distance, population and cost elasticity of interaction are examined and their magnitude are compared. As high mobility of people from central regions to other regions is hardly expected, cost seems to be the most suitable means to foster the change in interaction structure among regions. The cost elasticity of interaction is found to be -2.97, and it suggests the possibility of modifying the regional vitality differences among regions via changing interaction structure.

References

Blau, P. M. 1977, *Inequality and Heterogeneity*, New York, Free Press

Burt, Ronald S. 1982, *Toward A Structural Theory of Action*, New York, Academic Press.

Burt, Ronald. S. 1989, STRUCTURE, Version 4.1, Research Program in Structural Analysis, Center for the Social Sciences, Columbia University.

Dodd, S. C. 1950, "The Interactance Hypothesis: a model fitting physical masses and human groups" American Sociological Review 15:245-257.

Fotheringham, A. S. 1981, "Spatial structures and distance-decay papràmeters" Annals of the Association of American Geographers 71:425-436.

Fotheringham, A. S. and Webber, M. J. "Spatial structure and the parameters of spatial interaction models" Geographic Analysis 12:33-46.

Japan Economic Planning Agency, 1991, *Indexes of Japanese Districts 1988*, Tokyo, Government of Japan.

Leinbach, T. R. 1973, "Distance, information flows and Modernization: some observations from West Malaysia" The Professional Geographer 25:7-11.

Nippon Telephone and Telegram, 1989, Inter-regional Telephone Call Data: 1988 to 1989, Unpublished data, Tokyo.

Stewart, J. Q. 1940, *The Gravity of the Princeton Family*, Princeton Alumni Weekly 40:14-29

Stouffer, A. 1960, "Intervening Opportunities and Competing Migrants" Journal of Regional Science 1:1-20

Zipf, G. K. 1949, *Human Behavior And The Principles of Least Effort* MA, Addison-Wesley.

地域活性度と都道府県間交流構造の関連

—都道府県間通信交流のネットワーク分析—

〈要　　約〉

安　田　　雪

重力モデルに基づく従来の地域間交流研究は，経済的及び，人的資源の地域間の移動・交流というハード面の交流量を地域の人口と距離により推定するモデルを構築する試みであり，コミュニケーションという地域間交流のソフトな側面と地域の活性度との関連についての考察はなされてはこなかった。本研究は，地域間通信交流データを分析し，地域間交流構造の特性をネットワーク指標により把握すること，地域間交流構造内における各地域のネットワーク指標とその地域の活性度の関連について考察することを目的とする。また，交流頻度に地理的距離及び，交流コストの与える影響の推定を行う。

分析の結果，都道府県間の交流ネットワーク構造は地理的距離構造とは異なっており，交流構造内では，東京，大阪を中心とした，中心・周辺・準周辺の構造がみられることが判明した。そして，地域の活性度とネットワーク指標でとらえた地域の交流構造特性との間には強い相関関係があり，地域活性度の分散の約８割をネットワーク指標と人口により，約６割をネットワーク指標により，説明することが可能であった。

また，交流の価格弾力性の推定値から，交流コストを１％下げることにより，交流頻度が約2.9％増加することが判明した。この交流の価格弾力性は，交流の地理的距離弾力性，人口弾力性及び現在の地域活力の弾力性のいずれよりも大きく，地域活性度に交流コストの変化による交流構造の

変化が影響を与える可能性が示唆された。