Journal of Rural Development 10(June 1987): 73~84

A STUDY ON MEASURING DEGREE OF SPATIAL INTERACTIONS IN NEW TOWNS IN KOREA

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I. Introduction

Linkages between one place and other urban places are related to interactions between them. These interactions are, therefore, considered to be one reflection of the spatial structure between one city and other cities. Spatial interactions generally include migration, visits between people, journey-to-work, shopping, mail flow, newspaper circulation, telephone calls, retail trade contacts, capital flows, and other commerce back and forth between places, because all these occur over distance. Movement of every sort creates spatial structure and, once established, such spatial arrangements influnce subsequent movement. In this study, it is necessary to explore and compare existing patterns of interactions between new towns and other urban centers, in order to gain a clear picture of the present spatial structures of the new towns. This spatial structure is explored in an effort to predict the future of such relationships.

1. Study Area

This study selected two new towns, Sungnam which is a old new town, and Banweol which is a more recent new town in Korea. The city of Sungnam is located in the Seoul Metropolitan Region, about 20 kilometers southeast of the center of Seoul. Since the urban development plan was initiated in 1968, the population of Sungnam has increased to more than 380,000 in 1983. It is the eight largest urban center in Korea.

Banweol is located in the southwestern part of the Seoul Metropolitan Region, approximately 35 kilometers from the center of Seoul. Banweol was a typical rural village and relatively isolated before urban development began in 1977. Its population was slightly more than 50,000 in 1983.

These two new towns are appropriate sites for this research because Sungnam and Banweol have different urban characteristics, based on different periods of urban development in the Seoul Metropolitan Region. This situation provides an opportunity to compare features of spatial interactions between an older new town and a more recent new town on the basis of functions of the urban centers.

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2. A Method for Explaining Spatial Interactions

In order to explain spatial interactions by using data on a population and a distance variable, the gravity model is considered a useful empirical technique. The concept of the gravity model is simply that interactions between two places are positively related to the masses of the two places and negatively related to the distance between them.[1] That is,

$$(1) \qquad I_{ij}=k\ (M_i^a\ M_j^b/D_{ij}^c)$$

where, I_{ij}=interactions between place i and place j
M_i=population at i
M_j=population at j
D_{ij}=distance between i and j
k, a, b, and c =parameters.

In general, population was used as the measure of mass. In the telephone calls, one of the masses always represents the population of the place. For every observation, it is a constant which can be included in the constant, k. Therefore, a simplified expression of the model is:

$$(2) \qquad I_{ij}=k(M_j^b/D_{ij}^c).$$

The equation for the gravity model modified from equation (2) is:

$$(3) \qquad \log I_{ij}=\log k+b \log M_i - c \log D_{ij}$$

This equation represents spatial interactions between one new town and other urban centers.

3. Objectives of the Study

The objective of this study is to solve the following questions.

1) Is the population variable or the distance variable more effective in spatial interaction?
2) Why does more or less spatial interaction occur between the new towns and other urban centers than can be expected?

4. Hypothesis of the Study

The research hypothesis concerning the dominant functions of the new towns in relation to their interactions is set:

> Interactions with Banweol are more sensitive to the population sizes of other urban centers than those with Sungnam, whereas the interactions with Banweol are less sensitive to the distance between the new town and other urban centers than those of Sungnam.

[1] R. Abler, J.S. Adams, and P. Gould, *Spatial Organization* (London: Prentice Hall, 1972), p. 221.

This hypothesis is based on the observation that business calls are positively associated with the market function which is related to population size, whereas for personal calls, distance is a more important consideration. Banweol is dominated by broad market functions consistent with its industrial role, whereas Sungnam is dominated by a residential function which tends to generate personal interactions.

II. Analysis of Interactions between Sungnam and Other Urban Centers

1. Estimating Parameters in the Gravity Model for Sungnam

Interactions between Sungnam and fifty-one other urban centers were measured by data telephone calls in 1983. Using the average number of telephone calls per day was used for the interaction model, the resulting multiple regression equation is expressed as:

(4) $\log S_i = 0.845 + 0.495 \log P_i - 0.853 \log D_{Si}$

The constant log k, 0.845, is an index of the average propensity of the fifty-one places to interact with Sungnam by telephone. This constant has two meaningful characteristics. First, it includes the value of the variable of Sungnam's population, P_S. That is, P_S is a constant in the model because Sungnam's population is always the same in each comparison and it is included in the constant log k. Therefore, if Sungnam has a large population, the constant has a large value. Second, the constant makes the overall equation proportional to the rate characteristic of the phenomena in the model. When both monthly and daily data are used, The population and the distance variables remain the same but the magnitude of interactions will differ according to monthly or daily data. The constant is used to adjust for differences in magnitude.[2]

Interactions between Sungnam and other urban centers vary directly with the number of people who live in the other urban centers. When every unit of log P_i increases, log I_{Si} rise by b_S, 0.495, in the equation.

The effect of distance is opposite from that of population. As one unit of log D_{Si} increases, the value of log I_{Si} decreases by c_S. If the value of c_S is large, the number of interactions sharply decreases with distance between Sungnam and other urban centers. In equation 4, when one unit of log D_{Si} increases, the value if log I_{Si} drops by 0.853. The value of c_S in the equation is a relatively small one which is less than unity. A distance exponent of 2 has generally been used.

The value of the coefficient of determination, R^2 is 0.653 in Table 1. The

[2] Kingsley E. Haynes and A. Stewart Fotheringham, *Gravity and Spatial Interaction Model* (Beverly Hills : Sage Publications, Inc., 1984), p. 16.

coefficient of determination represents the proportion of variation in telephone interaction explained by population and distance. This means that the gravity equation accounts for 65.3 percent of the variation in the telephone call data explained by population and distance data. This figure indicates a substantially large explanation of variation based on the classification of association of variation based on the classification of association by Poister.[3]

TABLE 1 **R^2, Beta Weight, and F-Value for Sungnam**

R^2	Beta Weight		F-Value
	Population	Distance	
0.653	0.728	-0.815	45.237

In explaining significance of the multiple regression equation 4, the F-test is used, while the t-test is used for expressing the significance of partial regression coefficients. In the case of Sungnam, the critical F-value, 4.03 is much smaller than the 45.237 F-value produced at the 0.05 significance level. This result rejects the null hypothesis (H_o) that partial regression coefficients are identical$(b_S=c_S=0)$, and then accepts the alternative hypothesis (H_1) that partial regression coefficients are not identical $(b_S \fallingdotseq c_S \fallingdotseq 0)$. This means that the equation is significant in multiple regression.

The t-values of independent variables, population and distance, are 7.627 and −8.534 respectively. The critical t-value, 1,678, is smaller than the t-value of population, 7.627, and the the absolute t-value of the distance, 8.534, at the 0.05 significance level. In this case, the one-tailed t-test is used because the direction of values can be determined. The result of the t-test rejects the null hypothesis that there are no relationships between population size and telephone call interactions.

It is then necessary to show which partial regression coefficient has more relative importance in contributing to the dependent variable: telephone call interactions. The value of c_S, 0.853, is larger than that of b_S, 0.495, in the equation 4. In this case, it is difficult to indicate the relative importance of each independent variable with only the value of partial regression coefficients, b_s and c_s. To determine the relative importance, the standardized regression coefficients, beta weight, can be used. In Table 1, the absolute values of beta weight for population and distance are 0.728 and 0.815, respectively. That is, when the standard deviation of population changes by one unit, the standard deviation of telephone call interactions changes by 0.728. Also, when the standard deviation of distance changes by one unit, the standard deviation of distance changes by one unit, the standard deviation of telephone call interaction changes by 0.728. Also, when the standard deviation of distance changes by one unit, the standard

[3] T.H.Poister, *Public Programs Analysis: Applied Research Methods* (Baltimore:University Park Press, 1978), p. 456.

deviation of telephone call interaction changes by 0.815 units. Therefore, the beta weight of distance affects telephone call interactions more than population size.

2. Interpreting Residuals for Sungnam's Case

A residual is defined as the difference between the value of observed interaction and that of expected interaction. The value of expected interaction can be produced by using the gravity model equation. When these positive and negative residuals, a map of residuals can be drawn to show how the variation in the transformed data that is not explained by the gravity model is distributed among fifty-one places. In the case of Sungnam, the gravity model accounts for 65.3 percent of variation in telephone call data; 34.7 percent of variation remains uncounted for. The map of residuals explains the 34.7 percent residual variation (Figure 1). The positive residual represents the value of obsrved interactions larger than expected, whereas the negative residual interactions less than expected. In the case of Sungnam, the other places are classified into five categories according to the intervals of residual value shown in Figure 1: three positive and two negative residuals.

III. Analysis of Interactions between Banweol and Other Urban Centers

1. Estimating Parameters in the Gravity Model for Banweol

The data on telephone calls from Banweol to eighty-seven places were used for the interaction model. Using the average number of calls a day, the resulting multiple regression equation is expressed as:

(5) $\log I_{Bj} = -1.440 + 0.665 \log P_j - 0.539\ D_{Bj}.$

In the equation 5, the constant, log k, has a negative value of -1.440. The negative value of the constant indicates a very small value based on the small population of Banweol. In comparison with Sungnam's equation 4, the value of b_B in Banweol's equation (0.665) is larger than that of Sungnam (0.495). This indicates that the population variable in the Banweol equation 5, is more sensitive to the interaction variable of telephone calls than that in the Sungnam equation 4.

Meanwhile, the effect of distance was opposite to that of population size in the gravity model. With the increase of distance, interactions decreased. In equation 5, the partial regression coefficient of distance, c_B, has a value of 0.539, so that if one unit of log D_{Bj} increases, the value of log I_{Bj} decreases by 0.539. The value of c_B, 0.539, is less than unity and relatively small, which means that the effect of distance is a minor barrier to telephone call interactions. Moreover, compared with Sungnam, the value of c_B in the Banweol equation of 0.539 is smaller than the c_S of 0.853 in the Sungnam equation. This means that the distance effect of Sungnam is more sensitive in interactions than that of Banweol.

FIGURE 1 **Location of Places Based on Residuals(Sungnam)**

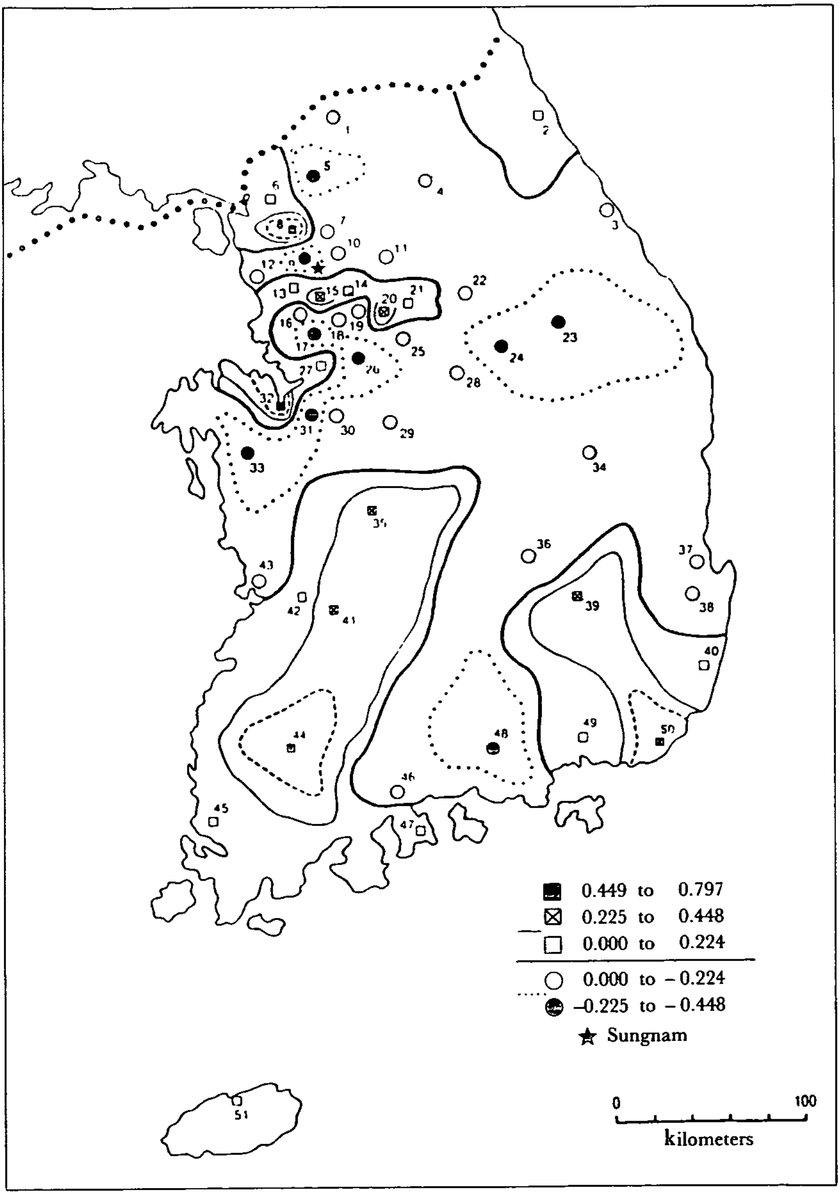

TABLE 2 **Fifty-one Places Corresponding with Sungnam**

Number	Place	Number	Place
1	Cholwon	26	Ansong
2	Sokcho	27	Pyongtaek
3	Kangnung	28	Chungju
4	Chunchon	29	Chongju
5	Dongduchon	30	Chonan
6	Munsan	31	Onyang
7	Uijongbu	32	Sinjang
8	Bundang	33	Hongsong
9	Seoul	34	Andong
10	Kurye	35	Taejon
11	Yangpyeong	36	Gumi
12	Inchon	37	Pohang
13	Anyang	38	Kyongju
14	Gwangju	39	Taegu
15	Pangyo	40	Ulsan
16	Suwon	41	Chonju
17	Osan	42	Iri
18	Yongin	43	Kunsan
19	Konjiam	44	Kwangju
20	Ichon	45	Mokpo
21	Yoju	46	Sunchon
22	Wonju	47	Yosu
23	Yongwol	48	Chinju
24	Chechon	49	Masan
25	Janghowon	50	Pusan
		51	Cheju

TABLE 3 **R^2, Beta Weight, and F-Value for Banweol**

R^2	Beta Weight		F-Value
	Population	Distance	
0.694	0.755	-0.370	95.427

The coefficient of determination, R^2, is 0.694 in Table 3. This indicates that the gravity model equation 5 accounts for 69.4 percent of the variation in the telephone call data explained by population and distance data. This is a substantially large explanation.

To explain the signigicance of equation 5, the F-test was used. The result accepted the alternative hypothesis that partial coefficients are not identical, that the multiple regression equation 5 is significant.

One-tailed t-test was used for explaining the siginificance of the relationship between each independent variable and the dependent variable because it allows for determination of the direction of relationship. This result rejected the null hypothesis that no relationship exists between population size and telephone calls, and between distance and telephone calls.

2. Interpreting Residuals for Banweol's Case

In Figure 2, eighty-seven places are classified into five categories based on intervals of residual value: two categories of positive residuals and three categories of negative residuals. Dominant characteristics of both Sungnam and Banweol are as follows.

FIGURE 2 **Location of Places Based on Residuals (Banweol)**

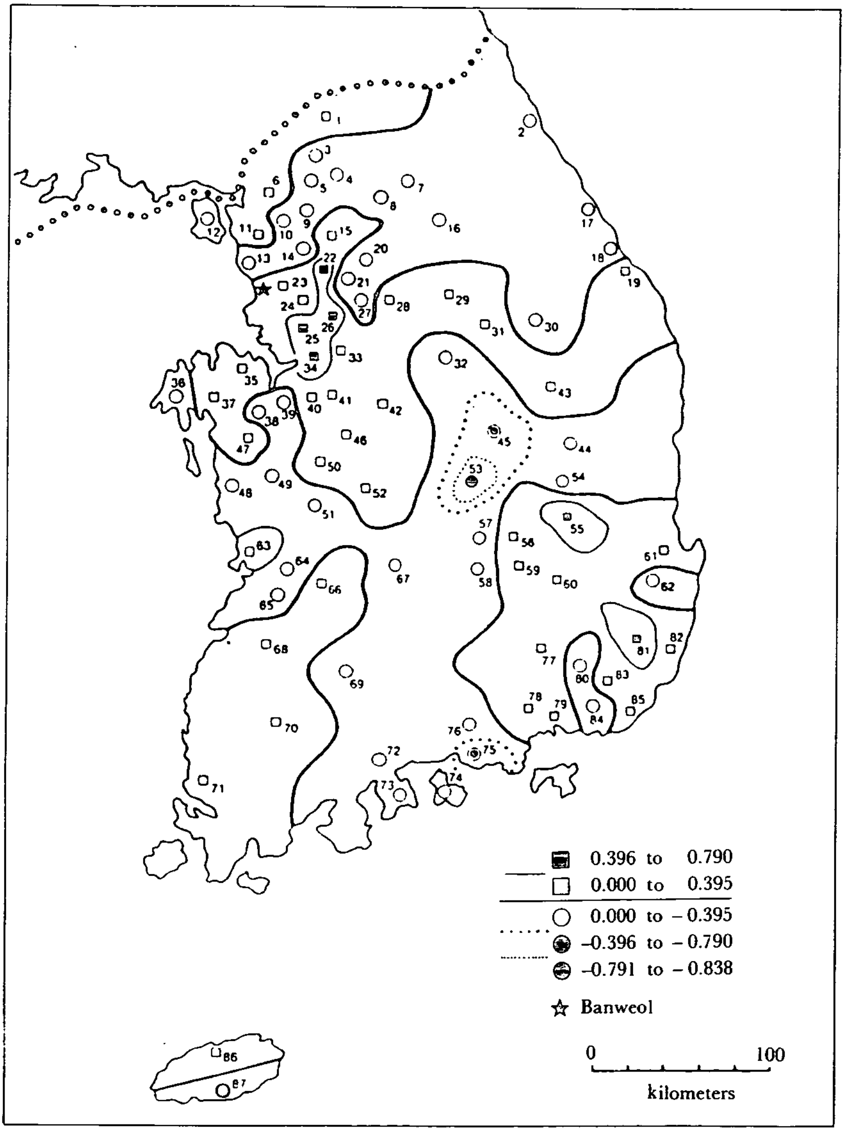

TABLE 4 **Places Corresponding with Banweol**

Number	Place	Number	Place
1	Cholwon	45	Chomchon
2	Sokcho	46	Chochiwon
3	Chongok	47	Hongsong
4	Pochon	48	Daechon
5	Dongduchon	49	Chongyang
6	Munsan	50	Gongju
7	Chunchon	51	Nonsan
8	Gapyong	52	Taejon
9	Uijongbu	53	Sangju
10	Wondang	54	Uisong
11	Kimpo	55	Kumsong
12	Ganghwa	56	Gumi
13	Inchon	57	Kimchon
14	Seoul	58	Daeya
15	Kurye	59	Yegwan
16	Hongchon	60	Taegu
17	Kangnung	61	Pohang
18	Donghae	62	Gyongju
19	Samchok	63	Kunsan
20	Yangpyeong	64	Iri
21	Gwangju	65	Kimje
22	Sungnam	66	Chonju
23	Anyang	67	Muju
24	Suwon	68	Chongup
25	Osan	69	Namwon
26	Yongin	70	Kwangju
27	Ichon	71	Mokpo
28	Yoju	72	Sunchon
29	Wonju	73	Yosu
30	Yongwol	74	Namhae
31	Chechon	75	Samchonpo
32	Chungju	76	Chinju
33	Ansong	77	Changryong
34	Pyongtaek	78	Haman
35	Dangjin	79	Masan
36	Taean	80	Milyang
37	Sosan	81	Eonyang
38	Yesan	82	Ulsan
39	Sinjang	83	Yangsan
40	Onyang	84	Kimhae
41	Chonan	85	Pusan
42	Chongju	86	Cheju
43	Yongju	87	Sogwipo
44	Andong		

First, regional origins of households were shown to be closely related to personal interactions by telephone. A dominant example was the frequency of telephone calls between Sungnam and the Kwangju area, which was the origin of a large portion of Sungnam's residents.

Second, mineral resources and convenient transportation facilities were shown to be closely related to interactions with the industrial new town. Examples were the greater than expected frequency of calls between Banweol and Kumsung, and between Banweol and Eonyang.

Third, military cities were seen to be more closely related to the industrial new town than the residential new town. There were many more calls between the industrial new town and military cities than expected, whereas there were fewer calls between the residential new town and the military cities Osan and Pyongtaek.

Finally, interactions by telephone calls were found to be more closely related to functions of the new towns than ages of the new towns. That is, the number of telephone calls were based more on the industrial or residential function of the new town rather than its age.

IV. Conclusions

Through examination of the multiple regression equations of Sungnam and Banweol, several detailed findings can be summarized.

First, the result of comparison of the partial coefficients for population and distance between Sungnam and Banweol supported the hypothesis that the population size function of Banweol affects telephone interactions more than that of Sungnam, while the distance function of Banweol has contributed less to the interactions than that of Sungnam. This result is closely related to the observation that business calls based on Banweol's industrial dominance correspond with market volume which is related to population size, whereas personal calls based on Sungnam's residential dominance significantly correspond with distance.

Second, when the data on telephone calls were used in the gravity model, the distance exponents in both Banweol's and Sungnam's equations were less than unity. Considering that many studies of migration, shopping trips, and intercity travel flows have placed the distance exponent at about 2, the exponents for Banweol and Sungnam were relatively small. This result indicates that when data on telephone calls are used, distance decay may be regarded as a minor barrier.

Third, based on the results of the preceding analysis, it may be concluding that the gravity model can contribute to planning new service centers for cities. For example, when a new city is created near the new towns, the equations of the gravity model can be used to project the expected frequency of telephone interaction between Banweol and the new city, and between Sungnam and the new city by using planning population of the new city and distances between Banweol and the new city, and between Sungnam and the new city.

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