Gakushuin Economic Papers, Vol.37, No.3・4, January 2001

ROXY Index Analysis of Spatial Cycles for Population Changes in Japan: Larger Metropolitan Areas and Smaller-and-Non-Metropolitan Areas

† Tatsuhiko KAWASHIMA ‡ Noriyuki HIRAOKA

Contents

Keywords

Concentration, Functional urban region, Metropolitan area, Non-metropolitan area, Population change, Roxy index, Spatial cycles, Urban dynamism

---

† Economics Department, Gakushuin University, 1-5-1 Mejiro, Toshima-ku, Tokyo 171-8588, Japan.
‡ Mitsubishi Research Institute, 2-3-6 Otemachi, Chiyoda-ku, Tokyo 100-8141, Japan.
This paper is the outgrowth of the papers presented (1) at the 46th North American Meetings of the Regional Science Association International (RSAI) on November 11-14, 1999, at Hotel Delta Montréal, Montréal, Québec, Canada, and (2) at the 13th Annual Meetings of the Applied Regional Science Conference (ARSC) on December 4-5, 1999, at the Kumamoto Gakuin University, Kumamoto-city, Japan. The authors are grateful for the research support from the Grant-in-Aid for Scientific Research (B) from the Ministry of Education, Science, Sports and Culture in Japan.

Abstract

The process of spatial concentration and deconcentration of population in Japan is investigated for the period 1947 through 1995. The spatial-cycle hypothesis and the Roxy-index method are applied to examine quantitatively the phenomena of urban dynamism, with special emphasis on (1) the spatial redistribution process for Spatial-system (I) which comprises the eight largest metropolitan areas with populations over two million in 1995 and (2) the spatial redistribution process for Spatial-system (II) which comprises (a) a set of seventy-nine medium and small metropolitan areas and (b) an aggregated non-metropolitan area. The results indicate: (1) that the spatial-cycle path for Spatial-system (I) seems to have already arrived at the second-half of the deconcentration stage, and (2) that the spatial-cycle path for Spatial-system (II) seems to be remaining at the second-half of the concentration stage. In other words, it is likely (1) that the spatial deconcentration of population is still taking place for the larger agglomeration entities, but this deconcentration stage is perhaps approaching its end, and (2) that the spatial concentration of population is presently taking place for the smaller agglomeration entities, though the speed of concentration is decelerating.

1 Introduction

The Roxy-index values generally provide us with useful information about the dynamic changes in the spatial redistribution of various socio-economic activities. In this paper, we apply the Roxy-index method for quantitatively examining the stages of the spatial-cycle paths in the light of Klaassen's spatial-cycle hypothesis[1).

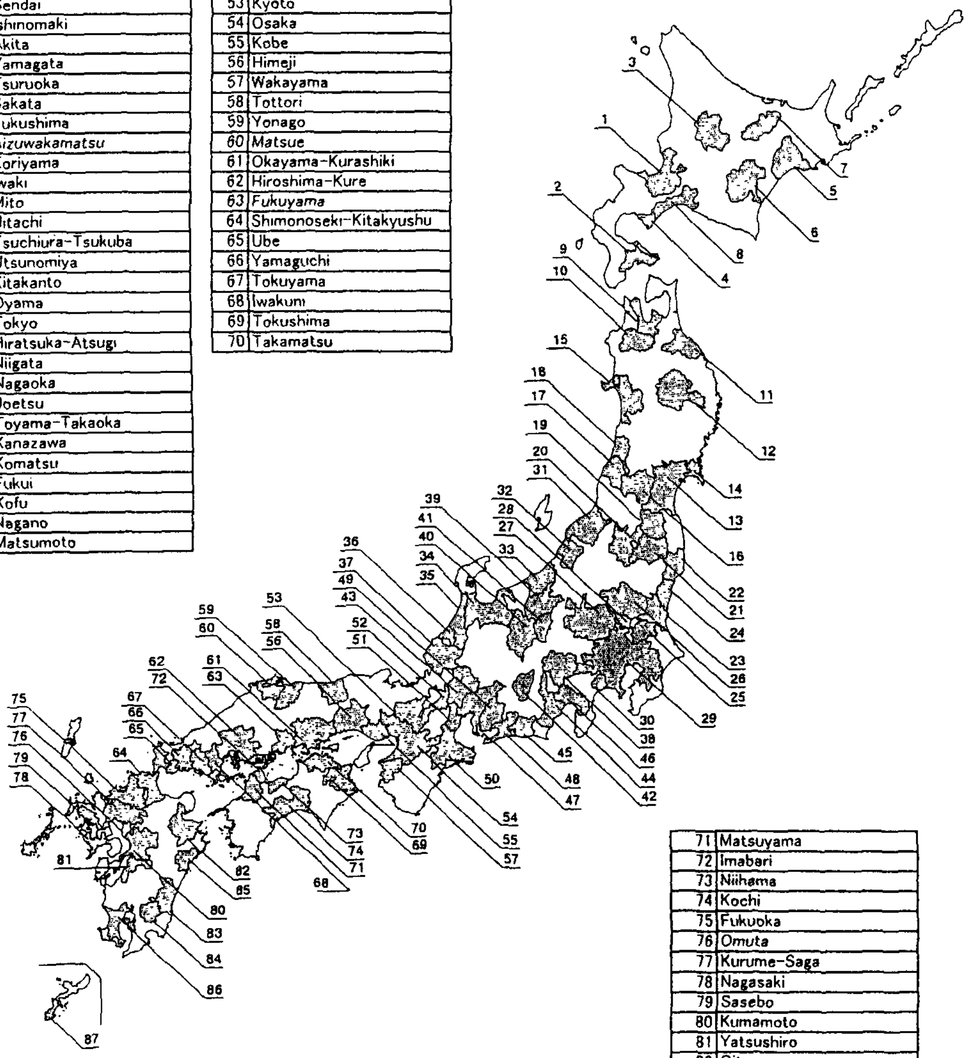
The prime object of this paper is to deal with the spatial system composed of eighty-seven (87) metropolitan areas in Japan which can be considered as functional urban regions (FURs[2)) . Their boundaries which are shown in Figure 1 have been delineated on the basis of the national census taken in 1995. The population data for them (sorted by 1995 population) in each census year from 1947 through 1995, are given by Table A- 1 in the Appendix.

Of these 87 FURs, we first consider the eight largest FURs with the 1995 population of over two million. We call this set of FURs "Spatial-system (I)." Table A-2 in the Appendix shows the population level in each of the census years from 1947 through 1995 for the eight largest FURs as well as for their total population. Based on this table, we calculate the Roxy-index values to examine the characteristics of the spatial-cycle path for the Spatial-system (I).

We then turn our attention to a set of the remaining seventy-nine (79) medium and smaller FURs with the 1995 population of less than two million, and integrate them into one spatial unit. This integrated spatial unit and the aggregated non-FUR area compose "Spatial-system (II)" for which we also calculate the Roxy-index values for our investigation. Table A-3 gives the population data (1) for the spatial unit composed of the 79 medium and smaller FURs ("smaller FURs" hereafter for convenience) as well as (2) for the aggregated non-FUR area.

Figure 1 Functional Urban Regions (FURs) in Japan (1995-Version)

Code	FUR
1	Sapporo
2	Hakodate
3	Asahikawa
4	Muroran
5	Kushiro
6	Obihiro
7	Kitami
8	Tomakomai
9	Aomori
10	Hirosaki
11	Hachinohe
12	Morioka
13	Sendai
14	Ishinomaki
15	Akita
16	Yamagata
17	Tsuruoka
18	Sakata
19	Fukushima
20	Aizuwakamatsu
21	Koriyama
22	Iwaki
23	Mito
24	Hitachi
25	Tsuchiura-Tsukuba
26	Utsunomiya
27	Kitakanto
28	Oyama
29	Tokyo
30	Hiratsuka-Atsugi
31	Niigata
32	Nagaoka
33	Joetsu
34	Toyama-Takaoka
35	Kanazawa
36	Komatsu
37	Fukui
38	Kofu
39	Nagano
40	Matsumoto
41	Ueda
42	Iida
43	Gifu-Ogaki
44	Shizuoka
45	Hamamatsu
46	Numazu-Fuji
47	Nagoya-Komaki
48	Toyohashi
49	Kariya-Toyota-Anjo
50	Tsu-Ise-Matsuzaka
51	Yokkaichi
52	Hikone
53	Kyoto
54	Osaka
55	Kobe
56	Himeji
57	Wakayama
58	Tottori
59	Yonago
60	Matsue
61	Okayama-Kurashiki
62	Hiroshima-Kure
63	Fukuyama
64	Shimonoseki-Kitakyushu
65	Ube
66	Yamaguchi
67	Tokuyama
68	Iwakuni
69	Tokushima
70	Takamatsu
71	Matsuyama
72	Imabari
73	Niihama
74	Kochi
75	Fukuoka
76	Omuta
77	Kurume-Saga
78	Nagasaki
79	Sasebo
80	Kumamoto
81	Yatsushiro
82	Oita
83	Miyazaki
84	Miyakonojo
85	Nobeoka
86	Kagoshima
87	Naha



In the following, the basic framework of the spatial-cycle hypothesis and the Roxy-index method are discussed in Section 2. In Section 3, the stages of the spatial-cycle paths for Spatial-systems (I) and (II) are discussed on the basis of the Roxy-index values obtained as results of our empirical analysis. The concluding remarks on urban genes are given in Section 4.

2 Analytical Approach: Theory and Method

2.1 Spatial Cycles: Klaassen's Hypothesis

The spatial terminologies presented in Table 1 are worth keeping in mind when we are studying the phenomena of the agglomeration and deglomeration of population (1) within a specific metropolitan area or (2) among a number of metropolitan areas. As indicated by this table, the spatial agglomeration and deglomeration processes are referred to respectively as concentration and deconcentration for the inter-metropolitan analysis (*i.e.*, inter-FUR analysis), and *centralization* (or urbanization) and *decentralization* (suburbanization) for the intra-metropolitan analysis (*i.e.*, intra-FUR analysis). We restrict the scope of this paper to the inter-FUR phenomena.

With regard to the inter-FUR analysis, Klaassen's revised paradigm[3] argues the existence of the four major recurrently transmuting successive stages along the spatial-cycle path as shown by Table 2. The four stages are ① *accelerating concentration*, ② *decelerating concentration*, ③ *accelerating deconcentration*, and ④ *decelerating deconcentration*. The term *revived-concentration or revived accelerating-concentration*, is occasionally used to indicate clearly the phenomena of the re-entry steps of the spatial-cycle path from the stage of spatial deconcentration into the stage of spatial concentration.

2.2 Roxy Index: Quantitative Method

For the purpose of carrying out the empirical analysis on the basis of the Klaassen hypothesis, we employ the measurement of the Roxy index[4] which is an instrument for identifying quantitatively the stages of the spatial-cycle path for various types of socio-economic activities. For the present paper which

Table 1 Two-by-two Matrix : Terminologies for Spatial Redistribution Phenomena of Population

SPATIAL REDISTRIBUTION PHENOMENA / ANALYSIS	SPATIAL AGGLOMERATION	SPATIAL DEGLOMERATION
INTER-FUR	CONCENTRATION	DECONCENTRATION
INTRA-FUR	CENTRALIZATION (URBANIZATION)	DECENTRALIZATION (SUBURBANIZATION)

Table 2 Four Stages of Spatial-cycle Path for Inter-FUR Analysis : Concentration and Deconcentration

INTER-FUR PHENOMENA	KLAASSEN'S FOUR-STAGES OF SPATIAL-CYCLE PATH	
CONCENTRATION	STAGE-1	ACCELERATING CONCENTRATION
	STAGE-2	DECELERATING CONCENTRATION
DECONCENTRATION	STAGE-1	ACCELERATING DECONCENTRATION
	STAGE-2	DECELERATING DECONCENTRATION

Table 3 Definition of ROXY Index for Inter-metropolitan Analysis of Spatial Redistribution Processes of Population: With Weighting Factor of Population in Each Metropolitan Area

The ROXY index (RI) is defined as follows for the case we have a spatial system which comprises n metropolitan areas.

$$RI\,(t,t+1) \equiv \Phi(t,t+1) \equiv \left(WAGR_{t,t+1} / SAGR_{t,t+1} - 1.0\right) \times 10^4$$

where

$RI\,(t,t+1)$: Value of ROXY index for the period between years t and $t+1$ (calculated on the annual growth-ratio basis)

$\Phi\,(t,t+1)$: Abbreviation of $RI\,(t,t+1)$

$WAGR_{t,t+1}$: Weighted average of the annual growth ratios of population, for the period between years t and $t+1$ over n metropolitan areas, which is equal to

$$\sum_{i=1}^{n}\left(w_i^t \times r_i^{t,t+1}\right) / \sum_{i=1}^{n} w_i^t$$

$SAGR_{t,t+1}$: Simple average of the annual growth ratios of population, for the period between years t and $t+1$ over n metropolitan areas, which is equal to

$$\sum_{i=1}^{n} r_i^{t,t+1} / n$$

x_i^τ : Population of metropolitan area i in year τ

n : Number of metropolitan areas

$r_i^{t,t+1}$: Annual growth ratio of population of metropolitan area i for the period between years t and $t+1$, which is defined as the k-th root of the k-year growth ratio of

$$r_i^{t,t+k} \equiv x_i^{t+k} / x_i^t$$

w_i^t : Weighting factor for metropolitan area i in year t (*i.e.*, population of metropolitan area i in year t, or population of metropolitan area i in year $t+\alpha$ where α is chosen to make the meaning of the weighting factor more consistent with the definition of ROXY index) conducts the inter-metropolitan analysis, the Roxy index is defined as shown by Table 3 for Spatial-system (I) and by Table 4 for the Spatial-system (II) .

The mathematical definition of the Roxy index provided by these two tables enables us to construct Table 5 which describes the implications of the Roxy-index values in relation to the speed of the spatial redistribution process of population among FURs (*i.e.*, among metropolitan areas) or among other types of spatial unit.

Table 4 Definition of ROXY Index for Inter-metropolitan Analysis of Spatial Redistribution Processes of Population: With Weighting Factor of Binary Digit

The ROXY index (RI) is defined as follows for the case we have a spatial system which comprises two spatial units; (1) a set of smaller metropolitan area disignated as spatial unit *1* and (2) an aggregated non-metropolitan area designeted as spatial unit *2*.

$$RI\,(t,t+1) \equiv \Phi\,(t,t+1) \equiv \left(WAGR_{t,t+1} / SAGR_{t,t+1} - 1.0\right) \times 10^4$$

where

$RI(t,t+1)$: Value of ROXY index for the period between years t and $t+1$ (calculated on the annual growth-ratio basis)

$\Phi\,(t,t+1)$: Abbreviation of $RI(t,t+1)$

$WAGR_{t,t+1}$: Weighted average of the annual growth ratios of population, for the period between years t and $t+1$ over two spatial units, which is equal to

$$\sum_{i=1}^{n}\left(w_i^t \times r_i^{t,t+1}\right) / \sum_{i=1}^{n} w_i^t = r_1^{t,t+1} / 1 = r_1^{t,t+1}$$

since we set in our analysis that $w_1^t = 1$, and $w_2^t = 0$ for any value of t and since $n=2$.

$SAGR_{t,t+1}$.: Simple average of the annual growth ratios of population for the period between years t and $t+1$ over two spatial units, which is equal to

$$\sum_{i=1}^{n} r_i^{t,t+1} / n = (r_1^{t,t+1} + r_2^{t,t+1}) / 2$$

since $n = 2$.

x_i^τ : Population of spatial unit i in year τ

n : Number of spatial units ($n = 2$ for our analysis)

$r_i^{t,t+1}$: Annual growth ratio of population for spatial unit i for the period between years t and $t+1$, which is defined as the k-th root of the k-year growth ratio of

$$r_i^{t,t+k} \equiv x_i^{t+k} / x_i^t$$

w_i^t : Weighting factor for spatial unit i in year t (In our analysis, we apply the weighting factor of the binary-digit scheme in which we have $w_1{}^t = 1$ and $w_2{}^t = 0$.)

This table suggests that, the value of the Roxy index turns out to be as follows, depending upon the stages of the spatial cycles.

(1) positive and increasing for the stage of accelerating concentration,

(2) positive and decreasing for the stage of decelerating concentration,

(3) negative and decreasing for the stage of accelerating deconcentration,

(4) negative and increasing for the stage of decelerating deconcentration, and

(5) zero or in its vicinity for the stage at which the spatial redistribution process is neutral[5)].

Based on Tables 3, 4 and 5, we can draw Figure 2 which displays the spatial-cycle path in the form of

Table 5 Implications of Roxy-index Values for the Study of Dynamic Spatial Redistribution of Population among Metropolitan Areas

A	B	C	D
Sign of Roxy-index value	Pattern of spatial redistribution of population among metropolitan areas	State of changes in Roxy-index value	Speed of spatial redistribution process of population among metropolitan areas
Positive	Concentration	Increasing	Accelerating
		Leveling-off	Constant
		Decreasing	Decelerating
Zero	Neutralilty from both concentration and deconcentration (*viz.*, symmetric growth or decline[(1)])	Increasing	Start of ACon[(2)]
		Leveling-off	Continuation of neutrality
		Decreasing	Start of ADcon[(3)]
Negative	Deconcentration	Increasing	Decelerating
		Leveling-off	Constant
		Decreasing	Accelerating

[Source] Constructed from Kawashima and Hiraoka (1993)

[Notes]

(1) The spatial redistribution pattern of the 'symmetric growth or decline' comprises the following three sub-patterns of BGD, BSGD and CSGD;

(i) Balanced growth or decline (BGD): The fitted growth-rate curve which is a function of the population size of the FUR, is nearly flat to reflect the constant shares of population by FURs over time.

(ii) Bell-shaped growth or decline (BSGD): The fitted growth-rate curve is bell-shaped, reflecting the 'medianization' of population over FURs. The phenomena of 'medianization' means both of ① the increase in population share by FURs with medium population size (as compared with other FURs), and of ② the decrease in population share by FURs with larger and smaller population size.

(iii) Cup-shaped growth or decline (CSGD): The fitted growth-rate curve is cup-shaped, reflecting the 'bipolarization' of population over FURs. The phenomena of 'bipolarization' means both of ① the increase in population share by FURs with relatively smaller and larger population size, and of ② the decrease in population share by FURs with medium population size.

(2) The abbreviatory notation 'ACon' stands for accelerating concentration.

(3) The abbreviatory notation 'ADcon' stands for accelerating deconcentration.

the wavelike-cyclic curve and Figure 3 in the form of the circular-cyclic curve. In Figure 3, the axis of abscissa indicates the value of the Roxy index (ROXY), while the axis of ordinate indicates the marginal value[6] of the Roxy index with respect to time (*i.e.*, ΔROXY/ΔT). It is to be noted that we set the negative value toward the right of the abscissa, in order to have the circular-cyclic curve moving in a counter-clockwise direction.

Figure 2 Wavelike-Cyclic Curve: Path of Spatial Cycles by ROXY (For Inter-metropolitan Analysis)

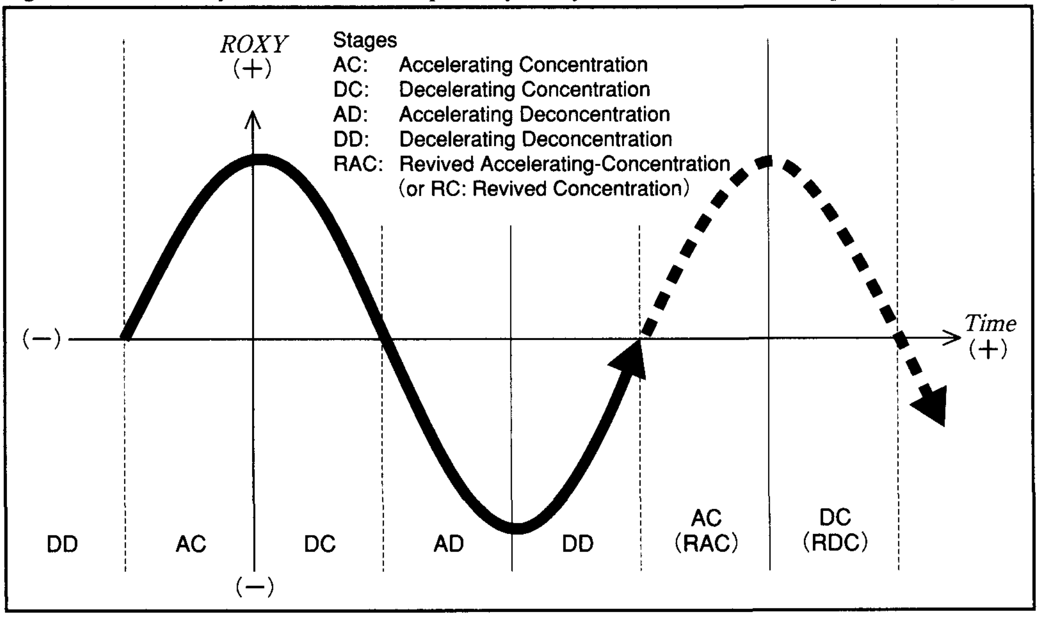
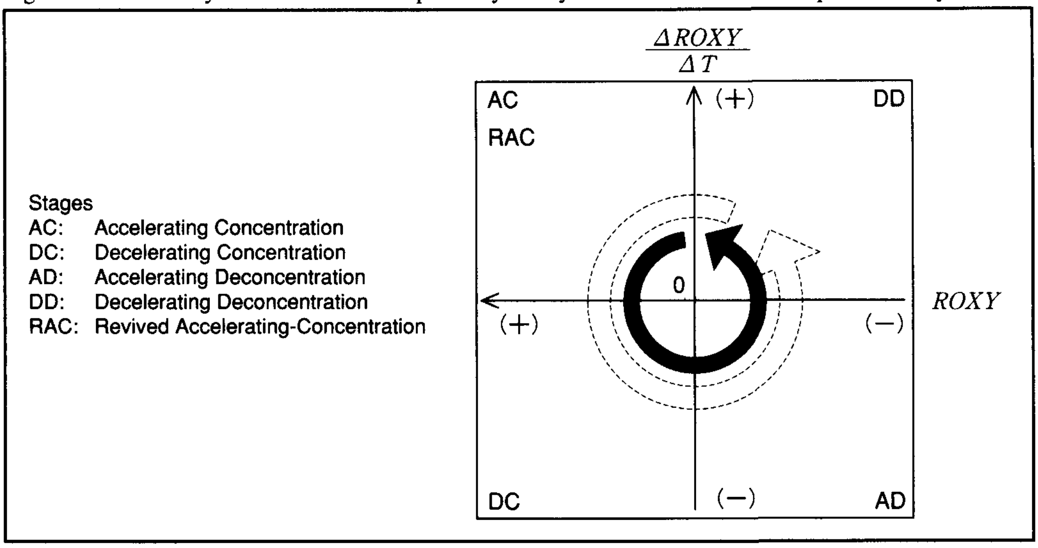


Figure 3 Circular-Cyclic Curve: Path of Spatial Cycles by ROXY (For Inter-metropolitan Analysis)



3 Roxy-index Analysis: Stages of Spatial-Cycle Path

3.1 Spatial-System (Ⅰ): Eight Largest Metropolitan Areas

From Table A-2, we can calculate the values of the Roxy index (ROXY) and the marginal values of the Roxy index (ΔROXY/ΔT) for the Spatial-system (Ⅰ) as shownby Table 6. Based on this table we can draw Figures 4 (for the wavelike-cyclic curve) and 5 (for the circular-cyclic curve). These two figures indicate that the Spatial-system (Ⅰ) seems to be approaching the end of the deconcentration stage along the spatial-cycle path. This would imply that the Spatial-system (Ⅰ) is likely to be at the stage of decelerating deconcentration in which "not-so-large FURs" among the eight largest FURs are more active than other "large FURs" in the Spatial-system (Ⅰ), in attracting people to them but with gradually reducing the magnitude of such attraction.

3.2 Spatial-System (Ⅱ): Smaller Metropolitan Areas and Non-Metropolitan Areas

From Table A-3, we can obtain the Roxy-index values and the marginal values of the Roxy index as shown by Table 7. This table enables us to draw Figures 6 (for the wavelike-cyclic curve) and 7 (for the circular-cyclic curve).

These two figures indicate that Spatial-system (Ⅱ) seems still to be remaining at the second-half of the

Table 6 Roxy Index (Roxy) and Its Marginal Value (ΔROXY/ΔT): For Spatial-System (Ⅰ)

Year	1948.5	1952.5	1957.5	1962.5	1967.5	1972.5	1977.5	1982.5	1987.5	1992.5
ROXY	64.94	61.36	73.53	74.27	40.34	-1.53	-16.76	-2.74	-0.75	-7.77
ΔROXY/ΔT	-0.90	0.95	1.20	-3.32	-7.58	-5.71	-0.12	1.60	-0.50	-1.41

Figure 4 Spatial Cycles for 1947-95 (Wavelike-Cyclic Form): Eight (8) Largest FURs

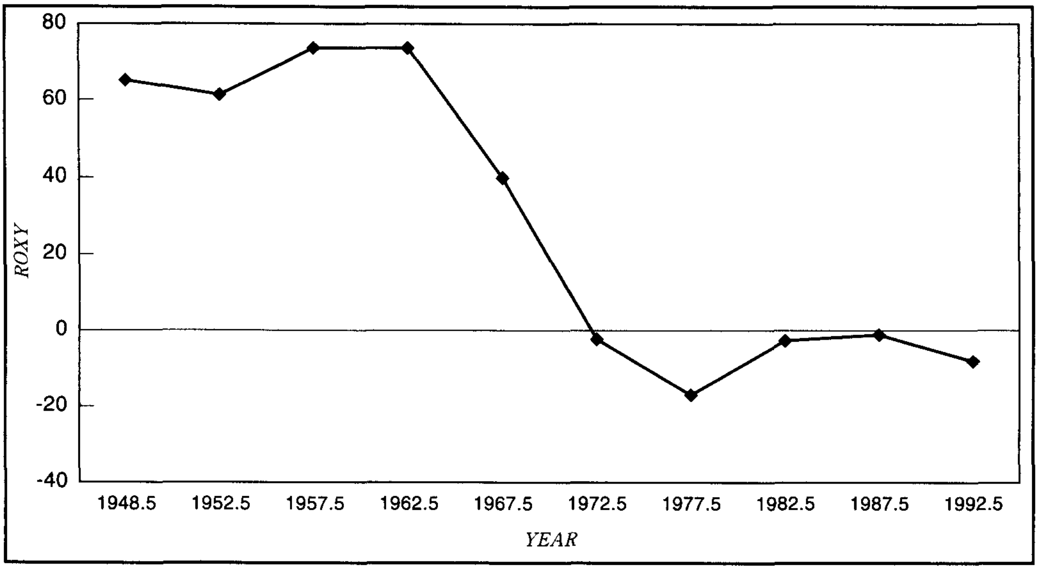
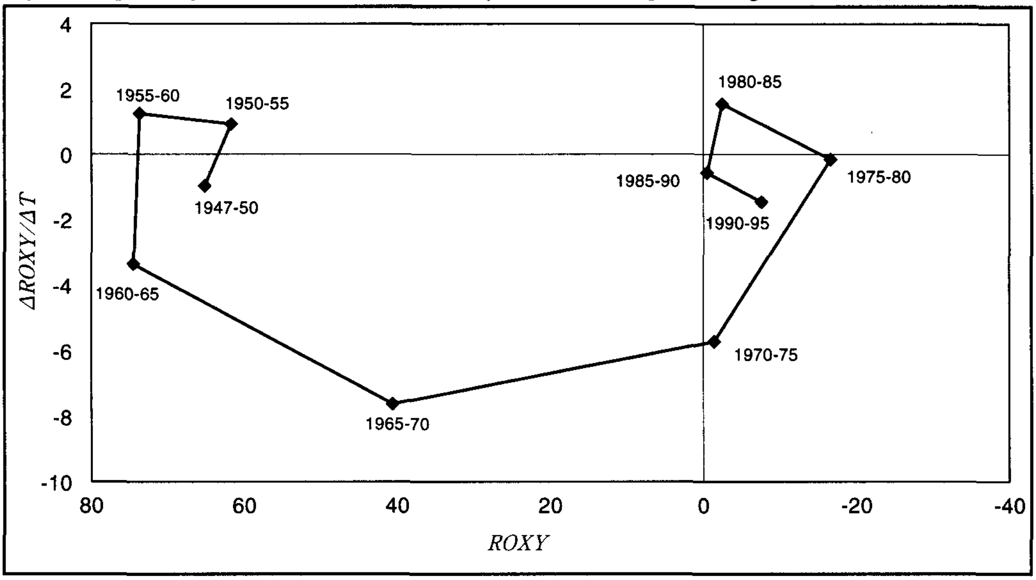


Figure 5 Spatial Cycles for 1947-95 (Circular-Cyclic Form) : Eight (8) Largest FURs



concentration stage in the realm of spatial cycles. This would imply that, among the smaller agglomeration entities, "not-so-small FURs" are more active than other "small FURs" in the Spatial-system (II), in attracting people to them but with gradually reducing magnitude of such attraction.

4 Conclusion

The aforementioned spatial-cycle interpretations of the signals sent from the domain of the spatial-cycle paradigm through the Roxy-index values, may be still weak and fuzzy in their theoretical justification. Having conducted our analysis, however, we are eager to search for the causalities which would substantially govern the dynamism of the spatial-cycle paths, if they existed.

In conjunction with this, I would not want to discount to any degree the tremendous importance of this kind of scientific approach through which we try seriously to find the basic variables to explain the phenomena of spatial cycles. At the same time, I wonder whether there are some self-embedded mechanisms (1) which administer the spatial-cycle dynamism more or less regardless of the social, economic, cultural, histrical or geographical differences among countries, and (2) which we can not easily manipulate externally.

An extreme interpretation of this viewpoint would hold that urban policy-makers have no choice in making urban plans but to accommodate the movement forward along the spatial-cycle path. They can neither stop the cyclical movement nor reverse it. They can, however, tune their urban policies to the velocity and/or amplitude of the movement along the "perhaps self-embedded" spatial-cycle path.

Table 6 Roxy Index (Roxy) and Its Marginal Value (ΔROXY/ΔT) : For Spatial-System (II)

Year	1948.5	1952.5	1957.5	1962.5	1967.5	1972.5	1977.5	1982.5	1987.5	1992.5
ROXY	-4.04	25.53	47.83	88.49	99.17	83.58	50.33	33.79	38.66	33.92
ΔROXY/ΔT	7.39	5.76	6.30	5.13	-0.49	-4.88	-4.98	-1.17	0.01	-0.95

Figure 6 Spatial Cycles for 1947-95 (Wavelike-Cyclic Form) : 79 Smaller FURs and Non-FUR

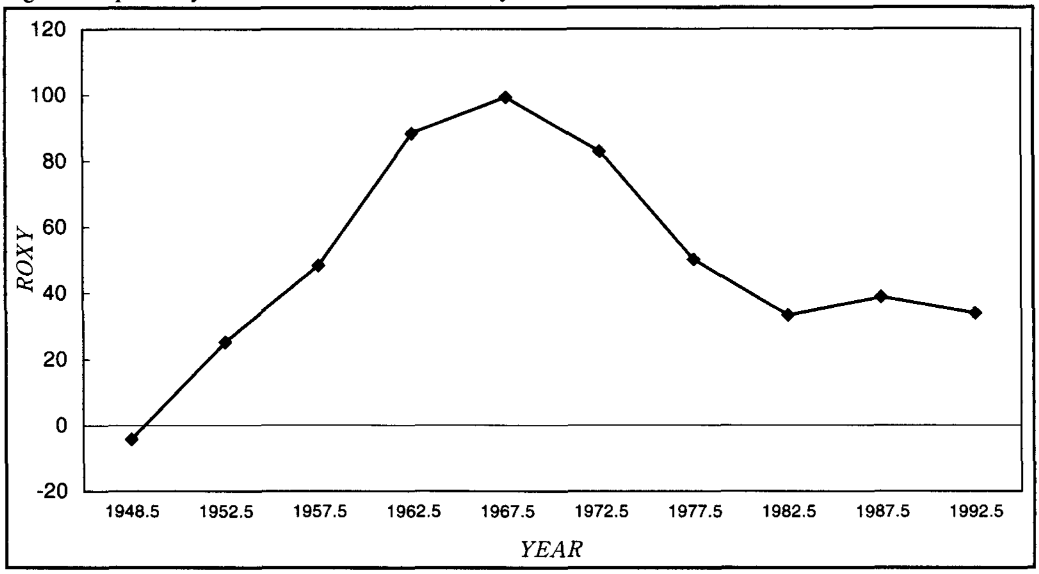
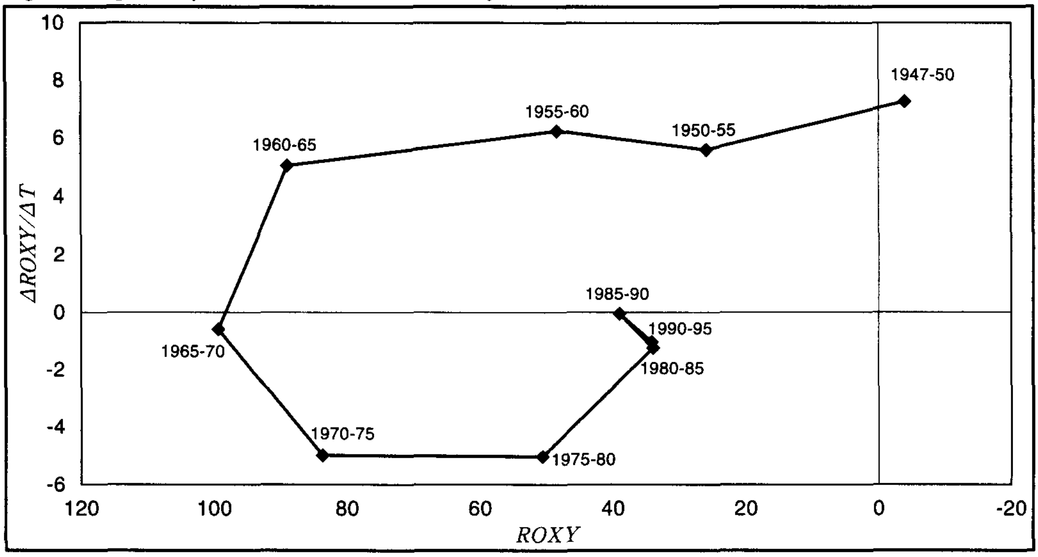


Figure 7 Spatial Cycles for 1947-95 (Circular-Cyclic Form) : 79 Smaller FURs and Non-FUR



Notes

1) The spatial-cycle hypothesis originally argues that the process of urban growth and decline would follow the basic cyclical path dynamically. See Klaassen and Paelinck (1979), and Klaassen, Bourdrez and Volmuller (1981) for the early discussion on this point.

2) As for the work on delineating the FURs of Japan, Kawashima delineated, with Glickman and Okabe, in the first half of the 1970s, the geographical boundaries of the FURs as Japanese metropolitan areas. They fixed the eighty-five (85) FURs based on the 1970 population census data, which would conceptually correspond to the Standard Metropolitan Statistical Areas (SMSAs) in the U.S.A. See Glickman (1979) for the outcomes of the delineation work of the 1970-version of the FURs in Japan. The set of 1970-version of the FURs comprises 1,021 administratively defined localities, and has a total population of 74,731,359 which makes up 71.4% of the national population of Japan in 1970. The average population of the 85 FURs was 889,659 in 1970. Using the 1970-version of the FURs as spatial units in his investigations, Kawashima conducted a number of studies of both inter-metropolitan and intra-metropolitan analyses of the dynamic spatial redistribution processes of the socio-economic activities.

Meanwhile, based on the 1990 population census data, Kawashima *et al.* (1993) delineated the geographical boundaries of the 1990-version of the eighty-eight (88) FURs. This set of the FURs comprises 1,607 administratively defined localities, and has a total population of 103,635,477 which made up 83.8% of the national population of Japan in 1990. The average population of the 88 FURs was 1,177,676 in 1990. This paper uses the set of 87 FURs whose geographical boundaries were delineated by the Mitsubishi Research Institute (1999) on the basis of the 1995 population census.

3) The Klaassen hypothesis originally tried to indicate the existence of the intra-metropolitan spatial-cycle paths in terms of the absolute change in the population levels of spatial units comprising a specific metropolitan area. This framwork has been revised and extended, without losing its original unique conceptual essence, (1) to the analysis of the inter-metropolitan spatial-cycles and (2) to the use of the growth ratio of population, instead of the absolute changes in population levels of each spatial unit.

4) Since the original basic concept of the Roxy index was initiated and applied in an empirical study by Kawashima (1978, pp. 9, 13&14), the methodological framework of the Roxy-index analysis has been further developed, and applied in a number of studies to test empirically both original and generalized versions of the Klaassen's spatial-cycle hypothesis. In parallel with this, Kawashima and others have made theoretical investigations into the mathematical characteristics of the Roxy index. See Kawashima (1981, 1982) as examples of the early works on the Roxy index, and Fukatsu and Kawashima (1999), Hirvonen, Hiraoka and Kawashima (1999) and Kawashima and Hiraoka (2000) as examples of the recent works on the Roxy-index approach. Meanwhile, Kawashima has written more than twenty-five papers on the Roxy index through which he has developed a series of generalized versions of Klaassen's original spatial-cycle hypothesis to facilitate research work on both

intra-metropolitan and inter-metropolitan analyses.

5) In the terminology *neutrality* of the pattern of the spatial redistribution means that the spatial-cycle stage corresponds to the phenomena of neither concentration nor deconcentration, that is, the phenomena of symmetric growth or decline as explained in the notes of Table 5.

6) The marginal value of the ROXY index is calculated as follows when we set the notations RI (T) for the ROXY-index value for the period T, and MRI (T) for the marginal value of the ROXY index for the period T:

(i) For the period 1947-50:
MRI (1947−50) = {RI (1950-55) − RI (1947−50)} / 4.0
[Cf. (1950+1955) / 2 − (1947+1950) / 2 = 8 / 2 = 4.0]

(ii) For the period 1950-55:
MRI (1950−55) = {RI (1955−60) − RI (1947−50)} / 9.0
[Cf. (1955+1960) / 2 − (1947+1950) / 2 = 18 / 2 = 9.0]

(iii) For the period 1990-95:
MRI (1990−95) = {RI (1990-95) − RI (1985−90)} / 5.0
[Cf. (1990+1995) / 2 − (1985+1990) / 2 = 10 / 2 = 5.0]

(iv) For other periods:
MRI (T) = {RI (T+1) − RI (T−1)} / 10.0
[Cf. The difference between the mid-point time for RI (T+1) and the mid-point time for RI (T−1), is ten years.]

7) The FUR-core means the central city of the FUR in the context that each FUR consists of its central city and suburbs. The values of the Roxy index (ROXY) and the marginal values of the Roxy index (ΔROXY/ΔT) for both the FUR system and the FUR-core system can be obtained from Table A-1, and are shown in Table 5.

Based on this table, we can draw figures A-1 (for wavelike-cyclic curve) and A-2 (for circular-cyclic curve). These figures indicate the following:

(1) The FUR system seems to have nearly completed its concentration stage, and to be approaching the first phase of the accelerating deconcentration stage.

(2) The FUR-core system seems to be nearly at the last phase of the decelerating deconcentration, and to be approaching to the first phase of the stage of revived-concentration (more precisely, the stage of revived accelerating-concentration).

(3) The FUR-core system seems to have, as would be expected, preceded the FUR systems along the spatial-cycle path by around a couple of decades.

References

Fukatsu A, and T.Kawashima, 1999, "Urbanization, Suburbanization and Revived-urbanization: ROXY-index Analysis for the Chuo-line Region of Tokyo," *Gakushuin Economic Papers,* Vol.36, No.3, Gakushuin University, Tokyo, pp.389-414.

Glickman N, 1979, *The Growth and Management of the Japanese Urban System,* Academic Press, New York, USA.

Hirvonen M, N.Hiraoka and T. Kawashima, 1999, "Long-term Urban Development of the Finnish Population: Application of the ROXY-index Analytical Method," *Gakushuin Economic Papers,* Vol.36, No.2, Gakushuin University, Tokyo, pp.243-263.

Kawashima T, 1978, "Recent Urban Evolution Processes in Japan: Analysis of Functional Urban Regions," presented at the Twenty-fifth North American Meetings of the Regional Science Association, Chicago, Illinois, USA.

Kawashima T, 1981, "Urbanization and Metropolitan Analysis," *Shin-toshi,* Toshi Kyohkai, Tokyo, August 1981, pp.1-12 (in Japanese).

Kawashima T, 1982, "Recent Urban Trends in Japan: Analysis of Functional Urban Regions," *Human Settelement System: Spatial Patterns and Trends,* T. Kawashima and P. Korcelli (eds.), International Institute for Applied Systems Analysis, Laxenburg, Austria, pp.21-40.

Kawashima T, and N.Hiraoka, 1993, "Centralization and Suburbanization: ROXY Index Analysis for Five Railway-line Regions in Tokyo Metropolitan Area," *Gakusyuin Economic Papers,* Vol.30, No.1, Gakusyuin University, Tokyo, pp.203-230.

Kawashima T, N.Hiraoka, A.Okabe, and N.Ohtera, 1993, "Metropolitan Analysis: Boundary Delineations and Future Population Changes of Functional Urban Regions," *Gakusyuin Economic Papers,* Vol.29, No.3 & 4, Gakusyuin University, Tokyo, pp.205-248.

Kawashima T, and N.Hiraoka, 2000, "Spatial-Cycle Race for Urbanization and Suburbanization: The Tokyo, Osaka and Nagoya Metropolitan Areas," *Regional Science Perspectives in Economic Analysis: A Festschrift in Memory of Benjamin H. Stevens,* M. L. Lahr and R. E. Miller (eds.), Elsevier Science B. V., Amsterdam, The Netherlands, pp.131-146.

Klaassen L H, and J.H.Paelinck, 1979, "The Future of Large Towns," *Environment and Planning A,* Vol.11, No.11,pp.1095-1104.

Klaassen L H, J.A.Bourdrez and J.Volmuller, 1981, *Transport and Reurbanization*, Gower Publishing Company Limited, Hants, England.

Mitsubishi Research Institute, 1999, *Toshikenbetu Jinkou Suikei Chosa (Population Projections by Functional Urban Region)*, Tokyo (in Japanese).

Appendix

Table A- 1 Population of Eighty-seven FURs (1995-Version) : Sorted by 1995 Population

Code	FUR	Area	1947	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995
29	Tokyo	Total	9,640,963	11,246,692	13,608,821	16,073,878	19,181,280	22,175,859	24,900,133	26,467,108	27,947,274	29,407,454	30,144,045
54	Osaka	Total	4,758,708	5,349,856	6,246,229	7,295,321	8,766,376	10,045,799	11,000,775	11,404,103	11,763,030	11,984,546	12,115,741
47	Nagoya-Komaki	Total	2,273,482	2,501,832	2,844,819	3,263,971	3,759,656	4,189,574	4,583,980	4,794,035	4,962,454	5,129,569	5,251,940
53	Kyoto	Total	1,546,892	1,646,412	1,753,610	1,837,787	1,985,465	2,177,607	2,391,710	2,542,489	2,641,666	2,699,572	2,762,083
27	Kitakanto	Total	2,036,363	2,063,898	2,074,633	2,037,042	2,094,418	2,200,073	2,351,994	2,487,463	2,605,021	2,687,106	2,753,840
75	Fukuoka	Total	1,107,101	1,228,670	1,354,805	1,418,358	1,462,281	1,596,649	1,836,958	2,042,763	2,196,222	2,341,810	2,481,405
1	Sapporo	Total	659,519	739,352	868,435	1,007,732	1,223,929	1,433,133	1,693,721	1,897,124	2,044,856	2,200,077	2,326,696
55	Kobe	Total	1,020,571	1,163,239	1,340,872	1,477,143	1,623,299	1,775,610	1,944,699	2,028,052	2,107,126	2,196,127	2,187,616
62	Hiroshima-Kure	Total	1,029,289	1,088,369	1,163,111	1,216,953	1,340,195	1,454,976	1,638,598	1,724,416	1,797,110	1,846,425	1,890,641
64	Shimonoseki-Kitakyushu	Total	1,390,145	1,567,957	1,758,955	1,868,620	1,855,671	1,825,673	1,870,482	1,914,339	1,923,896	1,875,942	1,863,753
13	Sendai	Total	989,675	1,059,450	1,109,708	1,139,296	1,180,383	1,264,687	1,407,663	1,529,261	1,624,079	1,709,453	1,794,147
61	Okayama-Kurashiki	Total	1,033,133	1,068,745	1,106,991	1,122,501	1,150,852	1,249,793	1,366,832	1,428,100	1,473,235	1,490,929	1,523,440
49	Kariya-Toyota-Anjo	Total	611,229	639,467	661,827	691,071	778,428	926,166	1,054,459	1,152,162	1,232,746	1,314,293	1,376,435
43	Gifu-Ogaki	Total	809,927	844,075	875,929	924,700	997,491	1,068,572	1,155,671	1,218,941	1,260,067	1,283,018	1,299,149
80	Kumamoto	Total	902,714	929,643	972,946	966,719	956,624	963,816	1,004,089	1,078,339	1,133,041	1,164,660	1,206,023
77	Kurume-Saga	Total	1,109,722	1,148,799	1,194,248	1,173,812	1,124,660	1,107,745	1,116,344	1,158,297	1,178,090	1,180,462	1,191,091
31	Niigata	Total	861,076	889,586	909,696	920,097	940,667	964,686	1,013,543	1,068,363	1,100,231	1,116,354	1,137,202
34	Toyama-Takaoka	Total	958,345	989,207	1,002,773	1,013,693	1,008,177	1,015,782	1,058,165	1,091,546	1,106,766	1,108,968	1,112,303
44	Shizuoka	Total	634,219	685,090	749,324	807,588	874,745	940,111	1,005,437	1,043,081	1,071,168	1,087,825	1,098,616
26	Utsunomiya	Total	798,137	807,883	808,156	791,531	796,450	829,659	906,041	966,954	1,016,042	1,061,189	1,093,942
45	Hamamatsu	Total	594,984	628,874	678,090	703,522	737,200	783,079	844,588	896,313	942,877	981,348	1,023,402
56	Himeji	Total	722,303	742,128	760,198	779,098	824,856	872,026	929,527	961,697	985,416	986,762	1,008,941
46	Numazu-Fuji	Total	529,922	548,935	580,496	613,140	676,535	747,054	820,432	856,480	892,584	920,300	940,973
87	Naha	Total	-	330,376	439,485	520,800	583,324	627,993	724,206	780,804	841,242	883,773	928,916
30	Hiratsuka-Atsugi	Total	277,740	286,314	302,091	313,064	377,377	475,388	600,696	701,078	785,926	861,090	905,827
86	Kagoshima	Total	666,992	695,204	721,874	708,265	712,741	720,107	769,412	829,216	860,877	866,439	880,018
70	Takamatsu	Total	673,488	698,321	705,187	694,724	691,964	709,610	762,919	800,398	823,712	828,568	837,023
50	Tsu-Ise-Matsuzaka	Total	658,966	677,941	689,214	676,830	675,425	682,248	710,944	728,648	745,138	749,894	759,662
35	Kanazawa	Total	465,898	487,544	504,361	517,281	540,762	569,897	630,221	675,536	708,273	732,013	757,694
48	Toyohashi	Total	450,620	472,297	497,459	513,431	552,074	585,415	634,982	670,292	702,628	726,699	746,356
23	Mito	Total	518,245	530,272	539,358	541,245	551,204	577,604	623,835	664,465	696,640	715,938	740,076
82	Oita	Total	525,992	535,301	556,306	554,249	562,967	583,723	644,666	686,609	713,364	720,358	731,300
25	Tsuchiura-Tsukuba	Total	500,703	498,546	495,758	470,150	464,112	477,386	524,710	590,924	632,467	670,449	715,102
69	Tokushima	Total	602,253	621,930	623,659	612,708	604,904	605,661	633,940	661,397	676,480	681,652	688,874
57	Wakayama	Total	516,708	533,822	554,443	564,037	603,423	638,397	666,644	682,548	685,058	679,433	684,919
37	Fukui	Total	566,546	591,349	592,312	596,402	598,720	597,444	623,056	642,309	660,521	664,418	674,677
63	Fukuyama	Total	510,054	518,900	522,237	527,725	538,948	590,800	643,124	659,498	671,451	668,195	671,923
78	Nagasaki	Total	421,616	479,012	529,094	570,922	586,248	603,188	630,995	655,327	670,806	668,085	667,816
38	Kofu	Total	590,127	588,737	579,828	559,822	544,669	545,283	565,341	587,916	603,934	620,341	656,102
39	Nagano	Total	562,739	567,520	563,537	555,104	555,425	564,641	588,911	611,969	626,104	632,564	644,387
71	Matsuyama	Total	360,502	381,086	402,980	416,521	436,590	465,355	516,310	558,558	587,128	603,903	623,512
51	Yokkaichi	Total	365,413	379,139	389,379	408,306	443,697	473,219	519,297	544,952	565,916	589,629	613,680
74	Kochi	Total	490,597	506,727	516,499	507,319	509,258	517,908	550,400	575,523	591,542	589,254	591,577
21	Koriyama	Total	441,568	457,902	459,248	467,937	467,232	475,504	495,726	521,795	539,759	554,770	549,467
16	Yamagata	Total	496,558	507,041	498,493	493,726	484,010	484,475	498,014	521,843	535,009	540,250	538,102
15	Akita	Total	393,644	418,479	440,054	447,400	446,356	457,220	479,226	505,875	515,874	517,064	523,324
83	Miyazaki	Total	327,933	346,969	359,629	366,243	363,106	373,223	407,600	450,334	473,420	487,474	506,123
12	Morioka	Total	286,233	310,241	336,204	354,530	361,260	368,429	395,976	430,886	453,538	465,806	482,346
19	Fukushima	Total	405,043	419,350	427,216	421,350	421,177	426,914	442,335	459,432	467,801	472,537	478,270
40	Matsumoto	Total	392,520	395,441	392,431	390,675	389,881	396,733	417,813	437,407	451,477	458,813	472,116
3	Asahikawa	Total	250,323	275,392	309,091	331,582	355,621	370,766	385,982	416,089	424,551	415,696	416,332
32	Nagaoka	Total	410,174	419,149	415,770	407,971	400,189	392,944	395,537	402,442	404,263	403,529	404,989
2	Hakodate	Total	322,164	343,132	361,415	359,788	367,121	376,337	392,791	408,761	408,133	394,953	391,002
11	Hachinohe	Total	270,784	296,269	320,378	345,982	351,345	363,199	375,842	390,303	392,942	389,110	390,897
24	Hitachi	Total	278,045	290,165	307,257	337,438	348,979	350,591	362,088	373,580	383,004	382,373	383,517
22	Iwaki	Total	331,222	358,185	368,712	361,544	348,134	340,318	342,893	355,775	364,314	369,725	374,841
79	Sasebo	Total	367,578	401,991	440,392	431,574	376,486	358,101	359,503	362,739	363,855	356,959	357,551
28	Oyama	Total	249,642	248,607	246,831	242,390	251,249	273,608	301,466	320,563	334,097	344,244	352,746
9	Aomori	Total	218,540	243,565	269,031	280,186	288,949	302,095	324,320	347,667	352,224	341,450	345,746
10	Hirosaki	Total	317,639	337,582	353,532	352,319	341,951	338,683	342,772	355,096	352,682	345,935	345,742
60	Matsue	Total	300,499	310,760	318,864	314,586	307,120	306,960	315,031	327,198	335,024	335,195	335,954
66	Yamaguchi	Total	279,058	286,036	293,319	286,201	272,872	270,844	281,556	295,967	311,518	314,695	320,642
52	Hikone	Total	266,460	265,636	260,833	254,170	254,366	257,767	270,172	273,142	285,443	291,658	300,418
20	Aizuwakamatsu	Total	324,275	326,275	327,969	317,146	300,862	284,506	278,365	282,529	284,170	283,189	282,504
6	Obihiro	Total	162,875	173,384	205,644	211,942	224,767	233,838	242,575	259,983	272,811	274,614	281,834
76	Omuta	Total	305,384	344,288	355,159	353,562	333,013	303,850	296,925	297,175	295,866	281,882	272,677
67	Tokuyama	Total	205,963	211,110	218,359	223,234	235,576	248,837	270,828	279,026	279,975	274,034	270,441
33	Joetsu	Total	319,612	316,698	313,270	303,042	292,084	276,781	271,106	271,768	270,936	265,372	264,138
59	Yonago	Total	237,443	243,943	252,043	246,699	241,187	238,311	246,336	258,142	262,503	260,400	260,703
58	Tottori	Total	237,930	244,532	250,077	244,126	235,793	231,803	235,653	243,508	249,296	252,139	252,302
5	Kushiro	Total	120,509	150,106	179,901	214,175	231,363	230,782	246,546	257,509	259,000	251,561	246,732
65	Ube	Total	198,798	223,097	237,024	242,216	220,085	211,317	221,867	229,750	237,276	237,402	237,017
41	Ueda	Total	219,822	218,178	211,189	205,648	202,615	202,741	209,243	217,107	223,588	227,513	232,741
84	Miyakonojo	Total	227,308	236,968	242,965	235,410	220,967	207,860	208,502	223,369	227,624	226,177	228,988
8	Tomakomai	Total	70,163	81,885	96,632	110,816	131,320	150,868	182,864	203,526	208,642	207,462	214,813
14	Ishinomaki	Total	190,473	200,407	201,954	203,126	200,230	202,489	208,260	213,691	215,387	212,081	209,555
36	Komatsu	Total	160,463	164,948	162,349	164,099	168,318	176,621	188,020	196,855	202,772	203,702	206,279
73	Niihama	Total	177,897	189,539	195,425	197,286	194,550	193,238	200,684	203,450	206,228	203,463	202,534
4	Muroran	Total	138,171	154,767	173,048	201,221	227,200	238,137	242,935	241,407	229,402	207,933	201,089
72	Imabari	Total	186,462	195,912	197,005	195,903	193,183	195,798	205,013	208,360	209,865	205,370	200,863
81	Yatsushiro	Total	200,238	208,751	218,274	216,785	204,196	193,631	189,805	192,426	190,692	185,629	181,743
42	Iida	Total	202,683	203,818	194,604	183,604	175,986	170,401	171,499	174,964	176,934	175,888	175,517
18	Sakata	Total	179,529	185,421	187,651	184,317	176,342	170,361	168,870	173,832	171,552	169,260	167,682
68	Iwakuni	Total	155,672	159,909	172,884	176,855	174,351	170,145	174,149	175,886	173,394	169,497	167,198
85	Nobeoka	Total	131,058	148,602	163,043	167,564	163,819	165,107	170,140	173,434	172,776	165,883	160,906
17	Tsuruoka	Total	178,613	183,060	188,610	178,133	168,933	162,037	158,731	161,809	161,147	159,103	157,697
7	Kitami	Total	93,001	101,309	111,514	118,254	121,174	121,883	126,413	136,217	138,855	136,167	137,325
	Total		56,973,587	61,757,296	67,385,026	72,315,233	78,708,788	85,485,449	93,162,422	98,292,010	102,323,823	105,344,841	107,586,268

[Source] Mitsubishi Research Institute (1999)

Table A- 2 Population of Eight (8) Largest FURs: Spatial-System (I)

Code	FUR	1947	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995
29	Tokyo	9,640,963	11,246,692	13,608,821	16,073,878	19,181,280	22,175,859	24,900,133	26,467,108	27,947,274	29,407,454	30,144,045
54	Osaka	4,758,708	5,349,856	6,246,229	7,295,321	8,766,376	10,045,799	11,000,775	11,404,103	11,763,030	11,984,546	12,115,741
47	Nagoya-Komaki	2,273,482	2,501,832	2,844,819	3.263,971	3,759,656	4,189,574	4,583,980	4,794,035	4,962,454	5,129,569	5,251,940
53	Kyoto	1,546,892	1,646,412	1,753,610	1,837,787	1,985,465	2,177,607	2,391,710	2,542,489	2,641,666	2,699,572	2,762,083
27	Kitakanto	2,036,363	2,063,898	2,074,633	2,037,042	2,094,418	2,200,073	2,351,994	2,487,463	2,605,021	2,687,106	2,753,840
75	Fukuoka	1,107,101	1,228,670	1,354,805	1,418,358	1,462,281	1,596,649	1,836,958	2,042,763	2,196,222	2,341,810	2,481,405
1	Sapporo	659,519	739,352	868,435	1,007,732	1,223,929	1,433,133	1,693,721	1,897,124	2,044,856	2,200,077	2,326,696
55	Kobe	1,020,571	1,163,239	1,340,872	1,477,143	1,623,299	1,775,610	1,944,699	2,028,052	2,107,126	2,196,127	2,187,616
	Total	23,043,599	25,939,951	30,092,224	34,411,232	40,096,704	45,594,304	50,703,970	53,663,137	56,267,649	58,646,261	60,023,366

[Source] Constructed from Mitsubishi Research Institute (1999)

Table A- 3 Population for the 79 Smaller FURs and Non-FUR Area: Spatial-System (II)

Year	1947	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995
Smaller FURs	33,929,988	35,817,345	37,292,802	37,904,001	38,612,084	39,891,145	42,458,452	44,628,873	46,056,174	46,698,580	47,562,902
Non-FUR	21,127,886	22,357,278	22,691,568	21,986,390	20,500,349	19,179,722	18,777,221	18,768,386	18,725,100	18,266,326	17,983,978
Total	55,057,874	58,174,623	59,984,370	59,890,391	59,112,433	59,070,867	61,235,673	63,397,259	64,781,274	64,964,906	65,546,880

[Source] Constructed from Mitsubishi Research Institute (1999)

Table A- 4 Roxy Index (Roxy) and Its Marginal Value (ΔROXY/ΔT) : For FUR System and FUR-Core System

(a) For FUR System

Period	1947-50	1950-55	1955-60	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90	1990-95
ROXY	74.54	76.67	96.08	126.39	104.20	56.00	11.67	24.54	40.48	15.38
ΔROXY/ΔT	0.53	2.39	4.97	0.81	-7.04	-9.25	-3.15	2.88	-0.92	-5.02

(b) For FUR-Core System

Period	1947-50	1950-55	1955-60	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90	1990-95
ROXY	159.96	104.93	90.67	27.35	-32.49	-53.15	-49.45	-9.80	0.67	-12.56
ΔROXY/ΔT	-13.76	-7.70	-7.76	-12.32	-8.05	-1.70	4.34	5.01	-0.28	-2.65

Figure A- 1 Spatial Cycles for 1947-95 (Wavelike-Cyclic Form) : 87 FURs in Comparison with Their Cores (FUCs)

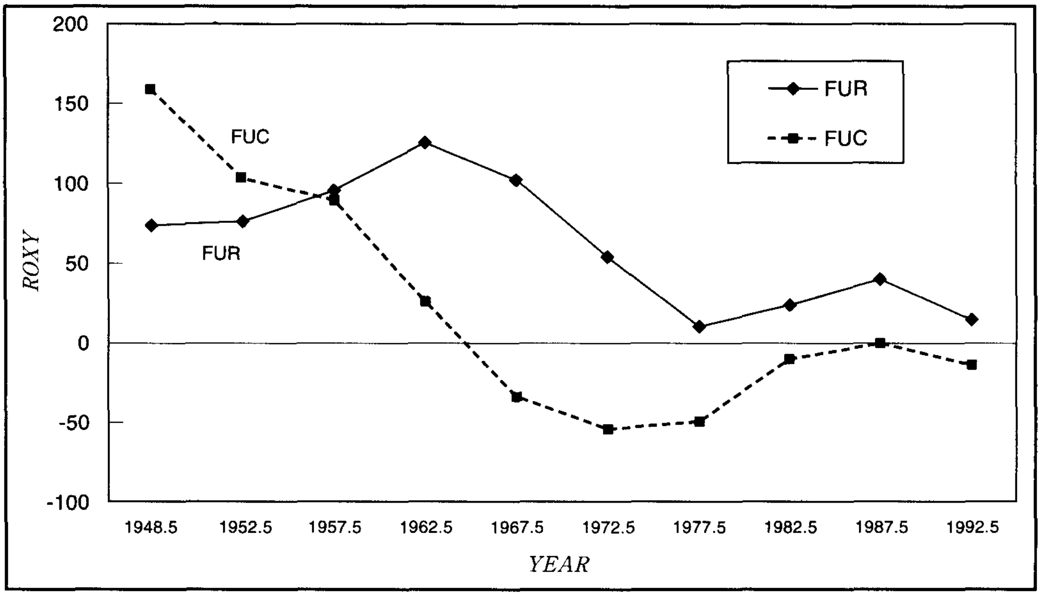


Figure A- 2 Spatial Cycles for 1947-95 (Circular-Cyclic Form) : 87 FURs in Comparison with Their Cores (FUCs)