

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

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## Keywords

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

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## 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

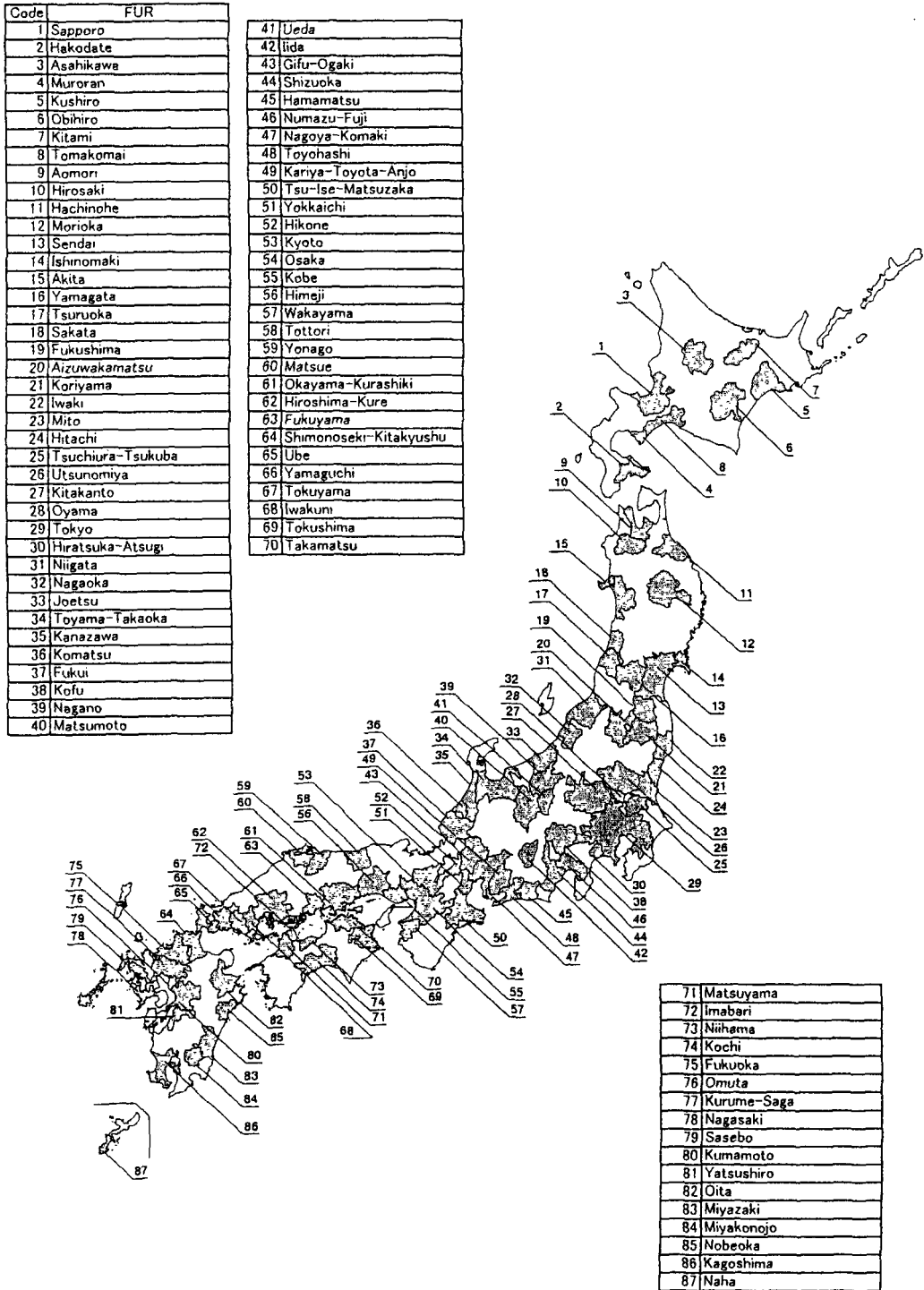
The Roxy-index values generally provide us with useful information about the dynamic changes in the spatial redistribution of various socio-economic activities. In this paper, we apply the Roxy-index method for quantitatively examining the stages of the spatial-cycle paths in the light of Klaassen's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

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<sup>2)</sup>). 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)



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<sup>3)</sup> 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<sup>4)</sup> 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.

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

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

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

$SAGR_{t,t+1}$  : 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

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

$x_i^t$  : Population of metropolitan area  $i$  in year  $t$

$n$  : 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  $\alpha$  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 designated as spatial unit 1 and (2) an aggregated non-metropolitan area designated as spatial unit 2.

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

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

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

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  $n=2$ .

$x_i^t$  : Population of spatial unit  $i$  in year  $t$

$n$  : 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<sup>(5)</sup>.

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	Neutrality from both concentration and deconcentration (viz., symmetric growth or decline <sup>(1)</sup> )	Increasing	Start of ACon <sup>(2)</sup>
		Leveling-off	Continuation of neutrality
		Decreasing	Start of ADcon <sup>(3)</sup>
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<sup>6)</sup> of the Roxy index with respect to time (*i.e.*,  $\Delta ROXY/\Delta T$ ). 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)

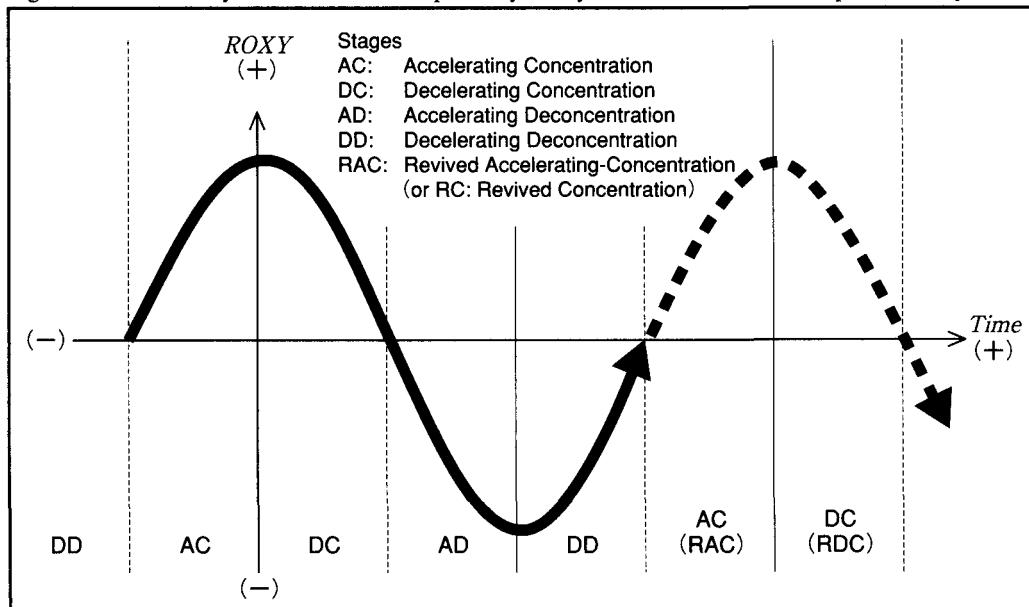
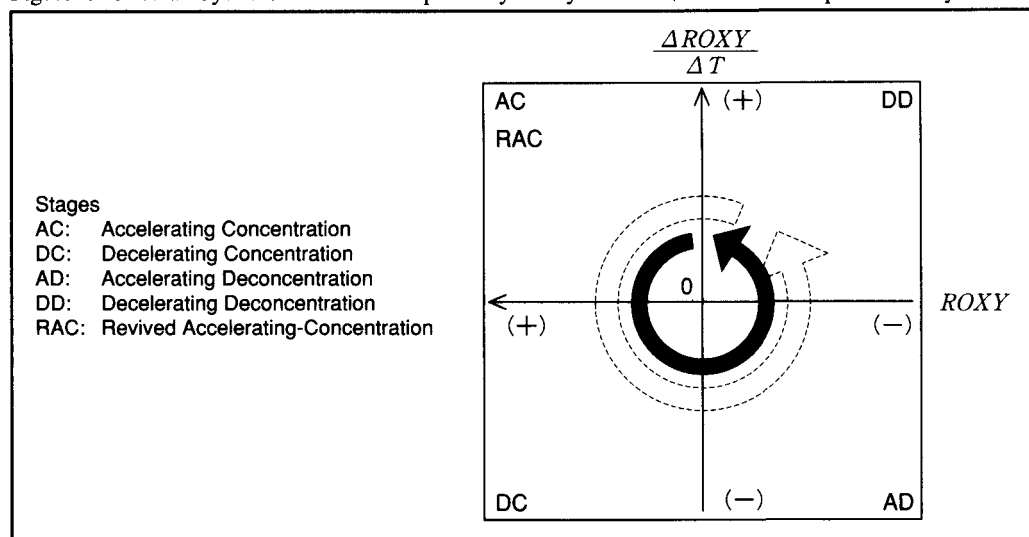


Figure 3 Circular-Cyclic Curve: Path of Spatial Cycles by ROXY (For Inter-metropolitan Analysis)





### 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 ( $\Delta ROXY/\Delta T$ ) 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 ( $\Delta ROXY/\Delta T$ ): 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
$\Delta ROXY/\Delta T$	-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

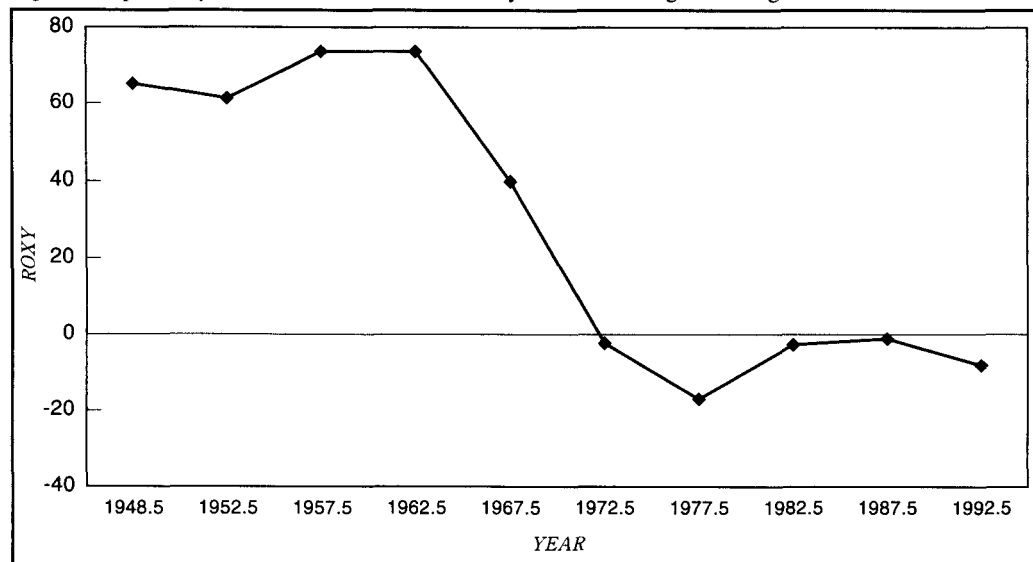
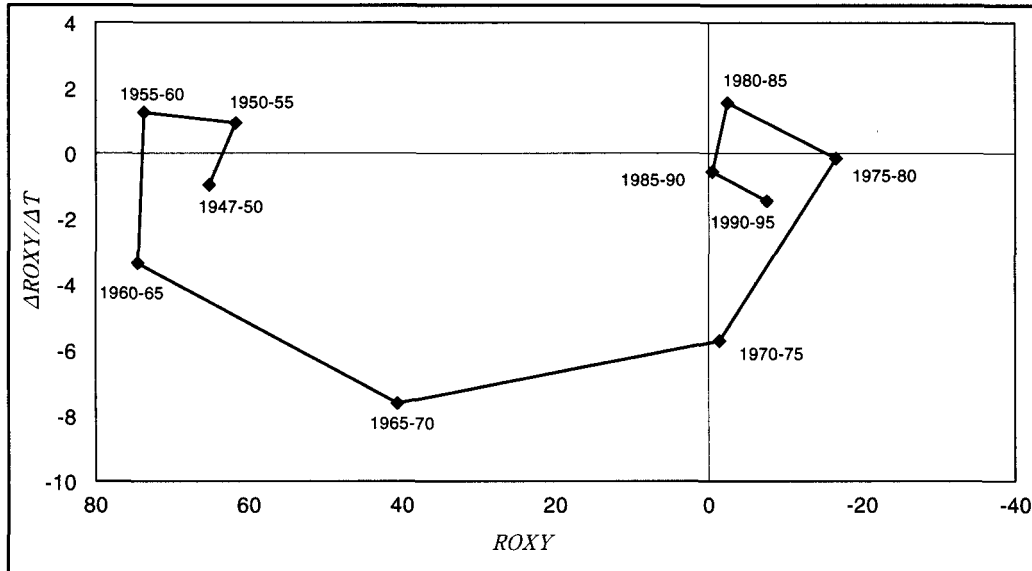


Figure 5 Spatial Cycles for 1947-95 (Circular-Cyclic Form) : Eight (8) Largest FURs



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 (  $\Pi$  ), 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, historical 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 ( $\Delta ROXY/\Delta T$ ) : 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
$\Delta ROXY/\Delta T$	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

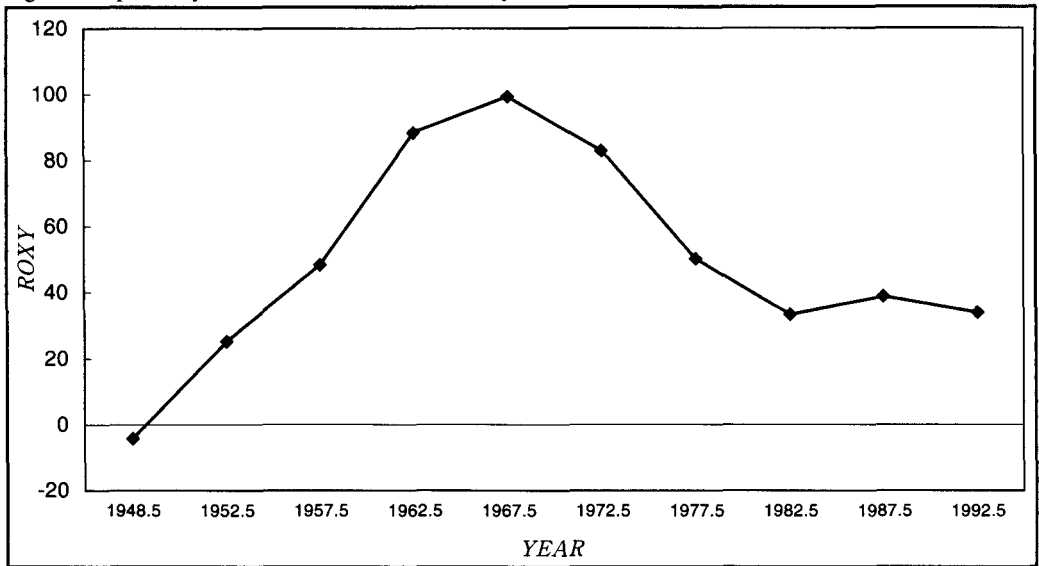
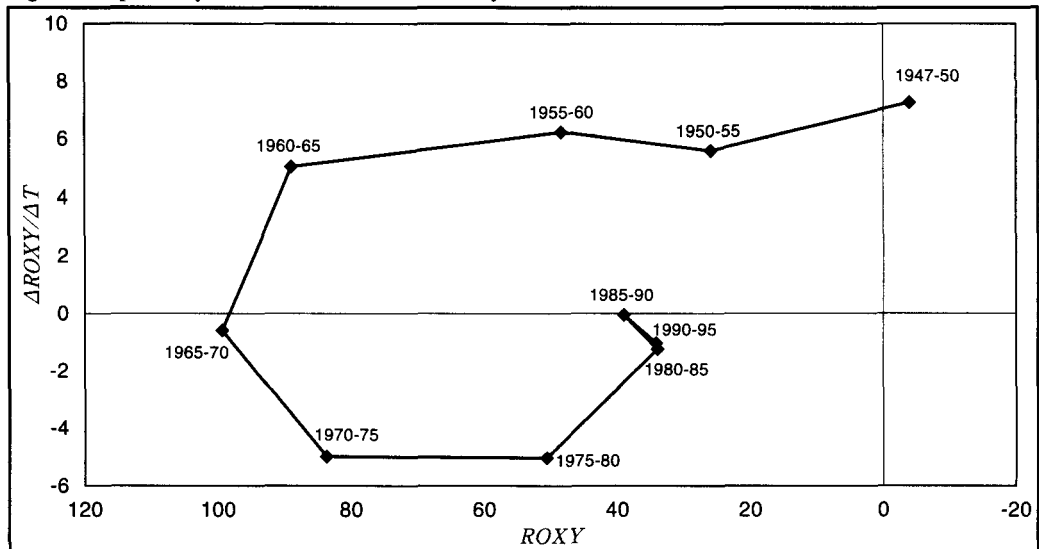


Figure 7 Spatial Cycles for 1947-95 (Circular-Cyclic Form) : 79 Smaller FURs and Non-FUR



## 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, Bourdreuz 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 framework 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:

$$\text{MRI} (1947 - 50) = \{ \text{RI} (1950-55) - \text{RI} (1947 - 50) \} / 4.0$$

$$[\text{Cf. } (1950+1955) / 2 - (1947+1950) / 2 = 8 / 2 = 4.0]$$

( ii ) For the period 1950-55:

$$\text{MRI} (1950 - 55) = \{ \text{RI} (1955 - 60) - \text{RI} (1947 - 50) \} / 9.0$$

$$[\text{Cf. } (1955+1960) / 2 - (1947+1950) / 2 = 18 / 2 = 9.0]$$

( iii ) For the period 1990-95:

$$\text{MRI} (1990 - 95) = \{ \text{RI} (1990-95) - \text{RI} (1985 - 90) \} / 5.0$$

$$[\text{Cf. } (1990 + 1995) / 2 - (1985 + 1990) / 2 = 10 / 2 = 5.0]$$

( iv ) For other periods:

$$\text{MRI} (T) = \{ \text{RI} (T + 1) - \text{RI} (T - 1) \} / 10.0$$

$$[\text{Cf. The difference between the mid-point time for RI} (T + 1) \text{ and the mid-point time for RI} (T - 1) , \text{ is ten years.}]$$

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 ( $\Delta \text{ROXY} / \Delta T$ ) 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.

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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 ( $\Delta ROXY/\Delta T$ ) : 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
$\Delta ROXY/\Delta T$	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
$\Delta ROXY/\Delta T$	-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)

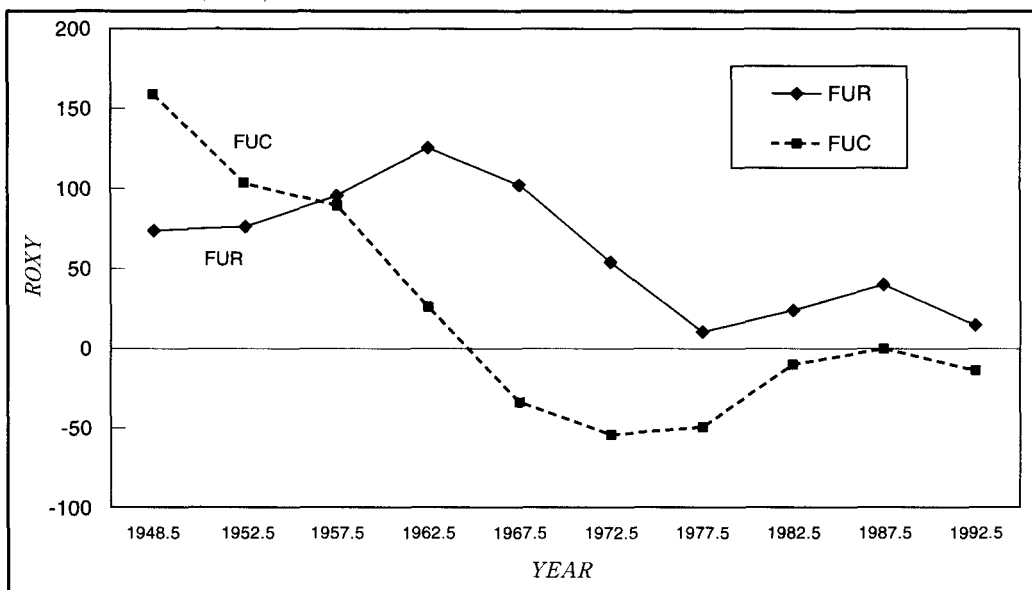


Figure A- 2 Spatial Cycles for 1947-95 (Circular-Cyclic Form) : 87 FURs in Comparison with Their Cores (FUCs)

