Robustness of Roxy Index in Analysis of Three Systems of Thirty Largest Cities in Japan: Constantly Fixed, Backwardly Variable and Forwardly Variable Member Cities

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CONTENTS

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Abstract

It would be convenient for urban and regional scholars to possess a tool for standardizing the Roxy index values in such a way that different spatial systems can be objectively compared with one another as to the stage of spatial convergence and divergence of societal-economic activities in the Klaassen spatial-cycle framework. This paper first describes the basic skeleton of the spatial-cycle hypothesis and the Roxy index method. It then proposes a standardization function to meet the above scientific needs. After that, it shows empirical results obtained through the application of the proposed standardization function to the spatial-cycle analysis of the three systems of the thirty largest cities in Japan. Finally, it concludes that the Roxy index possesses a reasonably significant robustness for the study of phase positions in the spatial-cycle realm.

Keywords

Backwardly variableness, Concentration, Constant fixedness, Convergence, Forward variableness, Klaassen's hypothesis, Phase analysis, Robustness, Roxy index, Spatial cycles, Standardization

function, Urban change, and Urban system.

1 Introduction

For a system of spatial units, the value of the Roxy index would provide us with a fundamentally informative perspective on its stage of spatial cycles in the realm of Klaassen's hypothesis which argues the cyclicly metamorphic evolution and devolution processes of urban dynamism. In other words, the Roxy index can be reasonably instrumental in quantitatively identifying the spatial-cycle stage which a specific system of spatial units faces at a specific point or period of time. Note here that the above mentioned stage, which may also be referred to as position, phase, or phase position of the spatial-cycle path, is closely associated with the concept of relative spatial convergence (*i.e.*, agglomeration, centralization, urbanization, or concentration) and divergence (*i.e.*, deglomeration, decentralization, suburbanization, or deconcentration) of societal-economic activities in a system of spatial units.

The Roxy index can also be instrumental in comparing relative stages along the spatial-cycle path among different systems of spatial units. Namely, it helps us to understand roughly whether a particular system of spatial units may be more advanced than other ones along the track for the spatial-cycle race at a given point or period of time. It would be, however, more desirable from the viewpoint of research efficiency in the comparative studies of urban changes, if a new methodological tool were available for us to map the value of the Roxy index to a standardized spatial-cycle stage in such a way that different systems of spatial units could be more objectively compared with one another.

The first purpose of this paper is therefore to propose a methodologicel tool to meet such a requirement. The proposed tool carries a form of the mathematical formulation of a phase function. This function which we call the standardization function in this paper, is constructed based on the phase approach often applied to the trigonometrical investigations in conducting phase analyses. The second objective is to show the results which we have obtained by use of the standardization function for the three systems of the thirty largest cities in Japan in our empirical analysis of population change in every fifth year from 1960 to 1995. The third objective is to show two aspects of the robust features of the Roxy index recognized in conjunction with the standardization function.

In the following Sections 2 and 3, the basic structures of the spatial-cycle hypothesis and the Roxy-index method will be discussed respectively. In Section 4, we propose a phase function to standardize the Roxy-index value. Section 5 shows the results of our empirical analysis for the three systems of the thirty largest cities in Japan. In Section 6, the conclusion examines the two kinds of robustness of the Roxy index.

2 Spatial Cycles

Klaassen has conceptualized the spatial-cycle hypothesis[1] to argue the existence of the general cyclical tendency underlying the phenomena of urban growth and decline. Table 1 shows one of the basic

spatial-cycle frameworks revised for the study of the system of cities. It describes four recursively transmuting stages: (1) accelerating concentration, (2) decelerating concentration, (3) accel-erating deconcentration, and (4) decelerating deconcentration.

Table 1 Spatial-cycle Framework for Spatial Concentration and Deconcentration of Population

Spatial redistrbution of population	Four stages appearing along spatial-cycle path	
Concentration toward larger cities	Stage-1	Accelerating concentration
	Stage-2	Decelerating concentration
Deconcentration from larger cities	Stage-3	Accelerating deconcentration
	Stage-4	Decelerating deconcentration

[Source] Constructed from Kawashima and Hiraoka (1993)

3 Roxy Index

The Roxy index[2] is an indicative instrument to quantitatively identify the stage of spatial cycles which a system of spatial units faces. In our study of the system of cities in which the population of

Table 2 Definition of Roxy Index for Study of a System of Cities with City Population Employed as a Weighting Factor

$$ROXY\ \text{Index} = \left(\frac{WAGR_{t,\,t+1}}{SAGR_{t,\,t+1}} - 1.0 \right) \times 10^4$$

$$= \left\{ \frac{\sum_{i=1}^{n} \left(x_i^{\,t} \times r_i^{\,t,\,t+1} \right)}{\sum_{i=1}^{n} x_i^{\,t}} \times \frac{n}{\sum_{i=1}^{n} r_i^{\,t,\,t+1}} - 1.0 \right\} \times 10^4$$

where

$x_i^{\,\tau}$: Population of city i in year τ

$r_i^{\,t,t+1}$: Annual growth *ratio* of population in city i for the period between years t and $t+1$, which is defined as the k-th root of x_i^{t+k}/x_i^t

n : Number of cities

$WAGR_{t,\,t+1}$: Weighted average of annual growth *ratios* of population in n cities for the period between years t and $t+1$. In case the population level of each city is used as the weighting factor, this is equal to

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

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

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

Table 3 Implications of Roxy-index Values for Study of a System of Cities : Roxy Index with City Population Employed as a Weighting Factor

A	B	C	D
Sign of Roxy-index value	Pattern of spatial redistribution of population among cities	State of changes in Roxy-index value	Speed of spatial redistribution process of population among cities
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* conceptually includes the following three sub-patterns;

(i) Balanced growth or decline (*BLGD*) : The growth-rate curve is nearly flat, reflecting the fixed share of population by cities.

(ii) Bell-shaped growth or decline (*BSGD*) : The growth-rate curve is bellshaped, reflecting the *medianization* of population over cities of different sizes of population. The phenomena of *medianization* means the increases in population share by cities of medium size in population and, at the same time, the decreases in population share by cities of smaller and larger populations.

(iii) Cup-shaped growth or decline (*CSGD*): The growth-rate curve is cupshaped, reflecting the *bipolarization* of population over cities of different sizes in population. The phenomena of *bipolarization* means the increases in population share by smaller and larger cities and, at the same time, the decreases in population share by medium-sized cities.

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

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

each city is used as a weighting factor to calculate the Roxy-index values, the Roxy index is defined as shown in Table 2. Based on this definition, Table 3 can be constructed which describes the implications of the Roxy-index value in association with the spatial-cycles stages. From this table, we can summarise that the Roxy index value would turn out to be:

(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) at or in the vicinity of zero for the stage at which the spatial redistribution process is neutral (that is, the spatial-cycle stage corresponds to neither concentration nor deconcentration phenomena).

4 Standardization of Roxy Index

As a possible means to standardize the values of the Roxy index in such a way that we can objectively compare relative stages along the spatial-cycle path among different systems of spatial units, we propose a standization function as given by Table 4.

Table 4 Standardization Function

$$ROXY_{est}(t) = A_0 \cos\{\omega_0(t-1900)+\phi_0\}+R_0$$

where A_0 : Amplitude
ω_0 : Angular velocity
ϕ_0 : Phase of 1990
R_0 : Center of oscillation
t : Time
$ROXY_{est}(t)$: Estimated value of Roxy index for time t.

It is to be noted that this is a phase function with four coefficients: (1) amplitude A_0, (2) angular velocity ω_0, (3) phase at a fixed specific point of time ϕ_0, and (4) center of oscillation R_0. These coefficents will be estimated by use of non-linear least squares method (Newton method) to fit the curve of the standardization function to the data of observed values of the Roxy index. The basic framework of this mathematical manipulation is as follows:

$$\text{Min}\ [\sum_t \{ROXY_{obs}(t)-ROXY_{est}(t)\}^2]$$

where $ROXY_{obs}(t)$: Observed value of Roxy index for time t.

5 Empirical Results obtained for Three Systems of Cities

5.1 Data for Three Systems of Largest Thirty Cities in Japan

In our empirical study of population changes in every fifth year from 1960 to 1995 in Japan, we select the following three systems each of which is composed of thirty cities:

(1) the system of the thirty largest cities that are selected according to the population level in 1990 (*i.e.*, the thirty largest cities that are constantly selected, or the largest thirty *constantly fixed*

Table 5 Population Level for 30 Largest Cities in Japan (1960-95) : Constantly Fixed Cities

No	Name	1960	1965	1970	1975	1980	1985	1990	1995
1	Tokyo-tokubetsu-ku area	8,310,027	8,893,094	8,840,942	8,646,520	8,351,893	8,354,615	8,163,573	7,967,614
2	Yokohama-shi	1,375,705	1,788,907	2,238,253	2,621,771	2,773,674	2,992,926	3,220,331	3,307,136
3	Osaka-shi	3,011,563	3,156,222	2,980,487	2,778,987	2,648,180	2,636,249	2,623,801	2,602,421
4	Nagoya-shi	1,697,093	1,935,430	2,036,053	2,079,740	2,087,902	2,116,381	2,154,793	2,152,184
5	Sapporo-shi	615,684	821,272	1,010,177	1,240,613	1,401,757	1,542,979	1,671,742	1,757,025
6	Kobe-shi	1,113,937	1,216,614	1,288,901	1,360,565	1,367,390	1,410,834	1,477,410	1,423,792
7	Kyoto-shi	1,284,818	1,365,007	1,419,165	1,461,059	1,473,065	1,479,218	1,461,103	1,463,822
8	Fukuoka-shi	682,365	769,176	871,717	1,002,201	1,088,588	1,160,440	1,237,062	1,284,795
9	Kawasaki-shi	632,980	854,874	973,497	1,014,951	1,040,802	1,088,624	1,173,603	1,202,820
10	Hiroshima-shi	557,988	657,366	746,287	852,611	899,399	1,044,118	1,085,705	1,108,888
11	Kitakyushu-shi	986,778	1,042,688	1,042,620	1,058,442	1,065,078	1,056,402	1,026,455	1,019,598
12	Sendai-shi	425,272	480,925	545,065	615,473	664,868	857,335	918,398	971,297
13	Chiba-shi	258,729	339,974	482,304	659,372	746,430	788,930	829,455	856,878
14	Sakai-shi	371,502	466,412	594,367	750,688	810,106	818,279	807,765	802,993
15	Okayama-shi	387,484	417,908	460,542	513,471	545,765	572,479	593,730	615,757
16	Kumamoto-shi	382,913	415,507	449,254	488,166	525,662	555,719	579,306	650,341
17	Kagoshima-chi	334,643	371,129	403,340	456,827	505,360	530,502	536,752	546,282
18	Hamamatsu-shi	357,098	392,632	432,221	468,884	490,824	514,131	534,620	561,606
19	Funabashi-shi	135,038	223,989	325,426	423,101	479,439	506,966	533,270	540,817
20	Sagamihara-shi	101,655	163,381	278,326	377,398	439,300	482,778	531,542	570,597
21	Higashiosaka-shi	318,001	443,081	500,173	524,750	521,558	522,805	518,319	517,232
22	Amagasaki-shi	405,534	500,472	553,696	545,783	523,650	509,115	498,999	488,586
23	Niigata-shi	325,018	356,302	383,919	423,188	457,785	475,630	486,097	494,769
24	Shizuoka-shi	350,897	382,799	416,378	446,952	458,341	468,362	472,196	474,092
25	Hachioji-shi	164,544	207,655	253,407	322,580	387,178	426,654	466,347	503,363
26	Matsudo-shi	86,372	160,001	253,591	344,558	400,863	427,473	456,210	461,503
27	Himeji-shi	334,520	373,653	408,353	436,086	446,256	452,917	454,360	470,986
28	Nagasaki-shi	387,910	411,733	427,083	450,194	447,091	449,382	444,599	438,635
29	Matsuyama-shi	262,044	290,662	322,902	367,323	401,703	426,658	443,322	460,968
30	Kanazawa-shi	313,114	335,830	361,382	395,268	417,684	430,481	442,868	453,975
	Total	25,971,226	29,234,695	31,299,828	33,127,522	33,867,591	35,099,382	35,843,733	36,170,772

[Note] Cities are sorted by 1990 population.

cities),

(2) the system of the thirty largest cities that are selected according to the population level in every term-end year for each five-year period (*i.e.*, the thirty largest cities that are *variably* selected for the *backward* investigation, or the thirty largest *backwardly variable cities*), and

(3) the system of the thirty largest cities that are selected according to the population level in every term-head year of each five-year period (*i.e.*, the thirty largest cities that are *variably* selected for the *forward* investigation, or the thirty largest *forwardly variable cities*).

The data for the thirty largest *constantly fixed cities*, is given in Table 5, while the data for the thirty largest *backwardly variable cities* and *forwardly variable cities*, are given respectively in Tables A1 and A2 in the Appendix.

5.2 Absolute and Marginal Values of Roxy Index

Tables 6 (a), (b) and (c) show the calculated absolute values (ROXY) and marginal values (ΔROXY / ΔT) of the Roxy index for the three systems of the constantly fixed cities, backwardly variable cities and forwardly variable cities respectively.

Table 6 Calculated Values of Roxy Index : Absolute Values (ROXY) and Marginal Values (ΔROXY/ΔT)

(a) Roxy index for a system of 30 largest cities in Japan (1960-95): Constantly fixed cities sorted by 1990 population

Period	1960 -1965	1965 -1970	1970 -1975	1975 -1980	1980-1985	1985-1990	1990-1995
ROXY	-128.9	-145.2	-114.3	-66.7	-24.7	-19.5	-24.7
ΔROXY/ΔT	-3.3	1.5	7.8	9.0	4.7	0.0	-1.1

(b) Roxy index for a system of 30 largest cities in Japan (1960-95): Backwardly variable cities

Period	1960 -1965	1965 -1970	1970 -1975	1975 -1980	1980 -1985	1985 -1990	1990 -1995
ROXY	-51.9	-92.6	-81.4	-52.4	-16.5	-24.1	-28.6
ΔROXY/ΔT	-8.2	-3.0	4.0	6.5	2.8	-1.2	-0.9

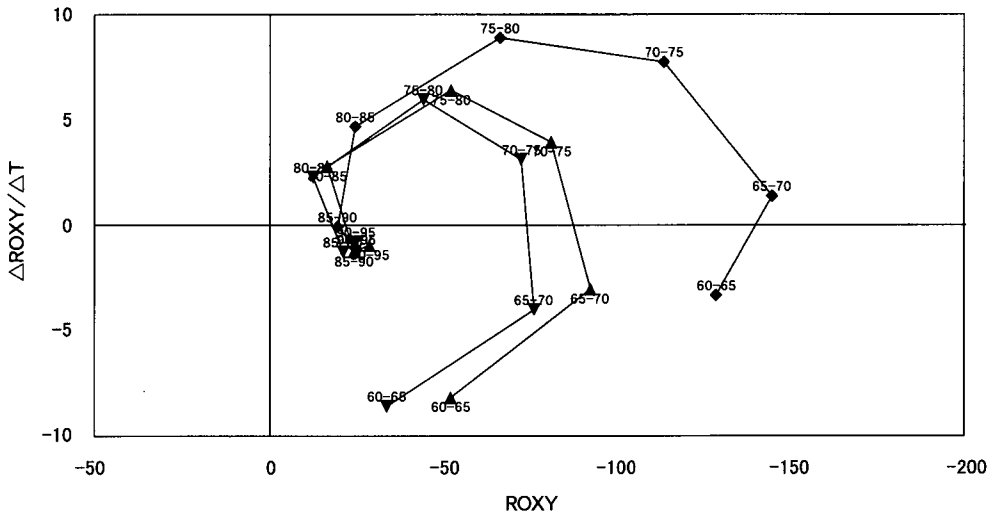
(c) Roxy index for a system of 30 largest cities in Japan (1960-95): Forwardly variable cities

Period	1960 -1965	1965 -1970	1970 -1975	1975 -1980	1980 -1985	1985 -1990	1990-1995
ROXY	-33.3	-76.2	-72.7	-44.4	-12.5	-21.0	-24.6
ΔROXY/ΔT	-8.6	-3.9	3.2	6.0	2.3	-1.2	-0.7

From the above three panels of Table 6, we obtain Figure 1 showing our results in a cyclical form for the spatial-cycle path traced by each of the three systems of cities.

Figure1 Spatial Cycles for Three Systems of 30 Largest Cities in Japan (Without Standardization)

Japan [Cyclical form]



◆ : ROXY index for a system of largest 30 cities in Japan (1960-95) : Constantly fixed cities sorted by 1990 population
▲ : ROXY index for a system of largest 30 cities in Japan (1960-95) : Backwardly variable cities
▼ : ROXY index for a system of largest 30 cities in Japan (1960-95) : Forwardly variable cities

It is to be noticed from this figure that the spatial-cycle stages for the three systems of cities look practically similar to each other for the period from 1990 to 1995.

5.3 Estimated Values for Coefficients of Standardization Function

In order to estimate the four coefficients of our standardization function, we adopt the least squares method with setting ϕ_0 as the value of phase for the year 1900. Tables 7(a), (b) and (c) respectively show the estimated values of each of the coefficients for the three systems of cities; the system of constantly fixed cities, the system of backwardly variable cities and the system of forwardly variable cities.

Table7 Estimated Values of Coefficients

(a) Values of coefficients for a system of 30 largest cities in Japan (1960-95): Constantly fixed cities sorted by 1990 population

Coefficient	A_0	Omega(ω_0)	Phi(ϕ_0)	R_0
Value	64.88	0.047π	-0.232π	-76.26

(b) Values of coefficients for a system of 30 largest cities in Japan (1960-95): Backwardly variable cities

Coefficient	A_0	Omega(ω_0)	Phi(ϕ_0)	R_0
Value	38.02	0.060π	0.648π	-49.85

(b) Values of coefficients for a system of 30 largest cities in Japan (1960-95): Forwardly variable cities

Coefficient	A_0	Omega(ω_0)	Phi(ϕ_0)	R_0
Value	33.42	0.064π	0.323π	-41.30

5.4 Phase Positions

Based on the estimated values for the coefficients of standardization function shown in Table 7, for each of the five-year periods we obtain values for the phase of the Roxy index for the three systems of cities as shown by Table 8.

From the three panels of this table we can draw, for the spatial-cycle path traced by each of the three systems of cities, Figure 2 showing our obtained results in a wave-like form and Figure 3 showing the obtained results in a cyclial form.

Table 8 Phase of Roxy Index

(a) Phase of Roxy index for a system of 30 largest cities in Japan (1960-95): Constantly fixed cities sorted by 1990 population

Period	1960 -1965	1965 -1970	1970 -1975	1975 -1980	1980 -1985	1985 -1990	1990 -1995
Phase	1.87π	0.05π	0.30π	0.55π	0.82π	1.00π	1.04π

(b) Phase of Roxy index for a system of 30 largest cities in Japan (1960-95): Backwardly variable cities

Period	1960 -1965	1965 -1970	1970 -1975	1975 -1980	1980 -1985	1985 -1990	1990 -1995
Phase	1.51π	1.89π	0.19π	0.48π	0.87π	1.08π	1.07π

(c) Phase of Roxy index for a system of 30 largest cities in Japan (1960-95): Forwardly variable cities

Period	1960 -1965	1965 -1970	1970 -1975	1975 -1980	1980 -1985	1985 -1990	1990 -1995
Phase	1.44π	1.84π	0.15π	0.47π	0.88π	1.09π	1.07π

Figure 2 Comparison of Three Systems of 30 Largest Cities in Japan (With Standardization)

[Wave-like form]

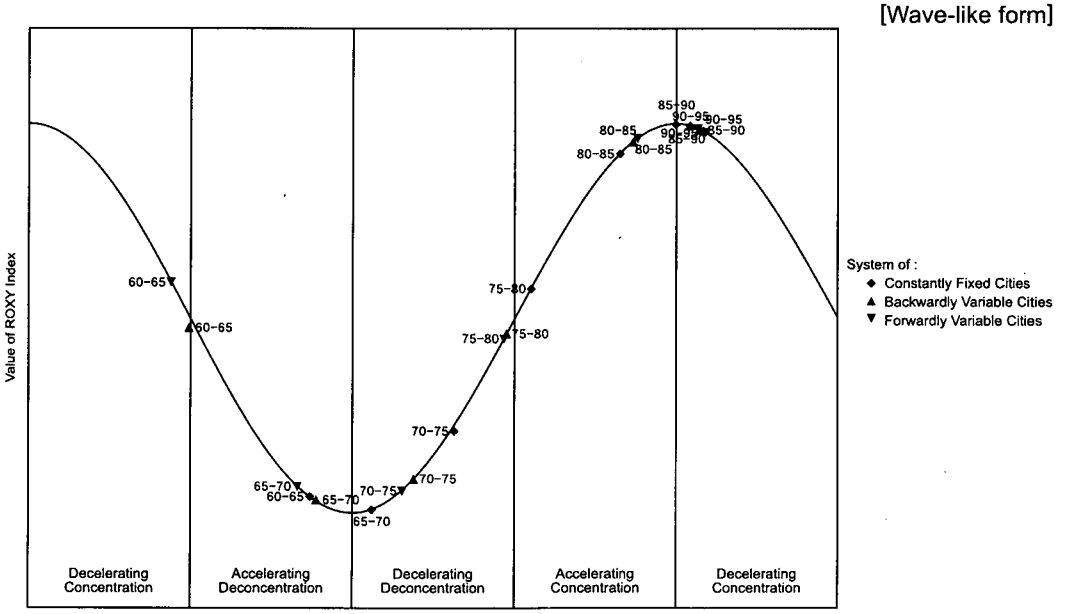
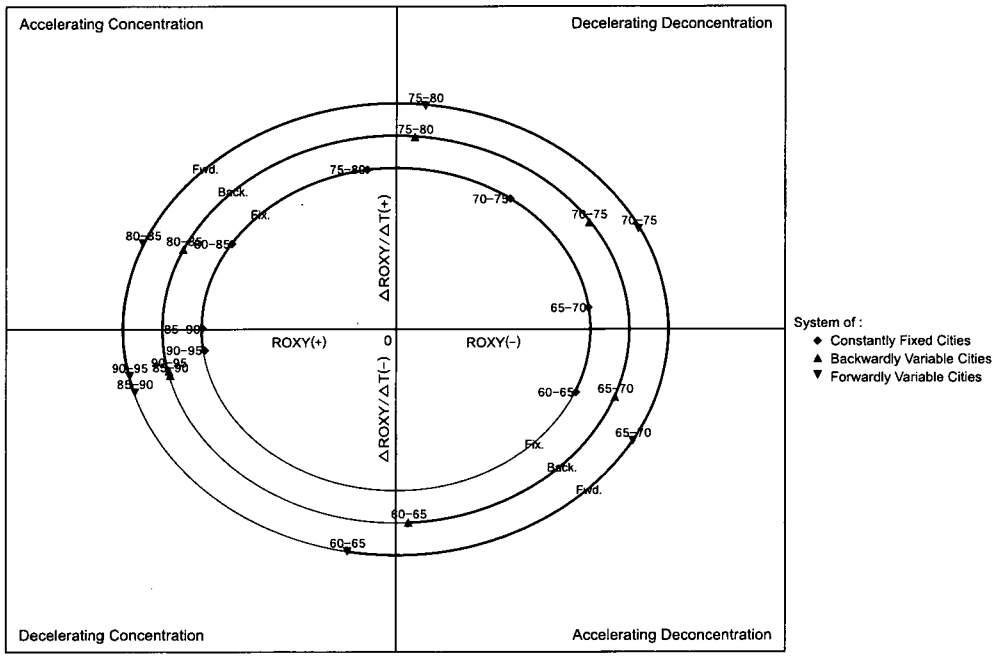


Figure 3 Comparison of Three Systems of 30 Largest Cities in Japan (With Standardization)

[Cyclical form]



6 Conclusion: Robustness of Roxy Index

Judging from Tables 6 and 8 as well as from Figures 1, 2 and 3, in both the case without standardization of Roxy-index values and the case with standardization, the system of constantly fixed cities had been most advanced along the spatial-cycle path until the period 1980-85 from the period 1960-65, followed by the system of backwardly variable cities which had in turn been followed by the system of forwardly variable cities. To be precise, the system of forwardly variable cities had always been following behind the other two systems of cities during the 1960-65 though to 1980-85 period.

It can also be noticed that, since the 1980-85 period, all the three systems of cities have been moving almost side by side along the spatial-cycle path with the system of constantly fixed cities running last for the 1985-90 period by a slim margin.

The aforementioned would perhaps indicate for us the following two points about the possible robustness of the Roxy index.

(1) The Roxy index seems to be reasonably robust concerning our proposed standardization process in the sense that the relative positions of the spatial-cycle stages among the three systems of cities in terms of the standardized Roxy-index values (*i.e.*, estimated Roxy-index values transformed through our standardization function) tend to remain almost the same as those in terms of the originally calculated (*i.e.*, originally obserred) Roxy-index values.

(2) The Roxy index seems to be reasonably robust concerning the three systems of cities in the sense that the relative positions of the spatial-cycle stages among the three systems of cities show *logically consistent* tendencies during the period from 1960 to 1995, where *logical consistency* means (i) that, for the period 1990-95 by the population of whose term-head year 1990 the thirty largest constantly fixed cities are sorted and selected, all the three systems show approximately the same spatial-cycle stages, (ii) that, the farther we move back from the period 1975-80 which roughly corresponds to the end of the stage of decelerating deconcentration for all the three systems of cities, the spatial-cycle stage of the system of forwardly variable cities and that of the system of backwardly variable cities both tend to fall further behind that of the system of constantly fixed cities, and (iii) that, the farther we move back from the period 1975-80, the spatial-cycle stage of the system of forwardly variable cities tends to fall further behind the system of backwardly variable cities.

Notes

1) For the early versions of the discussion on the spatial-cycle hypothesis, see Klaassen and Paelinck (1979), and Klaassen, Bourdrez and Volmuller (1981).

2) The original basic concept of the Roxy index was initiated and applied in an empirical study by Kawashima (1978, pp.9, 13 and 14). Since then, the method of Roxy-index analysis has been furthermore developed and applied in a number of empirical studies to examine the klaassen's type of spatial-cycle redistribution processes of population and other societal-economic activities for systems of spatial units. In parallel with this, some theoretical examinations on the peculiar characteristics of the Roxy index have also been conducted. See, for example, Kawashima (1985) for one of the early theoretical studies of the Roxy index.

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APPENDIX

Table A1 Population Level for 30 Largest Cities in Japan: Backwardly Variable Cities

(a) Sorted by 1965 population

1965				
No.		City	1960	1965
1	13100	Tokyo-tokubetsu-ku area	8,310,027	8,893,094
2	27100	Osaka-shi	3,011,563	3,156,222
3	23100	Nagoya-shi	1,697,093	1,935,430
4	14100	Yokohama-shi	1,375,705	1,788,907
5	26100	Kyoto-shi	1,284,818	1,365,007
6	28100	Kobe-shi	1,113,937	1,216,614
7	40100	Kitakyushu-shi	986,778	1,042,688
8	14130	Kawasaki-shi	632,980	854,874
9	1100	Sapporo-shi	615,684	821,272
10	40130	Fukuoka-shi	682,365	769,176
11	34100	Hiroshima-shi	557,988	657,366
12	28202	Amagasaki-shi	405,534	500,472
13	4100	Sendai-shi	425,272	480,925
14	27201	Sakai-shi	371,502	466,412
15	27227	Higashiosaka-shi	318,001	443,081
16	33201	Okayama-shi	387,484	417,908
17	43201	Kumamoto-shi	382,913	415,507
18	42201	Nagasaki-shi	387,910	411,733
19	22202	Hamamatsu-shi	357,098	392,632
20	22201	Shizuoka-shi	350,897	382,799
21	28201	Himeji-shi	334,520	373,653
22	46201	Kagoshima-shi	334,643	371,129
23	21201	Gifu-shi	312,667	358,259
24	15201	Niigata-shi	325,018	356,302
25	12100	Chiba-shi	258,729	339,974
26	28204	Nishinomiya-shi	263,029	337,391
27	17201	Kanazawa-shi	313,114	335,830
28	7204	Iwaki-shi	345,663	333,881
29	30201	Wakayama-shi	285,155	328,657
30	14201	Yokosuka-shi	287,309	317,411
Total			26,715,396	29,864,606

(b) Sorted by 1970 population

1970				
No.		City	1965	1970
1	13100	Tokyo-tokubetsu-ku area	8,893,094	8,840,942
2	27100	Osaka-shi	3,156,222	2,980,487
3	14100	Yokohama-shi	1,788,907	2,238,253
4	23100	Nagoya-shi	1,935,430	2,036,053
5	26100	Kyoto-shi	1,365,007	1,419,165
6	28100	Kobe-shi	1,216,614	1,288,901
7	40100	Kitakyushu-shi	1,042,688	1,042,620
8	1100	Sapporo-shi	821,272	1,010,177
9	14130	Kawasaki-shi	854,874	973,497
10	40130	Fukuoka-shi	769,176	871,717
11	34100	Hiroshima-shi	657,366	746,287
12	27201	Sakai-shi	466,412	594,367
13	28202	Amagasaki-shi	500,472	553,696
14	4100	Sendai-shi	480,925	545,065
15	27227	Higashiosaka-shi	443,081	500,173
16	12100	Chiba-shi	339,974	482,304
17	33201	Okayama-shi	417,908	460,542
18	43201	Kumamoto-shi	415,507	449,254
19	22202	Hamamatsu-shi	392,632	432,221
20	42201	Nagasaki-shi	411,733	427,083
21	22201	Shizuoka-shi	382,799	416,378
22	28201	Himeji-shi	373,653	408,353
23	46201	Kagoshima-shi	371,129	403,340
24	21201	Gifu-shi	358,259	385,727
25	15201	Niigata-shi	356,302	383,919
26	28204	Nishinomiya-shi	337,391	377,043
27	27203	Toyonaka-shi	292,050	368,498
28	30201	Wakayama-shi	328,657	365,267
29	17201	Kanazawa-shi	335,830	361,382
30	33202	Kurashiki-shi	289,504	354,674
Total			29,794,868	31,717,385

(c) Sorted by 1975 population

1975				
No.		City	1970	1975
1	13100	Tokyo-tokubetsu-ku area	8,840,942	8,646,520
2	27100	Osaka-shi	2,980,487	2,778,987
3	14100	Yokohama-shi	2,238,253	2,621,771
4	23100	Nagoya-shi	2,036,053	2,079,740
5	26100	Kyoto-shi	1,419,165	1,461,059
6	28100	Kobe-shi	1,288,901	1,360,565
7	1100	Sapporo-shi	1,010,177	1,240,613
8	40100	Kitakyushu-shi	1,042,620	1,058,442
9	14130	Kawasaki-shi	973,497	1,014,951
10	40130	Fukuoka-shi	871,717	1,002,201
11	34100	Hiroshima-shi	746,287	852,611
12	27201	Sakai-shi	594,367	750,688
13	12100	Chiba-shi	482,304	659,372
14	4100	Sendai-shi	545,065	615,473
15	28202	Amagasaki-shi	553,696	545,783
16	27227	Higashiosaka-shi	500,173	524,750
17	33201	Okayama-shi	460,542	513,471
18	43201	Kumamoto-shi	449,254	488,166
19	22202	Hamamatsu-shi	432,221	468,884
20	46201	Kagoshima-shi	403,340	456,827
21	42201	Nagasaki-shi	427,083	450,194
22	22201	Shizuoka-shi	416,378	446,952
23	28201	Himeji-shi	408,353	436,086
24	15201	Niigata-shi	383,919	423,188
25	12204	Funabashi-shi	325,426	423,101
26	21201	Gifu-shi	385,727	408,707
27	28204	Nishinomiya-shi	377,043	400,622
28	27203	Toyonaka-shi	368,498	398,384
29	17201	Kanazawa-shi	361,382	395,268
30	33202	Kurashiki-shi	354,674	392,755
Total			31,677,544	33,316,131

(d) Sorted by 1980 population

1980				
No.		City	1975	1980
1	13100	Tokyo-tokubetsu-ku area	8,646,520	8,351,893
2	14100	Yokohama-shi	2,621,771	2,773,674
3	27100	Osaka-shi	2,778,987	2,648,180
4	23100	Nagoya-shi	2,079,740	2,087,902
5	26100	Kyoto-shi	1,461,059	1,473,065
6	1100	Sapporo-shi	1,240,613	1,401,757
7	28100	Kobe-shi	1,360,565	1,367,390
8	40130	Fukuoka-shi	1,002,201	1,088,588
9	40100	Kitakyushu-shi	1,058,442	1,065,078
10	14130	Kawasaki-shi	1,014,951	1,040,802
11	34100	Hiroshima-shi	852,611	899,399
12	27201	Sakai-shi	750,688	810,106
13	12100	Chiba-shi	659,372	746,430
14	4100	Sendai-shi	615,473	664,868
15	33201	Okayama-shi	513,471	545,765
16	43201	Kumamoto-shi	488,166	525,662
17	28202	Amagasaki-shi	545,783	523,650
18	27227	Higashiosaka-shi	524,750	521,558
19	46201	Kagoshima-shi	456,827	505,360
20	22202	Hamamatsu-shi	468,884	490,824
21	12204	Funabashi-shi	423,101	479,439
22	22201	Shizuoka-shi	446,952	458,341
23	15201	Niigata-shi	423,188	457,785
24	42201	Nagasaki-shi	450,194	447,091
25	28201	Himeji-shi	436,086	446,256
26	14209	Sagamihara-shi	377,398	439,300
27	14201	Yokosuka-shi	389,557	421,107
28	17201	Kanazawa-shi	395,268	417,684
29	21201	Gifu-shi	408,707	410,357
30	28204	Nishinomiya-shi	400,622	410,329
Total			33,291,947	33,919,640

Table A1 (continued)

(e) Sorted by 1985 population

1985				
No.	City		1980	1985
1	13100	Tokyo-tokubetsu-ku area	8,351,893	8,354,615
2	14100	Yokohama-shi	2,773,674	2,992,926
3	27100	Osaka-shi	2,648,180	2,636,249
4	23100	Nagoya-shi	2,087,902	2,116,381
5	1100	Sapporo-shi	1,401,757	1,542,979
6	26100	Kyoto-shi	1,473,065	1,479,218
7	28100	Kobe-shi	1,367,390	1,410,834
8	40130	Fukuoka-shi	1,088,588	1,160,440
9	14130	Kawasaki-shi	1,040,802	1,088,624
10	40100	Kitakyushu-shi	1,065,078	1,056,402
11	34100	Hiroshima-shi	899,399	1,044,118
12	27201	Sakai-shi	810,106	818,279
13	12100	Chiba-shi	746,430	788,930
14	4100	Sendai-shi	664,868	700,254
15	33201	Okayama-shi	545,765	572,479
16	43201	Kumamoto-shi	525,662	555,719
17	46201	Kagoshima-shi	505,360	530,502
18	27227	Higashiosaka-shi	521,558	522,805
19	22202	Hamamatsu-shi	490,824	514,131
20	28202	Amagasaki-shi	523,650	509,115
21	12204	Funabashi-shi	479,439	506,966
22	14209	Sagamihara-shi	439,300	482,778
23	15201	Niigata-shi	457,785	475,630
24	22201	Shizuoka-shi	458,341	468,362
25	28201	Himeji-shi	446,256	452,917
26	42201	Nagasaki-shi	447,091	449,382
27	17201	Kanazawa-shi	417,684	430,481
28	12207	Matsudo-shi	400,863	427,473
29	14201	Yokosuka-shi	421,107	427,116
30	38201	Matsuyama-shi	401,703	426,658
Total			33,901,520	34,942,763

(f) Sorted by 1990 population

1990				
No.	City		1985	1990
1	13100	Tokyo-tokubetsu-ku area	8,354,615	8,163,573
2	14100	Yokohama-shi	2,992,926	3,220,331
3	27100	Osaka-shi	2,636,249	2,623,801
4	23100	Nagoya-shi	2,116,381	2,154,793
5	1100	Sapporo-shi	1,542,979	1,671,742
6	28100	Kobe-shi	1,410,834	1,477,410
7	26100	Kyoto-shi	1,479,218	1,461,103
8	40130	Fukuoka-shi	1,160,440	1,237,062
9	14130	Kawasaki-shi	1,088,624	1,173,603
10	34100	Hiroshima-shi	1,044,118	1,085,705
11	40100	Kitakyushu-shi	1,056,402	1,026,455
12	4100	Sendai-shi	700,254	918,398
13	12100	Chiba-shi	788,930	829,455
14	27201	Sakai-shi	818,279	807,765
15	33201	Okayama-shi	572,479	593,730
16	43201	Kumamoto-shi	555,719	579,306
17	46201	Kagoshima-shi	530,502	536,752
18	22202	Hamamatsu-shi	514,131	534,620
19	12204	Funabashi-shi	506,966	533,270
20	14209	Sagamihara-shi	482,778	531,542
21	27227	Higashiosaka-shi	522,805	518,319
22	28202	Amagasaki-shi	509,115	498,999
23	15201	Niigata-shi	475,630	486,097
24	22201	Shizuoka-shi	468,362	472,196
25	13201	Hachioji-shi	426,654	466,347
26	12207	Matsudo-shi	427,473	456,210
27	28201	Himeji-shi	452,917	454,360
28	42201	Nagasaki-shi	449,382	444,599
29	38201	Matsuyama-shi	426,658	443,322
30	17201	Kanazawa-shi	430,481	442,868
Total			34,942,301	35,843,733

(g) Sorted by 1995 population

1995				
No.	City		1990	1995
1	13100	Tokyo-tokubetsu-ku area	8,163,573	7,967,614
2	14100	Yokohama-shi	3,220,331	3,307,136
3	27100	Osaka-shi	2,623,801	2,602,421
4	23100	Nagoya-shi	2,154,793	2,152,184
5	1100	Sapporo-shi	1,671,742	1,757,025
6	26100	Kyoto-shi	1,461,103	1,463,822
7	28100	Kobe-shi	1,477,410	1,423,792
8	40130	Fukuoka-shi	1,237,062	1,284,795
9	14130	Kawasaki-shi	1,173,603	1,202,820
10	34100	Hiroshima-shi	1,085,705	1,108,888
11	40100	Kitakyushu-shi	1,026,455	1,019,598
12	4100	Sendai-shi	918,398	971,297
13	12100	Chiba-shi	829,455	856,878
14	27201	Sakai-shi	807,765	802,993
15	43201	Kumamoto-shi	579,306	650,341
16	33201	Okayama-shi	593,730	615,757
17	14209	Sagamihara-shi	531,542	570,597
18	22202	Hamamatsu-shi	534,620	561,606
19	46201	Kagoshima-shi	536,752	546,282
20	12204	Funabashi-shi	533,270	540,817
21	27227	Higashiosaka-shi	518,319	517,232
22	13201	Hachioji-shi	466,347	503,363
23	15201	Niigata-shi	486,097	493,769
24	28202	Amagasaki-shi	498,999	488,586
25	22201	Shizuoka-shi	472,196	474,092
26	28201	Himeji-shi	454,360	470,986
27	12207	Matsudo-shi	456,210	461,503
28	38201	Matsuyama-shi	443,322	460,968
29	17201	Kanazawa-shi	442,868	453,975
30	11204	Urawa-shi	418,271	453,320
Total			35,817,405	36,184,457

Table A2 Population Level for 30 Largest Cities in Japan: Forwardly Variable Cities

(a) Sorted by 1960 population

1960				
No.		City	1960	1965
1	13100	Tokyo-tokubetsu-ku area	8,310,027	8,893,094
2	27100	Osaka-shi	3,011,563	3,156,222
3	23100	Nagoya-shi	1,697,093	1,935,430
4	14100	Yokohama-shi	1,375,705	1,788,907
5	26100	Kyoto-shi	1,284,818	1,365,007
6	28100	Kobe-shi	1,113,937	1,216,614
7	40100	Kitakyushu-shi	986,778	1,042,688
8	40130	Fukuoka-shi	682,365	769,176
9	14130	Kawasaki-shi	632,980	854,874
10	1100	Sapporo-shi	615,684	821,272
11	34100	Hiroshima-shi	557,988	657,366
12	4100	Sendai-shi	425,272	480,925
13	28202	Amagasaki-shi	405,534	500,472
14	42201	Nagasaki-shi	387,910	411,733
15	33201	Okayama-shi	387,484	417,908
16	43201	Kumamoto-shi	382,913	415,507
17	27201	Sakai-shi	371,502	466,412
18	22202	Hamamatsu-shi	357,098	392,632
19	22201	Shizuoka-shi	350,897	382,799
20	7204	Iwaki-shi	345,663	333,881
21	46201	Kagoshima-shi	334,643	371,129
22	28201	Himeji-shi	334,520	373,653
23	15201	Niigata-shi	325,018	356,302
24	27227	Higashiosaka-shi	318,001	443,081
25	17201	Kanazawa-shi	313,114	335,830
26	21201	Gifu-shi	312,667	358,259
27	14201	Yokosuka-shi	287,309	317,411
28	30201	Wakayama-shi	285,155	328,657
29	1202	Hakodate-shi	271,172	281,029
30	33202	Kurashiki-shi	266,564	289,504
Total			26,731,374	29,757,774

(b) Sorted by 1965 population

1965				
No.		City	1965	1970
1	13100	Tokyo-tokubetsu-ku area	8,893,094	8,840,942
2	27100	Osaka-shi	3,156,222	2,980,487
3	23100	Nagoya-shi	1,935,430	2,036,053
4	14100	Yokohama-shi	1,788,907	2,238,253
5	26100	Kyoto-shi	1,365,007	1,419,165
6	28100	Kobe-shi	1,216,614	1,288,901
7	40100	Kitakyushu-shi	1,042,688	1,042,620
8	14130	Kawasaki-shi	854,874	973,497
9	1100	Sapporo-shi	821,272	1,010,177
10	40130	Fukuoka-shi	769,176	871,717
11	34100	Hiroshima-shi	657,366	746,287
12	28202	Amagasaki-shi	500,472	553,696
13	4100	Sendai-shi	480,925	545,065
14	27201	Sakai-shi	466,412	594,367
15	27227	Higashiosaka-shi	443,081	500,173
16	33201	Okayama-shi	417,908	460,542
17	43201	Kumamoto-shi	415,507	449,254
18	42201	Nagasaki-shi	411,733	427,083
19	22202	Hamamatsu-shi	392,632	432,221
20	22201	Shizuoka-shi	382,799	416,378
21	28201	Himeji-shi	373,653	408,353
22	46201	Kagoshima-shi	371,129	403,340
23	21201	Gifu-shi	358,259	385,727
24	15201	Niigata-shi	356,302	383,919
25	12100	Chiba-shi	339,974	482,304
26	28204	Nishinomiya-shi	337,391	377,043
27	17201	Kanazawa-shi	335,830	361,382
28	7204	Iwaki-shi	333,881	327,164
29	30201	Wakayama-shi	328,657	365,267
30	14201	Yokosuka-shi	317,411	347,576
Total			29,864,606	31,668,953

(c) Sorted by 1970 population

1970				
No.		City	1970	1975
1	13100	Tokyo-tokubetsu-ku area	8,840,942	8,646,520
2	27100	Osaka-shi	2,980,487	2,778,987
3	14100	Yokohama-shi	2,238,253	2,621,771
4	23100	Nagoya-shi	2,036,053	2,079,740
5	26100	Kyoto-shi	1,419,165	1,461,059
6	28100	Kobe-shi	1,288,901	1,360,565
7	40100	Kitakyushu-shi	1,042,620	1,058,442
8	1100	Sapporo-shi	1,010,177	1,240,613
9	14130	Kawasaki-shi	973,497	1,014,951
10	40130	Fukuoka-shi	871,717	1,002,201
11	34100	Hiroshima-shi	746,287	852,611
12	27201	Sakai-shi	594,367	750,688
13	28202	Amagasaki-shi	553,696	545,783
14	4100	Sendai-shi	545,065	615,473
15	27227	Higashiosaka-shi	500,173	524,750
16	12100	Chiba-shi	482,304	659,372
17	33201	Okayama-shi	460,542	513,471
18	43201	Kumamoto-shi	449,254	488,166
19	22202	Hamamatsu-shi	432,221	468,884
20	42201	Nagasaki-shi	427,083	450,194
21	22201	Shizuoka-shi	416,378	446,952
22	28201	Himeji-shi	408,353	436,086
23	46201	Kagoshima-shi	403,340	456,827
24	21201	Gifu-shi	385,727	408,707
25	15201	Niigata-shi	383,919	423,188
26	28204	Nishinomiya-shi	377,043	400,622
27	27203	Toyonaka-shi	368,498	398,3840
28	30201	Wakayama-shi	365,267	389,717
29	17201	Kanazawa-shi	361,382	395,268
30	33202	Kurashiki-shi	354,674	392,755
Total			31,717,385	33,282,747

(d) Sorted by 1975 population

1975				
No.		City	1975	1980
1	13100	Tokyo-tokubetsu-ku area	8,646,520	8,351,893
2	27100	Osaka-shi	2,778,987	2,648,180
3	14100	Yokohama-shi	2,621,771	2,773,674
4	23100	Nagoya-shi	2,079,740	2,087,902
5	26100	Kyoto-shi	1,461,059	1,473,065
6	28100	Kobe-shi	1,360,565	1,367,390
7	1100	Sapporo-shi	1,240,613	1,401,757
8	40100	Kitakyushu-shi	1,058,442	1,065,078
9	14130	Kawasaki-shi	1,014,951	1,040,802
10	40130	Fukuoka-shi	1,002,201	1,088,588
11	34100	Hiroshima-shi	852,611	899,399
12	27201	Sakai-shi	750,688	810,106
13	12100	Chiba-shi	659,372	746,430
14	4100	Sendai-shi	615,473	664,868
15	28202	Amagasaki-shi	545,783	523,650
16	27227	Higashiosaka-shi	524,750	521,558
17	33201	Okayama-shi	513,471	545,765
18	43201	Kumamoto-shi	488,166	525,662
19	22202	Hamamatsu-shi	468,884	490,824
20	46201	Kagoshima-shi	456,827	505,360
21	42201	Nagasaki-shi	450,194	447,091
22	22201	Shizuoka-shi	446,952	458,341
23	28201	Himeji-shi	436,086	446,256
24	15201	Niigata-shi	423,188	457,785
25	12204	Funabashi-shi	423,101	479,439
26	21201	Gifu-shi	408,707	410,357
27	28204	Nishinomiya-shi	400,622	410,329
28	27203	Toyonaka-shi	398,384	403,174
29	17201	Kanazawa-shi	395,268	417,684
30	33202	Kurashiki-shi	392,755	403,785
Total			33,316,131	33,866,192

Table A2 (continued)

(e) Sorted by 1980 population

1980				
No.		City	1980	1985
1	13100	Tokyo-tokubetsu-ku area	8,351,893	8,354,615
2	14100	Yokohama-shi	2,773,674	2,992,926
3	27100	Osaka-shi	2,648,180	2,636,249
4	23100	Nagoya-shi	2,087,902	2,116,381
5	26100	Kyoto-shi	1,473,065	1,479,218
6	1100	Sapporo-shi	1,401,757	1,542,979
7	28100	Kobe-shi	1,367,390	1,410,834
8	40130	Fukuoka-shi	1,088,588	1,160,440
9	40100	Kitakyushu-shi	1,065,078	1,056,402
10	14130	Kawasaki-shi	1,040,802	1,088,624
11	34100	Hiroshima-shi	899,399	1,044,118
12	27201	Sakai-shi	810,106	818,279
13	12100	Chiba-shi	746,430	788,930
14	4100	Sendai-shi	664,868	700,254
15	33201	Okayama-shi	545,765	572,479
16	43201	Kumamoto-shi	525,662	555,719
17	28202	Amagasaki-shi	523,650	509,115
18	27227	Higashiosaka-shi	521,558	522,805
19	46201	Kagoshima-shi	505,360	530,502
20	22202	Hamamatsu-shi	490,824	514,131
21	12204	Funabashi-shi	479,439	506,966
22	22201	Shizuoka-shi	458,341	468,362
23	15201	Niigata-shi	457,785	475,630
24	42201	Nagasaki-shi	447,091	449,382
25	28201	Himeji-shi	446,256	452,917
26	14209	Sagamihara-shi	439,300	482,778
27	14201	Yokosuka-shi	421,107	427,116
28	17201	Kanazawa-shi	417,684	430,481
29	21201	Gifu-shi	410,357	411,743
30	28204	Nishinomiya-shi	410,329	421,267
Total			33,919,640	34,921,642

(f) Sorted by 1985 population

1985				
No.		City	1985	1990
1	13100	Tokyo-tokubetsu-ku area	8,354,615	8,163,573
2	14100	Yokohama-shi	2,992,926	3,220,331
3	27100	Osaka-shi	2,636,249	2,623,801
4	23100	Nagoya-shi	2,116,381	2,154,793
5	1100	Sapporo-shi	1,542,979	1,671,742
6	26100	Kyoto-shi	1,479,218	1,461,103
7	28100	Kobe-shi	1,410,834	1,477,410
8	40130	Fukuoka-shi	1,160,440	1,237,062
9	14130	Kawasaki-shi	1,088,624	1,173,603
10	40100	Kitakyushu-shi	1,056,402	1,026,455
11	34100	Hiroshima-shi	1,044,118	1,085,705
12	27201	Sakai-shi	818,279	807,765
13	12100	Chiba-shi	788,930	829,455
14	4100	Sendai-shi	700,254	918,398
15	33201	Okayama-shi	572,479	593,730
16	43201	Kumamoto-shi	555,719	579,306
17	46201	Kagoshima-shi	530,502	536,752
18	27227	Higashiosaka-shi	522,805	518,319
19	22202	Hamamatsu-shi	514,131	534,620
20	28202	Amagasaki-shi	509,115	498,999
21	12204	Funabashi-shi	506,966	533,270
22	14209	Sagamihara-shi	482,778	531,542
23	15201	Niigata-shi	475,630	486,097
24	22201	Shizuoka-shi	468,362	472,196
25	28201	Himeji-shi	452,917	454,360
26	42201	Nagasaki-shi	449,382	444,599
27	17201	Kanazawa-shi	430,481	442,868
28	12207	Matsudo-shi	427,473	456,210
29	14201	Yokosuka-shi	427,116	433,358
30	38201	Matsuyama-shi	426,658	443,322
Total			34,942,763	35,810,744

(g) Sorted by 1990 population

1990				
No.		City	1990	1995
1	13100	Tokyo-tokubetsu-ku area	8,163,573	7,967,614
2	14100	Yokohama-shi	3,220,331	3,307,136
3	27100	Osaka-shi	2,623,801	2,602,421
4	23100	Nagoya-shi	2,154,793	2,152,184
5	1100	Sapporo-shi	1,671,742	1,757,025
6	28100	Kobe-shi	1,477,410	1,423,792
7	26100	Kyoto-shi	1,461,103	1,463,822
8	40130	Fukuoka-shi	1,237,062	1,284,795
9	14130	Kawasaki-shi	1,173,603	1,202,820
10	34100	Hiroshima-shi	1,085,705	1,108,888
11	40100	Kitakyushu-shi	1,026,455	1,019,598
12	4100	Sendai-shi	918,398	971,297
13	12100	Chiba-shi	829,455	856,878
14	27201	Sakai-shi	807,765	802,993
15	33201	Okayama-shi	593,730	615,757
16	43201	Kumamoto-shi	579,306	650,341
17	46201	Kagoshima-shi	536,752	546,282
18	22202	Hamamatsu-shi	534,620	561,606
19	12204	Funabashi-shi	533,270	540,817
20	14209	Sagamihara-shi	531,542	570,597
21	27227	Higashiosaka-shi	518,319	517,232
22	28202	Amagasaki-shi	498,999	488,586
23	15201	Niigata-shi	486,097	493,769
24	22201	Shizuoka-shi	472,196	474,092
25	13201	Hachioji-shi	466,347	503,363
26	12207	Matsudo-shi	456,210	461,503
27	28201	Himeji-shi	454,360	470,986
28	42201	Nagasaki-shi	444,599	438,635
29	38201	Matsuyama-shi	443,322	460,968
30	17201	Kanazawa-shi	442,868	453,975
Total			35,843,733	36,169,772