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FOREWORD

World population today stands at about 4½ billion and is increasing at a rate of about 1.7 percent per year. Roughly 42 percent of this population is located in urban areas and is growing at just under 3 percent per year.

Rapid rates of population growth and urbanization occurred first among nations that first experienced industrialization. It is therefore convenient to examine the world population situation separately for the highly urbanized, more developed countries and for the rapidly urbanizing, less developed nations of the Third World.

The populations of a large number of more developed countries are experiencing declining rates of growth, and many appear to be approaching stability. Declines in birth rates and changing patterns of migration are rearranging national settlement patterns. Established economic and political balances in the distribution of income, wealth, and jobs are being altered, creating problems of contraction, reallocation, and obsolescence.

The principal feature of urbanization patterns in the less developed parts of the world today is rapid urban growth. Rates of population growth of 2 to 3 percent per year and massive rural to urban migration are combining to create dramatic growth rates in cities of the Third World countries, some of whose city populations are projected to grow to unprecedented size by the turn of the century. Such rapid growth increases the problems of providing urban populations with the necessary sustenance, employment, services, and infrastructure.

An examination of future prospects for global population growth and urbanization reveals that the number of people in the world will continue to increase dramatically for some time to come, as will the proportion living in urban settlements. Populations in the larger urban agglomerations of the less developed world will continue to grow at an alarming rate. Territorial rearrangements of people and jobs in the more developed industrial and post-industrial nations will continue to be major issues of concern, both to communities of contraction and to those of expansion.

Against this background, scholars from a large number of nations have gathered at the International Institute for Applied Systems Analysis during the past several years to examine historical and current patterns of growth and change in national settlement systems. As part of this research activity, the Human Settlements and Services Area convened a conference in June of 1981 on Urbanization and Development, at which over 60 participants from developed and developing countries discussed the diverse problems associated with rapid population growth and structural change, urban growth and decline, and the spatial concentration of national populations in a few large cities. The six papers collected together in this issue of the INTERNATIONAL REGIONAL SCIENCE REVIEW consider urbanization trends and city size distributions, demoeconomic models of economic and urban growth, and emerging patterns of migration and urban change. All were written by past or current members of the Human Settlements and Services Area at IIASA.

Andrei Rogers, *Chairman*
Human Settlements and Services Area
International Institute for Applied Systems Analysis

ABOUT IIASA

IIASA, a nongovernmental, multidisciplinary, international research institution, was founded in October 1972 by the academies of science and equivalent scientific organizations of 12 nations from both East and West. Its goal is to bring together scientists from around the world to work on problems of common interest, particularly those resulting from scientific and technological development. The Institute now has 17 National Member Organizations:

- The Academy of Sciences of the Union of Soviet Socialist Republics
- The Canadian Committee for IIASA
- The Committee for IIASA of the Czechoslovak Socialist Republic
- The French Association for the Development of Systems Analysis
- The Academy of Sciences of the German Democratic Republic
- The Japan Committee for IIASA
- The Max Planck Society for the Advancement of Sciences, Federal Republic of Germany
- The National Committee for Applied Systems Analysis and Management, People's Republic of Bulgaria
- The National Academy of Sciences, United States of America
- The National Research Council, Italy
- The Polish Academy of Sciences
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- The Austrian Academy of Sciences
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The Factors of Urban Population Growth: Net Inmigration Versus Natural Increase

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ABSTRACT As a country evolves from a traditional to an advanced society, the part of urban growth that is due to net inmigration follows a simple pattern, which can be described by an inverted U-shaped curve: it first increases, then passes through a maximum, and decreases thereafter. This hypothesis is confirmed by quantitative analysis using time-series and cross-section data. The analysis suggests that in the second half of this century natural increase often provides a slightly higher contribution to urban population growth than net inmigration.

I. INTRODUCTION

Since the beginning of the last century, the world has experienced rapid urban population growth and urbanization. The population living in urban areas has increased from 25 million in 1800 to 1.6 billion in 1975. World population has grown from about 1 billion to roughly 4 billion. The part of the world population living in urban areas has increased from 2.5 percent in 1800 to 40 percent in 1975. According to the latest United Nations forecasts (United Nations 1980), these tendencies will continue for some time: by the year 2000, the world's urban population will reach 3.2 billion people — twice today's figure — whereas the urban proportion will slightly surpass 50 percent (51.3 percent).

Although urban population growth and urbanization seem to occur together, they do not necessarily have to: "urban growth can occur without urbanization if the rural population increases at a rate equal to or greater than that of the urban population" (Rogers 1977, p. 4). These two phenomena are essentially distinct, as can be easily seen by closely examining the process of rural and urban population growth.

Fundamentally, urban growth refers to an increase in the number of people living in urban settlements, whereas urbanization represents a rise in the proportion of the population located in urban areas.

Clearly, both processes are functions of the same two factors: (a) the population exchange between rural and urban areas through internal migration and (b) natural increase.[1] But while urban growth depends on the natural increase of the part of the total population that is already urban, urbanization is affected by the differential in natural increase levels between rural and urban areas.

In general, the rural-urban natural increase differential is relatively small in comparison with the rural net outmigration rate, so that urbanization is essentially fostered by the net transfer of population from rural to urban areas. By contrast, no such clear-cut conclusion can be drawn about the sources of urban population growth. Scholars such as Davis (1965) have argued that natural increase and not migration is the largest contributor to urban growth. Conversely, Todaro (1979) and others have stressed the role of migration as the principal factor. Presumably, neither of these polar viewpoints is universally correct; the contributions of migration and natural increase to urban growth differ widely over space and time. The main source of urban growth can be either factor, depending on circumstances.

This paper focuses on the question of the sources of urban growth. Like the recent contributions of several authors (Keyfitz 1980; Ledent 1978a, 1978b; Rogers 1982), it adopts a resolutely quantitative approach. It departs from previous studies in that it does not analyze the evolution of the components of urban growth as implied by the dynamics of particular models chosen a priori. Instead, it studies such an evolution from the standpoint of actual urban-rural population systems.

Five sections follow: Section II reviews the descriptive generalization known as the demographic transition, which suggests that the evolution of the contribution of net inmigration to urban growth, relative to natural increase, can be depicted by an inverted U-shaped curve. Section III presents the general mathematical framework underlying the quantitative analysis that substantiates such an assertion. Using this framework, Section IV proposes an assessment of the 1950-2000 evolution of the migration and natural increase components of urban growth in selected developing countries (India, Egypt, and Mexico). The last two sections extend the analysis, using simple but reasonable functional forms for the relevant attributes (natural increase of the total population and degree of urbanization), which are fitted to time-series as well as to cross-sectional data.

II. QUALITATIVE CONSIDERATIONS

A few years ago, the United Nations (1976b) published estimates of the component rates of urban population growth around 1960.

[1] Actually, there exists a third factor, which may influence urban growth as well as urbanization: the continuous qualification of additional areas as urban. For simplicity, however, we follow the United Nations practice of including the effects of reclassification into the rural-urban net migration component.

These estimates make it possible to determine for the world and its major regions the urban rates of natural increase and net inmigration and the corresponding net inmigration to natural increase ratios (see Table 1).

The world's urban areas were growing almost equally from net inmigration and natural increase, with a slight advantage to the former: the net inmigration to natural increase ratio amounted to 1.05. This observation was equally valid for both the more and the less developed countries: their net inmigration to natural increase ratios were 1.09 and 1.02, respectively. Is that to say that there exists no obvious relationship between the relative levels of the two factors of urban growth and urbanization and economic development?

The figures for the major world regions shown in Table 1 indicate that the more developed (urbanized) regions have comparatively lower urban natural increase and net inmigration rates than the less developed (urbanized) regions. They do not, however, support the existence of a monotonic variation of the urban net inmigration to

TABLE 1

COMPONENT RATES OF URBAN POPULATION GROWTH, URBAN NET INMIGRATION TO NATURAL INCREASE RATIO, AND DEGREE OF URBANIZATION: WORLD TOTAL AND MAJOR REGIONS, 1960

1 = Growth Rate (per thousand)
2 = Birth Rate
3 = Death Rate
4 = Natural Increase Rate (2 − 3)
5 = Net Inmigration Rate (1 − 4)
6 = Net Inmigration to Natural Increase Ratio (5/4)

Regions	1	2	3	4	5	6	Degree of Urbanization (%)
World	33.0	27.7	11.6	16.1	16.9	1.05	33.72
More developed countries	23.5	20.1	8.9	11.2	12.3	1.09	60.08
Less developed countries	45.5	37.9	15.4	22.5	23.0	1.02	20.93
Africa	44.8	41.6	18.0	23.6	21.2	0.90	17.60
North America	24.3	24.2	8.9	15.3	9.0	0.59	69.83
Latin America	44.6	35.1	10.8	24.3	20.3	0.84	48.51
East Asia	48.6	29.8	12.9	16.9	31.7	1.88	24.63
South Asia	36.7	40.0	17.2	22.8	13.9	0.61	18.05
Europe	17.9	17.8	10.2	7.6	10.3	1.36	59.22
Oceania	26.2	22.5	8.9	13.6	12.6	0.93	65.92
USSR	34.5	20.8	6.5	14.3	20.2	1.41	48.97

Source: United Nations 1976b, pp. 51-52.

natural increase ratio with economic development (degree of urbanization). Nevertheless, the observations that (1) such a ratio takes on similar values for relatively lower and higher levels of economic development and (2) it takes on comparatively higher values for intermediate levels of economic development suggest the following evolution over the development process: the urban net inmigration to natural increase ratio — and thus the contribution of migration as a factor of urban growth — increases, passes through a maximum, and then decreases.

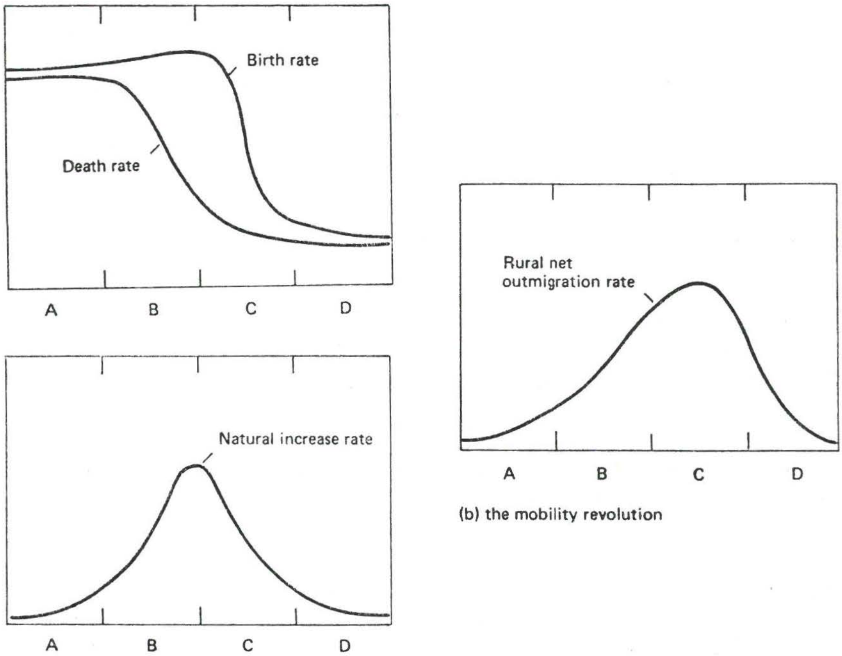
The process whereby traditional and predominantly rural societies evolve into modern and predominantly urban societies can be described by two generalizations: the vital revolution and the mobility revolution. Their joint and simultaneous occurrence constitutes the demographic transition. The general description of the vital revolution (Notenstein 1945), which was developed after the demographic experience of nineteenth century Europe, describes how societies with high birth and death rates move to low birth and death rates. In brief, such a revolution begins with the control of deaths, which is followed after some lag by the control of births. More specifically (see Figure 1a), after an initial phase of equally high birth and death rates (phase A characteristic of the Premodern Traditional Society), a subsequent phase (phase B characteristic of the Early Transitional Society) has a rapid decline in mortality, followed by a slight but significant rise in fertility. Then, in a third phase (phase C characteristic of the Late Transition Society), fertility declines while the mortality decline tends to slacken. Eventually (phase D characteristic of the Advanced Society),[2] the level of fertility approaches that of mortality, whose decline is terminated at a low to moderate value. A country going through the process of modernization begins with a low if not negligible rate of population growth in phase A. This rate of growth then increases in phase B and, after passing through a maximum, decreases in phase C, eventually reaching a small, if not negligible, value in phase D.

The general description of the mobility revolution (Zelinsky 1971) argues that during the process of modernization the ability to move from one community to another — in particular from rural to urban areas — follows an evolutive sequence parallel to that of the vital revolution. Here too, four phases can be distinguished, corresponding more or less to the four phases of the vital revolution (see Figure 1b). Initially (in phase A) there is little genuine migration from the countryside to the cities. In phase B, massive movements take place from rural to urban areas. Such movements tend to slacken in phase C, before sharply decreasing in absolute and relative terms in phase D. Thus, over the development process, the rural net outmigration rate exhibits the same evolution as the rate of population growth. However, it reaches its maximum somewhat later: around the transition from phase C to phase D rather than from phase B to phase C.

[2] The terms denoting the four phases are borrowed from Zelinsky (1971).

FIGURE 1

THE VITAL AND MOBILITY REVOLUTIONS CONSTITUTING THE DEMOGRAPHIC TRANSITION: A SCHEMATIC REPRESENTATION

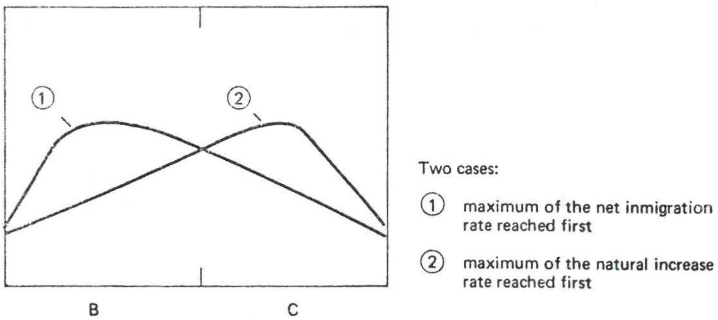


(a) the vital revolution

(b) the mobility revolution

FIGURE 2

EVOLUTION OF THE URBAN NET INMIGRATION TO NATURAL INCREASE RATIO IN THE TRANSITIONAL SOCIETY



Can we now infer from the above two generalizations the likely evolution of the urban net inmigration to natural increase ratio over the development process and thus possibly confirm the result suggested earlier by the UN figures of Table 1? Presumably, the urban natural increase rate evolves in much the same way as the total population growth rate, but what about the urban net inmigration rate? Can we infer its evolution from that of the rural net outmigration rate?

The urban net inmigration rate is equal to the quotient of the rural net outmigration rate and the ratio of the urban to rural populations. Since the latter ratio typically increases with modernization, the urban net inmigration rate experiences variations similar to those of the rural net outmigration rate; it first increases and then decreases after passing through a maximum that, however, is reached at a much earlier date. Unlike the maximum of the rural outmigration rate, the maximum of the urban net inmigration rate does not necessarily occur after the maximum of the urban natural increase rate is reached (during phase C), and therefore may take place during phase B. Thus the problem of determining the relative evolution of the factors of urban growth is one of establishing the variations of the quotient of two variables with similar inverted U-shaped evolutions. Since in the two extreme phases distinguished earlier the two relevant variables take on such low values that the urban growth factor issue loses most of its pertinence, our investigations are limited here to the two intermediate phases (Early and Late Transitional Societies).

Two cases are in order, depending on which of the two variables reaches its maximum first. Let us suppose that the maximum of the urban natural increase rate is reached first. At this maximum, the derivative of the urban natural increase rate is zero and the derivative of the urban net inmigration rate is positive (since the maximum of this rate has not yet been reached). The derivative of the urban net inmigration to natural increase ratio is then positive. Later, when the maximum of the urban net inmigration rate is reached, the derivative of the urban net inmigration rate is zero and the derivative of the natural increase rate is negative (since the maximum of this rate has already been reached). The derivative of the urban net inmigration to natural increase ratio is then positive. Then, having passed its maximum, the net inmigration variable tends to decline at a rate that, after some time, decreases faster than the rate of decline of the natural increase variable, thus causing the derivative of the urban net inmigration to natural increase ratio to become negative.

In this first case, the urban net inmigration to natural increase ratio increases throughout phase B and, after reaching a maximum sometime during phase C, decreases throughout the rest of phase C. Considering the mirror image of the preceding case, we turn to the second case, in which the urban net inmigration rate reaches its maximum before the natural increase rate does. We immediately obtain the result that the urban net inmigration to natural increase ratio increases at the start of phase B and, after quickly reaching a maximum, declines thereafter until the termination of phase C.

The two alternative cases just described lead to the same evolutive pattern; when a country goes through the transitional period leading from the Premodern Traditional Society to the Advanced Society, its urban net inmigration to natural increase ratio exhibits an inverted U-shaped evolution. Therefore, the contribution of natural increase to urban growth is comparatively lower in the early and late stages of this transitional period or, to put it differently, the contribution of net migration is higher in the middle stage. (Note that the maximum of the urban net inmigration to natural increase ratio may occur either in phase B or in phase C, depending on whether the maximum of the net inmigration rate occurs before or after the maximum of the natural increase rate; see Figure 2.) As a result, migration is more likely to be the main contributor to urban growth toward the middle stage rather than at the extremes, where natural increase is more likely to be the main contributor.

III. A MATHEMATICAL FRAMEWORK

To gain further insights into the sources of urban growth this paper adopts a quantitative orientation based on a simple model of rural and urban population growth. Let P_r and P_u denote the rural and urban populations, respectively, r and u denote the rural and urban rates of natural increase, respectively, and m denote the net migration rate out of the rural sector, with time subscripts implied but deleted in each case. The natural increase and net inmigration components of urban population change are uP_u and mP_r, respectively. The urban net inmigration to natural increase ratio, defined as the quotient of the migration component by the natural increase component, is then

$$R = mP_r/uP_u. \qquad (1)$$

Let S denote the urban to rural population ratio

$$S = P_u/P_r \qquad (2)$$

and α denote the degree of urbanization (or fraction of the total population that is urban)

$$\alpha = P_u/(P_r + P_u). \qquad (3)$$

We can then rewrite R as

$$R = m/uS = m(1 - \alpha)/u\alpha, \qquad (4)$$

an expression showing that R is also the quotient of the urban net inmigration rate and the urban natural increase rate u.

Equation 4 does not suggest any obvious variations for the R-statistics. Fortunately, it can be transformed into a more useful expression by taking advantage of a simple relationship linking m and α. The derivation of this relationship, established elsewhere (Ledent 1982), is repeated here for the sake of clarity.

In brief, the evolution of the rural-urban system considered in this paper can be described by the following system of differential equations (Keyfitz 1980; Ledent 1981):

$$DP_r = (r - m)\, P_r \qquad (5)$$

where DP_r is the derivative dP_r/dt (this notation for the derivative with respect to time is used in subsequent equations), and

$$DP_u = uP_u + mP_r. \qquad (6)$$

Recalling the definition of S, DS/S is the rate of change of the urban to rural population ratio and

$$DS/S = DP_u/P_u - DP_r/P_r. \qquad (7)$$

After substitution of (5) and (6),

$$DS/S = -\Delta + m(1 + 1/S) \qquad (8)$$

where $\Delta = r - u$ is the rural-urban natural increase differential. Using the expression of the urban proportion α in terms of S, i.e.,

$$\alpha = S/(1 + S), \qquad (9)$$

leads to (Ledent 1982)

$$m = D\alpha/(1 - \alpha) + \Delta\alpha. \qquad (10)$$

Hence the urban net inmigration rate is equal to

$$m/S = D\alpha/\alpha + \Delta(1 - \alpha). \qquad (11)$$

In addition, letting P_T denote the total population in the system, i.e.,

$$P_T = P_r + P_u, \qquad (12)$$

the growth (natural increase) rate of the total population can be expressed as

$$DP_T/P_T = u\alpha + r(1 - \alpha) \qquad (13)$$

so that the urban natural increase rate is

$$u = DP_T/P_T - \Delta(1 - \alpha). \qquad (14)$$

Finally, substituting (11) and (14) into (4) yields

$$R = [D\alpha/\alpha + \Delta(1 - \alpha)]/[DP_T/P_T - \Delta(1 - \alpha)], \qquad (15)$$

an expression that shows that the urban net inmigration to natural increase ratio depends on: (a) the total population growth rate DP_T/P_T, (b) the rate of urbanization $D\alpha/\alpha$, and (c) the rural-urban natural increase differential Δ.

Let us assume for the moment that the rural-urban natural increase differential is negligible. Then, the urban rate of natural increase equals the total population growth rate and the urban net inmigration rate equals the rate of urbanization. (These two results follow from setting Δ to zero in (14) and (11), respectively, but they could have been derived intuitively.) In this case, the R-statistic simply equals the quotient of the rate of urbanization by the total population growth rate, i.e.,

$$R^* = [D\alpha/\alpha]/[DP_T/P_T], \tag{16}$$

a conditional urban net inmigration to natural increase ratio.[3]

From (15) and (16), it follows that the difference between the unconditional and conditional values of the urban net inmigration to natural increase ratio equals

$$R - R^* = \frac{D\alpha/\alpha + \Delta(1-\alpha)}{\Delta P_T/P_T - \Delta(1-\alpha)} - \frac{D\alpha/\alpha}{DP_T/P_T}, \tag{17}$$

that is,

$$R - R^* = [\Delta/(DP_T/P_T)](1-\alpha)(1+R^*). \tag{18}$$

Thus, during the transition from a traditional to a modern society, the difference $R - R^*$ has the sign of Δ; the conditional value of the urban net inmigration to natural increase ratio underestimates (overestimates) its true value if the rural rate of natural increase is larger (smaller) than the urban counterpart. Moreover, since α is generally on the order of 0.5 and R on the order of 1.0, the absolute error made by approximating R by R^* has roughly the magnitude of the ratio of the rural-urban natural increase rate differential to the total population growth rate. Such a result is confirmed by Table 2, which displays for the world and its major regions in 1960 the unconditional and conditional values of the urban net inmigration to natural increase ratio. During the time that a country is changing from a traditional society to an advanced one, the conditional value of the urban net migration to natural increase ratio (the quotient of the urbanization rate and the total population growth rate) provides an adequate measure of the relative contributions of natural increase and net inmigration to urban population growth.

[3] In the remainder of this paper, the word conditional is used to refer to the case of zero rural-urban natural increase differentials. Thus the conditional urban rate of natural increase and the total population growth rate are equivalent. Similarly, the conditional urban net inmigration rate and the rate of urbanization are identical notions.

TABLE 2

TOTAL GROWTH RATE, RATE OF URBANIZATION, CONDITIONAL AND UNCONDITIONAL VALUES OF THE URBAN NET MIGRATION TO NATURAL INCREASE RATIO, RELATIVE RURAL-URBAN NATURAL INCREASE DIFFERENTIAL: WORLD AND MAJOR REGIONS, 1960

Region	Total Growth Rate[a]	Rate of Urbanization[a]	Urban Net Migration to Natural Increase Ratio: Conditional	Urban Net Migration to Natural Increase Ratio: Unconditional	Rural-Urban Natural Increase Differential[a, b]
World	19.2	15.3	0.80	1.05	0.24
More developed regions	12.5	10.6	0.85	1.09	0.22
Less developed regions	22.5	23.2	1.03	1.02	−0.00
Africa	22.9	21.4	0.93	0.90	−0.04
North America	15.3	8.9	0.58	0.59	0.01
Latin America	28.1	16.8	0.60	0.84	0.26
East Asia	17.4	31.6	1.82	1.88	0.03
South Asia	23.9	13.6	0.57	0.61	0.06
Europe	9.3	7.8	0.84	1.36	0.45
Oceania	16.9	6.3	0.37	0.93	0.57
USSR	16.2	18.3	1.13	1.41	0.24

Source: United Nations 1976b, pp. 51-52.
[a] Per thousand.
[b] This variable is defined as the ratio of the rural-urban natural increase differential to the total growth rate.

IV. EVOLUTION OF THE URBAN NET INMIGRATION TO NATURAL INCREASE RATIO IN SELECTED DEVELOPING COUNTRIES: 1950-2000

The mathematical framework described in the preceding section readily allows assessment of the evolution of the sources of urban population growth in countries for which data relating to the total population and the degree of urbanization are available at different points in time.

Let $P_T(t_1)$ and $P_T(t_2)$ be the total population of a given country at times t_1 and t_2, respectively, and let $\alpha(t_1)$ and $\alpha(t_2)$ be the corresponding degrees of urbanization. An average annual value of the conditional urban net inmigration to natural increase ratio over the period (t_1, t_2) is the quotient of the average annual value of the rate of urbanization and the average annual value of the total population growth rate, i.e.,

$$R^*(t_1, t_2) = \ln[\alpha(t_2)/\alpha(t_1)]/\ln[P_T(t_2)/P_T(t_1)]. \qquad (19)$$

TABLE 3

TOTAL POPULATION GROWTH RATE, RATE OF URBANIZATION, AND URBAN NET INMIGRATION TO NATURAL INCREASE RATIO (CONDITIONAL AND UNCONDITIONAL VALUES): AVERAGE ANNUAL ESTIMATES FOR SELECTED DEVELOPING COUNTRIES, 1950-2000

	1950-60	1960-70	1970-75	1975-80	1980-90	1990-2000
	A. Total Population Growth Rate (per thousand)					
India	19.3	23.9	24.3	24.8	23.3	19.0
Egypt	23.7	25.1	23.8	23.1	22.2	20.5
Mexico	31.3	32.5	32.5	33.4	33.3	30.4
	B. Rate of Urbanization (per thousand)					
India	6.4	9.6	10.3	14.1	19.0	23.5
Egypt	17.1	10.9	6.0	8.2	10.8	12.7
Mexico	17.4	15.1	13.1	11.3	8.8	6.0
	C. Urban Net Inmigration to Natural Increase Ratio: Conditional Value					
India	0.33	0.40	0.43	0.57	0.82	*1.24*
Egypt	0.72	0.43	0.25	0.36	0.49	0.62
Mexico	0.56	0.46	0.40	0.34	0.26	0.19
	D. Urban Net Inmigration to Natural Increase Ratio: Unconditional Value[a]					
India	0.34	0.41	0.44	0.58	0.83	*1.25*
Egypt	0.91	0.57	0.37	0.48	0.62	0.76
Mexico	0.57	0.47	0.41	0.35	0.27	0.20

Sources: United Nations (1980) and Ledent (1982).
[a] Based on constant rural-urban natural increase differentials equal to the corresponding average annual values observed in the early seventies (see Table 4).

To illustrate, we have applied this formula to estimated and projected values of the total population and the degree of urbanization in three developing countries — India, Egypt, and Mexico — for selected years between 1950 and 2000 (United Nations 1980). These three are the only countries (besides a few small Central American countries) for which the United Nations (1974, 1975, 1976a, 1977) has recently published annual data on fertility and mortality rates according to urban and rural residence, thus allowing one to obtain the estimates of rural-urban natural increase differential necessary for the determination of the unconditional ratio $R(t_1, t_2)$. Note that these three countries belong to three continents and represent significantly different levels of urbanization and economic development.

For each country, the average annual values of the total population growth rate and the degree of urbanization in each intermediate period between 1950 and 2000 are displayed in exhibits A and B of Table 3, respectively. First, exhibit A indicates that the conditional urban natural increase rate (total population growth rate) in each country follows a similar inverted U-shaped pattern; that is, the maximal value of this rate has been or will be reached at some point between 1950 and 2000. Second, exhibit B points to a monotonic evolution of the conditional urban net inmigration rate (rate of urbanization): upward in the case of India and Egypt,[4] downward in the case of Mexico. Confronting the latter result with the qualitative considerations originating from the mobility revolution developed in Section II, we conclude that the maximum of the urban net inmigration rate will be reached in the distant future (well after 2000) in the case of India and Egypt, whereas it has already been reached (before 1950) in the case of Mexico. This conclusion agrees with the observation that Mexico is economically more advanced than the other two countries.

Comparison of the evolutive patterns concerning the conditional values of the urban natural increase and net inmigration rates suggests that the maximum of the natural increase rate precedes that of the net inmigration rate for India and Egypt, but follows in the case of Mexico. Recalling the two alternative cases of Figure 2, we infer that the maximum urban net inmigration to natural increase ratio is likely to be reached in Mexico at an earlier stage of development than in India and Egypt.

The average annual values of the conditional urban net inmigration to natural increase ratio resulting from the natural increase and net inmigration figures just discussed are shown in exhibit C of Table 3, which shows a monotonic evolution of this ratio between 1950 and 2000 (between 1975 and 2000 in the Egyptian case): upward in the case of India and Egypt, downward in the case of Mexico. In other words, the maximal value of the R-statistic will be reached beyond the year 2000 in the case of the former countries, whereas it was reached before 1950 in the case of the latter.

The conditional net inmigration to natural increase ratios displayed in Table 3 are generally less than unity, suggesting that during the second half of the twentieth century the main source of urban population in the three countries is natural increase. However, in the case of India, net inmigration tends to become preponderant in the last decade.

In some circumstances, the simple derivation of average values of the conditional urban net inmigration to natural increase ratio, as just performed, may be insufficient. To have an instantaneous estimate of this ratio at any point in time during a given period, it is sufficient to know the functions P_T and α that describe the evolution of the total population and the degree of urbanization, respectively. From such knowledge, (16) readily provides a functional form describing the evolution of the conditional net inmigration to natural increase ratio R^*.

[4] In the Egyptian case, this statement refers to the sole period 1975-2000. (The period 1950-1975, considered exceptional because of the various wars in which Egypt was involved, is disregarded.)

In general, however, no functional forms of P_T and α are known beforehand. Therefore, the curves that describe the evolution of these two attributes must be obtained by interpolating between the observed values of the total population and degree of urbanization at different points in time. As an illustration of this, Figure 3 shows the 1950-2000 evolution of the conditional urban net inmigration to natural increase ratio R* obtained by use of polynomial functions (whose degree was one less than the number of observations) fitted to exhibits A and B in Table 3.[5] The three national curves thus obtained confirm the broad evolutions suggested by the average decennial (or quinquennial) values shown earlier in Table 3 (exhibit C) and represented in Figure 3 by dots placed at the mid-period of the relevant intervals. These average values are generally located near the curve representing the evolution of R*, except in the case of the last decennial period. This is in agreement with the well-known fact that polynomial interpolations tend to perform rather poorly at the extremes of the observation period.[6]

At this stage of the analysis, consider the rural-urban natural increase differential, which so far has been assumed to be negligible. For the three countries, yearly estimates of the crude birth and death rates according to urban and rural residence (United Nations 1974, 1975, 1976a, 1977) suggest that the rural-urban natural increase differential may vary rapidly from year to year as a result of changes in fertility/mortality patterns and shifts in age composition. The minimal and maximal values of Δ registered in the early seventies are set out in Table 4. The variations observed, however, appear to have occurred around a somewhat stable average value shown in the last column of the same table: 0.2, 3.6, 0.3 per thousand in India, Egypt, and Mexico, respectively.

On the basis of these average values of Δ, we can use (15) to derive for each of the three countries an unconditional estimate of the urban net inmigration to natural increase ratio related to the first half of the seventies. Not surprisingly, in light of the considerations developed at the end of Section IV, the unconditional value of this ratio is barely higher than the corresponding conditional estimate for the two countries with a rather negligible value of Δ, India and Mexico. In the case of Egypt, where the rural-urban natural increase differential is significantly different from zero, the conditional estimate of the urban net inmigration to natural increase ratio has, over the period 1970-1975, a 0.37 value as opposed to the 0.25 value derived earlier for the conditional estimate.

[5] Another effective way to perform such an interpolation would be to use a cubic spline function (see, for example, McNeil et al. 1977).

[6] To avoid a poor interpolation in the first decennial period (1950-1960), the observation period has been enlarged to include two pre-1950 observations for which data were obtained from Bose (1974) in the case of India, from Khalifa (1974) for Egypt, and from Unikel (1975) for Mexico.

FIGURE 3

EVOLUTION OF THE URBAN NET INMIGRATION TO NATURAL INCREASE RATIO (CONDITIONAL VALUE): SELECTED DEVELOPING COUNTRIES, 1950-2000

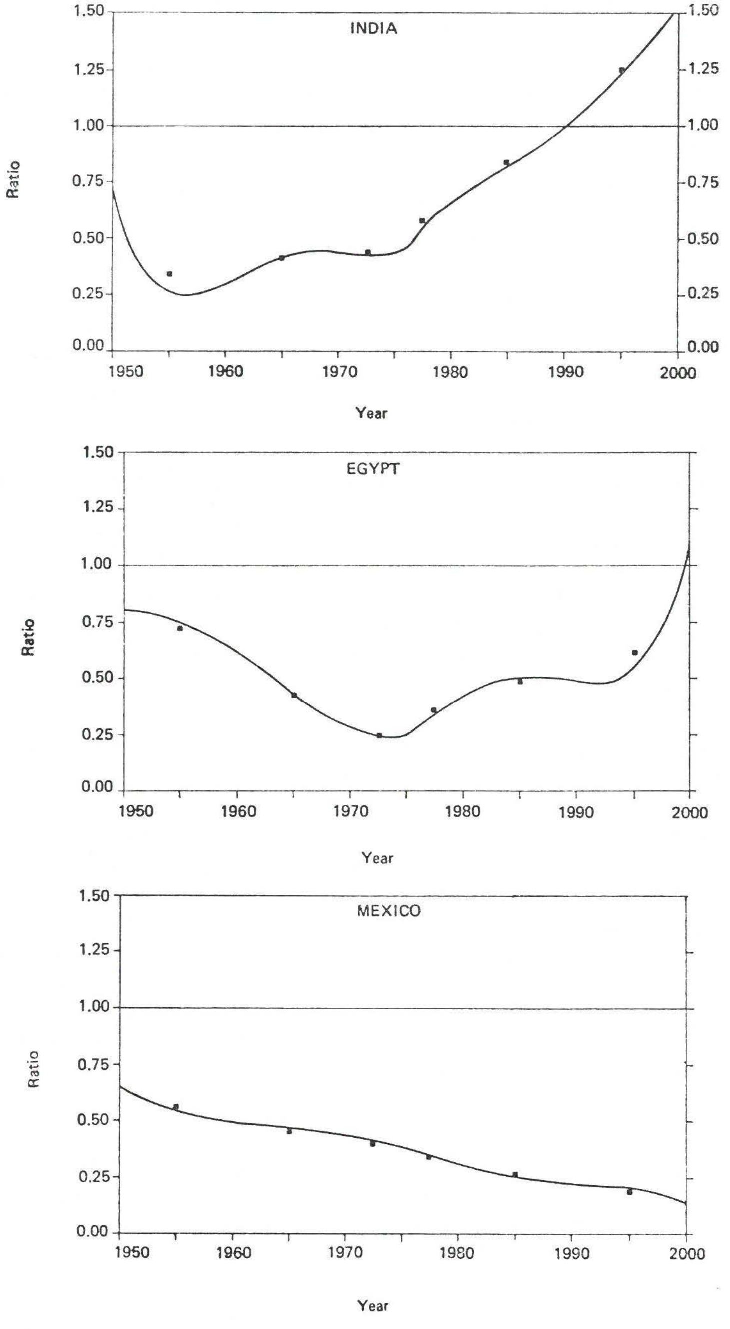


TABLE 4

EXTREME AND AVERAGE VALUES OF THE RURAL-URBAN NATURAL INCREASE DIFFERENTIAL (PER THOUSAND): SELECTED COUNTRIES IN THE EARLY SEVENTIES

Country	Period	Minimal Value	Maximal Value	Average Value
India	1972-75	−0.8	1.1	0.2
Egypt	1970-74	1.5	6.9	3.6
Mexico	1965-73	−2.2	4.0	0.3

Source: Calculated from fertility/mortality data in United Nations (1974, 1975, 1976a, 1977).

In the absence of any further information concerning the rural-urban natural increase differentials during the rest of the observation period 1950-2000, assume for illustrative purposes that the average values of the early seventies prevail throughout the whole period. Exhibit D of Table 3 shows the resulting unconditional values of the urban net inmigration to natural increase ratio. In the case of Egypt, the assumption of a constant value of Δ equal to its early seventies average causes the discrepancy between R and R* to diminish slowly from 0.19 in 1950-1960 to 0.14 in 1990-2000.

V. LONG-TERM EVOLUTION OF THE URBAN NET INMIGRATION TO NATURAL INCREASE RATIO IN SELECTED DEVELOPING COUNTRIES

Section IV illustrated the applicability of (15) and (16) to the case of available estimates and projections of the total population and degree of urbanization in a given country. This section will demonstrate the applicability of the same formulae to the case where functional forms of the relevant attributes are available. Such an exercise will provide projections of the urban net inmigration to natural increase ratios for the three countries over the period 2000-2050.

The problem here is determining appropriate functional forms for the total population level and the degree of urbanization. Taking up first the case of the total population level, its evolution is represented by a logistic curve justified by the inverted U-shaped evolution of the annual growth rates implied by the 1950-2000 UN data (United Nations 1980): see exhibit A of Table 3. In effect, if the variations of the total population can be depicted by a logistic curve

$$P_T = a + [b/(1 + ce^{-ht})] \qquad (20)$$

where a, b, c, and h are positive coefficients, then the annual growth rate is given by

$$DP_T/P_T = \frac{bch\, e^{-ht}}{(a + b + ace^{-ht})(1 + ce^{-ht})} \qquad (21)$$

TABLE 5

CALIBRATION OF THE LOGISTIC EVOLUTION OF THE TOTAL POPULATION LEVEL IN SELECTED DEVELOPING COUNTRIES: PARAMETER VALUES AND INDEX OF FIT[a]

	a	b	c	h	Sum of Squares
India	0.6725	3.7165	10.3713	0.0572	0.00002
Egypt	0.2137	7.3089	8.3253	0.0345	0.00007
Mexico	0.3393	14.7486	21.1793	0.0454	0.00021

[a] All curves were fitted to the 1950-2000 UN data (United Nations 1980).

whose evolution depends on the sign of

$$x(t) = ac^2e^{-2ht} - (a + b). \qquad (22)$$

Noting that the latter expression is positive for all t less than (and negative for all t greater than)

$$t_n = (1/2h)\ln(ac^2/a + b), \qquad (23)$$

the annual growth rate of a population whose trajectory follows a logistic curve first increases, then passes through a maximum, and finally decreases; that is, it is depicted by an inverted U-shaped curve.

A nonlinear least-squares method — the so-called Levenberg-Marquardt method (Levenberg 1944; Marquardt 1963) modified in the manner proposed by Brown and Dennis (1972) — was used to fit (20) to the seven 1950-2000 UN estimates of the total population for each country. The resulting parameter values are shown in Table 5. The ultimate size of the total population (determined by the sum of the coefficients a and b) equals 4.4 times the 1950 population for India, 7.5 times for Egypt, and 15.1 times for Mexico.

The 2000-2050 evolutions of the total population level based on the logistic curves just estimated show that the decelerated population growth of the latter 1900s, implied by UN projections, will continue in the next century: the Indian growth rate should decline from 16.6 per thousand in 2000 to 1.6 per thousand in 2050, the Egyptian rate from 19.2 to 7.0 per thousand, and the Mexican rate from 29.0 to 8.1 per thousand.[7]

The focus now shifts from the total population level to the degree of urbanization, whose evolution also is represented by a logistic curve. This choice naturally follows from the standard observation that the degree of urbanization can generally be depicted by attenuated S-shaped curves, one of which is the logistic curve (IBRD 1972;

[7] According to the logistic trends estimated above, the total population growth rate peaked at 25.4 per thousand in India (in 1975), at 24.5 per thousand in Egypt (in 1960), and 33.6 per thousand in Mexico (in 1975).

Berry 1973; Chenery and Syrquin 1975). The calibration of (20) — again performed by application of the modified Levenberg-Marquardt algorithm — to the seven 1950-2000 UN estimates of the degree of urbanization for each country appears in Ledent (1982). Only a brief summary of the results obtained is reported here.

Reasonable results were derived in just one case out of three: Mexico, for which the ultimate value of the degree of urbanization α_∞ equals 85.7 percent (see last line of Table 6). For the other two countries, no credible estimate of the ultimate degree of urbanization (that is, the value of a + b) was obtained, either because the urbanization level in the year 2000 will still be in the swiftly rising period preceding the point of inflection (India), or because the pace of urbanization is not monotonically increasing in the period 1950-2000 (Egypt). Because of this unsatisfactory result, an alternative method was adopted for India and Egypt. It calibrates (20) with an ultimate degree of urbanization α_∞ determined exogenously. (The observation period is reduced to the period 1975-2000 in the Egyptian case.) Different values of α_∞ were successively assumed to assess the sensitivity of the parameter values to the choice of α_∞. Table 6 displays the parameter values obtained for five predetermined values of α_∞ ranging from 75 to 95 percent. Note the increase in the index of fit as the level of α_∞ increases and the little influence of the level of α_∞ on the value of a.

The logistic curves estimated above, which describe the evolution of the total population level and degree of urbanization, readily allow on the basis of (16) determination of a functional expression of the conditional urban net inmigration to natural increase ratio R*. Both the numerator and denominator of this expression take the form of (21), where the national parameters a, b, c, and h take on the values shown in Tables 6 and 5. The resulting evolution of the conditional ratio R* over the period 1950-2050 (1975-2050 in the case of Egypt)[8] is set out graphically for each country in Figure 4.

In the light of the evolution observed in Section IV, the conditional urban net inmigration to natural increase ratio is expected to decrease further in Mexico during the period 2000-2050: by the year 2050, the contribution of migration to urban population growth should amount to no more than 3 percent. By contrast, the Indian conditional ratio is expected to increase well into the twenty-first century: in all five cases, except when α_∞ equals 75 percent (in which case the decline will start as soon as 2040), this ratio will not peak before the middle of that century. The conditional ratio is expected to range from 2.7 (if

[8] For each country, the curve that describes such an evolution appears over the "observation period" to smooth the curve obtained earlier by use of a polynomial interpolation and shown in Figure 4 by a dashed line. Comparison of the solid and dashed lines over the period 1990-2000 confirms the earlier presumption that the polynomial interpolation procedure is inadequate for that interval.

TABLE 6

CALIBRATION OF THE LOGISTIC EVOLUTION OF THE DEGREE OF URBANIZATION IN SELECTED DEVELOPING COUNTRIES:[a] PARAMETER VALUES AND INDEX OF FIT

	α_∞	a	b	c	h	Sum of Squares
India	0.75	0.1590	0.5910	55.91	0.06410	0.1004
	0.80	0.1584	0.6416	57.95	0.06260	0.0862
	0.85	0.1579	0.6921	60.16	0.06135	0.0758
	0.90	0.1574	0.7426	62.50	0.06030	0.0681
	0.95	0.1570	0.7930	64.91	0.05940	0.0622
Egypt	0.75	0.3944	0.3556	60.55	0.08291	0.0026
	0.80	0.3875	0.4125	48.62	0.07422	0.0003
	0.85	0.3820	0.4680	42.76	0.06820	0.0002
	0.90	0.3775	0.5225	39.57	0.06377	0.00004
	0.95	0.3737	0.5263	37.81	0.06037	0.000009
Mexico	0.8574	0.2015	0.6560	1.914	0.05138	0.0514

Source: Ledent (1982).
[a] All curves were fitted to the 1950-2000 UN data; in the case of Egypt only 1975-2000 data are used.

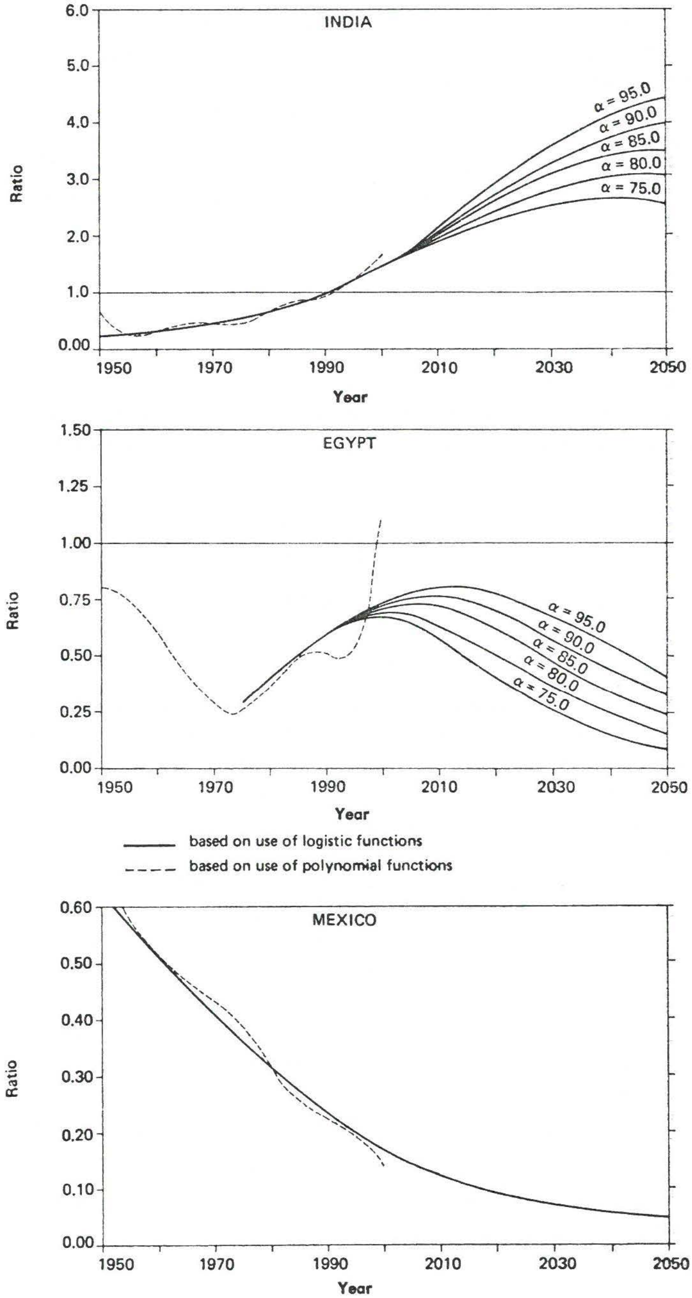
α_∞ equals 75 percent) to 4.4 (if α_∞ equals 95 percent) in the year 2050, suggesting a preponderant contribution of migration to Indian cities. The Egyptian conditional ratio is expected to peak more rapidly, most likely in the first decade of the next century: the year in which the peak will occur ranges from the turn of the century (if α_∞ equals 75 percent) to 2014 (if α_∞ equals 95 percent). The decline after the peak should be rather rapid in all cases, so that by 2050 the contribution of net inmigration to urban population growth should be less than half the contribution of natural increase. (The highest value of R^* obtained for that year is 0.42 when α_∞ equals 95 percent.)

VI. THE FACTORS OF URBAN POPULATION GROWTH AND ECONOMIC DEVELOPMENT: THE CASE OF THE "REPRESENTATIVE" COUNTRY

This paper has focused on the temporal evolution of the factors of urban population growth for a given country. Because intercountry comparisons play an essential part in understanding the processes of economic development, a cross-sectional perspective is adopted here. Its main objective is the quantification of the relationship between the urban net inmigration to natural increase ratio and the degree of economic development, measured by GNP per capita.

FIGURE 4

EVOLUTION OF THE URBAN NET INMIGRATION TO NATURAL INCREASE RATIO (CONDITIONAL VALUE): SELECTED DEVELOPING COUNTRIES, 1950-2050



The observation that for a given sample of countries such demographic attributes as the crude birth and death rates and the degree of urbanization are correlated with the logarithmic value of GNP per capita (see, for example, Chenery and Syrquin 1975) suggests that the mathematical framework presented in Section III can be used here, with a slight amendment, for the purpose of analyzing a cross-sectional sample of countries.

Let b(z) and d(z) denote the functions expressing crude birth and death rates in terms of the logarithmic value z of GNP per capita and $\alpha(z)$ denote the function expressing the degree of urbanization. From (15) the unconditional value of the urban net inmigration to natural increase ratio can be expressed as

$$R(z) = \frac{\frac{d\,\alpha(z)}{\alpha(z)\,d(z)}\,Dz + \Delta(z)[1-\alpha(z)]}{[b(z)-d(z)] - \Delta(z)[1-\alpha(z)]} \tag{24}$$

where $\Delta(z)$ denotes the rural-urban natural increase differential.

Generally the value of the rural-urban natural increase differential is small. In the first approximation, therefore, R(z) can be taken as

$$R^*(z) = \frac{\frac{d\,\alpha(z)}{\alpha(z)\,dz}}{b(z)-d(z)} \cdot Dz. \tag{25}$$

Recalling that z stands for the logarithmic value of the GNP per capita y,

$$Dz = D(\ln y) = Dy/y. \tag{26}$$

In other words, the conditional value of the urban net inmigration to natural increase ratio is the quotient of the logarithmic derivative of the degree of urbanization and the rate of natural increase multiplied by the instantaneous growth rate of GNP per capita.

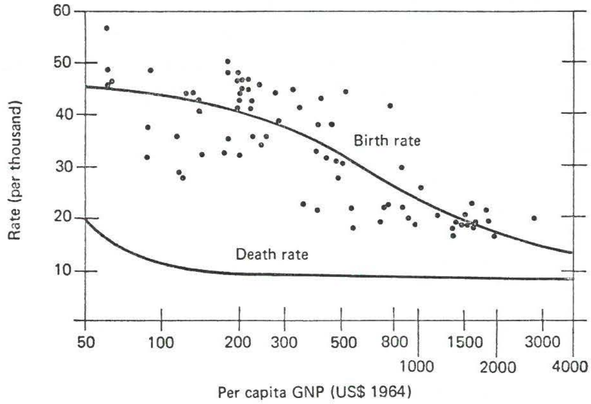
To apply this framework to an actual cross-sectional sample of countries to uncover the variations of $R^*(z)$ in terms of z, the variations of the following variables must be established: (a) crude birth rate, (b) crude death rate, (c) degree of urbanization, and (d) instantaneous growth rate of GNP per capita. The scatter diagram of Figure 5 for 73 non-centrally planned countries, redrawn from Chenery and Syrquin (1975), suggests the existence of a logistic variation of the birth rate with the logarithmic value of GNP per capita. A regression analysis (again based on the modified version of the Levenberg-Marquardt procedure) leads to the following estimated equation:

$$b(z) = 0.01277 + [0.03325/(1 + 5.58 \times 10^{-5}\,e^{1.157z})]. \tag{27}$$

The evolution of the crude birth rate in the "representative" country (i.e., the variations of this indicator with economic development as implied by this equation) is shown in Figure 5.

FIGURE 5

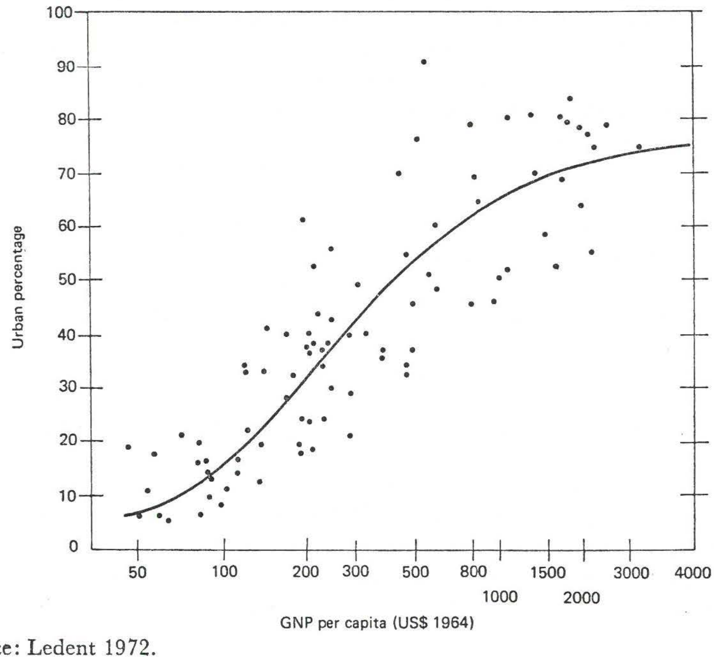
THE ASSOCIATION BETWEEN CRUDE BIRTH RATE AND GNP PER CAPITA: SCATTER FOR 73 NON-CENTRALLY PLANNED COUNTRIES (IN 1965) AND LOGISTIC EVOLUTION PERTAINING TO THE "REPRESENTATIVE" COUNTRY



Source: Chenery and Syrquin 1975, p. 57.

FIGURE 6

THE ASSOCIATION OF THE DEGREE OF URBANIZATION WITH GNP PER CAPITA: SCATTER FOR 88 NON-CENTRALLY PLANNED COUNTRIES (1965) AND THE LOGISTIC EVOLUTION PERTAINING TO THE "REPRESENTATIVE" COUNTRY



Source: Ledent 1972.

By contrast, the existence of a correlation between the crude death rate and economic development is less obvious. Most likely, there exists a significant correlation between mortality and economic development, a relationship that could be substantiated by plotting GNP per capita against a true mortality index such as life expectancy at birth. However, because the crude death rate is not a true mortality index, and because it reflects the age structure of the population concerned, at best a weak correlation may be expected between it and GNP per capita.

Actually, the crude death rate varies little across the 57 countries for which 1965 data are available (Chenery and Syrquin 1975): most observations are located between 10 and 14 per thousand. Only the crude death rate of countries with a typically low GNP per capita (from 50 to 100 US dollars of 1964) is significantly higher. Fitting a logistic curve to this sample leads, as expected, to a weak correlation between the crude death rate and economic development expressed by the following regression equation:

$$d(z) = 0.00926 + [0.23778/(1 + 0.00119\, e^{2.477z})]. \qquad (28)$$

The variations of the crude death rate implied by this equation are illustrated in Figure 5. The rate decreases rapidly from 20 per thousand (for y equals 50 dollars) to 10 per thousand (for y equals 125 dollars) and then remains more or less at that level.

The evolution of the other two variables (degree of urbanization and instantaneous growth rate of GNP per capita) that are relevant to economic development has been analyzed in an earlier paper (Ledent 1982), the main results of which are summarized below.

First, fitting a logistic curve to the 88 observations on urbanization levels in the scatter diagram of Figure 6 leads to the following estimated equation:

$$\alpha(z) = 0.0061 + [0.7332/(1 + 1615.75\, e^{-1.35192z})]. \qquad (29)$$

Second, fitting a polynomial of the second degree in the logarithm of GNP per capita to 100 observations of the average annual growth rate of GDP per capita (assumed to be equivalent to the corresponding growth rate of GNP per capita), obtained from IBRD (1976), leads to the following estimated equation:

$$Dy/y = -16.18 + 5.960 \ln y - 0.4353 (\ln y)^2, \qquad (30)$$

where the annual growth rate of GDP per capita is expressed in percent.

The availability of the estimated equations (27) through (30) makes it possible to derive from (25) the evolution of the conditional urban net inmigration to natural increase ratio R^*. It is shown by a thick line in Figure 7. Note that the curve describing the variations of R^* in the "representative" country has an inverted U-shape. From

FIGURE 7

EVOLUTION OF THE URBAN NET INMIGRATION TO NATURAL INCREASE RATIO (CONDITIONAL VALUE) WITH GNP PER CAPITA FOR ALTERNATIVE EVOLUTIONS OF THE ANNUAL GROWTH RATE OF GNP PER CAPITA

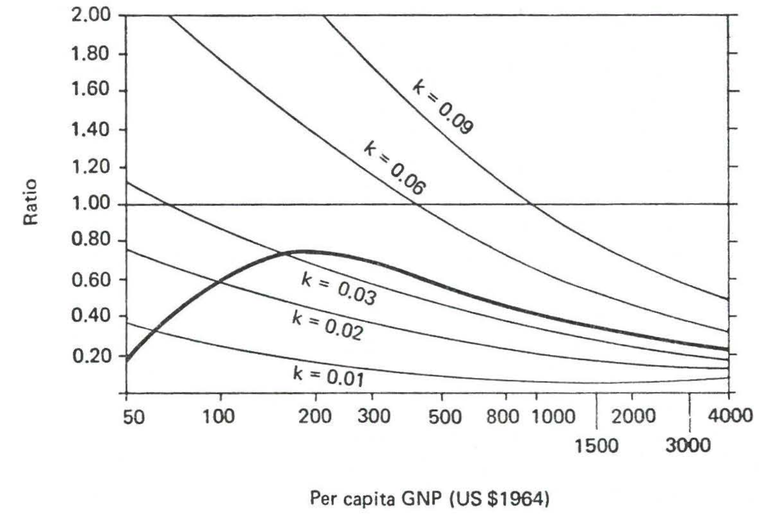
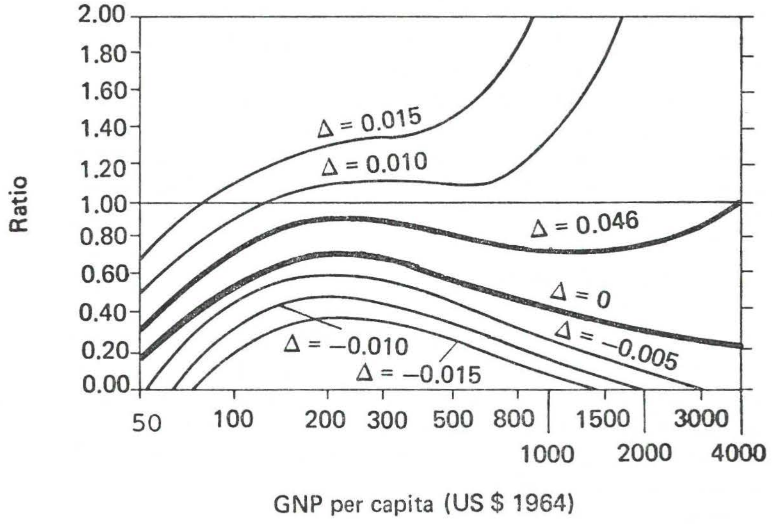


FIGURE 8

EVOLUTION OF THE URBAN NET INMIGRATION TO NATURAL INCREASE RATIO WITH GNP PER CAPITA FOR ALTERNATIVE CONSTANT VALUES OF THE RURAL-URBAN NATURAL INCREASE DIFFERENTIAL



a 0.18 value for a GNP per capita of 50 dollars, R* increases rapidly to 0.62 for 100 dollars and then more slowly to 0.75 for 200 dollars. After reaching a maximum of 0.76 for 210 dollars, it slowly decreases to 0.62 for 500 dollars and 0.33 for 100 dollars.

Note the importance of the relationship between the evolution of the annual growth rate of GNP per capita and economic development. Had a constant annual rate been taken instead of the varying rate stemming from the estimated equation (30), the variations of the conditional R* would have been monotonically decreasing. (See Figure 7, which shows various curves describing the evolution of R* for constant annual rates k equaling 1, 2, 3, 6, and 9 percent.)

Finally, moving away from the assumption of a zero rural-urban natural increase differential, the evolution of the urban net inmigration to natural increase ratio for various assumptions regarding the rural-urban natural increase differential is displayed in Figure 8. The uppermost thick line depicts the case of a constant natural increase differential of 0.046 (which was the observed value for the world total in 1960), whereas the thin lines correspond to assuming alternative constant values of this differential ranging from minus to plus 15 thousand. (The intermediate case of a zero natural increase differential studied earlier is shown by the lower thick line.) When the rural-urban natural increase differential takes on a constant and largely positive value, the urban net inmigration to natural increase ratio can rise again past a certain level of GNP per capita.

The rural-urban differential $\Delta(z)$ is not independent of the level of economic development. Because rural and urban areas tend to have similar fertility and mortality patterns in both traditional and advanced societies, this differential takes on a negligible value at both ends of the GNP per capita spectrum. Therefore, the curve that describes the evolution of the true urban net inmigration to natural increase ratio is a curve that (a) for low and high values of GNP per capita coincides more or less with the curve describing the evolution of the conditional ratio, and (b) for intermediate values of GNP per capita is located above the conditional ratio [where $\Delta(z)$ is most likely positive]. As a result, it is possible to assert that the relationship between the evolution of the urban net inmigration to natural increase ratio and economic development necessarily follows the general inverted U-shaped pattern depicted earlier.

The two thick lines of Figure 8 displaying the evolution of the conditional and unconditional values of the R-statistic are located below the horizontal line corresponding to a value of 1.0 for R. Thus, in the mid-sixties, the primary component of urban population growth was natural increase, though for intermediate values of GNP per capita (150 to 500 dollars) the contribution of net inmigration was almost equally important.

TABLE 7

TOTAL POPULATION GROWTH RATE, RATE OF URBANIZATION, AND URBAN NET INMIGRATION TO NATURAL INCREASE RATIO (CONDITIONAL VALUE) IN THE WORLD, THE MORE AND LESS DEVELOPED REGIONS: DECENNIAL AVERAGES, 1950-2000

	Year				
Region	1950-1960	1960-1970	1970-1980	1980-1990	1990-2000
	A. Total Population Growth Rate (per thousand)				
World	17.8	19.0	19.2	18.9	16.9
More developed regions	13.2	10.8	9.0	8.5	6.9
Less developed regions	20.0	22.7	23.3	22.4	20.0
	B. Rate of Urbanization (per thousand)				
World	15.8	10.1	9.7	10.5	11.1
More developed regions	11.0	9.5	8.0	6.4	5.0
Less developed regions	26.8	16.6	16.7	17.6	17.5
	C. Urban Net Inmigration to Natural Increase Ratio: Conditional Value				
World	0.89	0.54	0.50	0.56	0.66
More developed regions	0.83	0.88	0.88	0.75	0.73
Less developed regions	1.34	0.73	0.71	0.78	0.88

Source: United Nations (1980).

VII. CONCLUSION

This paper has sought to shed some light on the relative roles of net inmigration and natural increase as sources of urban growth. Its main conclusion — established qualitatively and quantitatively — is that, as a country evolves from a traditional society to an advanced one, the contribution of net inmigration to urban growth, relative to natural increase, follows a simple pattern: it increases, passes through a maximum, and subsequently decreases.

A thorough cross-sectional analysis places the maximal contribution of net inmigration at a level of economic development corresponding to a GNP per capita of roughly 200 US 1964 dollars. This empirical result readily illuminates the contrast observed in the current evolution of the components of urban population growth in India and Mexico: the contribution of net inmigration tends to grow in India, where the GNP per capita equaled 83.9 dollars in 1964, and to decline in Mexico, where it amounted to 434.2 dollars (figures from Chenery and Syrquin 1975).

Finally, throughout this paper the analysis has emphasized the evolution of the urban net inmigration to natural increase ratio rather than its level. However, regarding whether cities grow by natural increase or by migration, a question originally addressed by Keyfitz (1980), in the sixties urban growth in the world was on the average induced by both factors in equal proportions. The empirical examples show a slight advantage to net inmigration around 1960 (see Section II) and to natural increase in the mid-sixties (see Section VI).

Can the latter observation be extrapolated to conclude that, on the average, the contribution of migration to urban growth is likely to decline further in the last quarter of this century? In fact, the evolution of the component rates of urban growth in the more and less developed regions of the world as stated in the most recent UN forecasts (United Nations 1980) reveals an overall stabilization of the conditional values of the urban net inmigration to natural increase ratio in the last third of this century (Table 7). Thus, until the year 2000, urban populations are likely to continue growing under the influence of a slightly higher contribution of natural increase than of net migration.

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City Size Distributions and Spatial Economic Change

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ABSTRACT The concept of the city size distribution is criticized for its lack of consideration of the effects of interurban interdependencies on the growth of cities. Theoretical justifications for the rank-size relationship have the same shortcomings, and an empirical study reveals that there is little correlation between deviations from rank-size distributions and national economic and social characteristics. Thus arguments suggesting a close correspondence between city size distributions and the level of development of a country, irrespective of intranational variations in city location and socioeconomic characteristics, seem to have little foundation.

I. INTRODUCTION

The study of city size distributions has enjoyed recurrent popularity as a way of representing aspects of an urban system. Cities are compared by first isolating an urban system and then ranking the cities in that system from largest (one) to smallest in population size. Arranged on a graph with rank on the abscissa and actual population size on the ordinate axis, cities form a downward sloping line depicting their relative sizes. In constructing this distribution, the cities are removed entirely from their context. No information is retained about the relative location of the cities in space, their economic function, or any other aspects that might explain how they interact together within the system. Thus it must immediately be asked whether anything is retained in this graph that is of use in predicting how an urban system develops.

Yet city size distribution graphs have remained a popular tool for two reasons. First, they are easily constructed for any urban system, assuming that the boundaries to the system and the concept of a city can be reasonably defined. Few other features of an urban system can be so elegantly depicted. Second, early empirical work by Zipf (1949) suggested that a large number of observed city size distributions could

Thanks are due to Helga Leitner for advice and technical help with the empirical tests. This paper was written while the author was at IIASA on leave from the University of Minnesota.

be approximated by the so-called rank-size relationship (first suggested by Pareto, cf. McGreevey 1971). This relationship is particularly simple, since if the two axes of the city size distribution are scaled logarithmically the distribution becomes a negative sloping straight line. Zipf argued that a particular case of this, when the slope equals one, represents a desirable situation where forces of concentration balance those of decentralization. He characterized this as the rank-size rule.

Zipf presented urban research with an empirical regularity of a particularly elegant form — a form that in a sense was crying out to be explained. Simultaneously, he suggested that it represents a desirable norm for urban systems. This notion was reinforced by research showing that the United States urban system, representing a nation that many regarded as the most developed in the world, almost spectacularly fit the rank-size rule over a number of decades (Madden 1956). Such a belief in the rank-size relationship as a desirable feature has remained an undercurrent in the settlement system literature ever since.

It is not at all clear, however, how such a severe abstraction of the urban system can be related in any systematic way to the development of its cities. The range of city sizes results from the growth of individual cities, and growth in turn depends on the relative position of cities within the urban system. Since information on this is not retained within the city size distribution concept, it would seem difficult to construct any link between a system's growth and its city size distribution without invoking some kinds of macro-laws of urbanization that transcend or nullify the importance of the fates of individual cities. Such a challenge has not daunted urban researchers, and indeed a number of theoretical and empirical studies have appeared which attempt to do just this. The purpose of this paper is to evaluate and update these studies. The conclusions are both negative and positive. They are negative in that the theoretical justifications reviewed are found to be weak and that an empirical study reveals no evidence that deviations from the rank-size rule can be explained by socioeconomic indicators. The conclusions are positive in that they support intuition; city size distributions are so far removed from the reality of urban interdependencies and growth that they defy systematic explanation.

Section II of this paper briefly classifies theoretical explanations, attempting to show that theories justifying the rank-size relationship are themselves constructed in a manner that ignores the specifics of relationships between cities. In short, the level of abstraction achieved by the theories matches that represented by the rank-size rule. Section III reviews the large number of studies seeking empirical correlates for the shape of city size distributions and presents a methodologically superior empirical study, concluding that none of the variables suggested can account for variations from rank-size. In the light of this, Section IV returns to the theory accounting for such distributions, arguing that once interurban relations are specifically included, it becomes extremely difficult to construct a theory that accounts for any particular type of city size distribution. The conclusions explore implications for any attempts to propose the rank-size relationship as a desirable norm for the analysis of urban development.

II. EXPLANATIONS OF THE RANK-SIZE RELATIONSHIP

The rank-size relationship is:

$$P_r = P_1/r^q \tag{1}$$

where P_r is the population of the r-th largest city. This is a negative linear relationship with respect to the logarithm of population and rank:

$$\log P_r = \log P_1 - q \log r. \tag{2}$$

The rank-size rule is represented by the special case of (2) when q equals one. Because the rank-size relationship has come to be regarded as a norm, explanations of city size distributions have focused on this rule, as the comprehensive review by Richardson (1973) makes clear. Further, Richardson demonstrates that explanations tend to refer to the city size distribution as an equilibrium resulting from patterns of urban growth.

Rather than repeating Richardson's work, it is useful to ask to what degree the various explanations of city size distributions take into account interurban interdependencies as an important factor of urban growth. Logically, the growth of a city depends on interurban dependencies, shocks from outside the system, and impulses generated within the city and its hinterland. Of these three, the second receives little attention in the city size distribution literature, and when it is considered, the transmission of external shocks via interurban links is not even discussed. Therefore the literature can be conveniently classified according to whether theoretical explanations incorporate interurban relations as a growth factor.

Of the thirteen explanations reviewed by Richardson, six do not discuss the possibility of relationships between cities influencing individual growth rates. The so-called law of proportionate effect, or Gibrat's Law, is typical. The size of any city i may be accounted for by:

$$P_{it} = P_{io} \prod_{r=1}^{t} g_{ir} \tag{3}$$

with P_{it} being the population of i in time t, and g_{ir} being the rate of growth of i in time period r. If we assume that g_{ir} is an independent, identically-distributed random variable over all i and r, then the city sizes P_{it} will eventually be distributed as a lognormal distribution over i at some time t, no matter what the original distribution was at time zero. The right-hand tail of the lognormal distribution is in turn similar to the rank-size relationship.

Of the remaining seven theories, three are static equilibrium models describing city size distributions as the stable outcome of a hierarchy of urban centers. For example, Beckmann and McPherson (1970) show that if the population of cities at each level of a Christaller ($K = 3$) central place hierarchy are randomly perturbed, a rank-size relationship can result. Although by definition a hierarchy takes account of some interurban relationships, there is little evidence of central place equilibria persisting in reality. Thus, these approaches seem to be of limited use in studies relating to long-run economic change.

Three further theories incorporate some form of interurban interdependency, but in only a loose manner. One of these is Zipf's explanation discussed earlier, where the interactions are described in a manner too indistinct to be of any theoretical use. The other two, by Ward (1965) and Rashevsky (1943), both discuss inmigration as a source of growth. In each case, however, it is assumed that the level of inmigration depends solely on the characteristics of the destination city and not on those of the origin cities or their location. In addition there is no conception that the growth of one city implies a loss for other cities. Rather, it is assumed that the migration necessary to provide the required growth and resulting city size distributions will occur — as if conjured out of a hat.

The one approach with a well-specified conception of interaction is Richardson's extension of Fano (1969). Here the evolution of city sizes is regarded as a sum of internal growth forces and interurban interactions, summarized as:

$$\mathbf{P}_t = \mathbf{P}_{t-1}\,\mathbf{M} \tag{4}$$

where $\mathbf{P}_t$ is a vector containing the population sizes of all N cities in the urban system. An N by N square matrix is denoted by $\mathbf{M}$, with a typical element m_{ij} representing the influence of city i on city j: a measure of spatial interaction.

This approach, the only one able to incorporate all three types of forces influencing a city's growth, does not guarantee a rank-size distribution. It may be shown that if the matrix of interactions does not change over time, then eventually the vector of population sizes will converge to a constant city size distribution with each city growing at the same rate: a rate determined by the largest eigenvalue of $\mathbf{M}$. This stable distribution, the principal left-hand eigenvector of $\mathbf{M}$, will only exhibit a rank-size relationship if the interactions m_{ij} take on particular values. If, on the other hand, the interactions of $\mathbf{M}$ evolve over time, then there is no stable city size distribution that will persist unless the interactions themselves eventually stabilize. In general, interactions do change as the space-economy alters (Sheppard 1980), so even if a rank size distribution happens to exist at any one time period t, there is no a priori reason to expect it to persist. Simulations by

Haran and Vining (1973) indeed show that interactions changing in a manner analogous to the gravity model make the rank-size relationship unstable; it evolves towards a convex distribution.

Three of those four theories incorporating interurban interactions to explain growth (the exception being Zipf) are not well known and have not been applied by other authors. Thus it is not unreasonable to conclude that no well-developed theory exists of the rank-size relationship incorporating interurban interdependencies. Perhaps there cannot be such a theory, since very special assumptions would be necessary for interacting cities to evolve into a city size distribution that has a shape independent of the location of those cities. This issue will be pursued later.

A related question of some difficulty is that of identifying unambiguously whether an observed city size distribution is best represented by the rank-size relationship. Certainly an observed regularity should not be accepted without some comparison to alternative hypotheses. The difficulty is illustrated by Quandt's study (1964), which attempted to determine whether the rank-size relationship (a Pareto distribution of the first kind) provided a closer fit to the city size distribution for those United States cities with a population exceeding 50,000 than a series of competing distributions. In a fairly rigorous test because of the close correspondence of these data to the rank-size rule, only two of eight alternative distributions were eliminated as clearly inferior. The rank-size relationship was third best of the remaining six, but the results were sufficiently close to make any choice difficult. The two relationships that performed better were a modified Pareto distribution and the lognormal distribution:

$$P_r = (1/-q)\ P_1(r + c)^{-q} \qquad (5)$$

$$p(P^*) = [P^* \sigma 2\Pi]^{-1} \exp\{-(2\sigma^2)^{-1} (\log P^* - \mu)^2\} \qquad (6)$$

where c is a constant, $p(P^*)$ is the probability that a city will be of population size P^*, and σ,μ are the standard deviation and mean of the city size distribution.

Even with the United States example a number of distributions conform closely to the data. Each distribution in turn presumably has one or more theories that account for its possible existence. If interurban interactions are ignored, a large number of possible stochastic processes may generate the lognormal distribution alone (Robson 1973, p. 36; Aitchison and Brown 1963). In conclusion, even where a rank-size relationship seems to exist, many theories and hypotheses are consistent with the observed data; the variety cannot be narrowed down without further empirical and theoretical information.

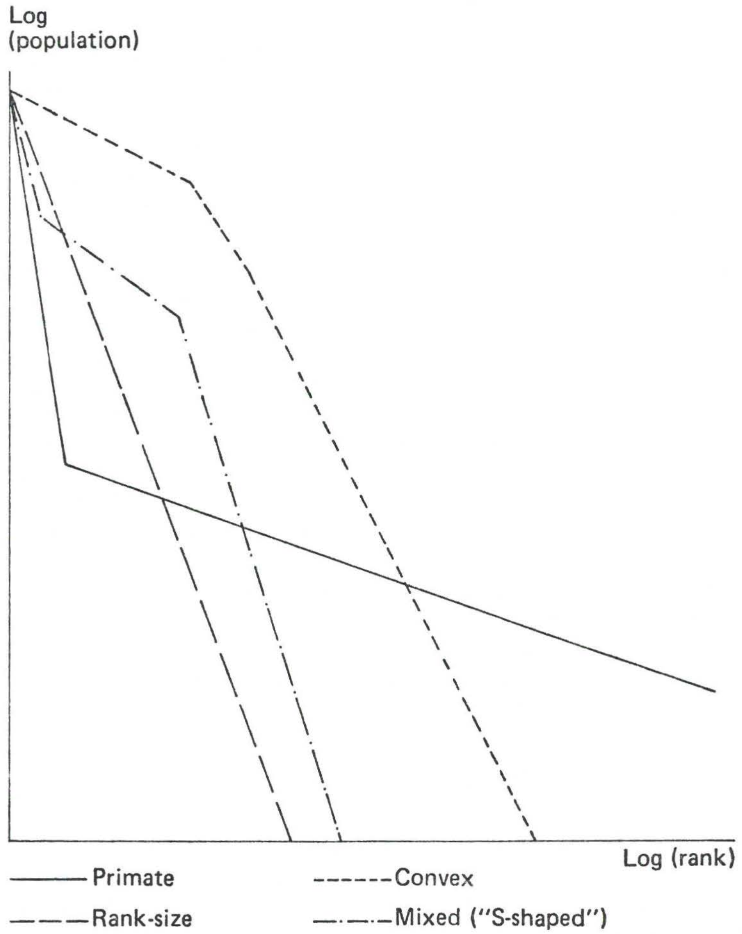
III. EMPIRICAL COMPARISONS

PAST EMPIRICAL TESTS OF PRIMACY

International comparisons of city size distributions reveal many cases where the rank-size relationship does not exist. These are typically

FIGURE 1

ALTERNATE STYLIZED TYPES OF CITY SIZE DISTRIBUTIONS



classified into primate distributions, where one or two large cities dominate the distributions; convex distributions, dominated by a number of large cities; and S-shaped distributions (Figure 1). Since primacy is a problem endemic to many Third World countries, there has been much speculation about the reasons for primacy and subsequently for other deviations from the rank-size relationship. A number of causal factors have been suggested, including measures of the size of the country, level of "economic development" and internal and external links.[1] Comparison of the studies is difficult. Measures of primacy and methods of hypothesis testing vary, and the fundamental problem of comparing city population statistics internationally confounds issues. Some general statements can be made, however:

(1) The literature is dated (only one study since 1972) and the statistical techniques are rather primitive (and in many cases non-existent). In particular there has been no attempt to partial out cross-correlations between independent variables in those cases where several independent variables were tested.

(2) Measures of primacy are in almost every case somewhat crude. In particular, if (1) is substituted into each of these measures, it will be seen that each index of primacy depends on q. In other words, rank-size relationships with different slopes will have different levels of primacy according to each of these indices. Thus it is not possible to discriminate between (a) a country whose primate city dominates a city size distribution, which otherwise may have a low and fairly consistent negative slope, and (b) a country exhibiting a rank-size relationship of steep slope. In short, according to each of these indices high primacy need not imply deviation from a rank-size relationship.

(3) There is little evidence of any well-specified theory being tested. Rather, the literature represents ways to evaluate likely hypotheses. As a result a wide range of variables is considered.

(4) The results of these tests do not exhibit a high level of internal consistency. Ten independent variables were tested more than once. Of these only four consistently produced a significant relationship in the same direction: populated area of the country, length of history of urbanization, complexity of economic life, and external orientation of the country. Of these only the first and the last were subjected to a statistical test more than once. Three of the remaining six were found to be insignificant at least once, and three exhibited both positive and negative relationships. It is little wonder that enthusiasm for such studies has waned.

Despite these problems, some general conclusions have been made. According to Berry (1964, 1971) countries that are small, have a short history of urbanization, are relatively simple in socioeconomic and political structure, have a low level of urbanization, have strong external links, and have internal interactions highly polarized along certain routes can be expected to have a primate city size distribution.

[1] See Jefferson (1939), Zipf (1949), Berry (1961), Stewart (1958), Mehta (1964), Linsky (1965), Vapnarsky (1969), McGreevey (1971), Harris (1971), Berry (1971), El-Shaks (1972), and Johnson (1980). A summary of the various hypotheses and empirical tests relating to primacy vis-a-vis and rank-size relationship is available from the author.

On the other hand, a number of authors have made a point of describing cases that contradict this conception. For example, Costello (1977) cites primacy in Iran and rank-size relationships in Israel and Saudi Arabia as counter-examples; Friedmann (cited in Robson 1973) notes that Venezuela does not fit, and McGreevey (1971) finds that many South American urban systems evolve to primacy as internal interconnections are developing. Even in Berry's original study (1961), there are examples that do not fit this stereotype at all. El Salvador, a country that has all the characteristics that Berry implies for a primate distribution, in fact exhibits a rank-size relationship. By contrast Spain, with many characteristics typical of a country expected to have a rank-size relationship, exhibits primacy.

Paralleling the bias in the theoretical literature, little attention has been given to explanations that in any sense discuss internal differentiations within the urban system and the links between the cities. Section IV argues that a most important factor influencing the development of city sizes in an urban system may have been unintentionally neglected.

A NEW TEST

Because of the methodological shortcomings of previous tests of primacy, an attempt is made to test more adequately some of the hypotheses suggested. First an index is developed of the deviation of a city size distribution from the rank-size relationship that is not sensitive to the slope, q. This index is then related to the independent variables suggested in the earlier studies, using a simultaneous "regression" format to reduce spurious correlations.

The index of primacy follows the approach of El-Shaks (1972) in being calculable for the entire distribution. El-Shaks's index is:

$$P = \frac{1}{N-1} \sum_{i=1}^{N-1} \left[\frac{1}{(N-i)P_i} \sum_{(j=i-1)}^{N} (P_i - P_j) \right] \qquad (7)$$

where N is the total number of cities in the system. However, if it is posited that the observed distribution conforms to the rank-size relationship and $P_k = P_1 k^{-q}$ is substituted in (7), the following is obtained:

$$P = \frac{1}{N-1} \sum_i \left\{ \frac{1}{N-i} \sum_j \left[1 - \left(\frac{j}{i}\right)^{-q} \right] \right\} . \qquad (8)$$

Since $j > i$, P is positively related to q. P may be high for a primate distribution or for a steep rank-size relationship; no discrimination is possible.

The index proposed here is:

$$I_N = \frac{1}{N-2} \sum_{i=1}^{N-2} \left(\frac{\log P_i - \log P_{i+1}}{\log P_{i+1} - \log P_{i+2}} \right) \left(\frac{\log(i+2) - \log(i+1)}{\log(i+1) - \log(i)} \right) . \qquad (9)$$

If the substitution $P_k = P_1 k^{-q}$ is made in (9):

$$I_N = \frac{1}{N-1} \sum_{i=1}^{N-2} \left[\frac{\log P_1 - q \log (i) - \log P_1 + q \log (i+1)}{\log P_1 - q \log (i+1) - \log P_1 + q \log (i+2)} \right] \cdot \left(\frac{\log (i+2) - \log (i+1)}{\log (i+1) - \log (i)} \right). \quad (10)$$

Cancelling out log P_1 and q from the first bracketed expression and multiplying the expressions together yields

$$I_N = \frac{1}{N-2} \sum_{i=1}^{N-2} 1 = 1.0. \quad (11)$$

Thus, for a rank-size relationship the index I_N has a value of 1.0 irrespective of the slope of the relationship. If a city size distribution has more (or more severe) cases where the primacy of city i over city (i + 1) is greater than the primacy of city (i + 1) over city (i + 2) than cases for which the converse holds, then I_N will exceed one. This result would suggest primacy. In distributions where the reverse is true, I_N will be less than one, suggesting convexity. Distributions where I_N is approximately equal to one will represent relatively balanced oscillations around a rank-size relationship.

Data were collected for all countries having five or more metropolitan areas with populations exceeding 100,000 according to United Nations data (United Nations 1980). Once again such data, even when collected by an international agency, will show great variation from country to country in terms of the way a metropolitan area is defined, the accuracy of the census, and the dates at which data were collected. Because of this, any international comparison is fraught with danger. The one consolation is that such differences are not as wide for data from cities within any one country, which is the basis for the calculation of the index. For each of these 55 countries,[2] I_N was calculated using (9) with N equaling five and also with N equaling three. A maximum of five cities was used in order to keep the sample of countries large. This strategy hardly reflects the full distribution of cities, but the largest cities traditionally have been given closest attention.

The independent variables are listed in Table 1. In many cases, the lack of available accurate estimates of the variable on an international basis necessitated use of an ordinal surrogate variable. All variables are regressed on both I_5 and I_3 for the full population of countries,

[2] Zambia, Zaire, Algeria, Egypt, Morocco, South Africa, Nigeria, Cuba, Mexico, Argentina, Chile, Brazil, Colombia, Peru, Venezuela, Canada, U.S.A., China, Japan, North Korea, South Korea, Burma, Indonesia, Malaysia, Philippines, Vietnam, Afghanistan, Bangladesh, India, Iran, Pakistan, Iraq, Saudi Arabia, Syria, Bulgaria, Czechoslovakia, G.D.R., Hungary, Poland, Romania, Sweden, the United Kingdom, Italy, Spain, Turkey, Yugoslavia, Austria, Belgium, France, F.R.G., the Netherlands, Switzerland, Australia, New Zealand, the U.S.S.R.

TABLE 1

LIST OF VARIABLES

AREA	Estimated populated area of a country (sq. km.)
POP	Number of inhabitants (per ten thousand)
POPGR	Rate of aggregate population growth (%, 1969-1970)
ENERGY	Energy consumption per capita, 1969 (kg. coal per cap.)
URBPCT	Proportion of the population living in urban areas (%)
INCCAP	Income per capita (US dollars)
AGR	Proportion of working population employed in agriculture (%)
TOTEXP	Proportion of GDP generated by exports (%)
PRIMEXP	Proportion of GDP generated by exports of primary commodities (%)
URBHIS	Length of time that the urban form of settlement has been in continuous existence [ordinal variable ranging from 1 (short history) to 5]
ELONG	The degree of elongation in the shape of the country [ordinal from 0 (rounded) to 4 (elongated)]
DEVELT	A generalized index of economic development (an ordinal ranking of component scores from the largest component in a principal components analysis of economic indicators; lowest ranks represent "higher" development)
COLON	The colonial status of the country [nominal: 0 — never a colony of another "advanced" country; 1 — a colony dominated by settlers from colonizing country (WHTCOL); 2 — a colony predominantly still settled by indigenous people (BLCOL)]
COMPLEX	An index of "social and economic complexity" [ordinal from 1 (least) to 5 (most complex), scored in an attempt to take into account the concepts suggested by Berry (1961)]
INTERDP	An index of the degree of interdependency of all kinds between the cities of the national urban system [ordinal from 1 (least interdependency) to 5 (most)]
I_5, I_3	Deviations from rank size relationship (see text)

Sources: ENERGY, INCCAP, TOTEXP, PRIMEXP from United Nations (1973); POP from United Nations (1972a); AGR from United Nations (1972b); URBPCT and all city populations from United Nations (1980); DEVELT from Cole (1980); other variables computed by the author. Area was adjusted by eliminating obviously sparsely populated areas from consideration. All data for 1970 unless noted.

using methods described by Leitner and Wohlschlägl (1980) that allow simultaneous use of data measured on ordinal and interval scales. The hypothesis to be tested is whether international variations in the variables suggested by previous studies explain international differences in the degree to which a country's largest five (or three) cities deviate in size from the rank-size relationship. The results are summarized in Table 2. For technical reasons of multicollinearity the full model could not be estimated. As a result, two strategies were tried. First, a large

TABLE 2

PRINCIPAL REGRESSION RESULTS[a]

	log I_5		log I_3	
Independent variables	"Best" regression	"Principal Components" regression	"Best" regression	"Principal Components" regression
AREA			−0.301[b] (.07)	
POP	−0.285[b] (.07)	−0.250 (.11)		−0.173 (.28)
POPGR			−0.346[c] (.04)	
ENERGY				
URBPCT				
INCCAP				
AGR		−0.119 (.57)		+0.021 (.89)
TOTEXP	−0.250 (.11)	−0.260[b] (.10)	+0.127 (.60)	+0.102 (.53)
PRIMEXP				
URBHIS	+0.060 (.75)	+0.012 (.94)	+0.162 (.57)	+0.004 (.98)
ELONG	+0.056 (.70)	+0.048 (.74)	+0.087 (.53)	+0.076 (.61)
DEVELT			+0.095 (.63)	
COLON: WHTCOL	+0.066 (.74)	−0.020 (.90)	+0.306 (.17)	−0.060 (.74)
COLON: BLCOL	+0.114 (.56)		+0.277 (.20)	
COMPLEX	+0.234 (.17)			
INTERDP				
$\bar{R}^2$	0.1377 (.41)	0.1003 (.52)	0.1891 (.26)	0.0658 (.77)

[a] Values in the table are standardized regression coefficients. The bracketed terms are a measure of the significance of the coefficients. These represent the probability that the null hypothesis of no relationship is true. We require these values to be less than 0.1 in order to reject the null hypothesis at a 90 percent confidence level.
[b] Significant at the 0.05 level.
[c] Significant at the 0.01 level.

number of subsets of independent variables were selected so that less than 10 percent of the simple pairwise correlations between these exceeded 0.5, with no such correlations exceeding 0.6. Thirty-six combinations were selected and multiple regressions were performed, using the methods of Leitner and Wohlschlägl (1980) to regress simultaneously nominal, ordinal and interval scaled data. The one combination with the largest adjusted R^2 was then selected. As a second method, a principal components analysis was performed on the independent variables. The principal components themselves could have been used as instruments for a multiple regression, avoiding multicollinearity. However, due to the theoretical dubiousness of the links between many of the independent variables and I_N, individual independent variables were selected as instruments to represent those components with eigenvalues exceeding 1.0, by selecting as representative variables those with the highest loading on each component. Two other variables with distinct patterns of loadings on all four components were included. Columns one and two represent results calculated for the first five cities, whereas columns three and four are estimated with the dependent variable calculated for only the first three cities.

All the models fail to achieve a significant level of explanation of the dependent variable. The variables postulated by various authors to date almost completely fail to explain empirical deviations from the rank-size relationship using international data, at least according to the index developed here. Two particularly important caveats should be noted, however. First, the sample of countries chosen is biased significantly in favor of more highly urbanized countries in general and highly "developed" countries in particular, due to the limitation of having five cities with populations exceeding 100,000. Although it is obviously dangerous to generalize from this sample, it does overlap significantly with the various samples of countries chosen by other authors. Second, since only the top five cities were studied, it would be misleading to apply the results to entire city size distributions. Yet once again, the studies of primacy that this attempt is designed to examine are by and large concerned with only the largest city relative to others, and the five largest cities should illustrate this relationship reasonably well.

CITY SIZES AND DEVELOPMENT

Despite the early pessimism of Berry (1961), several authors have investigated the relation between some index of the character of a city size distribution and a summary statistic of the level of economic development. Rosing (1966) found no relationship with respect to the rank-size rule. Both El-Shaks (1972) and Wheaton and Shishido

(1981) found an inverted U-shaped relationship between primacy and economic development. In each case the measure of primacy was different. El-Shaks used (7), whereas Wheaton and Shishido used (15), which can also be interpreted as a measure of inequality. In both cross-sectional studies, levels of primacy (or inequality) were found to be greatest for countries at an intermediate level of development — a result strongly analogous to the work of Williamson (1965) on inequalities in the distribution of income.

An explanation of this trend can be constructed on the basis of the common view relating interaction patterns and city size distributions, summarized by Johnson (1980) and elaborated by Ettlinger (1981). In cases where the capital city has strong links with other countries and their urban systems but poorly articulated links with the remainder of the national urban system, growth impulses received in the capital will not diffuse to secondary centers. Since most growth-inducing innovations develop in the capital city, the result is a persistent primacy characteristic of countries with a colonial history. Several rival cities of roughly equal size develop when the national urban system consists in fact of several rival subsystems having strong interactions within the subsystems, but relatively weak interactions between them. As a result, a national city size distribution will be convex. However, if the interdependencies are well-developed in a "balanced" (Johnson 1980) manner between all pairs of cities, a rank-size relationship will evolve.

It could be argued that very poorly developed countries will have low levels of interaction between cities and will thus have many autonomous subsystems, whereas "advanced" countries are highly integrated and exhibit the rank-size relationship. Intermediate countries, with moderately developed communications, often of an "unbalanced" nature, will be more primate in form. This argument, however, lacks a theoretical rationale that precisely relates imbalances in interactions to the existence of a rank-size relationship. The results from cross-sectional studies may not be isomorphic with a cross-temporal analysis of individual countries. In particular, the advances made by developed countries may in fact act to stop more newly developing countries from eventually following the same path in one or many aspects of their development. Indeed, this argument has been made with respect to the demographic transition, as well as to the evolution of dualism and underdevelopment in the Third World. The very existence of a developed group of nations with which they must interact can make it all but impossible for Third World countries to follow the same paths of change as the developed nations without incurring severe and permanent dislocation.

TABLE 3

RESULTS OF REGRESSING RANK-SIZE REGULARITY AGAINST DEVELOPMENT

$$\log I_5 = \underset{(.000)^a}{0.7549} + \underset{(0.918)}{0.00107}\ \text{DEVELT} + \underset{(0.29)}{0.00102}\ \text{DEVELT}^2 + E$$

$$R^2 = 0.053 \qquad \bar{R}^2 = \underset{(.302)}{0.0099}$$

$$\log I_3 = \underset{(.000)}{0.167} + \underset{(.581)}{0.0103}\ \text{DEVELT} - \underset{(.092)}{0.00302}\ \text{DEVELT}^2 + E$$

$$R^2 = 0.077 \qquad \bar{R}^2 = \underset{(.17)}{0.036}$$

[a] Values in parentheses represent the significance level, with a value of less than 0.1 considered significant.

Notwithstanding such criticisms, an attempt was made, using an index measuring deviations from the rank-size relationship, to see if the inverted U-shaped trends also exist. The two logarithmically transformed dependent variables I_3 and I_5 were regressed against Cole's (1980) index of development (DEVELT of Table 1) using Cole's original component scores as the independent variable. A second independent variable was formed as the square of DEVELT in order to identify any U-shaped relationship, much in the manner of trend surface analysis. The results are presented in Table 3. Again what is most noticeable is the poor level of explanation; in neither case did the percent of variance explained exceed 8 percent, and neither was significant at the 0.1 level. In the case of I_3 the positive sign on the second coefficient together with a negative sign on the third coefficient does give a hint of an inverted U-shaped distribution as suggested by El-Shaks, but investigation of the scatter diagrams (Figures 2 and 3) shows little evidence of such a tendency.

The index of deviation from a rank-size relationship as a measure of primacy does not turn out to be useful empirically, and, at least using Cole's development index, El-Shaks's results have not been replicated. This once more calls into serious question the use of a rank-size relationship as any kind of norm for discussing city size distributions.

IV. CITY SIZE AND SPATIAL INTERACTION

The growth of an urban population is the sum of internal population dynamics expressed as births, deaths, and migrations. Migration in particular has been and is the major force influencing variations in city sizes during the period of rapid urbanization in virtually every country. Ignoring these interactions in accounting for city size distributions would be myopic.

FIGURE 2

SCATTERGRAM OF I_5 AGAINST THE INDEX OF DEVELOPMENT (DEVELT)

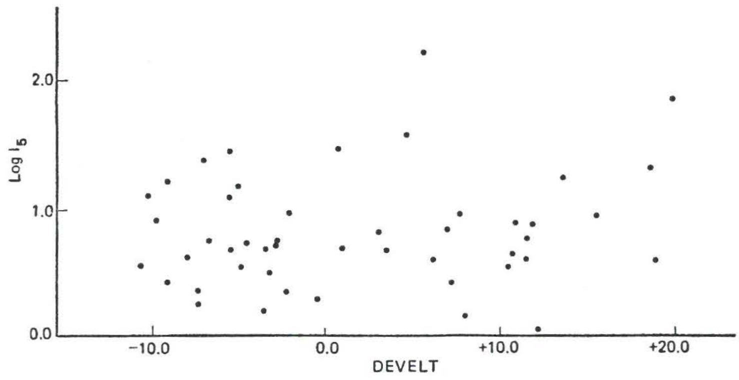
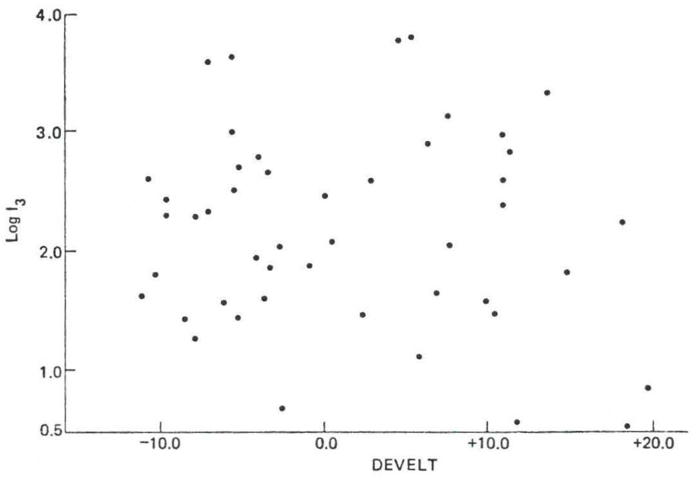


FIGURE 3

SCATTERGRAM OF I_3 AGAINST THE INDEX OF DEVELOPMENT (DEVELT)



Migration is a symptom of the spatial fluctuations of socioeconomic change, suggesting the need to draw on demoeconomic explanations. If generalizations are to be made about the types of city size distribution that may evolve, they must be couched in terms of the socioeconomic dynamics operative in a society. These dynamics are mediated by the spatial interdependencies between cities, a process that is not represented in city size distributions. Since the patterns of spatial development vary from country to country, it is of great interest to ask why a regularity such as the rank-size relationship can be observed in several very dissimilar countries. Two explanations are possible. First, a process might exist that is sufficiently general to account for a pattern of city sizes irrespective of either the relative location of the cities or other socioeconomic characteristics. In this view, national factors must operate in such a way as to dominate totally internal spatial variations in interdependencies. If this were true, empirical tests using national characteristics such as those described above would produce high levels of explanation if the correct variables were chosen. Such general factors would then suffice to classify countries into groups with characteristic distributions. The second explanation is that each particular type of city size distribution may be arrived at through any one of many different substantive processes. In this view, the empirical regularity does not indicate a common development process but rather is a symptom of an over-identified empirical phenomenon. In other words, a national urban system when viewed in certain ways (in this case via the city size distribution) may exhibit equifinality.

The choice between these two explanations is vital. The former suggests a definite one-to-one relationship between spatial economic change and city size distributions, implying that this distribution can indeed be viewed as a symptom, or indicator, of how economic change is operating. The latter explanation implies the lack of a one-to-one correspondence, suggesting that the empirical regularity is a surface phenomenon only, masking very different underlying processes. Then concentrating attention on the city size distribution would have little substantive meaning. The purpose of this section is to examine theoretical arguments in favor of each of these possibilities. They will then be posed against a third alternative: that there is no reason to expect any city size distribution to be a dominant empirical regularity.

GIBRAT'S LAW

Berry (1971) has addressed the question of relating Gibrat's Law to spatial interactions in such a way that the law in the long run evolves independently of the precise form taken by the spatial interactions. In short, if growth impulses diffuse from some points to all other key locations in such a way as to eventually stimulate growth as strongly as at the original locations, then in the long run all places will exhibit approximately the same growth rates. This is basically the argument of neoclassical regional growth theory: strong equilibrating trends in the economy will iron out original factor differentials through a price mechanism and thus set each region (and city) on the same growth path. This result would be consistent with the requirements of Gibrat's Law, where it is assumed that each city's growth rates fluctuate around the same average in some stochastic manner. The further requirement — that this growth rate remain approximately constant through time — is also captured by the dynamic equilibrium of the neoclassical conception.

The empirical validity of this theory, however, has come under severe criticism during the last decade (Richardson 1973; Holland 1975). Summarizing a lengthy debate, the types of equilibrating tendencies toward an equality of growth rates postulated by the neoclassical conception seem to be the exception rather than the rule. Even in a highly integrated capitalist economy such as the United States, persistent unevenness of development has maintained a stagnancy in some regions while others expand. Even the recent trends toward growth in the South and West seem more consistent with reversed, but still polarized, growth inequities than with a trend toward neoclassical equilibrium. Such inequities are only reinforced in situations where different modes of economic production attempt to coexist within one economy, exhibiting a "dualistic" or "neocolonial" relationship (Lipietz 1977).

Sheppard (1978, 1980) has argued that whether the spatial configuration of socioeconomic activities evolves in an equilibrating or disequilibrating manner has as much to do with the dynamic interdependency between interactions and locational patterns as with any initial endowment differences between locations. To ignore such dynamic relations, as has so often happened in theories of regional and urban system change (typified by the city size distribution literature), is to neglect a powerful component of any complete logic of explanation. The neoclassical model represents one view: interactions are so strongly shaped by equilibrating forces that they may be ignored. Other conceptions, however, produce different conclusions.

As a final comment on the empirical validity of Gibrat's Law, the spatio-temporal pattern of city growth rates in the United States bears examination. Given the close correspondence of the American city size distribution with the rank-size rule, and given the highly integrated nature of the economy, one might expect the assumptions of Gibrat's Law to apply here. However, the statistical independence hypothesized for city growth rates simply does not hold up (see Madden 1956 and Vining 1974). It has been characteristic of the evolution of the American urban system that individual cities will show a strong correlation between growth rates in successive decades — rates that diverge greatly from the system-wide average. Los Angeles (California) and Hudson (New York) are particularly dramatic examples. There are also strong spatial associations, for example the current trend of decline in large northeastern cities countered by stagnation in the South and growth in the West for cities of a similar size (Berry and Dahman 1977). Thus a reliance on Gibrat's Law does not seem empirically well founded.

CITY SIZE AND MIGRATION MODELS

Okabe (1979b) has examined the relation between city size distributions and a non-neoclassical migration model. The results of his work are worth summarizing, since they illustrate how city growth rates depend crucially on the nature of the interaction mechanism. Okabe develops a purely demographic model:

$$DP_i(t) = \alpha_i(t)P_i(t) + \sum_{j \neq i} M_{ji}(t) - \sum_{j \neq i} M_{ij}(t) \qquad (12)$$

where $P_i(t)$ is the population of city i, time t; $DP_i(t)$ is the change of this population at time t (its time derivative); $\alpha_i(t)$ is the rate of change due to natural increase; and $M_{ij}(t)$ is the number of people migrating from city i to city j at time t. Migration is modeled as a flow corresponding to the gravity model:

$$M_{ij}(t) = G_iP_i(t)^{\beta_i}P_j(t)^{\gamma_i}d_{ij}^{-K_i} \qquad (13)$$

where G_i, β_i, γ_i, and K_i are constants.

If $\alpha_i(t)$ is positive or negative, and if β_i equals γ_i equals 1, it is possible for the city system to evolve to a state where all cities grow at the same rate (implying persistency in the city size distribution). However, this state will not exist for more than an instant in time. Indeed it is only if β_i plus γ_i equals 1 that a state of simultaneous balanced growth can continue for all cities. This is a knife-edge equilibrium; it cannot be converged to by the system from any state of unequal growth rates, and the slightest deviation from equality will lead to larger and larger deviations in a cumulative causative sense.

Sheppard (1977) and Ledent (1978) have shown similar, though less complete, results, leading to the conclusion that interactions between cities may change in such a way as to fuel ever-increasing differences in city sizes. It should be noted that Okabe's research is deterministic, whereas Gibrat's Law refers to city growth rates that deviate randomly around some constant expected value. Okabe's model may also be viewed as the expected, or mean, outcome of a stochastic process (Sidkar and Karmeshu 1982), so it is reasonable to equate the (minimal) probability of equal growth rates for cities in Okabe's work with the probability of Gibrat's Law holding for observed urban systems linked together by this type of interaction model.

Gravity-like models of migration have performed as well empirically as neoclassical models. The gravity-like format also allows for consideration of vacancy- and skill-related aspects of labor markets not considered in most neoclassical models (Cordey-Hayes and Gleave 1973). Thus the choice of theory is still an open question, and the theory chosen will affect conclusions about the nature of city size distributions.

INTERACTIONS AND URBAN GROWTH

Research showing that evolving interaction patterns can bring about systematically unequal and diverging urban growth rates has damaging implications for any one-to-one identification of a city size distribution with some spatial economic process. Indeed, two fundamental implicit assumptions about the nature of interdependencies are challenged. The first is the persistence of "balanced" interactions, which has been suggested as necessary for a simple account of how rank-size relationships can evolve (Johnson 1980; Zipf 1949). Having identified the interdependencies through which growth impulses may flow, it must be assumed that as these links change in response to the evolving urban system they would not alter in such a way as to destroy this balance. Okabe's results show that this assumption is far from inevitable, calling into question the existence of a unique explanation of the rank-size relationship, or indeed of any city size distribution, because changing city growth rates make it difficult for the aggregate city size distribution to remain unchanging. A city size distribution may maintain a constant shape over time, as some cities grow while others contract. However, the likelihood of this happening as a result of a unique type of process that is equally applicable in a number of countries seems to be low. Rejection of this assumption would favor the explanation based on over-identification.

The second assumption commonly made concerns the feedback effects of increased interaction on urban growth. Many consider interurban interdependencies beneficial for urban economic prosperity, but interactions may have detrimental effects. For example, cities in the periphery of an economy may benefit little from being linked to the core metropolitan areas. Instead, skilled migrants are frequently drawn from the peripheral cities. Furthermore, any flows of investment in the reverse direction can set up capital intensive activities exploitative of local resources, the benefits of which primarily leak back to the owners of capital in the core. In such a case, high levels of interdependence are far from beneficial (Stöhr and Tödtling 1979), since the feedback effects from interaction are cumulative causative rather than equilibrating. Another example of this occurs when the internal terms of trade between cities turn increasingly against some cities, again widening rather than reducing economic inequalities.

Solutions based on vague notions of interaction are not enough. To understand how the urban system came about (and to discuss implications of further changes) demographic and economic factors must be integrated, drawing upon those theoretical paradigms that most adequately analyze the on-going system. A potentially fruitful source may be found in the production-oriented approaches of the Cambridge (England) school of political economy, which maintains a strong tradition in the classical economics of Marx, Sraffa, and Ricardo (Sheppard 1980). City size distributions are just one simple aspect of the urban system and cannot be easily analyzed without taking into account the social processes and spatial configuration of the national economy.

WHY THE RANK-SIZE RULE?

The implications of the previous section suggest that since there is no one-to-one identification of urban system change and city size distributions, no particular city size distribution would be more common than any other. However, certain characteristic types, notably the rank-size relationship, have been frequently identified, possibly because the rank-size relationship can be arrived at from a wide range of specific situations.

This problem is approached by discussing the most reasonable guess about the distribution of an urban population among cities of different sizes, giving each possibility as much chance as is reasonable of being true. Let p_i represent the proportion of the national urban population to be found in city i, where, summing up over all cities:

$$\sum_{i=1}^{N} p_i = 1.0. \qquad (14)$$

The universe of all possible city size distributions for N cities is the set of all possible combinations of p_i consistent with the accounting definition (14). If nothing was known about the urban system, the most reasonable guess would be $p_i = 1/N$ for all i.

This result can be derived analytically by maximizing the amount of prior uncertainty; where uncertainty may be defined as (Tribus 1969):

$$H = -\sum_{i=1}^{N} p_i \log p_i. \qquad (15)$$

If (15) is maximized subject to the constraint (14), then the solution $p_i = 1/N$ is obtained.

Virtually every contemporary urban system has a hierarchical structure. Thus a constraint or statement of prior information could be included regarding the degree to which it is hierarchically structured. One way would be to make a hierarchical index depend on the proportion of the total urban population in the r-th largest city p_r, weighted by the rank of that city, such that when the cities are fairly equal in size the weights give rise to a large number for the hierarchical index.

One such index is:

$$\frac{1}{N} \sum_{r=1}^{N} p_r \ln(r) = K_1. \tag{16}$$

If all the urban population is concentrated in one city, K_1 equals 0. If it is equally spread among cities, K_1 equals $N^{-2} \sum_{r=1}^{N} \ln(r)$. Values in between represent different levels of hierarchical inequality in city size, and K_1 would be chosen as a constant representing the hierarchical nature of any particular urban system.

If (15) is maximized subject to (14) and (16) the following equation is obtained, representing the most reasonable guess at the size distribution of cities:

$$p_r = p_1 r^{\mu} \tag{17}$$

which is a restatement of the rank-size relationship (1). In (17) μ must be negative because p_r equals $p_1 r^{\mu}$ which is less than p_1, and r is greater than 1. As K_1 decreases, μ decreases, implying an increasingly steep rank-size relationship as the hierarchical index becomes stronger.

Starting with only the two pieces of prior information — that the p_i sum to one (which is true by definition) and that the degree of hierarchical structure in a city size distribution may be described by (16) — the best guess as to the shape of the distribution is the rank-size relationship (17). In short, no specific theory is necessary to derive the rank-size relationship; rather it represents the most reasonable guess contingent on some basic prior information. This result tends to support the argument that the rank-size relationship is not related to any particular process, but may be arrived at in many different ways. (See also Curry 1964.)

Equation 16 is only one way to calculate a hierarchical index. Other examples are:

$$(1/N) \Sigma p_r r = K_2 \tag{18}$$

and

$$(1/N) \Sigma r \log (p_r) = K_3. \tag{19}$$

Maximizing (15) subject to (14) and (18) yields:

$$p_r = p_1 e^{\phi(r-1)} \tag{20}$$

whereas maximizing (15) subject to (14) and (19) yields:

$$p_r = p_1 \exp\{\psi(r\, p_r^{-1} - p_1^{-1})\} \tag{21}$$

with both ϕ and ψ being negative constants. Undoubtedly other hierarchical indices may be derived giving rise to best guesses of city size distributions. Thus from different simple starting positions a variety of most reasonable city size distributions can be deduced. In each case there is no unique theory for a unique distribution, underlining the difficulty of making inferences from any city size distribution to the type of spatial socioeconomic process generating it. Once again the over-identification hypothesis is supported.

The variety of possible distributions suggests a need to examine why the rank-size relationship has become the norm. As noted above, Quandt (1964) found it difficult to associate unambiguously the rank-size relationship with the classic empirical example of United States cities. No attempt appears to have been made to determine whether the rank-size relationship is more common internationally than any other shape for national urban systems. The work of Quandt and Rosing (1966) suggests that any firm conclusions would be difficult. If researchers had started with a different transformation of population and ranks, then a different straight line might have been observed leading to a different norm. The rank-size norm cannot even be argued to be a norm of capitalist or socialist development patterns. In Berry's 1961 study, rank-size relationships were found in only 6 of 20 western developed countries, one of two developed socialist countries, and 5 of 16 Third World countries. It is difficult to find any substantive reason for choosing this yardstick other than the sociology of comparative urban research.

V. CONCLUSIONS

The implications of this review for the rank-size relationship are important. First, this distribution has patently failed to perform as an empirical norm. Observed deviations from this relationship cannot be accounted for empirically; the extent to which other empirical studies performed better than those carried out for this study may be precisely due to the fact that they did not rigorously use the rank-size relationship as a norm. Second, when spatial interactions between cities are allowed for in a dynamically evolving social system, there does not seem to be any justification for the rank-size rule on theoretical grounds, because spatial economic growth processes seem to be disequilibrating in nature. Overwhelmingly, the theoretical evidence favors explaining the rank-size relationship as a profoundly over-identified concept. There is also little evidence to suggest that other city size distributions can be better identified with a unique set of social processes, for reasons that are not difficult to isolate. City size distributions, in only portraying restricted aspects of an urban system, provide a description that eliminates all locational and substantive socioeconomic information.

Nevertheless, in some restricted circles there continues to be a fascination with city size distributions as some fundamental concept to be explained. The power of the concept must depend on being able to show a one-to-one identification with processes, but this has not been the case. A principal methodological conclusion, then, is that the rank-size relationship and other city size distributions should be treated as derivative concepts: patterns that depend on the particular substantive processes of urbanization and development. Comparisons of city size distributions can be misleading, since the same pattern may be a symptom of very different situations. To treat such patterns as an index of the performance of a national or sub-national economy may be dangerous.

Such distributions still may be useful, however. For example, it may be very informative to know that a society has gaps in its urban hierarchy because a certain size class of city is absent or overly abundant. However, whether or not that constitutes a problem will depend on the situation at hand. For example, a Third World country with a primate distribution may be missing intermediate cities, but conceivably this might be good. Increasing integration of the urban hierarchy could mean that, as a result of polarized uneven development, certain people and regions would tend to a state of persistent economic stagnation or decline. If so, then a better strategy might be to give those regions more autonomy (Stöhr and Tödtling 1979), even though doing so may lead to an "oddly" shaped city size distribution. Questions such as this must be approached from an accurate theoretical understanding of the processes involved before the importance or desirability of certain city sizes can be determined.

The rank-size relationship should not be treated as a norm for national settlement policies. Until a desirable mode of social, political, and economic development is agreed upon, and unless that mode uniquely specifies a "best" city size distribution, such normative claims may do more harm than good. It is better, perhaps, to concentrate on the processes themselves, rather than on poorly identified symptoms of those processes. After all, no amount of tinkering with city-size distributions may be able to make up for the fact that the problems are caused by the nature of the socioeconomic system itself. Indeed, if tinkerings reinforce a poor social system, they do more harm than good.

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The Role of Emigration and Migration in Swedish Industrialization

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ABSTRACT A numerical general equilibrium model has been designed to describe Swedish demoeconomic development during its first phase of industrialization, the pre-World War I period. Three dynamic simulations analyze the role of rural-to-urban migration and emigration in Swedish industrialization and some results are presented concerning their importance for the development of the Swedish economy.

I. INTRODUCTION

Urbanization and development pose some of the most challenging modern problems. The historical experiences of developed countries may provide a better understanding of the interaction of economic growth and urbanization in developing Third World nations. An analysis of Swedish demoeconomic development in particular may give further insight into the interaction of economic and demographic variables.

Sweden's economy is small and open. In the 19th century, foreign demand for Swedish products contributed to a per capita income in Sweden that was among the highest in the world. The openness of the economy played a crucial role in demographic development as well. Industrialization in Sweden coincided with a period of mass emigration to North America of such magnitude that it affected the population growth pattern. Between 1870 and 1914 Swedish population increased from 4.2 to 5.6 million people, but at the same time emigration drained the country of roughly 1.1 million people. Substantial rural-to-urban migration also took place within Sweden, increasing the proportion of the population living in towns and cities from 13 to 31 percent

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during the prewar period. This extensive redistribution of population had a large impact on economic growth, but the linkage between demographic and economic factors cannot be captured in a simple, one-way direction. Causality in both directions must be taken into account, particularly when migration plays a role.

Within a general equilibrium framework, it is possible to reveal some of the important mechanisms in the rather complicated interplay among the variables causing demoeconomic development. The model for this study is a computable general equilibrium model within the tradition of multisectoral growth models. It is designed to fit Swedish prewar development and to enable counterfactual analysis. This paper reviews the Swedish model briefly. Section III comments on the data base, estimation procedure, and validation, and Section IV displays some comparative static experiments. Section V evaluates the capability of the model in replicating Swedish demoeconomic development between 1871 and 1890 before examining the counterfactual simulations which address the role of external and internal migration in Swedish industrialization.

II. THE MODEL

The model used for the analysis has been presented in detail in Karlström (1980); only a brief overview is given here.

SECTOR DIVISION

The structure of the model reflects the duality of a traditional agricultural sector and a more modern industrial sector. To capture adequately some of the mechanisms that have driven Swedish economic growth, the model is extended beyond a two-sector analysis (see Table 1). The traditional rural sector remains one unit, agricultural industries. The modern sector is divided into four: export-oriented industry, homemarket-oriented industry, services, and building and construction. The export-oriented sector consists of industries that primarily meet demand from abroad, such as wood, mining and metal, and paper and pulp. The homemarket sector covers the remaining manufacturing industries, mainly consumer goods. The services sector is an aggregate of various kinds of services: commerce, public administration, domestic services and services of dwellings. The building and construction sector accounts for a large share of the investment. These four non-agricultural sectors are treated as the urban sector in the model.

One specific feature of Swedish industrialization, however, is important: industries, to a great extent, were located in rural areas and not in towns and cities; the industries that initiated the new epoch —

TABLE 1

THE PRODUCTION SECTORS IN THE MODEL AND THEIR EMPIRICAL COUNTERPARTS

Subscript	Sector[a]
1	Agriculture, forestry, and fishing
2	Export-oriented industry (mining and metal, wood products, pulp, paper and printing, food products)
3	Homemarket-oriented industry (textile and clothing, leather, hair and rubber, chemical industries, power stations, water and gas works, stone, clay, and glass)
4	Services (commerce and other services, public administration, transport and communication, services of dwellings)
5	Building and construction

[a] Sectors 2-5 are sometimes treated as one group in the model, namely the urban sector (U), in contrast to the agriculture sector (A).

wood, mining and metal — were rural-based. In 1896, for example, 99.9 percent of workers in the mining and basic metal industry and 42.5 percent of workers in the metal manufacturing industry worked in rural areas. As a result, a typical feature of the Swedish urbanization process was the creation of new and larger towns through the growth of population agglomerations around rural industries. Thus urbanization in Sweden did not only reflect the movement of population from rural areas. This point is important when interpreting the model. In the model all nonagricultural activities are characterized as urban. Thus migration and urbanization reflect the total reallocation of population caused by industrialization, but the model results cannot be given a spatial/geographical interpretation.

PRODUCTION FUNCTIONS

In the Swedish model output is assumed to be a function of two types of inputs: resources and intermediate goods. In the four urban sectors, capital and labor are the two resources used. They are assumed to be substitutable factors, which are combined in a conventional neoclassical production function. To reflect the stylized fact that labor's share of value-added changed during the period of study, constant elasticity of substitution (CES) functions have been chosen for each of the urban sectors. In agriculture, land is treated as a factor of production in addition to capital and labor. Capital and labor are combined in a CES function, which is nested in a Cobb-Douglas function. The requirement for intermediate resources is given by fixed input-output coefficients.

Historical evidence indicates that technological progress had an extensive growth-creating effect on the economy of Sweden. It was not neutral but labor-saving (Jungenfelt 1966; Åberg 1969) in both the industrial sectors and the agricultural sector. The model formulation captures these characteristics; the technological factors are sector- and factor-specific and grow at different rates over time.

FACTOR MARKETS

The model assumes that firms maximize profits and that there is perfect competition in all product and factor markets. Therefore, the factors of production are paid in proportion to the value of their marginal products. All resources are assumed to be fully employed; thus no underemployment or unemployment occurs in the model. Instead, unemployment during certain periods of time is reflected by a downward adjustment of the wages.

When describing the factor markets, the distinction between rural and urban areas is important. In a pure general equilibrium model the labor force is allocated in each period of time in such a way as to equalize wages. In our model, which reflects conditions in Sweden, it is necessary to elaborate on this point.

First, there are two labor markets in the model, one rural and one urban, tied together through net migration of the population from rural to urban areas. Thus there are also two supply functions of labor. The supply is simply a certain share of the population in the two areas. But this share (total aggregate labor participation rate) is decomposed to capture different age and sex structures, as well as different sex-specific labor participation rates in rural and urban areas. With two labor markets, two wages will be determined so that supply and demand are matched in both markets.

The assumption of one urban wage, however, does not reflect the large differences that have been observed among wages in the sectors constituting the urban sector (see Figure 1 in Karlström 1980, p. 10). Therefore, the second modification of the model represents the labor force as always being allocated in the urban factor market so that a certain exogenously determined wage structure in the urban sector remains stable over time. The difference in urban sectoral wages may reflect, for example, different shares of skilled labor.

These two constraints on the wage equalization mechanism put into a general equilibrium framework give more realism to the model but do not really move it away from the neoclassical theory. Even though the labor force is not perfectly mobile, through migration it will be reallocated from a low wage sector to an urban labor market with higher wages (with migration acting as a function of relative wage differences). By specifying an urban wage structure that is stable over time, the relative increase in wages between two years is equalized among the urban sectors instead of assumed to be equalized in each period of time.

Total savings (endogenously determined in the model) make up the total gross investment. Investment is divided between rural and urban areas. Difficulties in modeling the imperfect capital market which prevailed in Sweden during the prewar period, as well as problems in formulating an empirically reasonable function of investment behavior, have made it necessary to determine the share of total investment allocated to the rural area exogenously. Within the urban sector the entire urban capital stock, not just new investments, is assumed to be completely mobile. Between the four urban sectors capital is allocated so that an exogenously given structure of the sectoral rates of return will be fulfilled in each period of time. (Many reasons exist to expect sectoral differences in the rate of return on capital, e.g., different risks connected with investments, different degrees of monopolization, and different average sizes of firms.)

HOUSEHOLD DEMAND AND INCOME

Consumption demand and its patterns have long been suppressed in the explanation of the long-run growth process of an economy. In some empirical studies, however, the importance of final demand and its structure have been stressed. When income grows, the budget share of different commodities changes due to both price and income effects. Changes in relative prices affect the allocation of expenditure. When per capita income grows, the marginal increase in demand for luxuries is larger than that for necessities. This so-called Engel effect has been a common feature of the growth process in various types of countries at different levels of development, and Sweden is no exception (Parks 1969).

The model endogenously determines commodity prices and the demand for different commodities, as well as capturing the Engel effect. Thus prices are allowed to influence demand and demand to influence prices. The selected form of demand functions is the linear expenditure system (LES). One demand system is specified for the urban area and another for the rural, allowing investigation of the importance of taste differences between rural and urban areas.

The expenditure on consumption is what remains of income after deductions for taxes and savings. Already in the 1870s a large range of taxes and duties existed in Sweden, including different property taxes, a proportional income tax, and a personal tax for adults independent of income. In the model, the 19th century taxation system is roughly described by a proportional tax on capital and wages. In addition to other incomes, the rural household also receives remittances from previous emigrants. These remittances have often been neglected in studies of this period, but they are substantial. In the Swedish case the amount fluctuates around an average of 0.5 to 1 percent of the Swedish national product.

SAVINGS AND INVESTMENT

Savings have two sources: private and government. Private savings are derived from labor and capital incomes in both agricultural and urban sectors. Income covering the basic needs of the population is subtracted from the base of savings. The savings shares are determined outside the model; the savings ratio from capital income is assumed higher than from labor income. Government savings remains after government expenditures (exogenously determined) are deducted from government income. This income has three sources: taxes, customs duties, and foreign borrowing (exogenously determined). Thus total savings is determined endogenously in the model and in turn determines investment in each period of time. Gross investment is added to the capital stock after deduction for depreciation, as previously described.

EXPORTS AND IMPORTS

Exports have played a crucial role in Sweden's economic development. A characteristic feature of the structural change in exports is the transition from exporting mainly raw materials and less refined commodities to exporting more manufactured products in both agriculture and industry. Imports, like exports, initially concentrated on only a few products, but as the economy grew imports became more and more diverse.

In order to allow for both exports and imports in the sectors, a finite elasticity of substitution is assumed between domestically produced commodities and those supplied by foreign producers. Relying on this assumption, separate export and import functions are formulated for each of the trade participating sectors. Exports from the agricultural and the homemarket-oriented sectors are determined by the ratio between domestic production costs and world market prices and the increase of world markets. World market prices are exogenous in the model because Sweden is assumed to be a small country which cannot influence world prices. Domestic production costs are endogenously determined. The export-limiting factor of the export-oriented sector is assumed to be the growth of the capacity of the industry. Exported products are assumed to be sold at world market prices on the home markets. Technically, exports of this sector are determined as a residual in the balance of payments — meaning, for instance, that the growth of the capacity of the export industry will implicitly be the limiting factor on exports through the development of other variables in the model. The imported share of the domestic supply on the home markets is determined by the relationship between domestic production costs and world market prices.

MIGRATION AND POPULATION GROWTH

The differences in economic forces between the agricultural sector and the more modern industrial sectors caused a reallocation of the most mobile production factor — the labor force. Industrialization stimulated migration, as can be seen by the strong relationship between the increase in migration and the industrial breakthrough. Population movements, however, were not only directed to Swedish growth centers but also to North America. Emigration occurred in waves (Figure 1) as a result of differences in economic performance between the United States and Sweden (Hamberg 1976).

In the model, migration is a function of the relative wages between rural and urban regions. A Harris-Todaro approach is used even though the model assumes full employment. On the other hand, wages in the model are fully mobile, adjust to differences in supply and demand, and therefore reflect implicitly, by downward adjustment, excess supply or unemployment. For the results presented in this paper, emigration is exogenously determined.

The natural increase of population is also determined outside the model. Making natural increase sector-specific in the model captures the big differences in the demographic variables between rural and urban regions. Urban areas had higher crude birth and death rates during the initial years of industrialization but these rates declined faster in the urban than the rural areas. The patterns of change in these two areas were similar, although their magnitude differed. Demographic dualism between rural and urban areas is thus reflected in the initial differences of the demographic variables rather than in patterns of change.

DYNAMICS

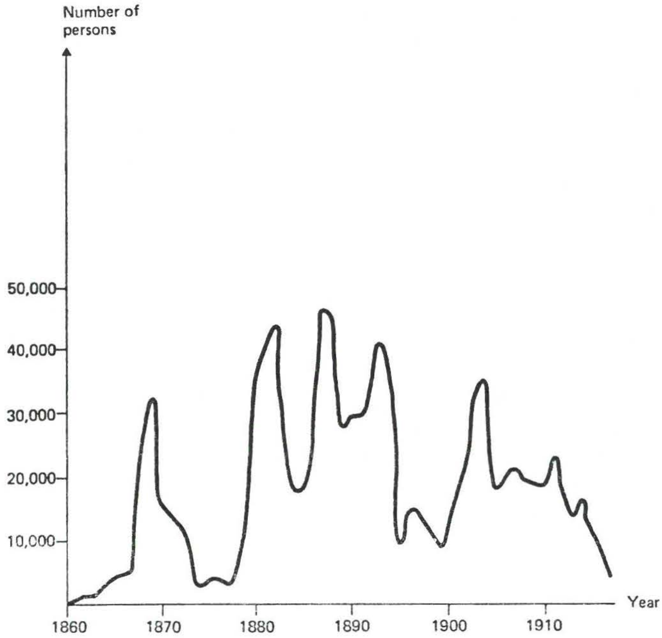
For each period of time the model is solved so that a static equilibrium is reached. The growth process is thus a sequence of static equilibria generated mainly by the following variables: (1) capital growth, determined by endogenously generated savings; (2) productivity growth, which is sector- and factor-specific at rates determined outside the model; and (3) population growth, with total population determined by fertility, mortality, and emigration and regional population determined endogenously to the extent that rural-to-urban migration is generated by the model.

III. DATA BASE AND VALIDATION

An extensive data base has been put together for the implementation of the model. In this section a brief overview of the principles of the data base, model estimation, and validation are given. (For a detailed discussion see Karlström, forthcoming.)

FIGURE 1

REGISTERED EMIGRATION FROM SWEDEN TO NON-EUROPEAN COUNTRIES, 1860-1915



Source: Runblom and Norman 1976, p. 117.

The first decision required for the numerical implementation concerns time. The 1870s are commonly looked upon as the beginning of Swedish industrialization; the year 1871 is picked for this study because some crucial data series do not exist before that year. This year also exemplifies both an upswing of the business cycle — although the peak of the general business activity is still to come (see Jörberg 1961) — and a downswing of the first emigration cycle.

For a system as large as this model, estimating all the coefficients is an overwhelming and even impossible task. For many of them no time series exists. Instead, because of the historical nature of the study and the nature of a computable general equilibrium model, cruder methods must be used.

The data base must be consistent. Available data has been assembled in the form of input-output tables for six years (1871, 1880, 1890, 1900, 1910, and 1913), the information coming primarily from Johansson (1967) and Krantz and Nilsson (1975). These are the principal source of base year estimates of the coefficients. Together with time-series estimates of some coefficients, sometimes from different studies, all of the coefficients have been estimated. The solution algorithms used are developed by Andras Pór (Bergman and Pór 1982).

The base solution in 1871 is the first step in validating the model. Because the parameters are estimated so that the data base should be reproduced in the base year solution, this step is only a technical validation of the model. Since the model displays a rather complicated nonlinear relationship between variables capturing different possibilities of behavioral choice, sectoral production, distribution of factors of production, and consumption patterns could easily differ from actual base year data. Yet in the base year all commodity prices are assumed to be unity, and none of the prices differs more than 1 percent from unity in the model replication. The rest of the endogenous variables are close to actual base-year data with the exception of one which differs only slightly more than 1 percent. Thus the model fulfills the criteria of technical validity. The next two steps of validation — sensitivity analysis and dynamic base-run solution — are discussed in the next sections.

IV. COMPARATIVE STATIC EXPERIMENTS

There are at least two reasons for carrying out comparative static experiments. First, by undertaking parameter changes and exploring the equilibrium effect on the model, further insights will be gained about the behavior of the model and its validity. Second, some of the comparative static experiments are interesting from the point of view of policy analysis, because they reveal the static, total effect on the economy of changes in some policy variables discussed by 19th century Swedish politicians. These experiments show how important it is to analyze economic policy within a general framework rather than a partial one. The experiments are organized into two groups: rural and population experiments.

RURAL EXPERIMENTS

Rural-to-urban migration is a consequence of the interplay between agricultural and industrial development. In this process the effect of different rural development policies is not obvious. There is no automatic link between an increase in productivity and an increase in rural wages or income. Even though the marginal productivity of labor increases after a certain policy change, the effect on the agricultural wage can be reversed because of a new, lower equilibrium price on agricultural goods. It is thus not only the partial effect within the agricultural sector that is of interest when evaluating different agricultural policies, but also the indirect effect via the linkages between the rural sector and the rest of the economy.

TABLE 2

COMPARATIVE STATIC I: RURAL EXPERIMENTS (PERCENTAGE DIFFERENCE COMPARED WITH BASE RUN)

Variable	Base Run	Experiment I	Experiment II	Experiment III	Experiment IV
Output agriculture	601.00	1.9	0.9	6.9	6.9
Wage in agriculture	0.26	−2.0	−0.2	−7.4	−0.1
Domestic price of agricultural goods	1.00	−2.5	−1.2	−8.5	−3.0
Gross investment	72.20	−0.9	−0.6	−2.9	2.0
Gross domestic product	966.7	0.5	0.2	1.5	2.7
GDP per capita	0.230	0.4	0.4	1.3	2.7
Migration pressure[a]	1.00	6.1	2.0	14.8	2.0

[a] Migration pressure is an index of the relationship between wages in rural and urban areas, set to 1 in the base run.

In the Swedish case, agricultural output per worker grew at an annual rate of 1.19 percent during the pre-World War I period, due to an increased output per unit of land (through more capital intensive production) and a growth in the land area per worker. The cultivation of new land played an important role. Against this background four rural experiments have been carried out — increases in the amount of cultivated land and agricultural capital stock, an increase in the efficiency of labor, and a change in world market prices. Some of the results of the rural experiments are summarized in Table 2.

Rural Experiment I: Increase in Land Acreage. An exogenous increase in the acreage of land by 10 percent results in a 1.9 percent higher output of agricultural goods. At a specific period of time, the capital stock and labor force is fixed in the rural area (migration occurs between two static solutions). Thus the marginal productivity of labor, as well as of capital, will increase. The higher supply on the agricultural market presses down the price. The new equilibrium price is 2.5 percent lower and outweighs the increase in marginal productivity, causing a wage decrease of 2 percent. The rate of return on capital and land rent decreases. Therefore the net income of rural households goes down, but not enough to counter the positive effect on demand of agricultural goods by the lower price. Rural demand increases by 0.3 percent.

The beneficiaries of the enlarged area of cultivated land are the urban, not the rural residents. Urban disposable income increases by 1.8 percent as a result of increases both in the demand for intermediate goods from agriculture and in the purchasing power of the urban region caused by the lowered price of agricultural goods. The urban households spend a larger share of their increased income on urban goods than on agricultural goods, thus strengthening the tendency to income differences. This whole process results in a widening of the relative difference in wages between rural and urban areas (urban wages increasing by 1.4 percent) and consequently in higher rural-to-urban migration.

Rural Experiment II: Increase in Capital Stock. A 10 percent increase in the capital stock of agriculture results in a 0.9 percent higher output, counterbalanced by a price reduction in the agricultural commodity market. Agricultural prices decrease by 1.2 percent and wages in agriculture by 0.2 percent. The effect in the urban sectors is similar to the consequences of an increase in land, but not as pronounced. Urban households face a wage increase of 0.7 percent, thus causing somewhat higher rural-to-urban migration.

Rural Experiment III: Increase in Labor Productivity. In this experiment the efficiency of labor is increased by 10 percent, by increasing the efficiency parameter in the production function. This increase results in a 6.9 percent higher output, agricultural production increasing from 601 Swedish Kronor (SKr) to 642.3 million. Such a large increase in supply causes dramatic changes in the commodity market. Parts of the increased supply are exported. When the domestic price level decreases, Sweden's relative prices are improved and exports increase. At the same time, agricultural imports go down because, in relative terms, imported goods become more expensive. Increased exports and decreased imports counteract the domestic agricultural commodity market, but a new equilibrium price is then established, 8.5 percent below the "base run" price. The price effect is large enough to counterbalance the increased productivity of labor. Wages decrease by roughly 7 percent.

The effects in the urban sector are very much the same as before; lowered agricultural prices augment the relative purchasing power. The increased agricultural demand for intermediary goods and the larger urban demand pushes up the income of urban households. Wages and rate of return on capital go up by a little more than 4 percent. Thus motivation to migrate increases, and a more rapid allocation of population occurs.

This experiment displays more or less the same picture as the previous two. Improvement in agriculture by increases in acreage, capital stock, or labor productivity makes the situation worse for the rural population because the increased supply faces a relatively inelastic demand and the price falls. Thus an agricultural development policy should be combined with a demand-increasing policy, as illustrated in the next experiment.

Rural Experiment IV: Increases in Labor Productivity and World Market Price. Higher demand for agricultural goods is simulated through an increase in foreign demand. The world market price was increased by 10 percent, while keeping the higher labor productivity discussed in the previous experiment.

A higher world market price initially has two effects on the economy: (1) exports increase, because Swedish goods are becoming relatively cheaper in the world market, and (2) prices of agricultural goods tend to rise in the domestic market, because the imported supply in this market is becoming more expensive. The model simulation confirms these effects. Exports of agriculture increase by 40 percent, caused not only by the higher world market price but also by increased labor productivity, which decreases costs of production. The effect on exports of increased productivity alone is around 25 percent. The new equilibrium price is 3 percent lower than the base solution. With the productivity increase alone, the price decrease is 8 percent.

The effect of increased exports on rural wages almost outweighs the effect of increased labor productivity; rural wages decrease by 0.1 percent. The aggregate effect on the economy is significant, with gross domestic product increasing by 2.7 percent.

POPULATION EXPERIMENTS

The role of population increase in the development and urbanization process is very complicated. Increased population adds to the labor force and thus affects the supply side of the economy. It also affects the demand for commodities and factors of production by enlarging the domestic market. The net effect on regional incomes, migration, and development of these interacting forces is not obvious. They have to be analyzed in a general equilibrium framework.

In the Swedish case emigration had a large impact on the evolution of the national population. Emigration started in the 1850s, and the first big wave of emigration ended before industrialization began to expand in the 1870s. The combined forces of restrained religious freedom and bad harvests in the 1860s caused this first wave. (For a discussion of Swedish emigration see Runblom and Norman 1976.) In 1871 the population would have been 5 percent higher if no emigration had occurred. This increase includes not only those who emigrated but also the expected population growth among the emigrants (Hofsten and Lundström 1976).

The comparative static experiments presented in this section examine the effect of 5 percent more people in the 1870 economy of Sweden. By choosing this amount of population increase, some of the consequences of emigration can be indicated. In the first experiment the total increase of population is added to the rural population; in the

TABLE 3

COMPARATIVE STATIC II: POPULATION EXPERIMENTS (PERCENTAGE DIFFERENCE COMPARED WITH BASE RUN)

Variable	Base Run	Experiment I	Experiment II	Experiment III
Total population	4204.20	5.0	0.0	5.0
Rural population	3043.8	6.9	0.0	3.3
Urban population	1160.4	0.0	0.0	9.1
Migration pressure	1.0	10.5	17.6	−6.0
Output agriculture	601.0	4.8	4.8	2.4
Gross investment	72.0	0.3	−0.1	5.4
GDP	966.7	1.4	1.1	5.5
GDP/capita	0.230	−3.4	1.1	0.4

second experiment the population is unchanged from the base run, but the labor participation rate is increased so that the agricultural labor force is the same in the two experiments. In the third experiment the 5 percent increase in population is equally distributed between rural and urban areas. Table 3 summarizes the results of the three population experiments.

Population Experiment I: Increase in Rural Population. The addition of 5 percent of the total population entirely to the rural population increases the latter by 6.9 percent. The rest of the parameters and the exogenous variables are the same as in the base run, so the increased population and the lower price on agricultural output results in a new equilibrium wage, 8.1 percent below the wage in the base solution.

The increased rural population, however, has a reverse effect on urban wages, an increase of 2.1 percent, resulting from a reallocation of labor among the urban sectors caused by price and income changes. Thus development in the rural as well as the urban regions has the same effect on rural-to-urban migration: the flow is increased. The relative wage differentials are increased by 10 percent. Gross domestic product increases by 1.4 percent to 980.2 million SKr, but this increase is not enough to balance the increased population, so per capita income decreases by 3.4 percent.

Population Experiment II: Increased Labor Participation Rate in Agriculture. The effect on the economy of the previous experiment can be divided into two parts: the effect via higher employment and the direct effect on demand because of more population (subsistence consumption is defined in per capita terms). These two effects can be separated by keeping the base run population unchanged but increasing the labor participation rate by 6.9 percent. Thus there is the same effect on agricultural output — it increases by 4.8 percent — but not the direct demand effect of a larger population.

The big difference between these experiments is in the commodity market of agricultural goods. The price falls by 6.1 percent instead of 3.8 percent even though there is a rise in exports of 18.6 percent instead of 11.1 percent and imports diminish by 6.6 percent compared with 2.2 percent in the previous run. The effect on agricultural wages is profound; they become 11.4 percent lower than in the base run. Even the return on capital and land goes down in rural areas (—3.5 percent).

In the urban region the effect is the same as in the previous experiment, although strengthened because of the increase in real purchasing power. Return on capital and wages increases by roughly 3 percent, causing an increase in high income-elastic goods. The consumer goods sector increases by 2.6 percent and the service sector by 0.5 percent. This change in the demand pattern results in a reallocation of factors of production from the export-oriented sector (Sector 2) to the sectors directed to final demand. Given that the resources of labor and capital in the urban region are fixed, the output and exports of sector 2 have to diminish. Domestic demand pulls factors of production away from the base industries.

The effect on GDP is slightly lower than in the previous run. Thus the direct effect via demand of a larger population is positive but not as important as the "employment increase" effect. Roughly 20 percent of the total effect on GDP can be associated with the direct demand-creating effect of more people.

Population Experiment III: Increase in Both Rural and Urban Populations. Here the 5 percent increase in total population has been allocated equally between rural and urban areas, resulting in a 3.4 percent increase in rural population and a 9.0 percent growth of the urban population. The output-creating effect in agriculture is half of the effect in the previous two experiments. The enlarged demand for agricultural commodities due mainly to increased subsistence consumption outweighs the supply effect, resulting in a higher equilibrium price and contributing to a positive effect on the income of rural households.

In the urban sector the higher supply of labor has a dramatic effect on factor returns. The relative cost of labor is lowered, and firms in the different urban sectors substitute labor for capital. At the same time, a higher aggregated income among urban households increases demand. The aggregate income of both capital and labor increases. The demand effect is stronger than the supply effect on the main urban commodity markets, especially the export-oriented sector, and domestic prices increase. The higher supply of labor and the substitution of labor for capital releases resources for production of sector 2, increasing its output by 9 percent, the main share of that being exported. Exports of sector 2 increase by 11 percent.

The positive effects on total income and the relatively larger increase in capital income enlarge savings — an increase of 9 percent compared with a more or less unaffected amount of savings when the population increase is concentrated in the rural sector. (The savings rate is higher for capital income compared with labor income, but there is no difference between rural and urban households.) Thus an increase in population, which is biased toward urban sectors, will have a significant growth-creating effect. This effect will not occur in a dynamic framework, however, if the population increase in urban sectors has to be created mainly by rural-to-urban migration. A comparison between the first and third experiments indicates that as the process of urbanization continues, the pressure to migrate is slowed by an increase in rural wages and a decrease in urban wages. The growth-increasing effect will, therefore, never be very pronounced, but this conclusion should be examined by dynamic simulation experiments.

V. DYNAMIC EXPERIMENTS

Counterfactual simulations of Swedish demoeconomic development must begin with a point of reference: a base run that replicates as closely as possible the historical trends of some of the crucial variables for the period 1871-1890. Imitating history also is the last step in validating the model. In this section, the base simulation is evaluated and three counterfactual simulations are discussed.

BASE RUN SIMULATION 1871-1890

From 1871 to 1890 Sweden underwent its first phase of industrialization. The 1870s was a period of rapid growth, especially for export-oriented industries, sawmills, and steelworks. During the 1880s, growth was slightly dampened by an international recession. The performance of the model generally reflects the historical record (see Table 4).

A crucial variable for the growth of the economy is capital formation. The formulation of capital growth in the model reflects the neoclassical theory of growth: savings determine investment. Savings are endogenously determined. As can be seen in Table 5, capital stocks of urban and rural sectors generated by the model are close to the historical figures.

The other important factor of growth is population. In the dynamic simulations, the populations of rural and urban areas are endogenously determined by their net natural increases, net migration between the two regions, and net emigration. No migration statistics are available on a yearly basis between the population censuses of 1870, 1880 and 1890. The existing employment figures for agriculture

TABLE 4

AVERAGE ANNUAL GROWTH RATES (PERCENT) 1871-1890

	1871-1880		1871-1890	
Variable	Historical	Model	Historical	Model
Output				
Sector 1	2.1	2.0	1.0	1.8
Sector 2	4.1	5.2	5.1	3.7
Sector 3	2.5	2.4	3.6	3.9
Sector 4	3.1	3.1	2.5	3.2
Sector 5	5.7	7.2	2.9	4.7
Exports				
Commodity 1	0.5	1.0	−2.8	−2.4
Commodity 2	3.8	6.0	3.8	2.3
Commodity 3	9.6	2.5	9.0	5.5
Commodity 4	4.1	4.3	2.5	1.6
Imports				
Commodity 1	2.5	2.4	3.9	3.4
Commodity 2	4.9	5.9	7.2	7.0
Commodity 3	5.7	7.2	4.3	1.7
GDP	2.6	3.1	2.3	2.9

TABLE 5

AVERAGE ANNUAL GROWTH RATES (PERCENT) 1871-1890

	1871-1880		1871-1890	
Variable	Historical	Model	Historical	Model
Total population	0.9	1.0	0.7	0.7
Urban population	2.6	2.9	2.4	2.7
Rural population	0.2	0.2	−0.1	−0.2
Total labor force	1.1	1.2	0.6	0.7
Urban labor force	2.5	2.8	1.3	1.9
Rural labor force	0.4	0.3	0.1	−0.1
Total capital stock	2.0	1.9	1.7	2.4
Urban capital stock	3.1	2.9	2.5	3.3
Rural capital stock	0.6	0.6	0.5	1.1
GDP	2.6	3.1	2.3	2.9
GDP per capita	1.7	2.2	1.6	2.2

TABLE 6

COUNTERFACTUAL SIMULATION I: NO EMIGRATION
(AVERAGE ANNUAL GROWTH RATES IN PERCENT)

Variable	1880 Base run	1880 No emigration	1890 Base run	1890 No emigration
Total population	1.0	1.1	0.7	1.2
Urban population	2.9	3.0	2.7	2.9
Rural population	0.2	0.4	−0.2	0.3
Total capital stock	1.9	1.9	1.5	2.8
Urban capital stock	2.9	2.9	3.3	3.4
Rural capital stock	0.6	0.6	1.1	1.1
Degree of urbanization[a]	0.327	0.325	0.397	0.384
Degree of industrialization[b]	0.636	0.634	0.672	0.662
GDP	3.1	3.3	2.9	3.2
GDP per capita	2.2	2.1	2.2	2.0

[a] Share of urban population out of total population.
[b] Share of value-added of urban sectors (in fixed prices) out of GDP (in fixed prices).

are interpolations between these benchmark years, so it is difficult to evaluate the migration pattern produced by the model. The resulting distribution of population in 1880 and 1890, however, can be compared with historical data (see Table 6). In both 1880 and 1890 the distribution between historical records and the model simulations is very close.

In summary, the base run simulation from 1871 to 1890 indicates that the model captures the essential factors of the demoeconomic development of Sweden. The ability of the model to replicate historical trends in some of the crucial variables permits use of the base simulation as a reference point when undertaking counterfactual simulations. The first simulation evaluates the effects of emigration on the Swedish economy; the remaining two assess the importance of rural-to-urban migration.

COUNTERFACTUAL SIMULATION I: NO EMIGRATION

What role did emigration play in Sweden's development? Its consequences have been discussed since Wicksell pointed out that emigration solved the proletarization problem in Swedish agriculture (Wicksell 1882). But what were the long-term consequences of emigration? Would a larger population have increased economic growth through enlargement of the home market? Was emigration a substitute for internal migration? These are some of the questions that need to be addressed when discussing the consequences of emigration. The model can help answer some of these questions.

By not allowing any emigration to take place and by keeping everything else equal, a hypothetical development path of the Swedish economy was simulated over the period 1871-1890. This counterfactual simulation is then compared with the base run to indicate the consequences of emigration.

The period 1871-1890 covers both a time of low emigration, the 1870s, and a time of high emigration, the 1880s (see Figure 1). In 1880, total Swedish population would have been 1.5 percent higher, and in 1890 8.9 percent higher, had there been no emigration. Some of the results are displayed in Table 6.

The immediate effect of closing the emigration possibility is growth in the rural population, since emigrants come from rural rather than urban areas. The resulting increase in the rural population has both a supply and demand effect on the commodity market. A greater supply of labor increases agricultural output and more population increases its demand. A larger labor force, ceteris paribus, decreases the marginal productivity of labor, and this downward pressure on rural wages is strengthened by a price fall on agricultural goods. Without emigration agricultural wages start to fall. The immediate changes are the same as in the static population Experiment I. When this experiment is carried out over a longer period of time, the effects are moderated by migration. The enlarged wage gap between rural and urban areas increases rural-to-urban migration. However, more internal migration does not outweigh migration altogether during the period of study. The rural population is still larger in 1890 than in the base run (11.3 percent higher). Thus, even though internal rural-to-urban migration increased, urbanization decreased.

The larger urban population, in absolute terms, increases labor supply and thus the capacity of urban industries. Output of urban sectors starts to grow somewhat faster than in the base run. The larger agricultural production causes a direct increase in demand for intermediary goods. In 1880 there is no significant difference, but in 1890 the annual growth rate of the export-oriented industry changes the most, from 3.7 percent to 4.0 percent.

The changes in the urban sectors *increase* urban income and savings. Even governmental income increases because of higher tax revenues and adds to total savings. Decreased rural savings do not reverse the effect on total savings but increase it. This results in a faster growth of capital, which contributes to the overall increase in output both in rural and urban areas. GDP growth is faster, but not enough to counterbalance the increase in total population, so GDP per capita falls.

Was the population better off with emigration? The model indicates that without emigration real rural wages would have been 1.8

TABLE 7

COUNTERFACTUAL SIMULATION II: NO EMIGRATION AND NO RURAL-TO-URBAN MIGRATION (AVERAGE ANNUAL GROWTH RATE IN PERCENT)

	1880	
Variable	Base run	No migration
Total population	1.0	1.2
Urban population	2.9	0.8
Rural population	0.2	1.3
Total capital stock	1.9	1.1
Urban capital stock	2.9	2.7
Rural capital stock	0.6	0.9
Degree of urbanization	0.327	0.268
Degree of industrialization	0.636	0.634
GDP	2.2	2.6
GDP per capita	3.1	1.4

percent lower in 1880 and 10.0 percent lower in 1890. Urban wages would have been unaffected in 1880 but 1.5 percent higher in 1890. (Money wages are deflated with a cost-of-living index generated by the model.) Emigration apparently had a positive effect on the standard of living in the rural areas, but perhaps even larger rural-to-urban migration than occurred in the simulation would have happened in the absence of emigration. The role of rural-to-urban migration is discussed in the remaining two counterfactual simulations.

COUNTERFACTUAL SIMULATION II: NO EMIGRATION AND NO RURAL-TO-URBAN MIGRATION

One way to evaluate the effects of migration on industrialization is to ask what would have happened if no migration had taken place. Such a path of development can be generated by simulating the model economy without any possibility of migration. Some results for 1880 are displayed in Table 7.

The effect on total population results from no emigration and a somewhat greater natural increase of population because of a larger concentration of the rural population. (Note the different degree of urbanization.)

The larger rural population has its most significant effect on the development of agricultural wages. In 1880, they are almost 17 percent lower than in the base run solution. The decrease in wages is larger than the increase in the labor force and the labor income of rural households will therefore diminish. The effect on capital is similar.

Return on capital goes down as well as the capital stock, resulting in a decreased income out of capital. The agricultural commodity market is primarily responsible for this effect, and the new equilibrium price is 11 percent lower.

For urban households the effect is reversed. The urban labor force is almost 12 percent lower, and even though urban capital stock is somewhat lower (—3.2 percent), labor becomes relatively more scarce and urban wages increase by 14.7 percent.

The lower income generated in a counterfactual simulation without the possibility of migrating generates less savings and thus the growth of capital stock is smaller. Even though agricultural output grows at a faster rate when no migration takes place, it does not outweigh the slower growth of the urban sectors and a slowdown in the rate of industrialization occurs.

Rural-to-urban migration apparently has a significant growth-creating effect. The reallocation of labor force to the more dynamic and high-wages urban sector with its modern technology and higher rate of productivity change is of great importance to the economic performance of the national economy.

COUNTERFACTUAL SIMULATION III: HIGHER RURAL-TO-URBAN MIGRATION

In the first counterfactual simulation an increased rural-to-urban migration counterbalanced the downward pressure on economic performance when there was no possibility of emigration; in the second simulation, stopping the migration to urban areas slowed down growth. However, will these indirect indications of the positive effect of rural-to-urban migration remain if the response to wage differentials between rural and urban areas increases? This question will be analyzed by changing the parameters of the migration function by 25 percent to increase the response.

The most notable change is the allocation of population. Rural population declines immediately and the urban population grows (see Table 8). This effect is much less pronounced in the second period. Which economic forces cause the "boomerang" effect of migration?

In agriculture the growth of output is lower in 1880 (+1.6 percent) compared with the base run (+2.0 percent). Demand for agricultural goods is relatively income inelastic, and therefore the lower supply pushes the price upwards. This price effect strengthens the increase in rural wages, and over the course of time rural wages increase and migration slows down. This process is also enhanced by a lower wage increase in the urban sector.

Increased migration augments the supply of urban labor and thus enhances the capacity of this sector. The export-oriented sector increases output from 5.2 percent (average growth rate in the base run)

TABLE 8

COUNTERFACTUAL SIMULATION III: HIGHER RURAL-TO-URBAN MIGRATION (AVERAGE ANNUAL GROWTH RATES IN PERCENT)

	1880		1890	
Variable	Base run	More migration	Base run	More migration
Total population	1.0	1.0	0.7	0.7
Urban population	2.9	4.2	2.7	3.2
Rural population	0.2	−0.5	−0.2	−0.6
Total capital stock	1.9	2.2	1.5	2.8
Urban capital stock	2.9	3.3	3.3	3.8
Rural capital stock	0.6	0.8	1.1	1.3
Degree of urbanization	0.327	0.336	0.297	0.440
Degree of industrialization	0.636	0.661	0.672	0.793
GDP	2.2	3.5	2.2	3.2
GDP per capita	3.1	2.5	2.9	2.5

to 6.9 percent in 1880, a tendency that continues in 1890. This sector absorbs relatively more of the increase in the labor supply, and even though the export-oriented sector is a high-wage sector, average urban wages rise at a slower rate than in the base run. Thus the effects on wages in both the rural and urban areas slow down rural-to-urban migration.

More migration also affects the growth of capital. Rural savings increase more than urban savings decrease. Governmental savings also grow due to larger total income and increasing taxes.

Increased rural-to-urban migration generates larger domestic production. The growth-creating effect of more migration, however, also has a tendency to diminish over time. The effect on GDP is greater during the 1870s than during the 1880s, because migration slows down. In 1890 migration is almost back to the same level as in our base run. Thus, more rural-to-urban migration has a temporary growth-creating effect, but in the long run this effect disappears, because it also decreases the wage gap between rural and urban areas and thus has a boomerang effect on itself.

VI. CONCLUDING REMARKS

This paper has shown the fruitfulness of using a general equilibrium simulation model to study the problems of urbanization and development. In the Swedish analysis the interaction of supply and demand (domestic as well as foreign) on the commodity markets is especially important for the development of wages, income, and migration. The model reveals the magnitude of these interacting forces. Also, the results of the dynamic simulations show the importance of using a dynamic framework with a rather long time horizon, especially for a study highlighting the role of internal and external migration in the process of industrialization.

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Economic Growth and Urbanization: A Study of Japan

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ABSTRACT This paper describes some results obtained from simulating a computable general equilibrium model calibrated with 1960 data for Japan. Of the two closures used, the Keynesian type, which assumes unutilized resources, performs better than the neoclassical closure, which assumes full employment of all factors of production. In other words, Japanese economic growth in the 1960s may be characterized by the decisions of investors who regarded the supply of quality labor as virtually unlimited. Spatial aspects of population shifts have a significant bearing on macro growth potentials if social capital demands are spatially differentiated.

I. INTRODUCTION

Economic growth and urbanization in Japan has occurred within a dualistic framework in which modern (imported) and traditional (indigenous) elements coexist. Their interaction has largely determined the pattern of industrialization (see for example Ohkawa 1972, 1980; Ohkawa and Rosovsky 1973; Minami 1973; Shishido 1979, 1981). Economic growth has influenced and been influenced by the shifts of population from primary to nonprimary activities and from traditional nonprimary to modern nonprimary activities.

During at least two periods in Japanese economic history the share of nonprimary employment has risen rapidly. Both were periods of high economic growth with a relatively large pool of surplus labor in primary and traditional sectors. During the 1910s surplus labor rose because of the stagnation of agriculture and during the 1950s and 1960s surplus labor increased because of war repatriation. The failure of modern sectors to increase employment sufficiently after World War I seems to have been one major cause of the persistent wage and productivity differentials between modern and traditional sectors (Nakamura 1971); the continued expansion of modern sector employment after World War II seems to have put an end to those differentials.

This paper provides insight into this process of dualistic development by simulating with a computable general equilibrium model calibrated with 1960 data. This kind of model analyzes urbanization and industrialization by examining the mobility of factors of production as a response to various rates of return. The mobility described here is mainly intersectoral, but a certain share of the laborers who shift from primary to nonprimary activities is assumed to stay within the rural areas. The size of this share is a function of agricultural and various non-agricultural wage rates.

The following section briefly describes the model used, and the last section reports the results of various dynamic sensitivity analyses. These analyses involve changing one or more parametric values and then examining the divergences of the solution from the base solution.[1]

II. THE MODEL

The model is a six-sector computable general equilibrium model. A detailed description is found in Shishido (1981). It is similar to the model by Karlström described in this issue, so only the distinctly different specifications are described here. They include (1) sector divisions and use of vintage capital in some sectors, (2) macro closure, (3) wage determination, (4) investment determination, (5) migration determination, and (6) import determination.

SECTOR DIVISIONS AND USE OF VINTAGE CAPITAL STOCKS

The sector division tries to capture the modern-traditional dualism in urban areas as well as the primary-nonprimary dualism in the economy. The six sectors are (1) modern manufacturing, (2) traditional manufacturing, (3) modern services, (4) traditional services, (5) construction, and (6) agriculture[2] (including forestry and fisheries). Vintage capital specifications are used in sectors 1, 2 and 3.

MACRO CLOSURES

Two different closures of the model are employed. One assumes that investment is endogenous and the sizes of the total urban and rural labor forces exogenous. Investment is determined by the amount of savings available in the model. This ordinary neoclassical way of closure is referred to as the NC model in this paper. The second way of closing the model is to assume that the nominal values of investments are predetermined by the expectations of investors in the previous year. To make investment exogenous, one previously exogenous variable must be made endogenous so that the system will not be overdetermined. Here the total urban labor force is freed, meaning that the

[1] A description of the method used to estimate the *ex ante* production parameters with limited data is available from the author.

[2] "Primary sectors" and "agriculture" are used interchangeably in this paper.

labor supply is elastic in the urban area (unemployment exists) and only demands are important. This Keynesian specification is called the FI model.

WAGE DETERMINATION

Urban employers are assumed to minimize labor cost, which consists of wages and those hiring and training costs lost through quits. The quit ratio in any nonprimary sector is a function of own and all other nominal wages plus agricultural income. Wages, therefore, are simultaneously determined and influenced by all other wages at any period.

INVESTMENT DETERMINATION

Investment is determined by the investor's expectation of demand and factor prices. Knowledge of the *ex ante* production function and the expectations of factor prices determine the most efficient technology (i.e., the capital-output ratio). The capital-output ratio is derived by differentiating the cost function with respect to expected capital cost (see, for example, Diewert 1974). This ratio is then multiplied by the expected increase of demand and an "animal spirit"[3] parameter, thus giving the desired real investment. The desired nominal investment is given by multiplying the real investment by the present capital price. In the FI closure, this product is the realized nominal investment in the next simulation period; in the NC closure, it is scaled up or down according to the savings available during the next period.

MIGRATION DETERMINATION

The share of people among the total primary employment who shift from primary to nonprimary activities is specified in two ways. One specification considers this share a function of expected income ratios in nonprimary and primary employment. In this case the expected nonprimary income is a weighted average of nonprimary sector wages, and weights are shares of job openings potentially available to migrants through new investments and quits. The other specification assumes that the share is a function of only the number of new jobs available through investment in the nonprimary sector.

[3] The term "animal spirits" expresses the actions of investors that are not totally explainable by observed variables. This parameter therefore includes investors' knowledge of existing opportunities to make profits that are unknown to others, as well as the purely spontaneous urge for action.

From a preliminary regression analysis[4] the latter specification seems to be appropriate for the post-World War II period, whereas the former seems to apply to the period before the war. In this paper, only the latter is used.

Shares of those job shifters who actually move to cities and those who do not move (even though they change employment and commute to non-agricultural jobs) are derived using a logit type of specification. Given that a person has already decided to obtain a non-agricultural job, the probability that he will move depends on utility differences, which in turn depend on the differences of present values of expected income for movers and non-movers. For simplicity, however, we assume that utility levels of movers and non-movers have the following specifications:

$$U_M = \beta_1(EW_M/P_C) + \beta_2(W_A/P_R) + \beta_3$$
$$U_{NM} = \beta_4(EW_{NM}/P_R) + \beta_5(W_A/P_R) + \beta_6$$

where U_M, U_{NM} are utility levels of movers and non-movers, respectively; EW_M and EW_{NM} are expected wage levels of movers and non-movers, respectively; W_A is the marginal value product of labor in the agricultural sector; and P_C and P_R are consumer price indices in cities and rural areas, respectively. β_1 and β_4 are assumed > 0 and $\beta_2 < \beta_5 < 0$. The second inequality comes from the fact that movers lose agricultural income completely, whereas non-movers can still contribute to agricultural production. EW_M is the weighted average of all urban wages, the weights being the employment share in each sector, whereas EW_{NM} is the weighted average of construction and traditional nonprimary wages, the weights again being the actual employment shares of these two sectors in each period.

Thus the conditional probability that a person stays in a rural area, given that he has decided to change from an agricultural to a non-agricultural job, is the reciprocal of

$$1 + \exp [\beta(EW_M/P_C) - \beta_4(EW_{NM}/P_R) + (\beta_2 - \beta_5)(W_A/P_R) + \beta_3 + \beta_6)].$$

Non-movers are assumed to retain their previous consumption and fertility behavior in the rural area.

[4] A two-stage, least-squares estimation of the migration (shift from primary to nonprimary employment) function with first-order serial correlation (see Fair 1970) has been carried out. Endogenous variables are the ratio of urban to rural wages and the net outmigration rate from primary activities. For the estimated equation with the left-hand side being the net outmigration rate, the included predetermined variable is lagged investment. For the pre-World War II period (1921-40), both relative wage and lagged investment variables have significant and positive coefficients. For the post-World War II period, however, the simultaneity breaks down and only the investment variable is important. The greater number of nonprimary job opportunities in rural areas, and thus the increase of non-moving shifters, probably changed the economics of information and therefore the structure of decision making for shifting from primary to nonprimary employment.

IMPORT DETERMINATION

Imports are determined following Armington (1969). Domestic goods and imported goods of the same sector are assumed to be substitutes with finite elasticities. Constant elasticity of substitution functions are used and their cost functions are the purchaser's prices of tradeable commodities.

III. PRELIMINARY DYNAMIC ANALYSES

INSTANTANEOUS DYNAMIC EFFECTS[5]

The two closures have distinctly different mechanisms for achieving macro equilibria (i.e., savings = investment). The FI version of the model adjusts to external and internal shocks by changing the general level of the real wages of urban sectors. The NC version adjusts through the reallocation of labor among urban sectors. In order to see the instantaneous dynamic effects of different closures, three one-year period, dynamic analyses with four different assumptions are carried out, illustrating the effects of growth on distribution in each set of assumptions. The results are shown schematically in the four diagrams of Figure 1 using two variables: the real GDP and the real wage rate in the traditional manufacturing sector.

The first experiment involves an FI closure with both wages and investment nominally fixed. In this case the output grows rapidly, but the real wage is reduced 10 percent by the third period — a trend that cannot continue for long. In Japan there was a similar situation in the 1910s when the real wage decreased during the investment boom. This trend terminated with the rice riot of 1918, which was a result of people feeling they had been unfairly treated for a long time.

In the second FI diagram, the assumption of a fixed nominal wage is removed. The growth rate is slowed down slightly; the decline of the real wage is reduced. (In fact, the real wage increases in the fourth period analysis.) Diagrams 1 and 2 assume zero intermediate inputs from agriculture to capital producing sectors.[6]

Diagrams 3 and 4 of Figure 1 illustrate NC closures. The first specifies agricultural input to the capital goods sector as zero, whereas the second diagram uses the full 1960 input-output table. The results are self-evident.

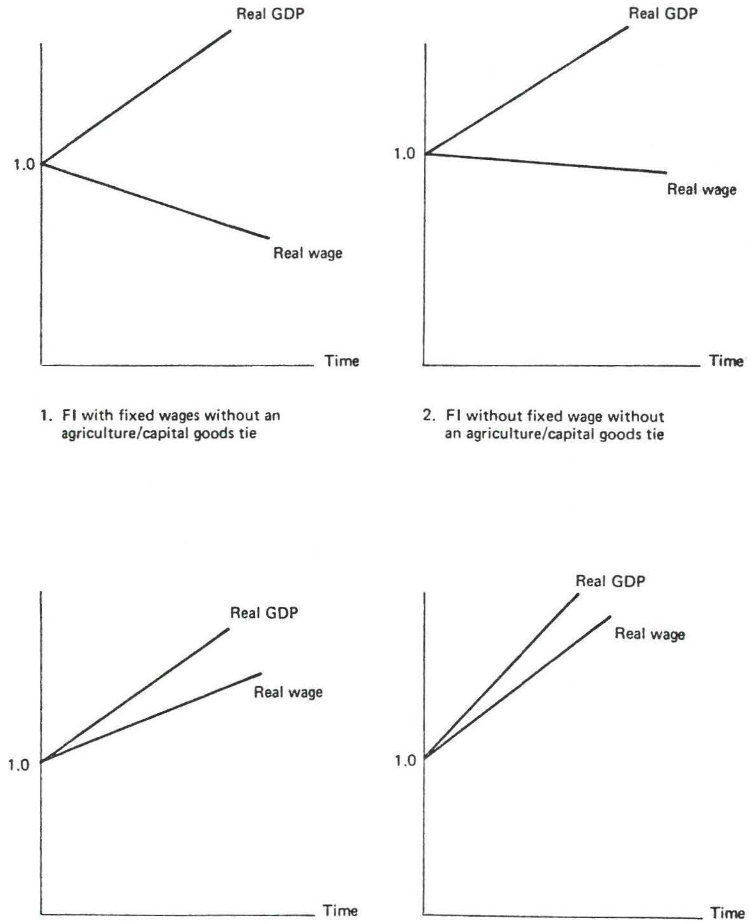
The higher the level of intersectoral interactions, the higher the output; agricultural income increases greatly with the growth in demand for the sector's produce. This higher agricultural income pushes

[5] "Instantaneous" means a short enough period of time for the many exogenous variables (foreign exchange rate, foreign prices, world demand, government demand, etc.) to be considered more or less constant.

[6] In the earlier phase of development, the agricultural input to capital formation in urban sectors could be regarded as slight. Because of this, a 1960 data base for studying less developed economies is not appropriate.

FIGURE 1

INSTANTANEOUS DYNAMIC EFFECTS OF THE FI AND NC CLOSURES



1. FI with fixed wages without an agriculture/capital goods tie

2. FI without fixed wage without an agriculture/capital goods tie

3. NC without an agriculture/capital goods tie

4. NC with an agriculture/capital goods tie

up urban wages. In the longer period the expectations of investors and producers change, even in the FI model, and the investment level may come down. A change of the real wage at below or above output growth cannot last with the same magnitude forever in any specification. The question is, do different closures in fact apply at different phases of development in Japan, and if so, which applies to which period?

TEN-YEAR SIMULATIONS[7]

Ten-year dynamic simulations (1960-69) have been carried out in order to answer the above question at least partially. In this period of rapid growth in Japan, GDP in real terms increased by 11.9 percent per annum and the "gainfully employed" in primary activities decreased by 4.17 percent per annum.

The historical values that correspond exactly to the sector growth rates in the base runs are not available because of differences in data aggregation. Figures 2 and 3 show the growth rates of real GDP and urban labor share relative to the respective NC, FI, and historical values for previous years. The NC version has higher average growth rates of GDP, but annual growth rates fall steadily, mainly because of the increase in government and housing investment (taken to be exogenous for historical values) that crowds out private investment in the model. The labor share of urban income fluctuates over time, although this fluctuation is less for the NC version than the historical values or the values for the FI version. There is, if anything, a slight tendency for the labor share to change with the GDP growth rate.

The FI version, on the other hand, has oscillating GDP growth rates but no general tendency to increase or decrease. The urban labor share moves in a completely opposite direction to GDP growth rates, i.e., the faster the GDP grows, the lower the labor share becomes.

The actual GDP growth rates and labor share move consistently in opposite directions during the 1960-69 period. Therefore, at least from a qualitative point of view, the FI method of closing the model may be more appropriate for studying the economic growth of the period concerned, i.e., in the model the supply of labor is considered virtually unlimited in the urban sectors. This result agrees with the statement made by Ackley and Ishi (1976) that historically urban entrepreneurs regarded the supply of quality labor as highly elastic during the decade of high economic growth.

Four simulations which were carried out in order to understand the dynamic behavior of the model are briefly described:

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[7] Only NC and FI versions with the full 1960 input-output tables are used here for comparison.

FIGURE 2

GDP GROWTH RATES IN THE NC AND FI MODEL SIMULATIONS AND HISTORICAL GDP GROWTH RATES

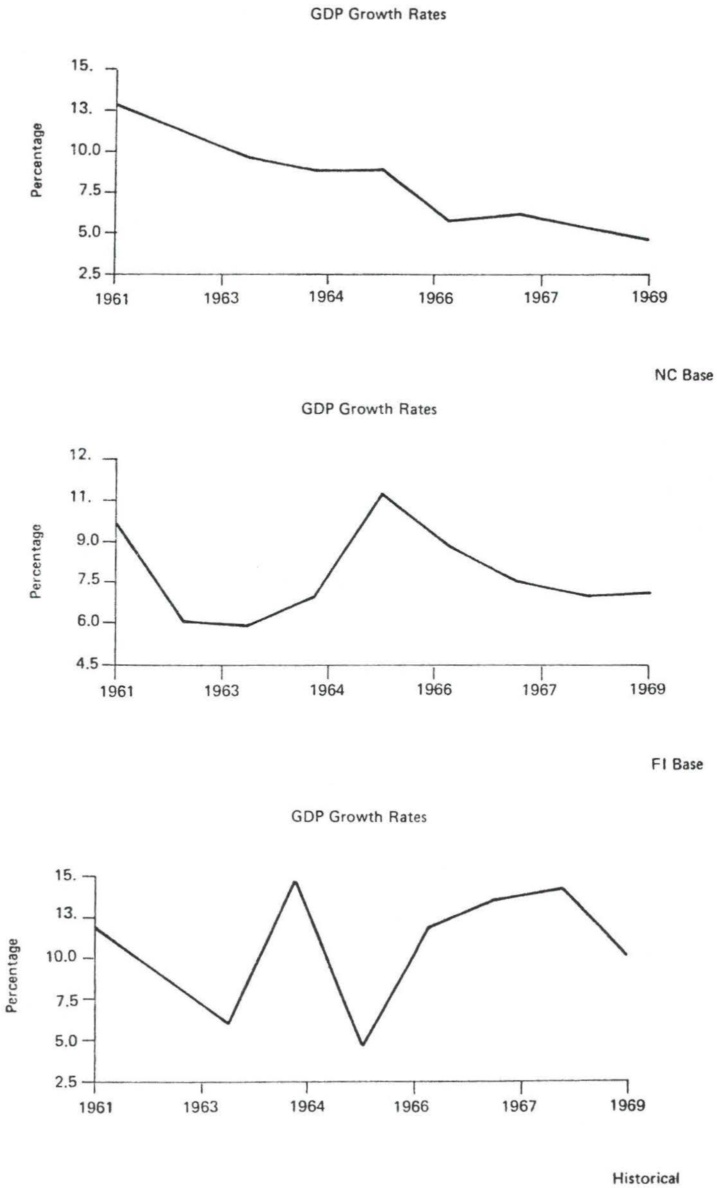
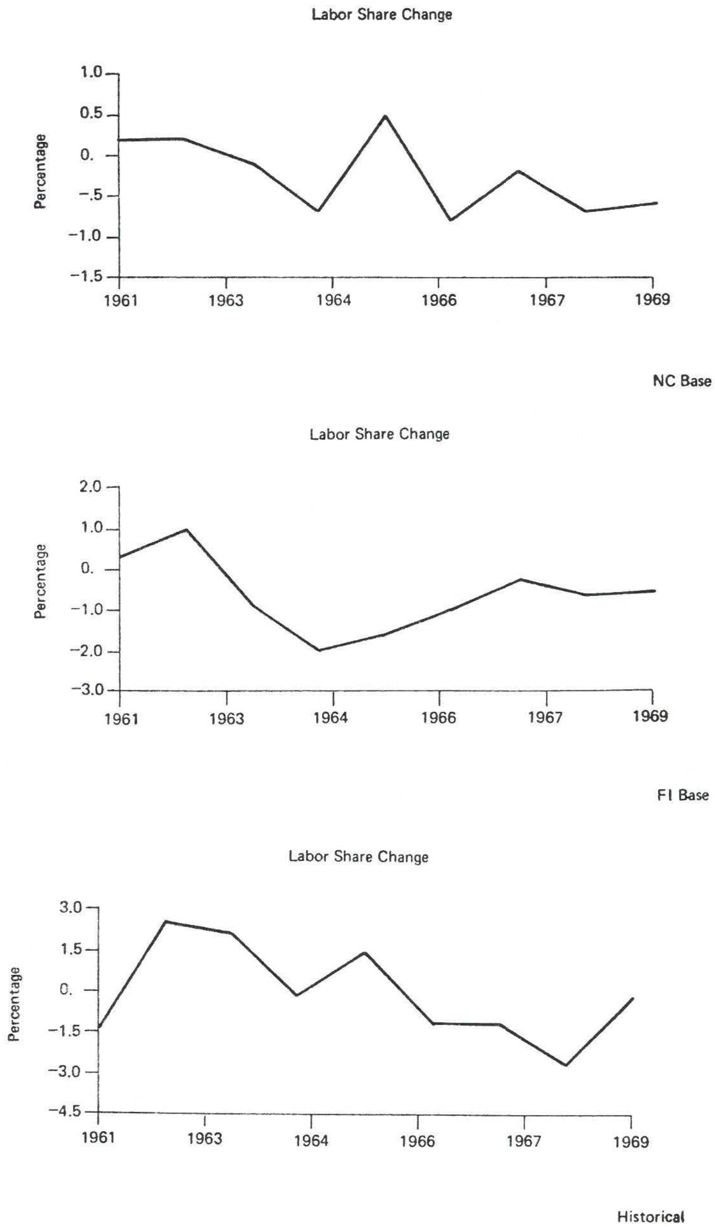


FIGURE 3

CHANGES IN LABOR SHARE IN THE NC AND FI MODEL SIMULATIONS AND HISTORICALLY



LMI — lowering migration propensity by 50 percent;
HWD1 — increasing the world demand for sector 1 goods in 1963, 1964, and 1965 by 40 percent;
CTR — changing consumers' subsistence minimum requirement every year by decreasing agricultural consumption and increasing the consumption of sector 2 goods to represent the shift of food consumption patterns away from traditional food toward more modern processed food;
LSL — lowering the savings propensity of urban labor by 10 percent.

Table 1 shows the average annual growth rates of some of the relevant variables. Because some of the results, even at this macro level, are counterintuitive, some explanation is given.

In LMI simulations, the economy grows less rapidly in an NC closure and more rapidly in an FI closure. The somewhat surprising behavior of the FI version[8] in LMI is explained by the assumption of unlimited labor supply in the urban area. Lower migration rates first increase the labor force in sector 6, pushing down rural income per capita. The lower rural income decreases the urban wage through the mechanism of wage determination explained earlier. Employers, therefore, can hire more labor at these lower wage rates, thus increasing production. Essentially this happens whenever rural income is lowered. There is, however, a limit to this pattern of growth: the supply of urban labor. If employment grows rapidly but migration is limited, there is bound to be a time when the surplus urban labor (the unemployed or underemployed) is exhausted. This mechanism then can no longer work. In fact, the amount of labor employed in urban sectors exceeds the potentially available labor force from the 1965 simulation. The economy would then have to follow the NC type of development or migration would have to be increased.

In HWD1 simulations, the overall growth of the economy slows down in the NC version, while the FI version shows relatively small changes in average growth rates. Stronger effects can be seen during the period (1963-65) when world demand increases. In order to see the effects of HWD1, it would be necessary to see the year-by-year changes in variables. For simplification we show only the GDP growth rates and the labor share growth rates of the FI and NC versions (Figure 4). Note that the FI version (Figure 4) grows faster with higher export demand than the base run (Figure 3), while the NC version (Figure 4) grows more slowly. The higher export demand in sector 1 in the NC closure decreases foreign savings, and hence the capital accumulation is lowered, causing migration to go down and a further decrease in economic growth. The FI version, on the other

[8] Past studies show that migration increases overall growth rates in general (see, for example, Yap 1976).

TABLE 1

AVERAGE ANNUAL PERCENTAGE GROWTH RATES OF RELEVANT MODEL VARIABLES

	LMI[a]		HWD1[b]		CTR[c]		LSL[d]	
Variables	FI	NC	FI	NC	FI	NC	FI	NC
Production of								
Sector 1	12.7	6.9	11.7	10.9	11.8	12.2	11.7	11.9
Sector 2	8.3	6.0	7.4	7.6	8.3	9.0	7.4	8.0
Sector 3	12.5	9.0	11.7	11.8	11.2	12.1	11.7	12.4
Sector 4	6.3	3.6	5.4	5.5	5.3	6.1	5.4	6.0
Sector 5	10.2	3.5	9.3	8.0	9.4	8.9	9.5	8.6
Sector 6	5.0	3.6	3.9	4.5	3.8	4.9	3.8	4.8
Exports of								
Sector 1	19.4	20.6	19.0	19.8	19.1	20.1	19.0	20.0
Sector 2	7.6	14.9	6.0	10.2	5.5	9.4	5.5	9.7
Imports of								
Sector 1	11.6	−1.4	12.8	7.5	12.3	7.3	12.9	7.2
Sector 2	16.6	7.9	16.8	13.6	18.4	15.8	17.3	14.4
Sector 6	19.2	12.4	19.2	17.3	19.5	18.6	19.5	18.3
GDP[e]	8.7	5.5	7.8	7.6	7.7	8.1	7.8	8.1
Labor force of								
Sector 1	4.3	−0.6	4.0	3.2	3.4	3.2	3.6	3.0
Sector 2	2.5	1.0	1.3	1.1	2.5	2.3	1.3	1.1
Sector 3	10.0	6.9	9.2	8.7	8.5	8.5	9.2	9.1
Sector 4	6.2	2.6	3.8	2.7	3.9	2.5	4.0	2.7
Sector 5	6.6	−1.5	5.3	3.0	5.5	3.6	5.6	3.5
Sector 6	−1.4	−0.4	−4.9	−4.1	−4.4	−4.6	−4.5	−4.4
Labor share	−0.67	−0.44	−0.60	−0.44	−0.62	−0.23	−0.64	−0.27

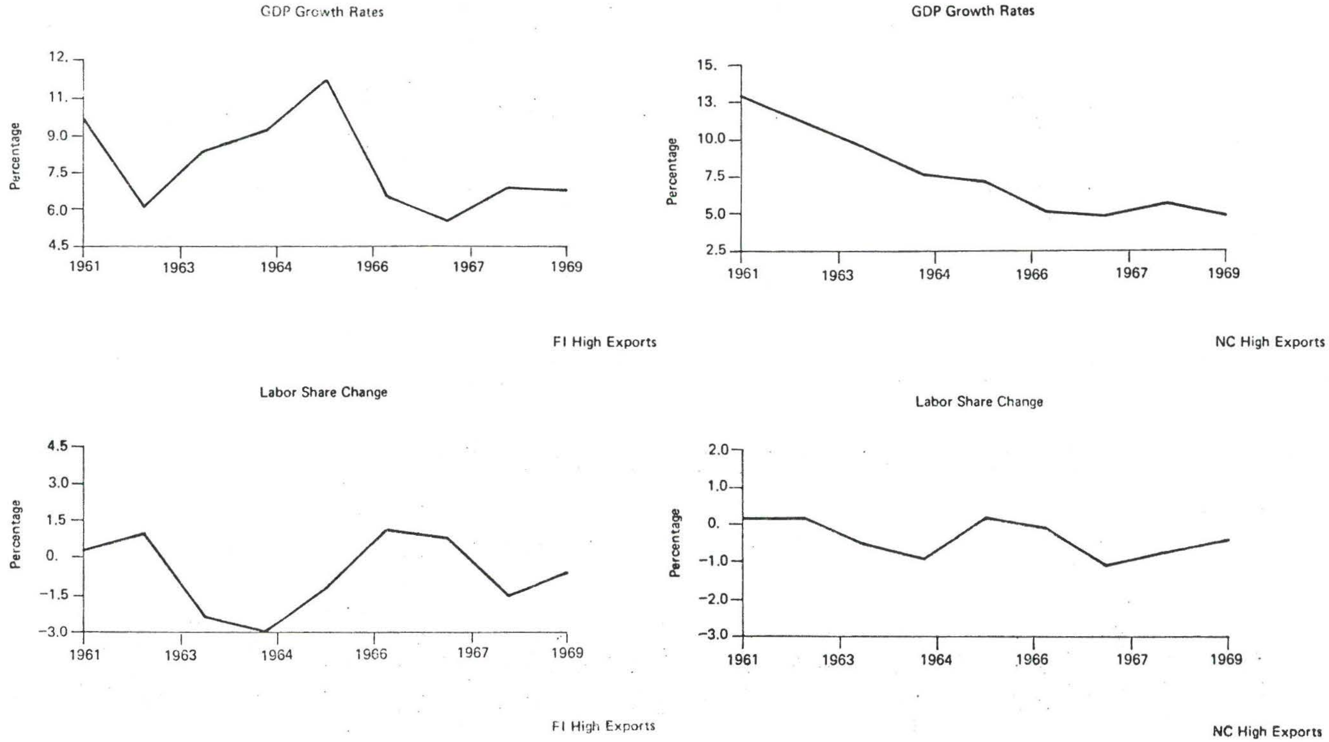
[a] LMI simulates lowering migration propensity by 50 percent.
[b] HWD1 simulates increasing the world demand for sector 1 goods in 1963, 1964, and 1965 by 40 percent.
[c] CTR simulates changing consumers' subsistence minimum requirement every year.
[d] LSL simulates lowering the savings propensity of urban labor by 10 percent.
[e] In base year prices.

hand, reacts to the external shock in a less surprising manner. The higher foreign demand increases production and investment. Decreased foreign savings is more than compensated by the sharp shift of income away from urban labor as a result primarily of forced savings through inflation. Inflation also dampens the decrease of foreign savings by decreasing growth of exports. The deflationary pressure in 1966 does exactly the opposite.

Changes in consumption patterns to processed food do not influence the overall growth rates in either the NC or the FI version, except for sector 2, whose demand is increased. This scenario decreases

FIGURE 4

GDP GROWTH RATES AND CHANGES IN LABOR SHARE WHEN THE AMOUNT OF WORLD TRADE OF SECTOR 1 GOODS INCREASES IN 1963-1965 (NC AND FI SIMULATIONS)



the consumer's demand for sector 6 goods but increases the intermediate input demand for these goods from sector 2 — the very sector for whose goods consumer demand has been increased. These changes in demand counterbalance each other and the total demand for sector 6 goods remains almost constant. The only change, therefore, is an increase in the demand and supply of sector 2 goods.

In LSL simulations, the FI version shows little change, while the NC version experiences a slowdown of growth. The outcome in the FI version can be explained by using the Keynesian story. When resources are underutilized (in this case urban labor resources) all that matters is the aggregate demand. The higher the demand, the higher the rate of utilization of resources; a lower savings propensity increases the consumption demand. In this simulation, growth rates look similar to the base run, except that the first-year values of production are already higher than those of the base run.

The result of the NC simulation is also as expected. It shows that the frugality of the population is important for an economy to grow in the NC framework. If all resources are fully utilized, less savings and higher consumption would result in an increase in prices and a decrease in accumulation, which is exactly what is happening in this simulation.

A SPATIAL ASPECT OF THE INTERSECTORAL SHIFT OF LABOR

One aspect of the model that is explicitly spatial is considered, i.e., the proportion of intersectoral job shifters staying in rural areas. Only FI closure is used, in light of its better performance qualitatively in the last section. The conditional probability of shifters staying in the rural area takes a logit form as described earlier.

Some dynamic sensitivity analyses were carried out in order to examine the pattern of movers' or non-movers' behaviors and their feedbacks into the economy. First, the conditional probability that determines the shares of non-movers among the total job shifters is scaled up 10 percent for each year. The immediate effect of this experiment is to increase the number of people having the rural consumption pattern. The non-movers are assumed to be employed mainly in traditional services and construction sectors, an assumption based on historical facts. These sectors have higher wages than the agricultural sector and lower wages than other urban sectors. Thus more non-movers means higher disposable income per capita in both urban and rural areas. As agricultural terms of trade improve, however, total agricultural income per capita soon exceeds the traditional service sector wage level and eventually the construction sector wage level. The utility per capita in rural areas relative to the base run constantly declines in this experiment, whereas urban utility per capita increases rapidly. The macro effects in this experiment are very small and are mainly sectoral.

When the assumption that non-movers need less new housing construction is introduced, the macro effects become profound. The immediate effect is a decline in final demand and a slowdown in economic growth. Capital goods, especially construction goods, become relatively less expensive and investment increases. As a result the economy grows less rapidly during the first four periods, but grows faster in the rest of the simulation periods than in the base run.

Some further sensitivity analyses have been carried out in order to examine specifically the patterns of behavior of movers and non-movers. Each analysis involves the increase of a relevant parametric value by 10 percent. These parameters are (1) "animal spirit" parameters of investment equations in the agricultural sector (HAIV), in urban modern sectors (HMIV), and in urban traditional sectors (HTIV); (2) training costs of laborers in urban modern sectors (HMTC), resulting in primarily higher wage rates for modern sectors; and (3) parameters of "migration" equations (HMIG). The results are summarized in Figures 5, 6, and 7 in ratios of relevant variable values in HMIV, HTIV, HAIV, and HMTC runs to those of the base run. (HMIG has essentially the same results as HMIV, but much more pronounced.) There are more job shifters than in the base run in all cases except the increase in wages in urban modern sectors.

The higher "migration" parameter has the most impact on total shifts and total non-movers. Higher investments in urban modern and traditional sectors have similar effects. They raise the total shift relative to the base run during the first three periods, but the divergence tapers off gradually. The ratio of non-movers to total shifts behaves similarly in these three runs: HMIG, HMIV, and HTIV. The ratio shows a monotonic increase in all three runs.

In the three cases mentioned above, the higher value of total shifts reduces the labor force in agriculture — potential shifters — so rapidly that wages are raised in agricultural and traditional sectors. The smaller number of workers left in agriculture is the primary cause of the gradual decline in total shifts, and the high agricultural and traditional wages are the main reason for the behavior of the non-movers/total shifts ratio. These forces dominate others including substitution effects, i.e., new capital stocks having more capital-intensive technologies because of higher relative wages.

Higher agricultural and urban investment parameters cause total shifts to behave similarly, although the peak of the former comes two periods later than the latter. The ratio of non-movers to total shifts, however, behaves differently. It increases once, then declines and increases again when the agricultural investment parameter is increased. The first increase is caused by the higher demand for agricultural goods, while the agricultural capital stock is still at the base run level. It pushes up the agricultural relative price and wages. But the higher investment in agriculture eventually expands the supply, pushing

FIGURE 5

RATIOS OF THE TOTAL POPULATION LEAVING AGRICULTURE IN EACH RUN TO THE SAME NUMBER IN THE BASE RUN

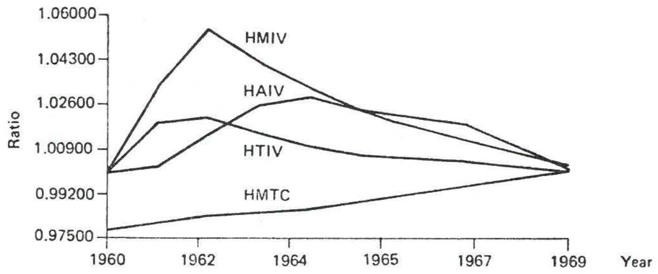


FIGURE 6

RATIOS OF CONDITIONAL PROBABILITY THAT JOB-SHIFTERS FROM AGRICULTURE STAY IN RURAL AREAS IN EACH RUN TO THE SAME PROBABILITY IN THE BASE RUN

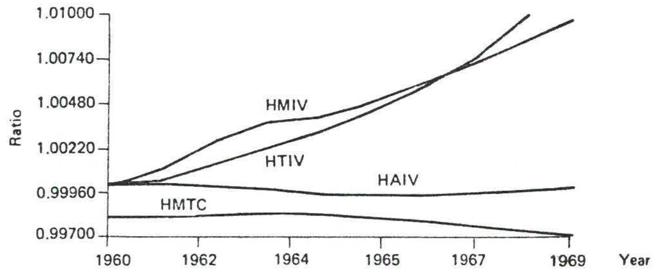
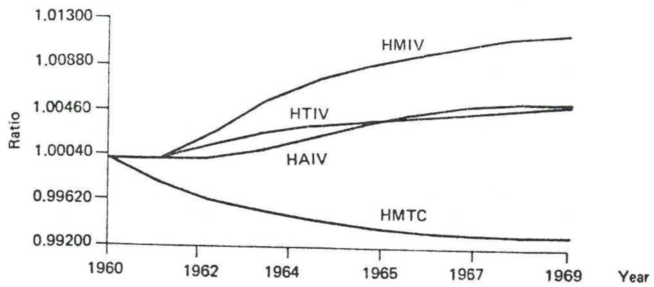


FIGURE 7

RATIO OF THE TOTAL NUMBER OF NON-AGRICULTURAL WORKERS STAYING IN RURAL AREAS IN EACH RUN TO THE SAME VALUE IN THE BASE RUN



down its prices and wages and therefore the non-movers/total shifts ratio. A lower price in agriculture, however, increases the urban investment because of higher demand in these sectors, and total shifts increase as in Figure 5. The last climb of the ratio is then caused by the wage increase in agricultural and traditional sectors resulting from the smaller labor force in agriculture.

Finally, the only case where total shifts are lower than in the base run is when wages are higher in the urban manufacturing and modern service sectors. The total shifts are 2.2 percent lower than in the base run in the first period. These reduced shifts arise because of higher capital goods prices and lower labor quit rates. The divergence gradually decreases, and by the tenth period the value becomes equal to that of the base run. The real GDP (not shown) behaves in a similar way. It starts 0.2 percent below the base level and ends 0.3 percent higher than the base-run value. The substitution effects between capital and labor are important during the first half of the simulation when the demand effect is low. As a consequence of higher wages, the level of investment goes up because new technologies become more capital intensive. The ratio of non-movers to total shifts declines because of a larger agricultural labor force than in the base run.

Four lessons are to be learned from this set of experiments. (1) The inclusion of spatial aspects of population movement into the model gives insight into the different sectoral developments; for macroeconomic effects, however, a careful inclusion of spatially differentiated social capital demand becomes very important. (2) Expanded investment in either non-agricultural or agricultural sectors increases migration with the latter lagging behind the former. The share of laborers remaining in rural areas who have left agricultural employment goes up monotonically in the HMIV and HTIV runs and goes down in the HAIV run until lower agricultural wages stimulate urban investment. (3) High urban modern wages depress both intersectoral shifts and the share of non-movers. (4) If the social capital cost needs in urban areas are higher than in rural areas for any job shifter, a larger number of non-moving shifters (those who change jobs without moving) means a higher growth potential in the medium run.

IV. CONCLUSIONS

First, the degree of interrelatedness across sectors is an important factor for determining the pattern of economic growth. For example, the level of intermediate inputs for traditional sectors to modern sectors greatly influences the level of welfare of the traditional sector's population in a growing economy. As a matter of fact, the less interrelated an economy is, the more growth "hurts" the traditional population.

Second, the "turning point" of economic development can be defined as the time when surplus labor in both rural and urban areas disappears. In the simulation, the FI closure, which assumes surplus labor, replicates history qualitatively better than the NC closure. Thus the turning point may not have arrived during the 1960s in Japan.

Third, the spatial aspects of working populations become important to the macro growth patterns and distribution when social capital (in this case, housing) demands are considered. In fact, even in the neo-Keynesian framework of the FI closure, when more job-shifters stay in rural areas, growth potentials become higher because of price effects.

Finally, a model that is built using one base year can show completely different static and, especially, dynamic reactions to external or even internal shocks when different closures are used. This finding is a warning to those who model an economy using only one method (e.g., a neoclassical full employment model), however complicated the model may be. The way different closures produce different patterns of development even in the largely neoclassical general equilibrium framework is interesting and warrants further research.

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Migration and Urban Change

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ABSTRACT This paper examines the population development of large urban regions. Several hypotheses about patterns of settlement change in highly urbanized countries are discussed using empirical material derived from IIASA's Comparative Migration and Settlement Study. These hypotheses refer to interrelations between population growth and urban size, the role of migration and natural increase as components of urban population change, overall spatial mobility, hierarchical migration, and the age distribution of migrants moving between, out of, and into large urban areas.

I. INTRODUCTION

Many authors, including Morrison (1975) and Alonso (1978), have argued that declining population growth rates and population aging — phenomena typical of later stages in the demographic transition — have markedly contributed to the slowing of the growth of large cities in developed, highly urbanized countries. This paper examines several hypotheses pertaining to interrelations between population growth and urban size, the role of migration and natural increase as components of urban population change, overall spatial mobility, hierarchical migration, and the age distribution of migrants moving between, out of, and into large urban areas. The focus of this study is on developed countries. Empirical material is derived from IIASA's Comparative Migration and Settlement Study. The discussion of individual hypotheses is preceded by a brief description of spatial units for which data were compiled.

II. REGIONAL UNITS

High spatial aggregation is justified not only by computational and data limitation problems, but also on the grounds of assumed interdependence between distance of migration and its cause. At an advanced stage of urbanization the bulk of labor-oriented migrations take place between individual labor-market areas that are focused on large urban centers (see, e.g., Boudeville 1978), whereas moves within such areas represent adjustments to changing socioeconomic and family status of migrants and to the evolving urban environment. Accordingly, the adoption of functional urban regions as spatial units in multiregional demographic analysis permits a focus on labor-oriented migration.

The spatial units actually used in the Comparative Migration and Settlement Study at IIASA were typically much larger than labor-market regions and, depending on the country, capture between 20 and 50 percent of registered moves involving the crossing of local administrative boundaries. Nevertheless, 13 out of 17 countries include one or more units whose identity in terms of the settlement structure can be clearly interpreted (see Table 1).[1] Of the 124 regions on which the Migration and Settlement reports for the 13 countries are based, 35 can be identified as urban-oriented units. They jointly represent 9.7 percent of the countries' area but more than 30 percent of their total population and about 45 percent of their total urban population. All the capital regions and a number of major industrial agglomerations have been accounted for. Whereas the areas of both "old" and "new" urbanization are represented in the sample, the balance is slightly tilted in favor of the former — particularly in France and the Federal Republic of Germany, where areas of recent urban expansion in the southern parts of the countries could not be singled out using the available spatial disaggregation. The 35 regions represent a broad spectrum of population size, density, share in a multiregional system, and degree of correspondence to boundaries of a metropolitan area or functional urban region. This diversity should be taken into account in interpreting population trends.

The initial disaggregation of spatial units into three categories is shown in Figure 1. The first group, consisting of eight administrative cities, occupies low to medium ranks in terms of absolute population size but has the highest intensity of settlement. The next group consists of city-regions, predominantly monocentric. The third group represents larger urban agglomerations and more loosely interconnected, extensive urbanized regions; their overall density figures fall around the mean, but their absolute population numbers are the largest of the set of regional units under analysis.

The degree of regional closure can be expressed as a proportion of regional population and area to the respective values for the metropolitan regions defined by Hall and Hay (1980) or functional urban regions defined by Kawashima and Korcelli (1982). Deviation from one indicates the degree to which an individual region may be considered over-bounded or under-bounded when compared with these

[1] These countries include Austria, Czechoslovakia, Bulgaria, the Federal Republic of Germany, Finland, France, the German Democratic Republic, Great Britain, Hungary, Japan, the Netherlands, Poland, and Sweden. The data for Canada, Italy, the USA and the USSR could not be readily adapted for the purposes of the present analysis.

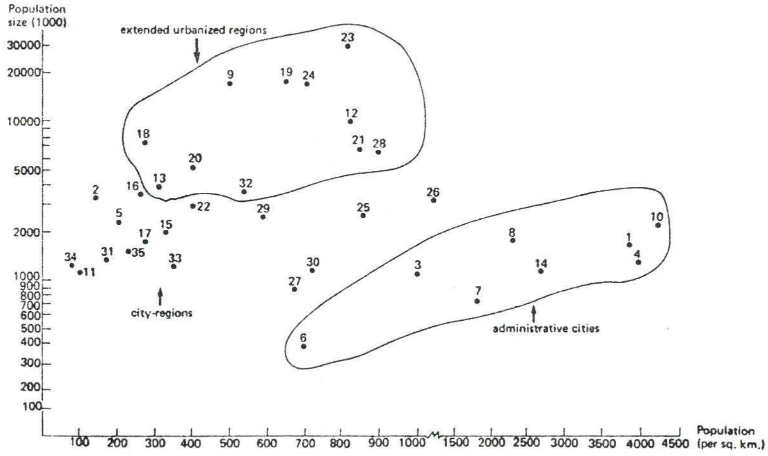
TABLE 1

BASIC CHARACTERISTICS OF 35 URBAN REGIONS IN THE CROSS-SECTIONAL ANALYSIS

Code	Region	Year	Population (1000)	Area (km^2)	Persons per km^2	Single (S) or Poly (P) center
1	Vienna	1971	1,615	414	3901	S
2	East Austria (inc. Vienna)	1971	3,301	23,543	141	S
3	Sofia	1975	1,077	953	1026	S
4	Prague	1975	1,161	291	3990	S
5	Central Bohemia (inc. Prague)	1975	2,301	11,299	204	S
6	Bratislava	1975	331	368	700	S
7	Bremen	1974	724	404	1792	S
8	Hamburg	1974	1,734	753	2303	S
9	Nordrhein Westfalen	1974	17,219	34,044	506	P
10	West Berlin	1974	2,034	480	4238	S
11	Uusimaa province (Helsinki region)	1974	1,073	10,351	97	S
12	Paris region	1975	9,878	11,984	824	S
13	North France	1975	3,914	12,542	312	P
14	Berlin capital dist.	1975	1,098	403	2726	S
15	Karl-Marx-Stadt dist.	1975	1,979	6,009	329	P
16	Leipzig-Halle district	1975	3,322	13,737	242	P
17	Dresden district	1975	1,836	6,733	273	P
18	South of GDR	1975	7,135	26,484	269	P
19	Southeast England	1970	17,316	27,408	642	S
20	West Midlands	1970	5,178	13,013	398	P
21	Northwest England	1970	6,789	7,993	849	P
22	Central Hungary (Budapest)	1974	2,968	7,489	396	S
23	Kanto region	1970	30,258	36,742	824	S
24	Kinki region	1970	16,511	23,237	711	P
25	Noord-Holland (Amsterdam)	1974	2,283	2,654	860	S
26	Zuid-Holland (Rotterdam)	1974	3,019	2,869	1053	P
27	Utrecht province	1974	849	1,328	640	S
28	West Netherlands (Randstad)	1974	6,150	6,854	897	P
29	Warsaw Voivodship	1972	2,207	3,788	588	S
30	Lódź Voivodship	1977	1,099	1,526	723	S
31	Gdansk Voivodship	1977	1,288	7,394	176	P
32	Katowice Voivodship (Upper Silesia)	1977	3,557	6,650	538	P
33	Cracow Voivodship	1977	1,144	3,255	354	S
34	Stockholm	1974	1,487	6,493	229	S
35	South Sweden	1974	1,159	13,866	84	P
TOTALS			119,136	299,316	398	

FIGURE 1

DISTRIBUTION OF URBAN REGIONS BY POPULATION SIZE AND DENSITY



independently defined regions. The three administrative cities for which the respective quotients could be calculated have the lowest proportions: around .60 for population and .03 to .10 for area. The city regions have values close to 1.0, and the third group values are over 1.0.

III. FIVE HYPOTHESES CONCERNING PATTERNS OF URBAN CHANGE

A number of hypotheses may be derived relating to the demographic aspects of contemporary patterns of urban change (see Korcelli 1981 for a more detailed discussion). Three hypotheses to be examined here consider spatial mobility patterns and the remaining two deal with total population change and its components. Some empirical evidence may refer to more than one hypothesis at a time, as the data produced with the help of multistate demographic models (Willekens and Rogers 1978) capture the effects of interaction between fertility, mobility, and mortality patterns. Most figures presented are either ratios or differences calculated with respect to national figures (or mean values for respective multiregional systems). Doing so introduces a common denominator, although it by no means solves the difficult problems involved in international comparisons of population data. Developed countries are characterized by low natural increase and advanced urbanization levels, yet in this respect the countries covered are not quite a uniform group. The proportion of their population living in urban areas in 1975 ranged from .50 (Hungary) to .80 (Sweden). The variation of their natural increase was also substantial; in 1977 between minus 1.9 per thousand population (Federal Republic of Germany) and 10.1 (Japan and Poland).

In spite of such differences, all countries included in the sample are in advanced stages of both the demographic and urbanization transitions. Their location at different points within these corresponding stages may be considered a positive feature for this analysis because the time factor may be introduced implicitly.

HYPOTHESIS 1. THE RATES OF POPULATION GROWTH IN URBAN AREAS ARE INVERSELY RELATED TO THE LEVEL OF URBANIZATION (AT A NATIONAL SCALE) AND TO CITY-SIZE.

The later stages of the demographic and mobility transitions (Zelinsky 1971) are characterized by diminishing growth rates of the urban population. Typically, the level of urbanization becomes stable after reaching roughly 80 percent. Large urban areas lead the trend. Whereas during periods of rapid urbanization (such as the 1950s throughout most of Europe) the large cities expanded faster than the total urban population, this pattern was reversed during more advanced urbanization stages. There is ample empirical evidence of this evolution, although it suffers from the lack of comparability among spatial units for which data are usually available (for example, cities in their administrative boundaries). Yet the few studies based on comparable units point toward similar conclusions. For example, in the case of cores of functional urban regions in 17 European countries the relation between growth and size was found to be increasingly negative or to evolve from positive to negative between 1950 and 1975 (Korcelli 1980). Typically, the growth rates shift from higher to lower than the national rate and subsequently towards absolute population decline. However, population growth tends to be a negative function of urban size, although it varies positively within an urban region with distance from its core. Thus the relationship between growth and size can be obscured by variations in the proportion accounted for by hinterland zones within individual urban regions.

The data derived from the Comparative Migration and Settlement Study basically support the above observations. During the mid-1970s 19 out of 35 urban regions experienced population growth slower than national growth; half the remaining units exceeded the respective national rates by less than 2 percent. Whereas 13 regions suffered absolute population losses, if present fertility, mortality, and spatial patterns continue, the number may increase to 16 by the year 2000 and to 21 by 2020, according to multiregional population projections (Willekens and Rogers 1978).

The data offer only limited support for the postulated association between urban growth and size. Perhaps this statement would not have been true if national population increase and urbanization level had been kept constant within the data sample, or if the regions were disaggregated into cores and rings. Unfortunately, the small number of observation units prevents such comparisons.

HYPOTHESIS 2. THE ROLE OF MIGRATION AND NATURAL INCREASE AS COMPONENTS OF URBAN POPULATION GROWTH EVOLVE IN THE COURSE OF THE URBANIZATION PROCESS. DURING ITS ADVANCED STAGES THE CONTRIBUTION OF MIGRATION TO THE GROWTH OF LARGE CITIES BECOMES OF SECONDARY IMPORTANCE.

A substantial body of literature has recently accumulated pertaining to the changing proportions and interaction among the two major components of urban growth. Keyfitz (1980), in view of contrasting empirical evidence, attempted to put this question on a theoretical plane. Among other things, he identified conditions for the crossover point beyond which, with all rates kept constant, the urban population growth becomes predominantly endogenous. Following his argument, one may conclude that in the developed countries of today the growth of cities should be increasingly due to the natural increase of the urban population. Such a development is likely to occur when, at an advanced urbanization level, the core-periphery development patterns (Friedmann 1977) evolve in favor of peripheral zones. Higher investments in the countryside are translated into a lower natural increase of its population, lower outmigration to urban areas, and finally, higher urban-rural migration rates.[2]

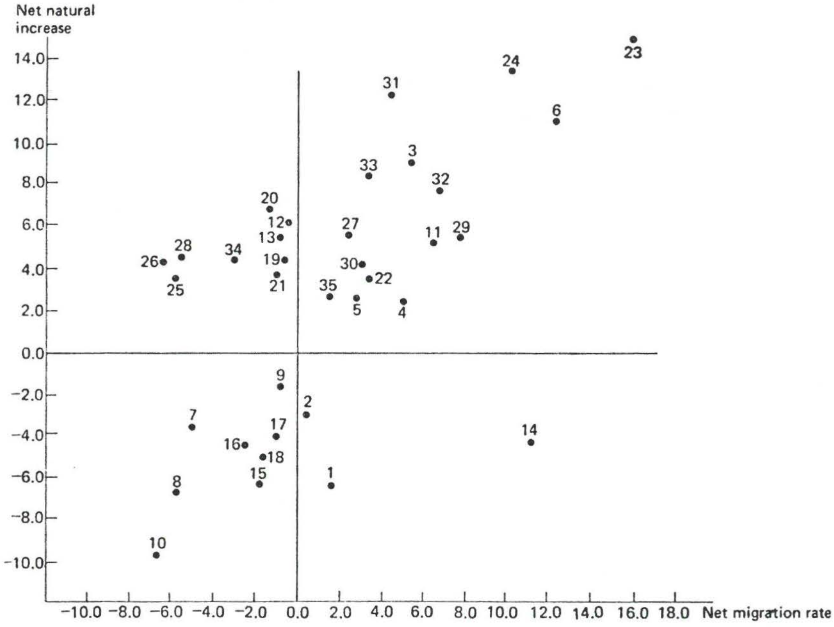
Consideration of aggregate national growth rates of the urban population is not sufficient for the purposes of this paper, which is concerned with changes within settlement systems. Hypothesis 2 rests on the assumption (also reflected in Hypothesis 1) that large cities actually lead the trends generally established for the urban sector, especially as they account for a substantial share (estimated at between 0.4 and 0.8 depending on the country and definition used) of the total urban population at advanced urbanization levels. Hence, the larger the urban region and the higher the urbanization level, the smaller the expected contribution of migration (as compared with natural increase) to the total population change.

The empirical evidence coming from the Migration and Settlement Study quite strongly supports the statements above. Of the 35 regions, 24 feature a positive natural increase, whereas only 18 show positive migration. Natural increase appears the greater contributor in 19 cases, migration in 16. Of the latter group, 7 regions are characterized by a negative migration balance (also less pronounced when compared with natural population decrease); in 5 regions with both rates positive, the migration component was just marginally larger. About half of the regions with a higher contribution of natural increase — including Paris (12), London (19), and Randstad (28) — had a negative migration balance, but only one — Bremen (7) — had both rates negative (see Figure 2).

[2] This discussion pertains to migration and natural increase, measured by one-year rates. In a sense, all urban growth is attributable to migration, as present-day urban populations represent the accumulation of successive generations of migrants and their offspring.

FIGURE 2

MAJOR COMPONENTS OF POPULATION CHANGE IN 35 URBAN REGIONS



Similar net values, however, may conceal substantial differences in demographic behavior. It is therefore necessary to look at some of the theoretically postulated relationships. For example, the data show a rather high correlation between the crude birth and death rates for the 35 spatial units under analysis — a pattern typical of a late stage in demographic transition (the majority of regions fall into the class with high death and low birth rates). The association between gross inmigration and outmigration rates postulated by Cordey-Hayes (1975) and others finds limited support. Finally, the relationship between birth rates and outmigration rates is of a totally symmetric nature.

None of the above conclusions disproves the earlier findings on the contribution of the two aggregate components of population change in the urban regions. Still, the greater role of natural increase as a contributor to growth is due to the poor performance of urban regions in attracting migrants from other units within the respective multiregional systems rather than to the high fertility of their resident populations. More than two-thirds of the urban regions have natural increase rates lower than the relevant national rates. The patterns of net reproduction rates are even more striking: only five regions are situated above the respective national (multiregional) values.

The decrease of net migration, both in absolute magnitude and as a contributor to total population change, appears to be a recent phenomenon. For example, during the 1960s migration accounted for between 75 and 95 percent of the total urban population growth in a number of European countries (Economic Commission for Europe 1979, p. 204). In the case of cores of the largest Japanese urban regions (the urban agglomerations of Tokyo and Osaka) the ratios of natural increase to net migration have evolved from 1:2 during the late 1950s to 3:1 for Tokyo and 30:1 for Osaka during the 1970-75 period (Nanjo, Kawashima, and Kuroda 1982). As has been noted, the analyses by Keyfitz (1980) are restricted to the case where total population is disaggregated into rural and urban parts. Still, the data just presented point to a behavior of large urban regions that tends to be similar to the expected behavior of the total urban population under the migration and natural increase regimes prevailing in highly urbanized societies — as if all urban inmigration corresponds to rural outmigration.

The knowledge of disaggregate patterns of population growth and decline is essential for the study of urban change. In the simplest case, urban population may be treated as consisting of the metropolitan (P_a) and other urban (P_{u-a}) sectors. The accounting formula used by Keyfitz (1980, p. 153) and Rogers (1968) to describe the evolving rural (P_r) and urban (P_u) population over time is:

$$DP_r = (r - m)\ P_r + n\ P_u$$
$$DP_u = m\ P_r + (u - n)\ P_u$$

where r and u are rates of natural increase of the rural and urban population, respectively, D denotes the derivative with respect to time, and time subscripts are implied for the population variables. Expanding the formulae would yield:

$$DP_a = (r - m_u)\ P_r + n_r P_{u-a} + q_r P_a$$
$$DP_{u-a} = m_{u-a} P_r + q_{u-a} P + [(u - a) - (n_r + n_a)]\ P_{u-a}$$
$$DP_a = m_a P_r + n_a P_{u-a} + [a - (q_r + q_{u-a})]\ P_a$$

where m_{u-a} is the fraction of the rural population that moves to urban, non-metropolitan areas; m_a is the fraction of the rural population that moves to metropolitan areas; n_a is the fraction of the urban, non-metropolitan population that moves to metropolitan areas; n_r is the fraction of the urban, non-metropolitan population that moves to rural areas; q_{u-a} is the fraction of the metropolitan population that moves to urban, non-metropolitan areas; q_r is the fraction of the metropolitan population that moves to rural areas; and u and a are the natural increase rates of the metropolitan and remaining urban populations.

Following this approach one could find out to what extent the recently observed decrease in net migration towards large urban agglomerations has been due to the declining fraction of the rural population within a country as a whole, or, alternatively, to the reorientation of urban-to-urban migrations (see Alonso 1978). Such an analysis could be further expanded into a number of city-size and/or functional-type categories using a matrix format. Unfortunately, the data on which this paper is based are of little help in pursuing this analysis.

The approaches and findings discussed so far all pertain to the case where the contribution of natural increase and migration is defined as a difference between respective rates for a given spatial aggregate — a city, region, or total urban population of a given country. However, the question of the components of population change may be considered in terms of their variability within a spatial system. When such a definition is preferred, migration generally appears as the greater contributor, for example, in a study by Kenneth (1977) of patterns of population change for 126 MELAs (Metropolitan Economic Labor Areas) in Great Britain from 1961 to 1971. Whereas the overwhelming majority of these areas had natural increase rates approximating Britain's 6 percent decennial increase, the net migration rates extended over a broad range from −10.0 to 40.0. Thus the differentiating effect in the population growth pattern within an urban system can be mainly attributed to the migration component. Similar conclusions are derived by Borchert (1980) for Dutch municipalities during 1961-73 and by Simmons (1977) for 124 urban regions in Canada. In the latter analysis net internal migration explains more of the variations in the total population change during 1966-71 than natural increase and net foreign inmigration combined. Although during the subsequent period (1971-76) the variation in natural increase among the regions increased while that of net migration declined, the differentials between the two were still substantial. At the same time the rates of natural increase remained considerably higher than those of net migration for all the major hierarchical levels within the system (Simmons 1979).

One cannot expect such trends to continue for more than a few decades if current national population projections are to hold true. Once the natural increase at the national level falls toward zero, migration will gain ascendancy even in terms of rates. However, definitional problems are not easily resolved. For example, it is not clear whether the contribution should be measured in terms of change or of growth only. As to spatial effects of such an evolution, the following generalization by Bourne (1982) seems instructive:

> During periods of rapid aggregate growth, particularly high rates of natural increase, almost all areas witness growth. During periods of high foreign immigration growth tends to become more focused spatially. Similarly, as the contribution of natural increase to aggregate growth declines, spatial variability increases (p. 144).

HYPOTHESIS 3. THE POPULATION OF LARGE CITIES IS CHARACTERIZED BY GREATER SPATIAL MOBILITY THAN RURAL AND NON-METROPOLITAN POPULATIONS.

According to the concept of mobility transition (Zelinsky 1971), spatial mobility increases during the rapid urbanization stage and remains high afterwards. As Rogers (1977) pointed out, however, the decrease of interregional welfare disparities may eventually bring about a decline in geographical mobility. Also, short-distance migration may be largely replaced by daily commuting between residence and workplace.

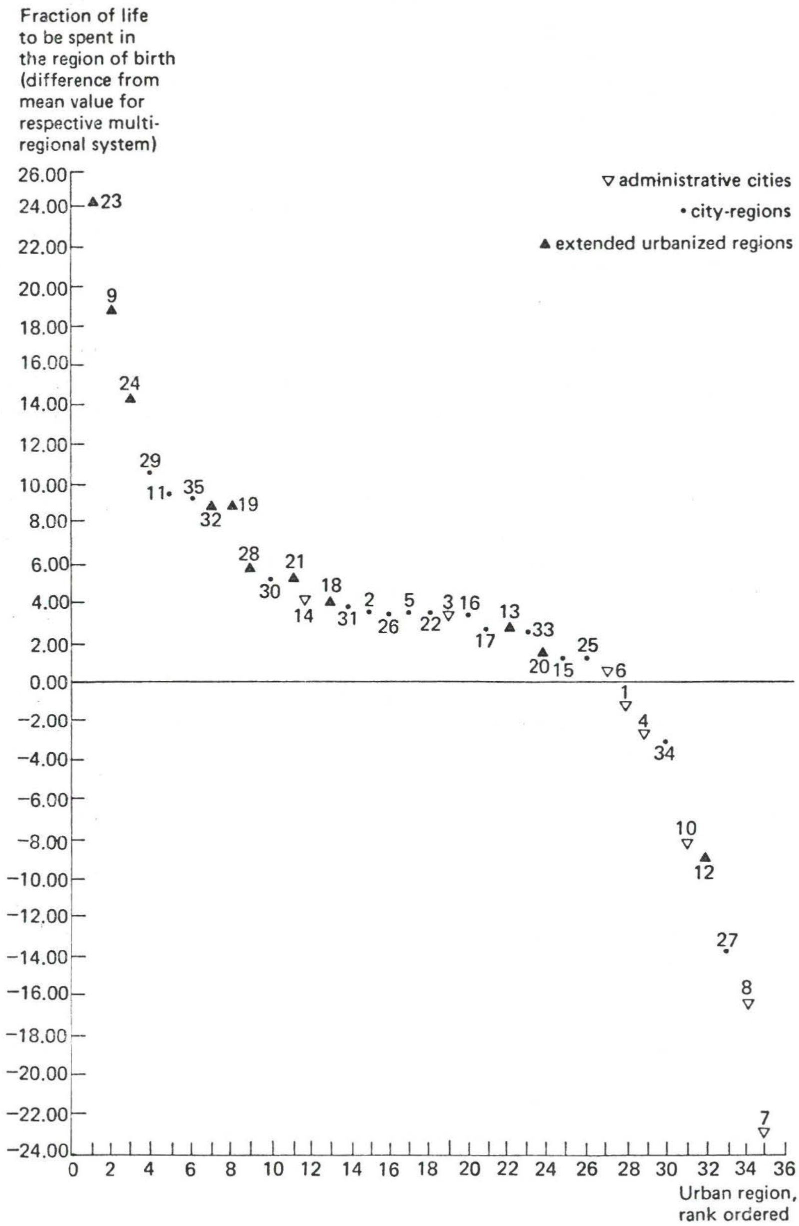
No matter which way the overall mobility indices evolve during the later stages of the demographic and urbanization transitions, the large-city population is expected to be more mobile than either the rural or the small-city (non-metropolitan) population. This expectation stems from positive relationships found in a number of developed countries between the propensity to move and such variables as educational level and female labor participation (Brown and Neuburger 1977). Other factors reportedly contributing to the greater spatial mobility of the large-city population include a delayed family formation and growth process and the accumulation within cities of individuals with previous migration experience and a high repeat-migration (including return-migration) probability (see DaVanzo and Morrison 1978 and DaVanzo 1980). Conversely, large urban places may be sending out and attracting disproportionately fewer migrants because of the greater internal opportunities they offer (Simmons 1979).

This observation finds empirical support when mobility is measured by the expected fraction of life of an individual to be spent in the region of birth, calculated on the basis of age-specific migration and mortality rates. For a typical urban region this fraction is some 3 to 4 percent higher than the mean share for the respective multiregional system (Figure 3). For only eight regions are such probabilities lower than mean national values: four of these regions have experienced negative total population change and five show net migration loss. As might have been anticipated, the pattern represented in Figure 3 is not independent of the population size of urban regions. Among eight regions for which the fraction of life to be spent in the region of birth is highest relative to corresponding mean values, five constitute large, polynucleated regions, including the urban agglomerations of Kanto (23), Kinki (24), Nordrhein Westfalen (9), Southeast England (19), and Upper Silesia (32). On the other hand, administrative cities are clustered within lowest relative-fraction intervals.

The distribution of the values of another summary measure of population mobility, the net migraproduction rate (Willekens and Rogers 1978), is very close to the allocation of the expected length of

FIGURE 3

SPATIAL MIGRATION LEVELS FOR 35 URBAN REGIONS



stay in a region.[3] Only in the case of 16 urban regions (out of 35) is a locally born individual expected to make more moves during his life span than an average person in the respective national (multiregional) system. Six of these regions recorded absolute population losses around 1975, and seven regions experienced negative migration balance. No regularities can be found concerning the relationship between net migraproduction rates and population size of urban regions.

In sum, the interregional migration patterns suggest that the large-city population seems to be less rather than more mobile than the total population. Though causal interpretation is not attempted at this point, various explanatory factors may be relevant in different national contexts, some related to settlement policies (for example, restrictions on inmigration tend to discourage outmigration), others to substitution between migration and daily travel. The initial hypothesis, however, should not be totally discarded, since the evidence is positive for regions (basically administrative cities) with highest population losses. Still, a typical urban region with a slowly growing or decreasing population is characterized by relatively low overall mobility.

HYPOTHESIS 4. THE DOMINANT MIGRATION FLOWS WITHIN HIGHLY URBANIZED COUNTRIES ARE AMONG MAJOR URBAN REGIONS. THE TRADITIONAL CONFIGURATION OF INTERURBAN MOVES, WHICH CORRESPONDS TO AN URBAN HIERARCHY, EVOLVES TOWARD A PATTERN CHARACTERIZED BY A LACK OF INTERDEPENDENCE BETWEEN NET INFLOW AND CITY SIZE.

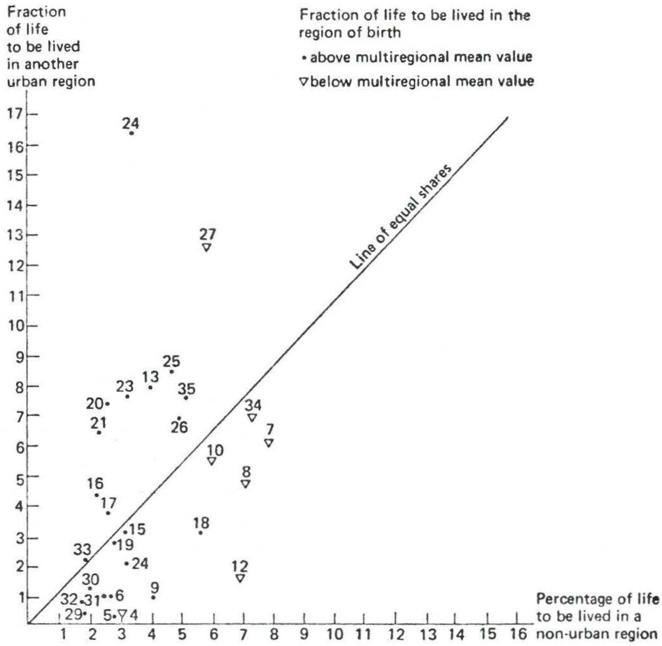
Unlike the previous one, this hypothesis is concerned with *directional* mobility. It refers to the third stage in Zelinsky's scheme of mobility transition, during which rural-to-urban migration is gradually replaced by urban-to-urban flows and commuting within urban regions as well as by an increasing population shift outwards from the large cities toward smaller communities.

The structure of national settlement systems in highly urbanized societies has been described as a combination of vertical (hierarchical) and horizontal linkages (see for example, Bourne 1975). The latter component is mainly represented by interconnections among the large cities that perform high-level service and decision-making functions. This is the basis for Pred's (1975) model of city-systems development and Dziewoński's (1980) concept of the system of main urban centers. Translated into population-related terms, such concepts suggest that the origin and destination-specific migration rates, spatial migraproduction rates, and other demographic mobility measures attain levels higher among urban regions than among non-urban regions or between urban and non-urban regions.

[3] This rate describes the average number of migrations a person will make during his lifetime.

FIGURE 4

SPATIAL ALLOCATION OF LIFE EXPECTANCY AT BIRTH FOR 29 URBAN REGIONS



Looking at in- and outmigration rates region by region would not be a helpful exercise in view of the divergences in population size and the role played by physical distance. Instead the data are arranged to enable a comparison of demographic interaction occurring between a given urban region and an aggregate of other urban regions vis-à-vis "non-urban" regions within the multiregional system. Figure 4 shows the spatial allocation of life expectancy at birth for 29 urban regions (the remaining six, Vienna, East Austria, Randstad, Helsinki, Sofia, and Budapest, have no urban counterparts within the respective systems). One of the regularities to be observed pertains to the importance of the gravity factors, mass and distance. Strong interactions among urban regions occur typically when the units are situated close to each other and have large population potential compared with other regions. Relatively weak linkages are characteristic of smaller regions (including administrative cities) and of those urban regions whose urban counterparts represent much smaller potential. For example, an individual born in the West Midlands region (20) of England is expected to spend an average of 7.41 percent of his life span in each of the two other urban regions, Southeast and Northwest England, but only an average of 2.82 percent in each of the seven "non-urban" regions. A person born in Prague (4), however, would live only 0.24 percent of his life in Bratislava (the only other urban region in the multiregional system), versus an average of 2.95 percent in each of the "non-urban" regions. This case also illustrates data inadequacies: the latter proportion may be heavily accounted for by flows towards such cities as Brno and Ostrava, which constitute cores of "non-urban" regions. Note also that due to variations in the number of regions, only proportions between the "urban" and "non-urban" components, and not the percentage figures, are of any comparative value.

The pattern of spatial net migraproduction rates conforms to the life expectancy pattern. Regions with strong "non-urban" connections are somewhat more numerous than those with predominantly urban-oriented linkages. However, as indicated earlier, "non-urban" is not a uniform category; it may include traditional nodal regions and city hinterlands as well as remote rural periphery. Generally speaking, urban regions characterized by relatively high outmigration rates display stronger interactions with the "non-urban" units. For example, according to observed migration patterns, a person born in Bremen (7) may be expected to move out of an average "non-urban" region more frequently than an average urban region within the system. In fact, a substantial fraction of the former moves is accounted for by the neighboring region of Lower Saxony, the main destination of Bremen-born migrants. The average share of urban regions as origins of outmigration by the natives of Bremen is lower than their respective life expectancy share, because of higher average outmigration rates experienced by "non-urban" as compared with urban regions. (In the calculations individuals assume mobility rates of the region of destination.)

The second part of the hypothesis relates to interdependence between net migration and urban size. Traditional theories of settlement structure imply that population flows among urban places represent a reversal of innovation diffusion patterns, i.e., the direction of the predominant numbers of moves is up the urban size hierarchy. During earlier stages of the urbanization transition, typical moves are those from rural to urban communities (both small and large), whereas more advanced stages witness concentration within the settlement network, with smaller towns losing their population in favor of metropolitan areas. This process may involve a number of generations of moves as well as of migrants.

Thus, according to the concept of hierarchical migration, categories of urban places record net migration gains in their interaction with each of the smaller-sized categories and net losses with respect to each of the larger-sized groups of cities. This regularity found in growing urban systems such as those of Japan (Kawashima 1982) and Poland (Dziewoński 1980) is not likely to hold true when the largest cities register absolute population losses (although it is still possible because of variations in the natural increase). Such a situation, however, may arise under various interurban and urban/non-urban (core-hinterland) patterns of population movements. As Alonso (1978) pointed out, under a low level of natural increase and rural outmigration, the flows among metropolitan areas represent a zero-sum game, in which individual urban units may fall into the category of net losers as a consequence of their relatively poor economic base and environmental quality, characteristics not necessarily related to overall population potential.

The concept of hierarchical migration has been questioned by Simmons (1977, 1979) and Drewett et al. (1978). Their analyses of migration flows among urban regions in Canada and Great Britain, respectively, take account of population deconcentration from large urban cores to peripheral areas and subcenters. From 1966 to 1971 the net migration among 124 urban regions in Canada, aggregated into five hierarchical groups, showed moderate net losses for regions of order 5 (composed of the two largest metropolitan areas of Montreal and Toronto) and 3 (regions centered on medium-sized towns), and heavier losses for order 1 (regions with small towns as cores). Net gainers were regions focused on cities with some 100,000 to 1,000,000 inhabitants (order 2), as well as regions of order 4, in particular those located in the proximity of large urban centers. When regions were rearranged to form 11 spatial subsystems centered on metropolitan areas of the two upper levels, the net migration patterns were dominated by interregional population shifts from eastern to central and from central to western provinces (Simmons 1977). In the subsequent period of 1971 to 1976 the relation between the urban size (hierarchical level) and net migration became more pronouncedly negative, with increasing losses in the two largest metropolitan areas, declining gains in the remaining large urban regions, and a change from a heavy loss to a nominal gain for regions centered on the smallest towns in the system. In the 11-region breakdown the most visible changes were shifts from a positive to negative internal migration balance for the metropolitan region of Toronto and a decline in the gains of Vancouver, the third largest urban region.

Drewett et al. (1978) have demonstrated that flows from bigger to smaller Metropolitan Economic Labor Areas in Britain accounted for a higher proportion of total moves within short distances than over long distances. This implies that hierarchical migration patterns are still characteristic of an interregional scale; however, deconcentration from large city-cores to metropolitan rings has rendered this generalization inadequate when intraregional population shifts are examined. Migration patterns of the seven largest urban regions of Great Britain (each with more than one million inhabitants) reveal a positive association between population number and net migration loss from 1966 to 1971. Still, the London region maintained a positive migration balance with each of the remaining six large metropolitan areas (Kenneth 1977).

The data on migration between pairs of urban regions do not disprove the hierarchical migration concept. On the contrary, in 30 cases the destination-specific outmigration rates are higher for urban regions with a smaller population size (see Table 2).[4] The size and direction of net flows, as measured by the index of migration effectiveness, reveals a somewhat different pattern, however. Although smaller regions recorded a net migration gain only in 12 out of 33 cases, this pattern was typical of countries with 75 to 85 percent urban population, including the Netherlands, both Germanies and Sweden. Some of these flows, for example, Stockholm to the south of Sweden and Noord-Holland to Utrecht, can be attributed to environmental factors. Vienna and Prague maintained positive migration balances with their hinterlands, but the effectiveness values were very small. This is also true of interactions among the three urban regions of England. In any event the size of net flows cannot be explained by differences in population size between the origin and destination.

The material presented both falls short of providing consistent evidence against the concept of intermetropolitan linkages and offers little to support it. Intensive migration takes place mostly among those urban regions that form a contiguous territory (the Randstad, the south of the German Democratic Republic, Hall's Megalopolis England) or that are situated fairly close to each other.

In support of the hypothesis one may argue (as many authors have) that the importance of intermetropolitan migration rests not as much on volume as on composition and "quality." Such flows tend to be highly selective in social, economic, and demographic terms. The data allow a closer look at one of the crucial characteristics of migrants, i.e., their age structure.

HYPOTHESIS 5. THE AGE PROFILE OF INTERURBAN MIGRATION IS TYPICAL OF THE OUTFLOW SCHEDULE FOR A CAPITAL REGION, I.E., IT IS LESS LABOR DOMINANT AND LESS LABOR SYMMETRIC THAN THE CORRESPONDING INFLOW SCHEDULE.

This statement paraphrases the hypothesis identified by Rogers and Castro (1981) pertaining to differences between inflow and outflow profiles for capital regions. Their data relate to 8 of the 35 urban regions analyzed in this paper.

The age structure of migrants represents perhaps the most important characteristic of population flows from the point of view of both

[4] Because of its function as a capital, Berlin was treated as a "larger" unit than the Leipzig-Halle, Karl Marx Stadt, and Dresden regions. Similarly, Warsaw was considered "larger" than the Katowice region, despite a smaller population size. Such exceptions would not have to be made had regional size been measured by the aggregate population of the main urban center.

TABLE 2

MIGRATION BETWEEN 33 PAIRS OF URBAN REGIONS: RATES AND NET FLOWS

No.	Pairs of regions (A<>B)[a]	Out-migration rate from A to B	Out-migration rate from B to A	Effectiveness[b]	Mean age of migrants (A/B)
1	Vienna-Lower Austria	0.0035	0.0048	9.07	33/29
2	Prague-Central Bohemia	0.0044	0.0056	12.12	38/34
3	Prague-Bratislava	0.0001	0.0004	23.76	42/46
4	Hamburg-Bremen	0.0006	0.0014	− 3.43	32/33
5	Nordrhein Westfalen-Hamburg	0.0003	0.0029	− 6.21	32/33
6	West Berlin-Hamburg	0.0009	0.0007	−18.74	33/31
7	Nordrhein Westfalen-Bremen	0.0002	0.0041	− 6.37	31/32
8	Nordrhein Westfalen-West Berlin	0.0005	0.0051	7.43	32/35
9	West Berlin-Bremen	0.0004	0.0009	− 6.85	32/33
10	Paris-North	0.0005	0.0026	38.68	34/29
11	Berlin-Leipzig/Halle	0.0007	0.0009	42.15	25/26
12	Berlin-Karl Marx Stadt	0.0004	0.0006	41.53	26/24
13	Berlin-Dresden	0.0004	0.0009	55.39	27/25
14	Leipzig/Halle-Karl-Marx-Stadt	0.0008	0.0015	3.41	27/25
15	Leipzig/Halle-Dresden	0.0007	0.0011	− 6.90	27/25
16	Karl-Marx-Stadt-Dresden	0.0011	0.0009	−13.70	27/26
17	Southeast England-Northwest England	0.0008	0.0026	11.92	32/31
18	Southeast England-West Midlands	0.0008	0.0031	8.05	31/33
19	Northwest England-West Midlands	0.0009	0.0013	4.36	31/32
20	Kanto-Kinki	0.0026	0.0057	17.13	34/31
21	Zuid-Holland-Noord-Holland	0.0040	0.0051	− 1.58	34/37
22	Zuid-Holland-Utrecht	0.0030	0.0084	−11.16	36/34
23	Noord-Holland-Utrecht	0.0045	0.0084	−17.95	38/34
24	Warsaw-Łódź	0.0001	0.0005	29.65	53/36
25	Warsaw-Gdańsk	0.0002	0.0004	18.96	43/56
26	Warsaw-Katowice	0.0002	0.0002	14.87	45/35
27	Warsaw-Cracow	0.0001	0.0003	29.45	52/38
28	Katowice-Łódź	0.0001	0.0003	30.66	42/30
29	Katowice-Gdańsk	0.0001	0.0003	− 5.88	35/39
30	Katowice-Cracow	0.0004	0.0022	25.94	43/34
31	Gdańsk-Cracow	0.0001	0.0001	10.30	52/34
32	Cracow-Łódź	0.0001	0.0001	6.06	38/34
33	Stockholm-South Sweden	0.0023	0.0025	− 9.31	32/28

[a] A has larger population than B (see footnote 4).
[b] Effectiveness of migration is defined as the net exchange between two regions divided by total migration between them or $[(M_{AB} - M_{BA})/(M_{AB} + M_{BA})]\ 100$.

economic and demographic change. Its interrelation with labor force formation and service demand is as strong as its fertility and mortality implications. The large cities have traditionally benefited from a heavy concentration of migrants within the early labor force and reproductive age groups as well as from sending more of their elderly and mid-career members of the labor force to smaller urban and non-urban places. However, as interurban moves become a major component of interregional migration and the positive association between migration patterns and urban hierarchy tends to disappear, the differences between the inflow and outflow schedules will also diminish. This trend would have pronounced and (largely negative) long-term effects on the economic and demographic development of large metropolitan areas.

Such a hypothesis may not apply on an intraregional scale, in particular to migration between cores and peripheries within urban regions. The typical pattern is one in which moves toward large-city cores are dominated by young individuals, whereas families prevail among the outmigrating population (see Borchert 1980; van der Knapp and Sleegers 1981; Ley and Mercer 1980). There are no indications that such a pattern may undergo major change under conditions of interregional deconcentration of settlements.

As a preliminary step in the study of interurban migration profiles, the model migration-by-age schedule developed by Castro and Rogers (1979) was fitted to the data for urban regions of the Federal Republic of Germany, Poland, and Japan. The resulting generalized profiles are compared with conclusions of Rogers and Castro (1981) concerning aggregate migration into and out of selected capital regions.

The aggregate-flow profiles are very similar to those identified for the eight capital regions. Contrary to expectations, however, the origin-destination-specific schedules do not greatly depart from the aggregate schedules for inmigration. The outmigration profiles (from Hamburg to Nordrhein Westfalen and from Hamburg to Bremen) are more interesting in this respect as they show a shift in the labor peak, also reflected in the higher mean age of migrants, when compared with the total out-of-Hamburg schedule (Figure 5).

A different pattern emerges when migration profiles for the two Japanese urban regions are examined (Figure 6). In this case the origin-destination-specific flows closely resemble the aggregate out-of-Kanto (Tokyo) schedule and sharply contrast with the aggregate into-Kanto migration. This is true of the height of the labor peak as well as the rate of ascent and descent of the labor force curve.

The age profiles for flows into, out of, and between the five urban regions of Poland display some peculiar characteristics. As to the initial hypothesis, the evidence is mixed, with some of the parameter values for origin-destination-specific flows typical of either the aggregate in- or outmigration schedules (see Figure 7). A striking feature of the observed schedules is a large difference between the mean age of in- as

FIGURE 5

MIGRATION AGE PATTERNS FOR URBAN REGIONS: FEDERAL REPUBLIC OF GERMANY, 1974

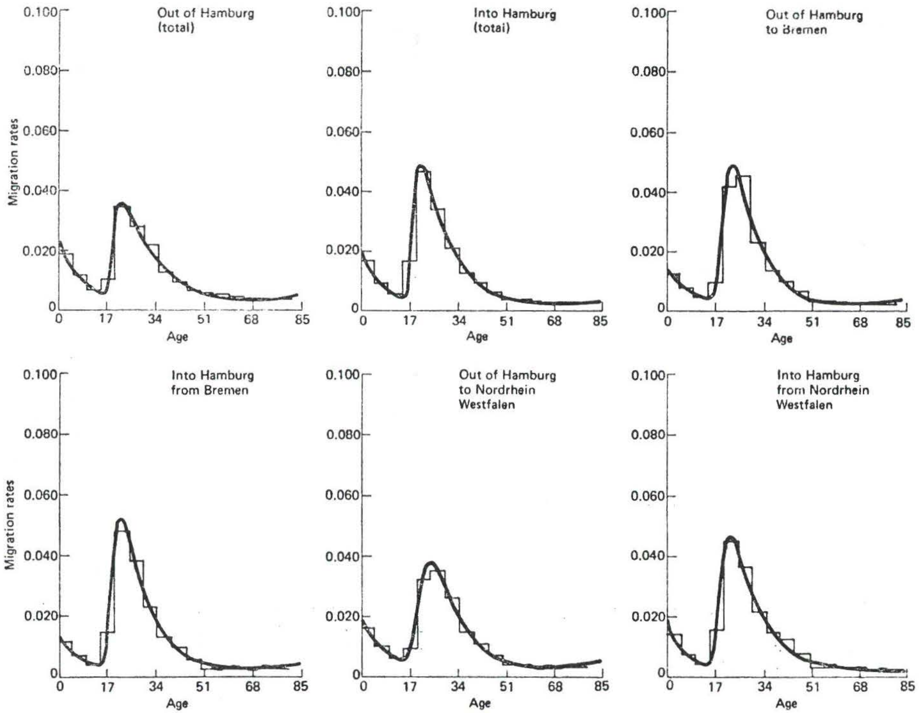


FIGURE 6

MIGRATION AGE PATTERNS FOR URBAN REGIONS: JAPAN, 1970

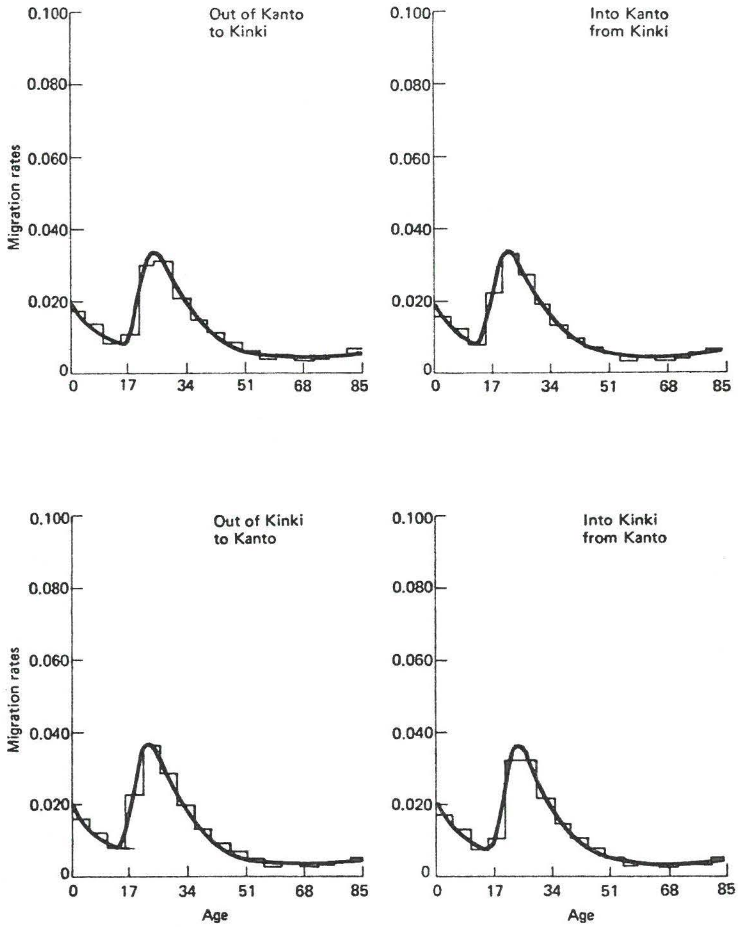
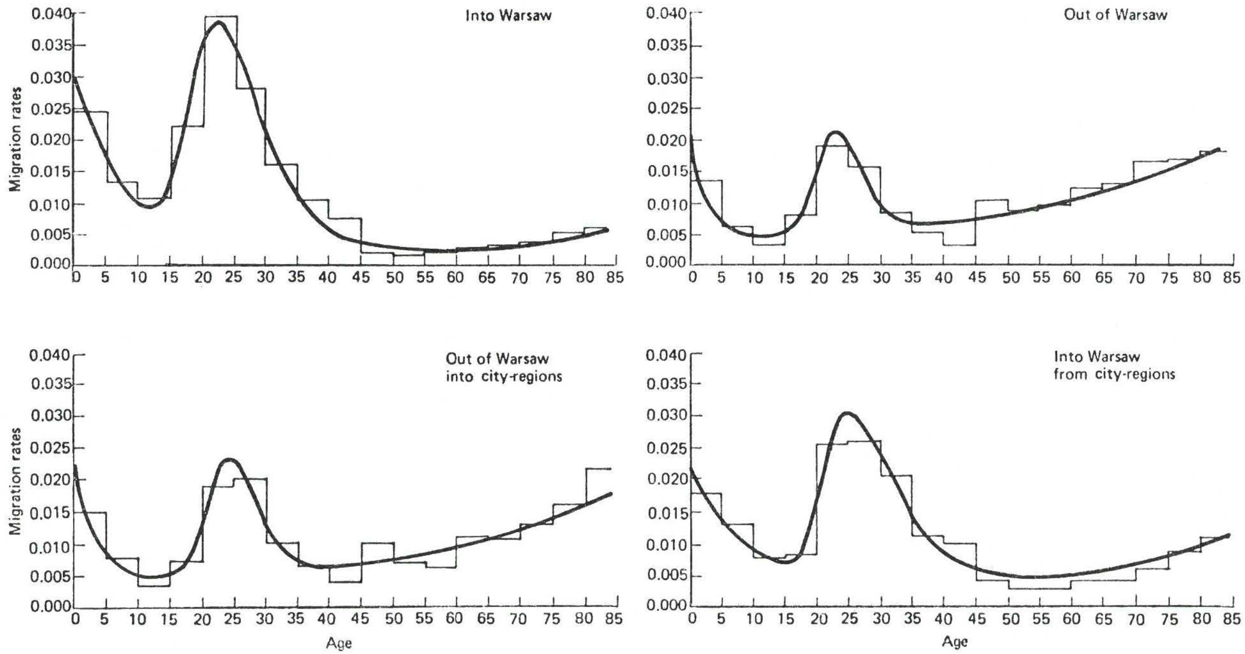


FIGURE 7

MIGRATION AGE PATTERNS FOR URBAN REGIONS: POLAND, 1977



opposed to outmigrants, a consequence of both the under-representation of younger migrants from the large cities and the prominence of outmigration by the elderly. This phenomenon has been documented and interpreted in sociological literature (Latuch 1970).

Another nonconventional characteristic of the age profiles of migrations between the urban regions of Poland is a secondary peak in the 45-50 age group. It is especially noticeable in the case of total outflows from Warsaw but can also be found in the outmigration profiles for the Katowice (Upper Silesia) region. This elevation can be attributed to such factors as mid-career moves by senior executives from the main administrative and industrial centers towards provincial capitals and smaller cities in general. An introduction of longitudinal data would be required to test the viability of this irregularity in the age profiles.

The hypothesis concerning age composition of interurban migrations thus finds a partial confirmation in the reviewed material. Compared with aggregate inmigration flows, the flows from and between urban regions are characterized by a shift of the labor force-related peak towards higher age groups (mainly from the 20-25 to the 25-30 category), lower relative height, and to some extent a mid-career migration peak.

III. CONCLUSION

Several social sciences have contributed to the study of spatial migration patterns by focusing on different aspects and determinants of moves. The sociological approach assumes the importance of family and kinship ties, the geographical hypothesis refers to the role of distance and size of the interacting centers, the demographic framework explores the impacts of the age and sex structure of the population at risk, and the economic approach refers to variations in income, labor demand, education, housing, or environmental quality. The policy approach is concerned with ways in which interaction between all the factors and variables can be translated into normative terms.

This paper has examined migration as a correlate of and proxy for the changing place of large cities within national settlement systems. It emphasizes relationships between the population composition of urban regions and spatial mobility. The nature of the data only allowed the description of observed patterns and exploration of their implications for future development. A rigorous economic or policy interpretation is not possible at the chosen comparative scale even if much richer data were available.

Two limitations of the background material should be noted: (a) the set of urban regions was not large and homogeneous enough to allow extended statistical analysis, and (b) population shifts between cores and peripheries of urban regions could not be accounted for owing to the large size of the spatial units. Bearing these restrictions in mind, the findings derived from the Migration and Settlement Study are basically in accord with the first, second and fifth hypotheses. When the analysis is limited to those urban regions that have actually experienced population decline during the 1970s, the fourth hypothesis is also partially supported. The only case in which there is basically no positive evidence pertains to the interregional mobility level of the population living in large urban areas.

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Modeling Urban Decline: A Multilevel Economic-Demographic Model for the Dortmund Region

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ABSTRACT Selected results of a multilevel dynamic simulation model of the economic and demographic development of the urban region of Dortmund are presented. In particular, the capability of the model to capture both urban growth and urban decline processes is illustrated. The mechanisms that control spatial growth, decline, or redistribution of activities in the model are first outlined, and a demonstration of how the model reproduces the general pattern of past spatial development follows. Finally, results of simulations covering a wide range of potential overall economic and demographic development in the region are discussed.

I. INTRODUCTION

Like other highly industrialized countries, the Federal Republic of Germany has experienced a fundamental change of direction in the development of its settlement structure. Whereas the fifties and sixties were characterized by massive growth and expansion of urbanized areas at the expense of rural regions, the seventies saw an increasing outmigration of population and industry from the centers of the agglomerations to their peripheries and beyond. In combination with decreasing birth rates and continuing economic change, a decline of population has resulted in all larger agglomerations and a decline of employment in some of them.

On the scale of an urban region, four phases of development encompassing this shift of direction can be distinguished (van den Berg and Klaassen 1978). Consider an urban region divided into two components: the urban core and the suburban periphery (see Figure 1). In phase 1, the urbanization phase, both components grow, but more

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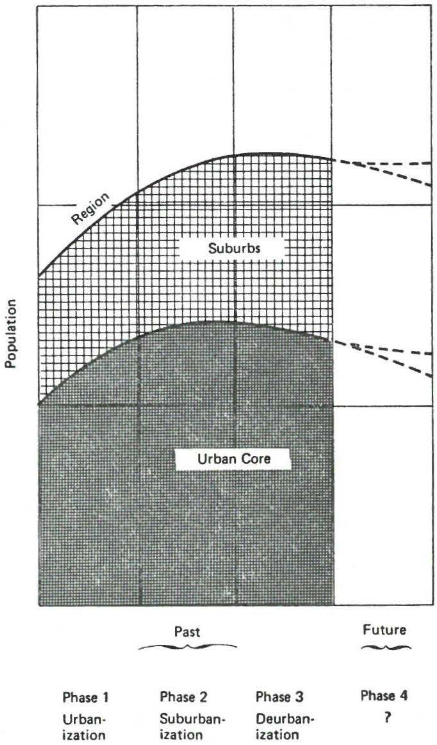
FIGURE 1

URBANIZATION, SUBURBANIZATION, AND DEURBANIZATION



Source: Van den Berg and Klaassen 1978.

growth occurs in the core. In phase 2, the growth curve of the urban core flattens, as more growth is attracted to the less urbanized periphery. In phase 3, the urban core declines, while growth continues in the suburbs at a diminishing rate and at some point in time the total region starts to decline. Phase 4 is the uncertain future.

The basic causes underlying phases 1 through 3 seem to be well known. At times of high overall population growth, job opportunities in cities were the major force behind the urbanization process. Rising incomes and modern transport technologies (the automobile) made suburbanization possible. Deurbanization does not seem to be a third, entirely new phenomenon, but rather the continuation of suburbanization under conditions of overall population decline. There seems to be no agreement on the prospects of phase 4: Will deurbanization persist, will it level off, or will forces, such as rising costs of travel, stimulate a new contraction of urban form?

Unfortunately, regional science and related disciplines have not had much to offer to reduce the uncertainty about the future prospects of urban change. Empirical studies in the 1970s revealed a variety of different patterns of spatial urban development under different economic and demographic conditions (e.g., Leven 1978; Hall and Hay 1980). Most authors agree that a number of economic, demographic, social, and other factors contribute to urban change (Korcelli 1981), but how these factors interact with the spatial urban system is still a question of much speculation.

Perhaps most successful are studies that combine the results of intuitive reasoning in a scenario-like approach (e.g., Arras 1980). Quantitative models of urbanization have been mostly growth oriented, and only very few contain mechanisms that can produce forecasts of decline. Most national or multiregional demoeconomic models treat urbanization as a correlate of sectoral economic change that is not likely to reverse its path (see, for instance, Karlström 1980; Shishido 1982). Even elaborate models that forecast rural-to-urban migration as a function of urban-rural wage or employment differentials and include urbanization constraints such as land supply (e.g., Kelley and Williamson 1980) will not produce migration flows going from the urban core to the urban periphery. Multiregional migration models (Rogers 1975; Rogers and Philipov 1980; Long and Frey 1982) can do so and therefore seem to be well suited to capture the population redistribution aspects of urban decline. However, as these models are based on the probabilistic interpretation of observed frequencies of past behavior, they will not forecast any kind of trend reversal unless explicitly told to. This property makes them superior to any other model for short-term predictions, but in a long-term framework they are most suited for studying the demographic impacts of exogenously entered migration trends.

From the urban analyst's point of view, none of the national or multiregional models will capture the essential causes of urban decline, because they lack the spatial resolution necessary to take account of agglomeration diseconomies and scarcity of resources, most notably of land. Unfortunately, models of urban spatial development have been designed mostly to allocate growth and therefore have failed to address the issue of urban decline. This critique applies to most Lowry derivative or interaction-based land use allocation models (Lowry 1964; Wilson 1974), although some do consider possible causes of urban decline such as aging of the population, economic recession (Gordon and Ledent 1980), or scarcity of buildable land (Putman 1980; Mackett 1980). However, these models fall short of reproducing the preferences as well as the economic and other constraints determining urban location and relocation decisions. Models that attempt to do that, mostly in a microeconomic or random-utility framework, are either restricted to a limited sector of the urban process (like the housing market, e.g., Kain et al. 1976; McFadden 1978), or are still too spatially aggregated to be of interest to the urban planner (e.g., Zahavi et al. 1981). In none is urban decline actually modeled.

Forrester's *Urban Dynamics* (1969) claimed to model growth *and* decline in the evolution of an urban system. Forrester's model, although not spatially disaggregated, put forward a new way of looking at the dynamic interactions between different components within the urban system. More recent dynamic urban models based on bifurcation theory explicitly address the *spatial* evolution of urban systems, i.e., the spatial-temporal pattern in which various activities grow and decline within an urban region (Allen et al. 1981; Beaumont et al. 1981); however, the present results of these models still seem to be at odds with the slow pace and virtual irreversibility of real-world urban change processes.

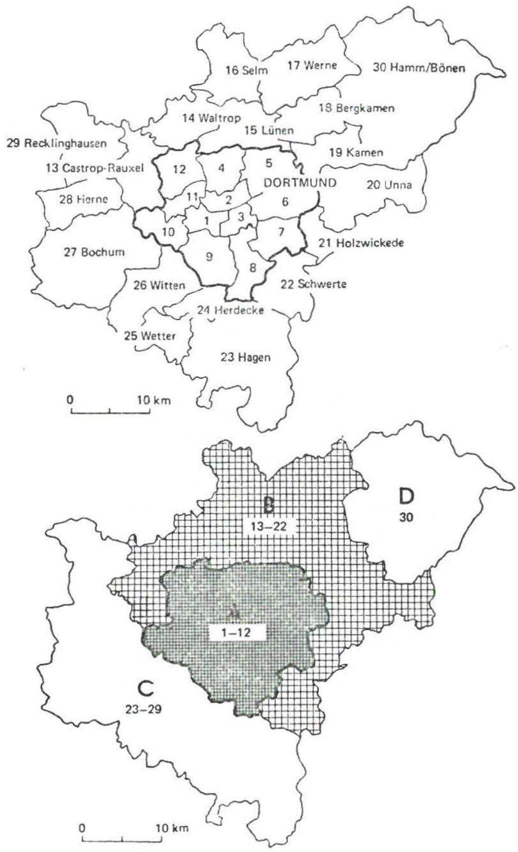
At the core of the difficulties in modeling the spatial evolution of urban systems lies the fact that there is still no agreed upon unified theory of spatial decision behavior of urban actors such as enterprises, households, or individuals. Such a theory would need to be so general as to explain spatial processes of growth and decline, agglomeration and deglomeration, and contraction and dispersal in agreement with empirically founded economic and social theories.

The model discussed in this paper is an attempt to contribute to such a theory. It was designed to simulate location decisions of industry, residential developers, and households; the resulting migration and commuting patterns; the land use development; and the impacts of public programs and policies in the fields of industrial development, housing, and infrastructure. The model is currently operational for the urban region of Dortmund in the Federal Republic of Germany, including Dortmund (pop. 610,000) and 19 neighboring communities with a total population of 2.4 million. For use in the model, the urban region is divided into 30 zones (see Figure 2, top). For summarizing model results, these 30 zones have been grouped into four subregions: (A) Dortmund core area, (B) suburban periphery, (C) Bochum area, and (D) Hamm (see Figure 2, bottom). In this paper, only subregions A (zones 1-12) and B (zones 13-22) will be considered, because they most clearly represent the core and its periphery. Results of all four subregions are discussed in Wegener (forthcoming).

Figure 3 shows that the three phases of urbanization, suburbanization, and deurbanization of Figure 1 have been well replicated by the actual development in the Dortmund region. The fifties clearly are the last years of the urbanization phase: the populations of the core and the periphery grow at annual rates of 2.2 and 2.0 percent, respectively. The sixties may be called the suburbanization phase: population figures of the core zones stagnate, whereas those of the peripheral zones continue to grow at an annual rate of about 0.5 percent. During the seventies deurbanization begins. The core declines at an average

FIGURE 2

THE 30 ZONES (TOP) AND 40 SUBREGIONS (BOTTOM)
OF THE DORTMUND URBAN REGION

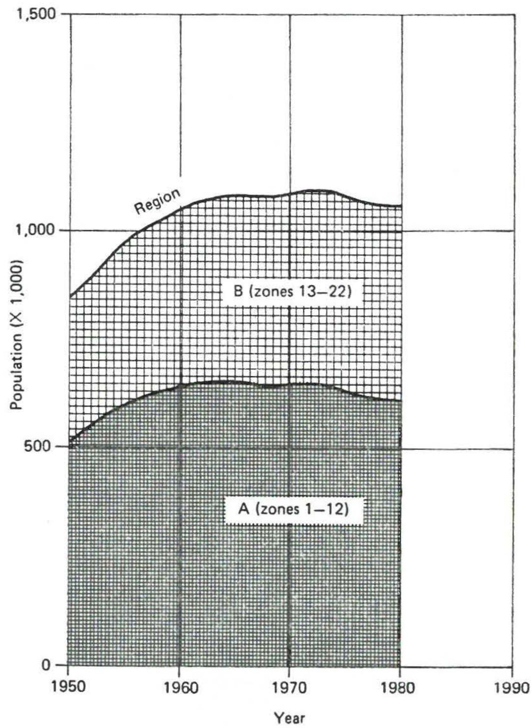


annual rate of 0.6 percent, and growth continues in the peripheral zones, but with a diminishing rate of only 0.3 percent per year, which results in a total annual loss of population in both the core and the periphery of about 0.2 percent per year.

What is going to happen in the region during the next decade, i.e., in phase 4? The discussion proceeds in three sections. In Section II, the mechanisms that control spatial growth, decline, or redistribution of activities in the model are outlined. In Section III, it is demonstrated how the model reproduces the general pattern of past spatial development in the region. In Section IV, results of simulations covering a wide range of potential overall economic and demographic development in the region are presented.

FIGURE 3

URBANIZATION, SUBURBANIZATION, AND DEURBANIZATION IN THE DORTMUND REGION, 1950-1980



II. MODELING URBAN DECLINE

Growth or decline of a region may have exogenous and endogenous causes. Exogenous factors are supply and demand on national and international markets, new technologies or products, trade and labor regulations, or the availability of public subsidies. These make up the framework for regional development, which can hardly be changed by decisionmakers in the region itself. However, regions can respond in different ways to changes in their external framework by adapting their economic and spatial structure more or less efficiently to changing external conditions. These responses are the endogenous factors establishing the comparative advantage of a region competing with other regions for capital, jobs, and people. The endogenous factors consist of public or private decisions. Public decisions are planning or implementation programs enacted by regional or subregional authorities in the fields of industrial development, public housing, land use, transport, or public facilities. Private decisions comprise location, relocation, and mobility decisions by private actors, such as firms, real estate investors, landlords, households, and individuals.

The endogenous adaptation of urban regions to changing exogenous conditions through public and private decisions is the subject of the model discussed in this paper. The model is organized in three spatial levels corresponding to the three lower tiers of the national planning system of the FRG: (1) **Nordrhein-Westfalen**: a model of economic and demographic development in 34 labor market regions in the state of Nordrhein-Westfalen. (2) **Dortmund region**: a model of intraregional location and migration decisions in 30 zones of the urban region of Dortmund. (3) **Dortmund**: a model of land use development in one or more urban districts of Dortmund.

The first model level is a multiregional demoeconomic model of the state of Nordrhein-Westfalen. Its regions are functionally defined as labor markets, each one comprising one or more adjacent employment centers and their hinterland. On this level, information about exogenous, i.e., statewide, economic development in terms of employment and productivity by industrial sector enters the model; the Nordrhein-Westfalen model predicts how regions compete to attract industries and migrants under these exogenous preconditions. Policy variables on this level generally represent policies of the state government such as public subsidies for industrial development, housing programs, or infrastructure investments in specific regions, as well as large-scale location or relocation decisions by major industrial corporations. The Nordrhein-Westfalen model yields forecasts of employment by industry and population by age, sex, and nationality in each of the 34 labor market regions as well as the migration flows between them.

These results are the framework for the second spatial level of the model hierarchy. On this level, the study area is the urban region of Dortmund with its 30 zones (see Figure 2). For these 30 zones, the model predicts intraregional location decisions of industry, residential developers, and households; resulting migration and commuting patterns; the land use development; and the impacts of public policies in the fields of industrial development, housing, or infrastructure investment programs. The results of the Dortmund region model are employment by industry; population by age, sex, and nationality; households by size, income, age, and nationality; dwellings by size, quality, tenure, and building type; and land use by land use category for each of the 30 zones of the urban region, plus the migration and commuting flows between them. These results are in turn the framework for the third model level. On this level, the activities allocated to zones on the second model level are further allocated to any subset of 171 statistical tracts within the urban districts of Dortmund.

A comprehensive description of the three model levels and the information flows between them is contained in Wegener (1980). The first model level, the Nordrhein-Westfalen model, is described in Schönebeck (1982). More detailed information on the second model level, the Dortmund region model, is given in Wegener (1981a) and Gnad and Vannahme (1981); recent applications of this model are reported in Wegener (1981b; forthcoming) and Wegener et al. (1982). The third model level, the Dortmund district model, is still under development; a first account is given in Wegener et al. (1982). In this paper, only those parts and causal links of the model system that are essential for modeling urban decline will be pointed out. The discussion will focus on the second model level, in which the spatial distribution of activities within the urban region is modeled. Throughout the paper, the results of the first model level, i.e., regional totals of population and employment, are taken as exogenous inputs. For the experiments reported here, these inputs are arbitrarily varied to provide a wide range of possible future courses of regional development.

THE URBAN SYSTEM

The second level, or urban region, model is a spatially disaggregate, recursive simulation model of spatial urban development. The model's spatial dimension is derived from the subdivision of the urban region into 30 geographical subunits (zones) and its temporal dimension from 2-year increments (periods) over a time span of up to 20 years. Base year data of the model consist of zonal data on employment, population, households, housing, industrial and commercial buildings, public facilities, and land use, and of network data representing two transportation networks, public and private transport.

Employment is classified in the model by 40 industrial sectors corresponding to the sectoral forecasts of the Nordrhein-Westfalen model. Several subsets of these 40 industries can be established, either by sector (e.g., service or nonservice), space or locational requirements, or zoning compatibility.

Population is disaggregated in the model by 20 five-year age groups, by sex, and by nationality, i.e., native or foreign. The economically active part of the population is classified by sex and skill and is either employed or unemployed.

In addition, population is represented as a distribution of households classified by nationality, age of head, income, and number of persons. Similarly, housing is represented as a distribution of dwellings classified by type of building, tenure, quality, and number of rooms. Cross-classification of the above attributes results in 120 household types and 120 housing types. They are aggregated to 30 household and 30 housing types for use in the occupancy matrix, each element of which represents the number of households of a certain type living in a dwelling of a certain type. Besides the occupancy matrix, there are households without dwelling and vacant dwellings (see Gnad and Vannahme 1981).

Industrial and commercial buildings in terms of workplaces or jobs for each of the 40 sectors of the employment submodel have to be synthesized within the model, as no such data exist. Public facilities are represented by various facilities in the fields of health care, welfare, education, recreation, and transport. Land use is represented by 30 land use categories, 10 of which apply to built-up areas, i.e., different kinds of residential, commercial, or industrial land use.

Network data are link data of the public transport and road networks containing link information such as length, travel time or speed, lines and headway (public transport only), and capacity. Each zone is connected to both networks by at least one link.

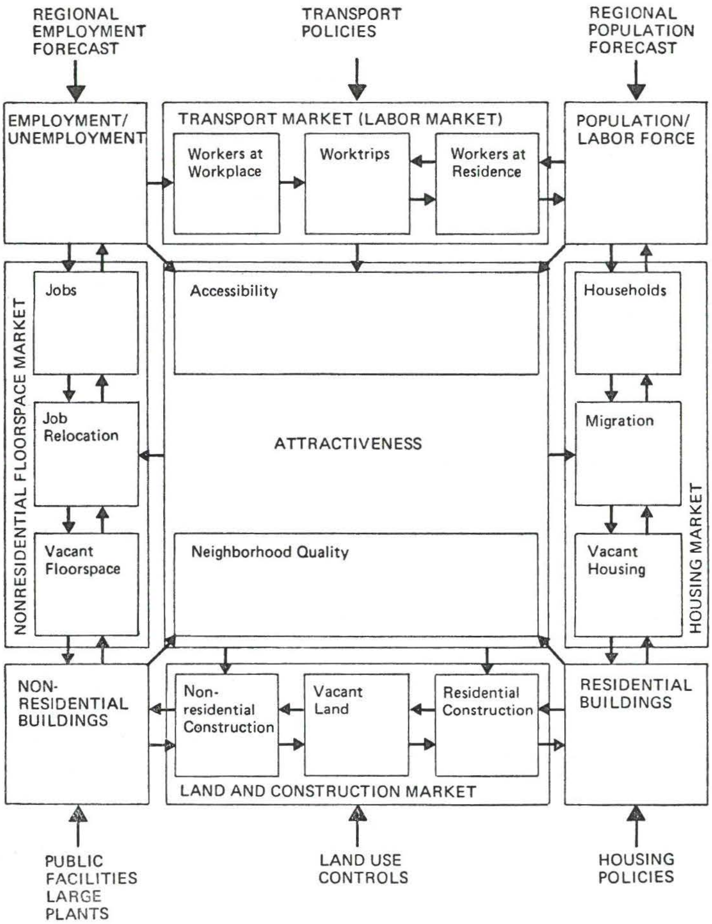
Figure 4 is a schematic representation of the urban system in the Dortmund region model. The four square boxes in the corners of the diagram show the major stock variables of the model: population, employment, residential buildings (housing), and nonresidential buildings (industrial and commercial workplaces and public facilities). The actors representing these stocks (travelers, workers, households, developers, entrepreneurs) interact through competitive choice processes or markets: the transport market, the regional labor market, the housing market, the land and construction market, and the market for industrial and commercial buildings. Choice in the markets is constrained by supply (transport supply, jobs, vacant housing, vacant land, vacant industrial or commercial floorspace) and guided by attractiveness, which generally is an actor-specific aggregate of neighborhood quality and accessibility. The larger arrows in the diagram indicate exogenous inputs: forecasts of regional employment and population (from the Nordrhein-Westfalen model) or policies in the fields of industrial development, housing, public facilities, or transport specified by the model user.

GROWTH AND DECLINE PROCESSES

Urban growth or decline is discussed in terms of the spatial (zonal) distribution or redistribution of three major urban activities: employment, housing, and population. The model variables representing these three activities will be traced as they are generated and changed during a model run. Because of the large number of submodels involved, the presentation will be narrative except for a few core equations, which directly determine the spatial distribution of activities in the model. References to more detailed information will be made where necessary.

FIGURE 4

THE URBAN SYSTEM IN THE DORTMUND REGION MODEL



EMPLOYMENT

The employment sector of the model is central for modeling urban decline. It establishes the link by which major economic and technological developments such as economic recessions, sectoral changes, or increases in productivity are entered into the simulation process.

These changes affect the spatial structure of the region as changes in the demand for industrial and commercial floorspace and, eventually, for buildings and land. Thus, both the nonresidential floorspace market and the land and construction market of the urban system are involved. The model treats each of the 40 industrial sectors as a separate submarket and makes no distinction between basic or nonbasic industries, i.e., all sectors are located or relocated endogenously. Employment of all sectors, however, may also be controlled exogenously by the model user in order to reflect major events such as the location or closure of large plants in particular zones.

The model starts from existing employment $E_{si}(t)$ of sector s in zone i at time t. There are six different ways for $E_{si}(t)$ to change during a simulation period:

Sectoral Decline. Declining industries make workers redundant — by assumption at the same rate all over the region. Thus,

$$ {}^{rs}E_{si}(t,t+1) = E_{si}(t)[1 - E_s(t+1)/E_s(t)] \qquad (1) $$

is the number of workers made redundant, where $E_s(t)$ indicates total employment of sector s in the region and $E_s(t+1)$ is the exogenous projection of total regional employment for time $t+1$. For sectors where $E_s(t+1)$ is not less than $E_s(t)$, the number of redundant workers is set to zero.

Lack of Building Space. One consequence of the ongoing mechanization and automation of most production processes is an increase of building floor space per workplace. Accordingly, in each period a number of jobs have to be relocated because of lack of space:

$$ {}^{rb}E_{si}(t,t+1) = [E_{si}(t) - {}^{rs}E_{si}(t,t+1)][1 - b_{si}(t)/b_{si}(t+1)] \qquad (2) $$

where $b_{si}(t+1)$ is the projected floor space per workplace at time $t+1$, which will always be greater or equal to its value at t.

Large Plants. When a major plant employing a large number of workers in a particular zone closes down, it is considered a "historical" event that no model can be expected to reproduce correctly. Therefore, such singular events may be entered exogenously into the model. Redundancies produced in this way are called ${}^{rx}E_{si}(t,t+1)$. Similarly, where and when a major plant is to be opened may be specified exogenously. New jobs thus generated are indicated by ${}^{nx}E_{si}(t, t+1)$.

New Jobs in Vacant Buildings. Declining industries also leave vacant buildings that may be used by industries with similar space requirements. Before starting new buildings, the model checks how many jobs can be accommodated in existing buildings. For this purpose, the 40 industrial sectors have been divided into groups with similar space requirements, e.g., heavy-load manufacturing or offices. If the total demand for new workplaces of a sector in the whole region is less than the supply of suitable floor space, it is allocated *pro rata* over the supply. The number of jobs accommodated in vacant buildings is indicated by ${}^{nv}E_{si}(t,t+1)$.

New Jobs in New Buildings. For any remaining demand, new industrial or commercial buildings have to be provided. The remaining demand is

$$\begin{aligned} {}^{n}E_{s}(t,t+1) = {} & E_{s}(t+1) - E_{s}(t) + {}^{rs}E_{s\cdot}(t,t+1) + {}^{rb}E_{s\cdot}(t,t+1) \\ & + {}^{rx}E_{s\cdot}(t,t+1) - {}^{nv}E_{s\cdot}(t,t+1) \\ & - {}^{nx}E_{s\cdot}(t,t+t), \qquad (3) \end{aligned}$$

where the dot subscript indicates summation over i. This demand is allocated to vacant industrial or commercial land in the zones by the following allocation function:

$$ {}^{nc}E_{si}(t,t+1) = \frac{C_{sli} \exp\left[\varphi\, A_{sli}(t)\right]}{\sum\limits_{i} \sum\limits_{l} C_{sli} \exp\left[\varphi\, A_{sli}(t)\right]}\, {}^{n}E_{s}(t,t+1), \qquad (4)$$

where ${}^{nc}E_{si}(t,t+1)$ are new workplaces of sector s built in zone i between t and t + 1. C_{sli} is the current capacity for workplaces of sector s on land use category *l* in zone i; since it is continually reduced during the simulation period, it bears no time label. The A's are the attractiveness of location for particular types of user. They are weighted aggregates of relevant attributes of the location expressed on a standardized utility scale. In this case, the attractiveness of a land use category in a particular zone for a building investor is composed of attributes indicating the neighborhood quality, the suitability of the site for the intended building use, and the land price in relation to expected profit. Where several building uses compete for a particular piece of land, the building use with the highest expected profit is assumed to prevail.

Demolition. New buildings for industry, housing, or public facilities may be built on vacant zoned land or, under certain conditions, on land cleared by demolition of existing buildings. To take account of relocation of jobs displaced by demolition, the last two steps described above are iterated several times during each simulation period.

HOUSING

The housing sector of the model is no less important for modeling urban decline than the employment sector. New life styles and changing consumption patterns have their impact on the spatial structure of the region. The housing sector establishes the link between population and physical structure. On the one hand, the existing housing stock constitutes the supply side of the housing market and thus finally determines the spatial distribution of population and all migration. On the other hand, new housing construction largely determines the future direction of spatial growth in the region. Housing construction is effected in the land and construction market, where it competes with other land uses. Changes of the housing stock may occur in three ways.

Filtering. In each period, a portion of the housing stock is assumed to filter down the quality scale, i.e., to deteriorate by aging, eventually leading to decay and demolition unless efforts to maintain and repair buildings are undertaken. These changes of the building stock are treated as events that occur to a dwelling with a certain probability in a unit of time. These "basic event probabilities" are specified exogenously. They are aggregated to transition rates between quality groups of the aggregate (30-type) housing classification on the basis of information about their internal composition from the disaggregate (120-type) classification. The result is a $K \times K$ matrix $\mathbf{d}(t,t+1)$ of transition rates where K is the number of aggregate housing types. Because dwellings are associated with households by means of the occupancy matrix, a similar analysis of transitions has to be made for households (see next section). If $\mathbf{h}(t,t+1)$ is an $M \times M$ matrix of transition rates of households and $\mathbf{R}(t)$ is the occupancy matrix with dimensions $M \times K$ at time t,

$$\mathbf{R}(t+1) = \mathbf{h}(t,t+1)\,\mathbf{R}(t)\,\mathbf{d}(t,t+1) \qquad (5)$$

is the occupancy matrix updated or aged by one simulation period.

In addition to the dwellings contained in the occupancy matrix, vacant dwellings also undergo the filtering process: vacant dwellings left over from the previous period or created by the dissolution of households in the current period, or new dwellings built in the previous period and released to the market in the current one. All are multiplied by the transition matrix $\mathbf{d}$ and assembled into a vector $\mathbf{D}(t+1)$ of vacant dwellings (for details, see Wegener 1980).

Public Housing. As in the employment model, the user may specify singular events exogenously, i.e., major changes of the housing stock in particular zones and years. This device is useful for entering large public housing or rehabilitation projects.

New Housing Construction. The submarkets of the housing construction model are the housing types of the aggregate (30-type) housing classification, or rather a subset of them, as only good quality housing is assumed to be built. The demand for new housing of a certain type to be built during the period is estimated by the model as a function of price changes in that submarket compared with other investment alternatives, i.e., as a function of its relative profitability. The price of housing of each type in each zone is reevaluated each period as a function partly of inflation and partly of the demand observed on the housing market of the previous period (see next section).

The housing demand thus estimated is allocated to vacant residential land by an allocation function similar to (4):

$$ {}^{n}D_{ki}(t,t+1) = \frac{C_{kli}\exp[\psi A_{kli}(t)]}{\sum_{i}\sum_{l} C_{kli}\exp[\psi A_{kli}(t)]}\,{}^{n}D_{k}(t,t+1) \qquad (6) $$

where ${}^{n}D_{ki}(t,t+1)$ is new dwellings of type k built in zone i between t and t + 1 and C and A are capacity and attractiveness, respectively. As before, A is a weighted aggregate of attributes expressing neighborhood quality, the suitability of the site, and the land price in relation to expected profit.

POPULATION

The population sector of the model is where long-term demographic and social developments such as changes in fertility, household formation patterns, income distribution, life styles, and consumption patterns are introduced into the model. The population sector is linked to the physical structure of the region by the housing market and the land and construction market, and to the employment sector by the transport market (which in this case includes only work trips, i.e., coincides with the regional labor market; see Wegener forthcoming).

The population model consists of two distinct but interrelated parts. The first part projects the existing population of each zone by age, sex, and nationality. The second part projects the same population in terms of households classified by size, income, age of head, and nationality. The rationale for having these two parallel population models is that demographic aging, including births and deaths, is modeled best on the basis of individual persons, whereas in the modeling of migration, households seem to be the most appropriate decision units. Having these two population models requires reconciliation when there are inconsistencies between their results.

Modeling aging and migration in two separate models may seem to be a step backward methodologically compared with multiregional or multistate demographic models (Rogers 1975; Rogers and Philipov 1980). The primary reason for this approach is the desire to have a causally or behaviorally specified migration model incorporating concepts such as spatial choice, housing preference, budget and information constraints, and, above all, the constraint of the current housing supply, which may be the foremost determinant of intraregional or intraurban migration.

Linking a probabilistic aging model with a behavioral migration model poses problems of sequencing, because what is modeled in two separate models in reality occurs within a continuous interwoven fabric of events. This simultaneity of aging and migration is reproduced much better in the integrated approach of multistate demography, but here a much cruder procedure is followed. First, all probabilistic processes are performed, i.e., aging and household formation. Then all migrations are processed, just as if they occurred on the last day of the simulation period. This sequence of model steps is explained below.

Aging. The aging submodel projects a population of individual persons classified by five-year age groups, sex, and nationality (native, foreign) by one simulation period, including births and deaths, on the basis of time-invariant life tables and dynamic, age-specific, and spatially disaggregate fertility projections, exclusive of migration. Standard unidimensional cohort-survival techniques adapted to simulation periods of variable length are used (see Wegener et al. 1982). In addition, in each simulation period a proportion of the foreign population is transferred to the native population by naturalization.

Household Formation. There are basically two ways to forecast a household distribution for time $t + 1$: (1) use projected headship rates to calculate households of different types from age and sex information of the projected population of time $t + 1$, or (2) update household information of time t by modeling changes occurring to households over time. The latter approach has been followed here. In essence, transitions between household states are calculated in the same way as transitions between age groups in the population projection.

Transitions between household states can occur on four dimensions: (1) nationality — naturalization; (2) age of head — aging; (3) income — increase or decrease of income, retirement, or new job; and (4) size — marriage, divorce, birth, death, death of child, marriage of child, new household of child, or relative joins household. The probabilities of occurrence of these transitions are again called basic event probabilities. Most can be determined endogenously from the population or employment submodels, but others have to be specified exogenously.

The basic event probabilities are aggregated to transition rates of household types of the aggregate (30-type) household classification, using information about their internal composition from the disaggregate (120-type) classification. This procedure is analogous to the conversion of event probabilities to transition rates in the housing submodel. The result is the $M \times M$ matrix $\mathbf{h}(t,t + 1)$ already used for updating the occupancy matrix $\mathbf{R}$ in (5), i.e., households and housing are updated in one common semi-Markov model.

Special provisions are necessary to provide for households outside of the matrix $\mathbf{R}$, such as subtenant households, households currently without a dwelling, households being forced to move because of demolition of their dwelling, and new or "starter" households (for details, see Wegener 1980). These households are first aged by multiplication with $\mathbf{h}$ and then assembled into a vector $\mathbf{H}(t + 1)$ of households without dwellings.

Reconciliation of Aging and Household Formation. Consistency requires that the number of household members in a population equal the number of individuals in it. Because of possible specification or aggregation errors, the result of the two models projecting persons and households separately may need to be reconciled. If so, the results of the aging model are considered to be more reliable, and the household size groups are adjusted so that the number of household members matches the number of persons in the population without changing the number of households (for details, see Wegener et al. 1982).

Migration of Households. Intraregional or intraurban migration is largely determined by housing considerations. Because of this, the migration submodel used is in fact a housing market model. The principal actors of the migration or housing market model are the landlords representing housing supply and the households representing housing demand. Landlords attempt to make a profit from earlier housing investments by offering their dwellings on the market; during a market simulation period they are assumed to keep volume of supply and prices fixed. Households looking for a dwelling try to improve their housing situation. They are assumed to act as satisficers while searching the housing market within given budgetary and informational constraints. The satisfaction of a household with its housing situation is assumed to be a function of housing size and quality, neighborhood quality, location, and housing cost.

Modeling the housing market introduces, among other things, two methodological difficulties. The first is the size of the problem. With only a modest disaggregation as in this model with its 30 household types, 30 housing types, and 30 zones, there are 27,000 different kinds of mover households each facing a theoretical choice set of 900 potential kinds of dwellings, or 24.3 million possible kinds of moves. For a variety of reasons, however, only a small fraction of these moves (two or three) is ever inspected before a choice is made. The second difficulty lies in the fact that the housing market, unlike many others, is largely a second-hand market, because new dwellings constitute only a very small share of the housing supply in each market period. Therefore, in the housing market supply and demand are interlinked in an intricate way: with each move a vacant dwelling is occupied and thus removed from the supply, but at the same time a dwelling becomes vacant and is added to the supply. In effect, the composition, but not the volume, of the supply has been changed.

To cope with these difficulties, a micro simulation approach using the Monte Carlo technique has been adopted to simulate the housing market as a sequence of search processes by households looking for a dwelling or by landlords looking for a tenant. This approach reduces the size problem by simulating only a sample of representative search processes, and solves the problem of supply-demand linkage in an appealing and straightforward way by reinserting vacant dwellings into the housing supply immediately after each move. The simulation of the housing market consists of a sequence of random selection operations by which hypothetical market transactions are generated. A market transaction is any successfully completed operation by which a migration occurs, i.e., a household moves into or out of a dwelling or both. The simulation of each market transaction has a sampling phase, a search phase, a choice phase, and an aggregation phase.

In the sampling phase, a household looking for a dwelling or a landlord looking for a tenant is sampled *pro rata* from households without a dwelling and from vacant dwellings. Households in the matrix **R**, i.e., who are occupying a dwelling, are sampled as a function of their propensity to move, which is assumed to be related to their satisfaction, or rather dissatisfaction, with their present dwelling. The satisfaction of a household of type m with its dwelling of type k in zone i, u_{mki}, is a weighted aggregate of the housing attributes. Then

$$p(k|mi) = [R_{mki} \exp(-\alpha u_{mki})]/[\sum_k R_{mki} \exp(-\alpha u_{mki})] \quad (7)$$

is the probability that of all households of type m living in zone i, one occupying a dwelling of type k will be sampled.

In the search phase, the sampled household looks for a suitable dwelling, or the sampled landlord looks for a tenant for his dwelling. The household first decides upon a zone in which to look for a dwelling. If the household already lives and works in the region, this choice is not independent of its present residence and work zone. The probability that the household tries zone i′ is:

$$p(i'|mki) = [\sum_{k'} D_{k'i'} \exp(\beta s_{ii'})]/[\sum_{i'} \sum_{k'} D_{k'i'} \exp(\beta s_{ii'})], \quad (8)$$

where $s_{ii'}$ is an expression indicating the locational attractiveness of zone i′ as a new residential location for a household now living in zone i and working in any of the zones near i. (For a full discussion of $s_{ii'}$, see Wegener 1981b.) The household then looks for a vacant dwelling in zone i′. The probability of inspecting a dwelling of type k′ is

$$p(k'|mkii') = [D_{k'i'} \exp(\gamma u_{mk'i'})]/[\sum_{k'} D_{k'i'} \exp(\gamma u_{mk'i'})]. \quad (9)$$

In the case of the landlord, the search phase looks similar, but the sequence of steps is different. (For a full description of all sampling and search probabilities, see Wegener 1981a.)

In the choice phase, the household decides whether to accept the inspected dwelling or not. As a satisficer, the household accepts the dwelling if this will improve its housing satisfaction by a considerable margin. Otherwise, it enters another search phase to find a dwelling, but after a number of unsuccessful attempts it abandons the idea of a move. The amount of improvement necessary to make a household move is assumed to depend on its prior search experience. Accordingly, the minimum improvement a household accepts in the model is decreased by a certain unit after each unsuccessful search, while it is increased by a unit after each successful transaction. In other words, households are assumed to adapt their aspiration levels to changing supply conditions on the market.

If the household accepts, all necessary changes in **R**, **H**, and **D**, multiplied by the sampling factor, are performed. After this aggregation phase, the next market transaction is simulated. The market process comes to an end when there are no more households considering a move.

Migration of Persons. The migration flows generated by the migration or housing market model need to be translated into persons by age, sex, and nationality to allow for migration-induced changes of the population distributions of the zones. For this purpose, for each household type of the disaggregate (120-type) household classification, a vector containing the age distribution of its members is endogenously estimated. As the number of households of each household type and the total of each population age group is known, these vectors can be adjusted to conform with the age distribution of the total population by biproportional scaling techniques. By multiplying the number of households of each migration flow with its age distribution vector, all household migration flows can be expressed in terms of migrant persons by age, sex, and nationality. With this information, adjustment of the population distributions of the source and target zones to migration-induced changes is straightforward.

III. MODEL VERSUS REALITY

The model described in the preceding section has been calibrated using employment, housing, and population data for 1970 and 1972, work trip data for 1970, and migration data for 1970 and 1971. No particular effort has been made to estimate statistically all model parameters. When unavailable or incompatible data, the form of the model functions, or the great number of variables and feedback relationships precluded statistical estimation, model structure was considered more important than estimability. In such cases, "softer" approaches to determine parameter values including trial and error, expert opinion, and plausibility checks were applied. More details on the calibration techniques used are contained in Wegener (1981b).

As a crucial test of the credibility of the model, it will now be demonstrated how well the model reproduces the general spatial development in the Dortmund region in the period from 1970 to 1980 using *only* the information of the base year 1970 and one additional year, 1972. For brevity, only predictions of population and migration flows will be inspected.

Table 1 shows measures of goodness-of-fit between observed and predicted figures for populations of the 30 zones of the Dortmund region. At first glance, the correspondence in terms of r^2 seems to be extremely high, but as is frequently the case with spatial data, this measure tends to be distorted by the predominance of a few very large

TABLE 1

GOODNESS-OF-FIT OF POPULATION PREDICTIONS, DORTMUND REGION, 1970-1980

Year	n	Population r^2	Population MAPE[a]	Population in % of 1970 r^2	Population in % of 1970 MAPE[a]
1972	30	0.9997	1.3	0.7024	1.2
1974	30	0.9992	2.4	0.6540	2.2
1976	30	0.9986	3.0	0.6944	3.0
1978	30	0.9978	3.4	0.6838	3.9
1980	30	0.9965	4.1	0.6398	4.8

[a] Mean absolute percentage error.

observations. In such cases, a more meaningful measure of goodness-of-fit is the mean absolute percentage error (MAPE) calculated as

$$\text{MAPE} = 100 \cdot [\sum_i | X_i - X_i^o | / \sum_i X_i^o], \quad (10)$$

where X_i are the predicted and X_i^o are the observed values.

A much more rigorous way of evaluating the goodness-of-fit is to neutralize the size effects by expressing the results in percent of their base values in the year 1970, i.e., to look only at the rates of change. Now the r^2 values give a more realistic picture of the performance of the model. It is interesting to note that in both kinds of analysis the MAPE statistic displays similar values.

These results compare favorably with r^2 levels usually achieved with residential allocation models of the interaction type, particularly if one considers that in most applications only the r^2 based on absolute numbers, as shown on the left-hand side of Table 1, are calculated (see, for instance, Floor and de Jong 1981). Indeed, an inspection of prediction errors on a zone-by-zone basis showed that only 5 out of 30 zones had prediction errors of more than 10 percent over the ten-year period from 1970 to 1980 and none were over 15 percent, while 17 out of 30 zones were predicted with an error of less than 5 percent. Goodness-of-fit deteriorates the more the simulation moves away from the calibration interval, which will be a concern of future research.

Table 2 shows the results of a similar analysis applied to migration flows. Again the r^2 values suggest a very good correspondence between observed and predicted flows; however, the MAPE statistic indicates that the prediction errors still may be substantial (cf. Wegener 1981b). Looking only at relatively small flows with an observed flow volume of less than 1,000 migrants, the predictive performance of the model is much inferior and gets worse as the model proceeds over time. One reason for these errors in the small migration flows may be the insufficient resolution of the sampling procedure of the migration or housing market model, which could be improved at the expense of additional

TABLE 2

GOODNESS-OF-FIT OF MIGRATION PREDICTIONS, DORTMUND REGION, 1970-1980

	All migration flows			Migration flows < 1,000		
Period	n	r^2	MAPE[a]	n	r^2	MAPE[a]
1970-1971	961	0.9810	20.7	856	0.4853	71.2
1972-1973	961	0.9708	22.8	850	0.4927	71.2
1974-1975	961	0.9736	25.9	853	0.4198	78.9
1976-1977	961	0.9711	26.9	853	0.2684	89.5
1978-1979	961	0.9572	34.8	855	0.2622	86.1

[a] Mean absolute percentage error.

computer time. These errors in predicting migration are largely responsible for the errors of the population prediction discussed above. Improvements in the prediction of small migration flows are a key issue of further work.

More important for the topic of this paper is the question whether the model correctly reproduces the process of spatial differentiation between the urban core and the suburban periphery. The two subregions A and B of the total urban region, which were used in Figure 3 to portray the relation between core and periphery, are taken as units of reference. Figure 5 shows model results aggregated for these two subregions and their respective observed counterparts. The variable shown is again population as a percent of 1970 population, which is the most rigorous test conceivable. The result suggests that at this level of aggregation the model seems to follow reality closely, with no deviation ever exceeding 1 percent. As before, no zonal information after 1972 was used for calibration. Moreover, the two subregions A and B are only part of the whole model region (see Figure 2); i.e., they constitute a completely open system, which is to say there are no hidden balancing mechanisms that keep the model from allocating more or less growth into C or D instead of A or B.

These comparisons of model results with actual data are far too limited, far too aggregate, and far from being perfect to establish any reasonable degree of credibility of the model at this stage. However, validation tests of other model variables such as housing and employment have been performed, and similar results have been obtained (see Wegener forthcoming). The predictive performance of the model appears to be excellent on the aggregate level and still compares favorably with many other models on more disaggregate levels.

IV. SIMULATION EXPERIMENTS

In this section, the results of three simulation experiments exploring the general direction of spatial development in the region will be presented. Other recent applications of the model have focused on more specific issues such as the regional housing market, intraregional migration, regional unemployment, and household incomes. Results can be found in Wegener (1981b; forthcoming) and Wegener et al. (1982).

For the present simulation experiments, three scenarios embracing a wide range of possible future developments of the region have been defined. They differ only in the assumptions made for total regional employment and population after the year 1980:

SCENARIO 1 This scenario is the base-line simulation. It was derived from a base-line run of the Nordrhein-Westfalen model, which in turn was based on a synopsis of recent employment forecasts for Nordrhein-Westfalen.

SCENARIO 2 The second scenario is a "growth" scenario. For this scenario, the base-line totals were arbitrarily modified by increasing regional employment by 7,500 jobs each year and by reducing outmigration by 15 percent and increasing inmigration by 10 percent.

SCENARIO 3 The third scenario is a "decline" scenario. For this scenario, the base-line totals were arbitrarily modified by reducing regional employment by 7,500 jobs each year and by increasing outmigration by 15 percent and reducing inmigration by 10 percent.

No particular meaning should be attached to the arbitrary specification of scenarios 2 and 3. The intent was simply to produce alternative scenarios with fairly massive changes of population and employment in order to find out how the model would react to extreme situations of growth and decline. The principal results of the three simulations are displayed in Table 3 and Figure 6. All three scenarios are identical until the year 1980, when the first changes were introduced for scenarios 2 and 3.

The base-line simulation, scenario 1, clearly exhibits the continuation of present trends. Employment decreases only slightly, by some 10,000 jobs in both subregions, although most recent unemployment figures suggest that this scenario may be too optimistic (cf. Wegener forthcoming). Both subregions decrease in population by about 55,000 persons or 5.2 percent over the decade, but the core (A) decreases faster, with the result that its share of the population of both subregions goes down from 57.4 to 55.4 percent (after having been 60.8 percent back in 1961). Despite this loss of population, housing construction goes on in both subregions because of rising incomes and changing household formation patterns. Of the 20,000 new dwellings built during the decade, however, only some 3,000 are built in subregion A, presumably because residential land in the core is less attractive yet more expensive than in the suburbs.

If scenario 1 is the most likely scenario of spatial urban development, scenarios 2 and 3 indicate the margin within which deviations from this most likely scenario may reasonably be expected to remain.

FIGURE 5

POPULATION IN SUBREGIONS A AND B OF THE DORTMUND URBAN REGION, 1970-1980

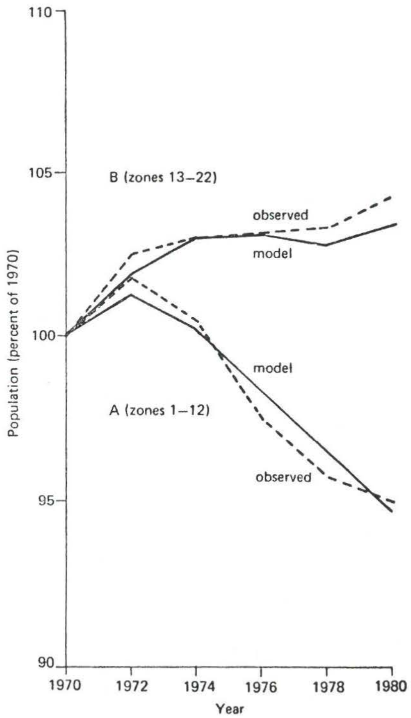


FIGURE 6

POPULATION IN SUBREGIONS A AND B OF THE DORTMUND URBAN REGION, 1950-1970, ACTUAL DEVELOPMENT, AND 1970-1990, SIMULATION RESULTS

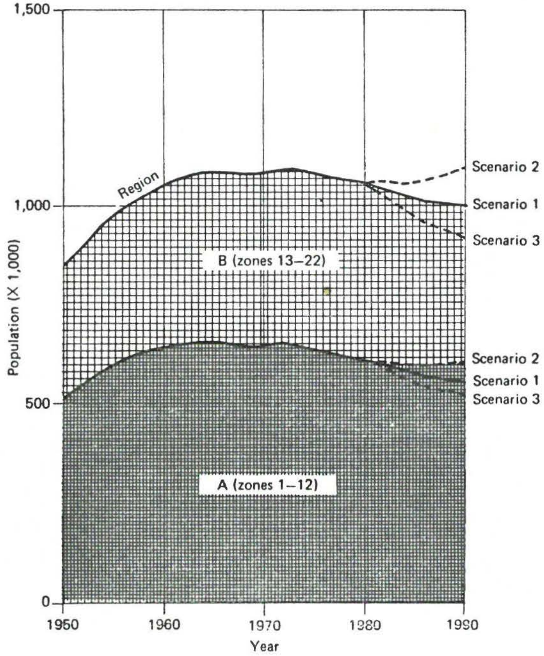


TABLE 3

EMPLOYMENT, HOUSING, AND POPULATION IN SUBREGIONS A AND B OF THE DORTMUND URBAN REGION, 1970-1990, SIMULATION RESULTS

		A		B		A + B
Year	Scenario	Absolute	%	Absolute	%	Absolute
Employment						
1970		278,004	*65.6*	145,603	*34.4*	423,607
1980		268,620	*64.1*	150,460	*35.9*	419,080
	1	263,355	*64.4*	145,603	*35.6*	408,958
1990	2	281,693	*63.9*	158,905	*36.1*	440,598
	3	241,985	*64.9*	131,014	*35.1*	372,999
Housing						
1970		257,153	*62.6*	153,905	*37.4*	411,058
1980		282,183	*60.7*	182,802	*39.3*	464,958
	1	284,509	*59.0*	187,980	*41.0*	482,489
1990	2	292,113	*59.7*	202,155	*40.9*	494,268
	3	278,956	*60.6*	181,702	*39.4*	460,658

Scenario 2, the "growth" scenario, must today be considered extremely optimistic with respect to the economic development of the region; it certainly defines the upper limit of feasible development. More than 30,000 new jobs are created in subregions A and B during the decade, and nearly 100,000 additional migrants are attracted by them, compared with the base-line simulation. The suburban zones (B) attract more than their proportionate share of this additional in-migration, bringing the percentage of population living in the core zones down to 54.9. This shift might have been even more pronounced if the model had not run out of vacant residential land after 1985. As a result, less attractive, expensive land in the urban core had to be utilized. Nevertheless, the model failed to provide enough dwellings for the new arrivals, so many of them had to move into formerly vacant, unattractive dwellings or become subtenants, again benefiting the core zones. Even under these abnormal circumstances, the core zones continue to decline in population, suggesting that for a city like Dortmund there is presently no feasible way to prevent a further decline in population.

Scenario 3 is a "decline" scenario, which given recent unemployment records is not nearly as unlikely as originally supposed. Compared with the base-line simulation, jobs in the two subregions decline by some 36,000 or 8.8 percent, and more than 80,000 people, 8.3 percent of the population, migrate out of the region. Practically no new dwellings are built; in fact, the housing stock decreases by a constant rate of deterioration and eventually of demolition. Because most new dwellings, if they had been built, would have been built in the suburbs, the core again benefits by keeping a higher proportion of the population than in any other scenario.

V. CONCLUSION

This modeling approach attempts to interpret the process of urbanization, suburbanization, and deurbanization observed in contemporary urban agglomerations as a consequence of responses of various urban actors to externally induced changes in their economic and social environment. The macro behavior of the urban system is explained through the micro behavior of its elementary components. At a certain level of aggregation, the model is capable of reproducing characteristic patterns of spatial choice behavior. An illustrative application demonstrated that there is no realistic scenario in which the urban core of the region would not continue to lose population during the next decade.

Future work on the model will focus on the validation and interpretation of the results on a more disaggregate level. In addition, the data base and time frame of the model will be extended back as far as to the year 1950 in order to reproduce a longer time period of urban evolution — encompassing phases of urban growth as well as phases of suburbanization and eventually of deurbanization.

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ABSTRACTS IN FRENCH

NOTE The following translations have been prepared by Vicki Bogard of the University of Iowa.

Jacques Ledent LES FACTEURS DE CROISSANCE DANS LA POPULATION URBAINE: L'IMMIGRATION NETTE PAR OPPOSITION À L'ACCROISSEMENT NATURELLE A mesure que la société traditionelle d'un pays se transforme en société développé, la partie de la croissance urbaine attribuable à l'immigration nette suit un patron peu complexe. On peut décrire celui-ci comme étant une courbe en forme de "u" renversé: il y a d'abord une augmentation de croissance, puis, une fois le maximum atteint, suit une décroissance. Cette hypothèse est confirmée par une analyse quantitative qui utilise des données tirées par des méthodes de succession temporale et de coupe en profil. Le résultat de l'analyse suggère que dans la deuxième moitié du siècle l'accroissement naturelle apporte une contribution à la croissance de la population urbaine légèrement plus haute que celle de l'immigration nette.

Eric Sheppard DISPOSITIONS DES SURFACES URBAINES SELON LEURS TAILLES ET CHANGEMENT ÉCONOMIQUE ET SPATIAL Le concept de la disposition des surfaces urbaines est critiqué parce qu'il ne prend pas en considération les effets d'interdépendence des villes sur la croissance de celles-ci. Des justifications théoriques du rapport rang/taille montrent les mêmes défauts; une étude empirique révèle peu de corrélations entre des déviations des dispositions rang/taille et les caractéristiques économiques et sociales au niveau national. Donc, les arguments indiquant une correspondance étroite entre la disposition des villes selon leurs tailles et le niveau du développement d'un pays — indépendante des variations intranationales de l'emplacement des villes et des caractéristiques socioeconomiques — semblent avoir peu de fondement.

Urban Karlström LE RÔLE DE L'ÉMIGRATION ET DE LA MIGRATION DANS L'INDUSTRIALISATION SUÉDOISE Cette étude traite de la création d'un modèle général de l'équilibre du type numérique afin d'illustrer le développement démo-économique de la Suède pendant sa première phase d'industrialisation, c'est à dire pendant la période qui précédait la première guerre mondiale. Trois simulations dynamiques analysent le rôle de la migration et de l'émigration des milieux ruraux vers les villes dans l'industrialisation suèdoise; quelques résultats sont présentés qui examinent l'importance de ces mouvements dan le développement de l'économie suèdoise.

Piotr Korcelli MIGRATION ET ÉVOLUTION URBAINE Cette étude examine en profondeur la question du développement de la population dans les agglomérations. Quelques hypothèses sont présentées concernant des patrons de peuplement dans des pays hautement urbanisés. Les données empiriques étaient tirées de l'étude comparative de l'IIASA sur la migration et le peuplement. Ces hypothèses font référence aux rapports complexes entre la croissance de la population et la taille des villes; 2) au rôle de la migration et de l'accroissement naturel comme éléments dans l'évolution de la population urbaine; 3) à la mobilité spatiale vue d'ensemble; 4) à la migration hiérarchique et à l'âge des migrants qui, avec leurs mouvements d'entrée et de sortie, circulent entre les agglomérations.

Hisanobu Shishido CROISSANCE ÉCONOMIQUE ET URBANISATION AU JAPON Cette étude décrit quelques résultats obtenus à partir de la simulation d'un modèle général d'équilibre calculable calibré avec des données pour l'année 1960 au Japon. Des deux clôtures utilisées, celle du type Keynesien, qui suppose des ressources non utilisées, s'est montrée plus efficace que la clôture néoclassique. Cette dernière suppose le plein emploi de tous les facteurs de production. Autrement dit, la croissance économique du Japon dans les années 1960 s'est caractérisée par les décisions des investisseurs qui considéraient la quantité de main-d'oeuvre qualifiée comme étant pratiquement illimitée. Les aspects spatiaux des glissements de la population ont une portée magistrale sur les potentiels de croissance si les demandes sociales de capital sont spatiallement différentiées.

Michael Wegener CRÉER UN PATRON DU DÉCLIN URBAIN: UN MODÈLE DÉMO-ÉCONOMIQUE À PLUSIEURS NIVEAUX POUR L'AGGLOMÉRATION DE DORTMUND Cette étude présente quelques résultats d'un modèle dynamique à plusieurs niveaux simulant le développement économique et démographique de l'agglomération dortmundienne. On voit ici en particulier la capacité du modèle à cerner les deux procédés d'accroissement et de déclin urbains. D'abord, les mécanismes qui règlent la croissance, la décadence ou la redistribution spatiale des activités dans le modèle sont exposés dans leurs grandes lignes, suivis par une démonstration de la façon dont le patron général du développement spatial précédent est reproduit par le modèle. Il y a, pour conclure cette étude, une discussion des résultats de simulations recouvrants une grande gamme de potentiels développements démo-économiques dans l'agglomération.

ABSTRACTS IN ITALIAN

NOTE The following translations were prepared by Dott. Cinzia Sartini of the University of Iowa. Her efforts are most gratefully acknowledged.

Jacques Ledent I FATTORI DI CRESCITA DELLA POPOLAZIONE URBANA: IMMIGRAZIONE NETTE CONTRO CRESCITA NATURALE Allorchè un paese evolve da una società tradizionale ad una società avanzata, la parte di crescita urbana che è dovuta all migrazione netta segue uno schema semplice, che può essere descritto da una curva a forma di U invertita: prima cresce, poi passa attraverso un massimo e quindi decresce. Questa ipotesi è confermata da un' analisi quantitativa che fa uso di spaccati e di serie temporali. L' analisi suggerisee che nella seconda metà di questo secolo la crescita naturale fornisce spesso alla popolazione urbana un contributo leggermente superiore a quello dell' immigrazione netta.

Eric Sheppard DISTRIBUZIONI DELLA DIMENSIONE DELLE CITTÀ E MUTAMENTO ECONOMICO SPAZIALE Il concetto della distribuzione della dimensione città viene criticato per la mancanza di considerazione degli effetti delle interdipendenze urbane sulla crescita delle città. Guistificazioni teoretiche del rapporto per ordine di dimensione hanno gli stessi difetti ed uno studio empirico rivela che c'è poca correlazione tra deviazioni da distribuzioni per ordine di dimensione e caratteristiche nazionali economiche e sociali. Pertanto queste argomentazioni suggeriscono una stretta corrispondenza fra distribuzioni della dimensione della città ed il livello di sviluppo di un paese che non tengano conto di variazioni intranazionali nella locazione delle città e nelle caratteristiche socioeconomiche.

Urban Karlström IL RUOLO DELL' EMIGRAZIONE E DELLA MIGRAZIONE NELL' INDUSTRIA-LIZZAZIONE SVEDESE Un modello numerico di equilibrio generale è stato creato per descrivere lo sviluppo demoeconomico svedese durante la sua prima fase di industrializzazione, il periodo antecedente la Prima Guerra Mondiale. Tre simulazioni dinamiche analizzano il ruolo della migrazione dalle zone rurali alle zone urbane e dell' emigrazione nell' industrializzazione svedese e vengono presentati alcuni risultati concernenti la loro importanza per lo sviluppo dell' economia svedese.

Piotr Korcelli MIGRAZIONE E MUTAMENTO URBANO Questo saggio prende in esame lo sviluppo della popolazione di vaste aree urbane. Varie ipotesi su schemi di mutamento dell' insediamento in paesi ad alto livello di urbanizzazione vengono discussi, facendo uso di materiale empirico derivato dallo studio comparativo della IIASA sulla migrazione e sull' insediamento. Queste ipotesi si riferiscono ad interrelazioni tra la crescita della popolazione e la dimensione urbana, al ruolo della migrazione e della crescita naturale quale componenti del mutamento della popolazione urbana, soprattutto alla mobilità spaziale, alla migrazione gerarchica ed alla distribuzione dell' età di coloro che migrano spostandosi tra, fuori di e all' interno di vaste aree urbane.

Hisanobu Shishido CRESCITA ECONOMICA E URBANIZZAZIONE: UNO STUDIO SUL GIAPPONE Questo saggio descrive alcuni risultati ottenuti attraverso la simulazione di un modello computabile di equilibrio generale calibrato con dati del 1960 per il Giappone. Delle due chiusure usate, il tipo Keynesiano, che presuppone risorse inutilizzate, funziona meglio delle chiusura classica, che presuppone la piena utilizzazione di tutti i fattori di produzione. In altre parole, la crescita economica del Giappone negli anni sessanta può essere caratterizzata dalle decisioni di investitori che considerarono l'offerta di manodopera qualificata come virtualmente illimitata. Aspetti spaziali degli spostamenti della popolazione hanno un significativo rapporto con i potenziali di macro crescita se la domanda di capitale sociale è spazialmente differenziata.

Michael Wegener ELABORAZIONE DI UN MODELLO DI DECLINO URBANO: UN MODELLO ECONOMICO-DEMOGRAFICO A PIÙ LIVELLI PER LA REGIONE DI DORTMUND Vengono presentati risultati selezionati di un modello di simulazione dinamico a più livelli dello sviluppo economico e demografico della regione urbana di Dortmund. In particolare, viene illustrata la capacità del modello di riprodurre tanto i processi di crescita urbana, quanto i processi di declino urbano. Vengeno dapprima delineati i meccanismi che controllano la crescita spaziale, il declino o la redistribuzione delle attività nel modello. Segue quindi una dimostrazione di come il modello riproduce lo schema generale del passato sviluppo spaziale. Vengono discussi, in fine, i risultati di simulazioni che coprono un vasto raggio di potenziale sviluppo globale economico e demografico, nella regione.

ABSTRACTS IN JAPANESE

NOTE The following translations were prepared by Naoki Nakamura of the University of Illinois at Urbana-Champaign. His efforts are most gratefully acknowledged.

Michael Wegener. 都市衰退のモデル化：ドルトムンド地方のための複数レベル経済・人口モデル. ドルトムンド都市圏の経済的および人口的発展の複数レベル・ダイナミック・シミュレーション・モデルの結果のいくつかが紹介されている特に，都市の成長と衰退を掌握するこのモデルの能力が解説されている．地域の成長，衰退，または活動の再配分をコントロールするこのモデルのメカニズムがまず概説されており，そののちにこのモデルが過去の地域成長の全般的なパターンをいかに再現するかが示されている．最後に，この地域における全般的な経済や人口変動の広範囲にわたる可能性のいくつかに関するシミュレーション結果が検討されている．

Urban Karlström. スウェーデンの工業化における人口移出と人口移動の役割．この論文ではスウェーデンの工業化の第一段階にあたる第一次世界大戦前におけるスウェーデンの人口および経済的な発展を描写するための計量的な一般均衡モデルがデザインされている．三種類のダイナミック・シミュレーションによってスウェーデンの工業化における地方から都市への人口移動および人口移出の役割が分析されており，それら人口移動がスウェーデンの経済発展にいかに関連しているかについての分析結果が示されている．

Piotr Korcelli. 人口移動と都市の変化． この論文は広域都市圏の人口変動を研究している．IIASA の人口移動と人口定着に関する比較研究から取られた実証的データを用いて，高度に都市化の進んだ国々における人口定着パターンに関するいくつかの仮説が検討されている．これらの仮説は人口増加と都市規模，都市人口変化の要因としての人口移動と自然増加の役割，全般的な地域間の流動性，段階的な人口移動，大都市圏間および大都市圏へのそしてからの移動者の年齢分布に関するものである．

Hisanobu Shishido. 経済成長と都市化：日本に関する研究． この論文は日本の 1960 年データによってカリブレートした計量的な一般均衡モデルをシミュレーションした結果を解説している．二種類のモデルが採用されており，未雇用の資源を前提とするケインズ型は全生産ファクターの完全雇用を前提とするネオ・クラシック型よりもすぐれた性能を示している．いいかえれば，1960 年代における日本の経済成長は，高質労働力の供給がほとんど無限に近いとみなした投資家の決定によって特徴づけられている．人口変動の地域的側面は，社会資源需要に地域差がある場合においてマクロ経済の成長ポテンシャルに大きな影響力をもっている．

Eric Sheppard. 都市規模分布と地域の経済変動． 都市規模分布コンセプトが都市成長への都市間相互依存効果を無視しているという観点から批判されている．ランク・サイズ関係に対する理論的な正当化も類似した短所を持っており，ランク・サイズ分布からの偏差と国内の経済・社会的特質があまり相関していないことが実証的研究によって示されている．そのため，都市規模の分布とその国の発展レベルが国内における都市立地と社会・経済的な特質とは無関係に緊密に相関しているという論議にはあまり根拠がないと思われる．

Jacques Ledent. 都市人口増加の要因：正味人口移入と自然増加. 国が伝統的な社会から進歩的な社会へ発展するにともなう正味人口移入による都市成長は逆U-字形の単純なパターンをたどる. 正味人口移入は初期においては増加し, 最高点に達したのちに減少する. この論文ではその仮説がタイム・シリーズ・データとクロス・セクション・データを用いた計量的分析によって確認されている. この分析は, 今世紀後半期における都市人口増加には正味人口増加よりも自然増加がしばしばより大きく貢献していることを示唆している

ABSTRACTS IN SPANISH

NOTE The following translations were prepared by Prof. Leon Vivas of the University of the Andes, Merida, Venezuela. His assistance is gratefully acknowledged.

Jacques Ledent LOS FACTORES DEL CRECIMIENTO URBANO DE LA POBLACION: INMIGRACION NETA VERSUS CRECIMIENTO NATURAL Cuando un país evoluciona de una sociedad tradicional a una sociedad avanzada, la parte del crecimiento urbano que se debe a una inmigración neta sique un patrón simple, el cual puede describirse como una curva en forma de U invertida: primero aumenta luego pasa através de un maximum para disminuir después. Esta hipótesis se confirma mediante análisis cuantitativo usando como datos series de tiempo y secciones transversales. El análisis sugiere que en la segunda mitad de este siglo, el crecimiento natural a menudo proporciona una contribución ligeramente más alta al crecimiento urbano de la población que la inmigración neta.

Urban Karlstrom EL PAPEL DE LA EMIGRACION Y DE LA MIGRACION IN LA INDUSTRIALIZACION SUECA Se diseñó un modelo de equilibrio numérico general para describir el desarrollo demoeconómico sueco durante su primera fase de industrialización: el período previo a la Primera Guerra Mundial. Tres simulaciones dinámicas avalizan el papel de la migración y emigración rural a urbana in la industrialización suece; asimismo, se presentan algunos resultados concernientes a su importancia para el desarrollo de la economía sueca.

Piotr Korcelli MIGRACION Y CAMBIO URBANA Este articulo examina el desarrollo de la población de regiones urbana amplias. Se discuten diversas hipótesis acerca del cambio del patrón de asentamientos en países altamente urbanizados, median te el uso de material empírico derivado del Estudio Comparativo entre Migración y Asentamiento de IIASA. Estas hipótesis se refieren a los interrelaciones entre crecimiento urbano y tamaño urbano, al papel de la migración y del crecimiento natural como componentes del cambio de las población urbana, al conjunto de la movilidad espacial a la migración jerárquica y a la distribución por edad de los migrantes que se movilizan entre fuera de, y dentro de las grandés áreas urbanas.

Eric Sheppard DISTRIBUCION DE LAS CIUDADES POR TAMAÑO Y CAMBIO ECONOMICO ESPACIAL El concepto de distribución de las ciudades por tamaño se critica por su falta de consideración de los efectos de las interdependencias interurbanas en el crecimiento de los ciudades. Las justificaciones teóricas de las relaciones del rango por tamaño tienen los mismos defectos y el estudio empírico revela que hay una correlación pequeña entre las desviaciones por la distribucíon de los rangos de tamaño y las características socio-económicas nacionales. Los argumentos sugieren una correspondencia estrecha entre la distribución del tamaño de las ciudades y el desarrollo económico de un país, independientemente de los variaciones intranacionales de la localización de la ciudad y las características socio-económicas.