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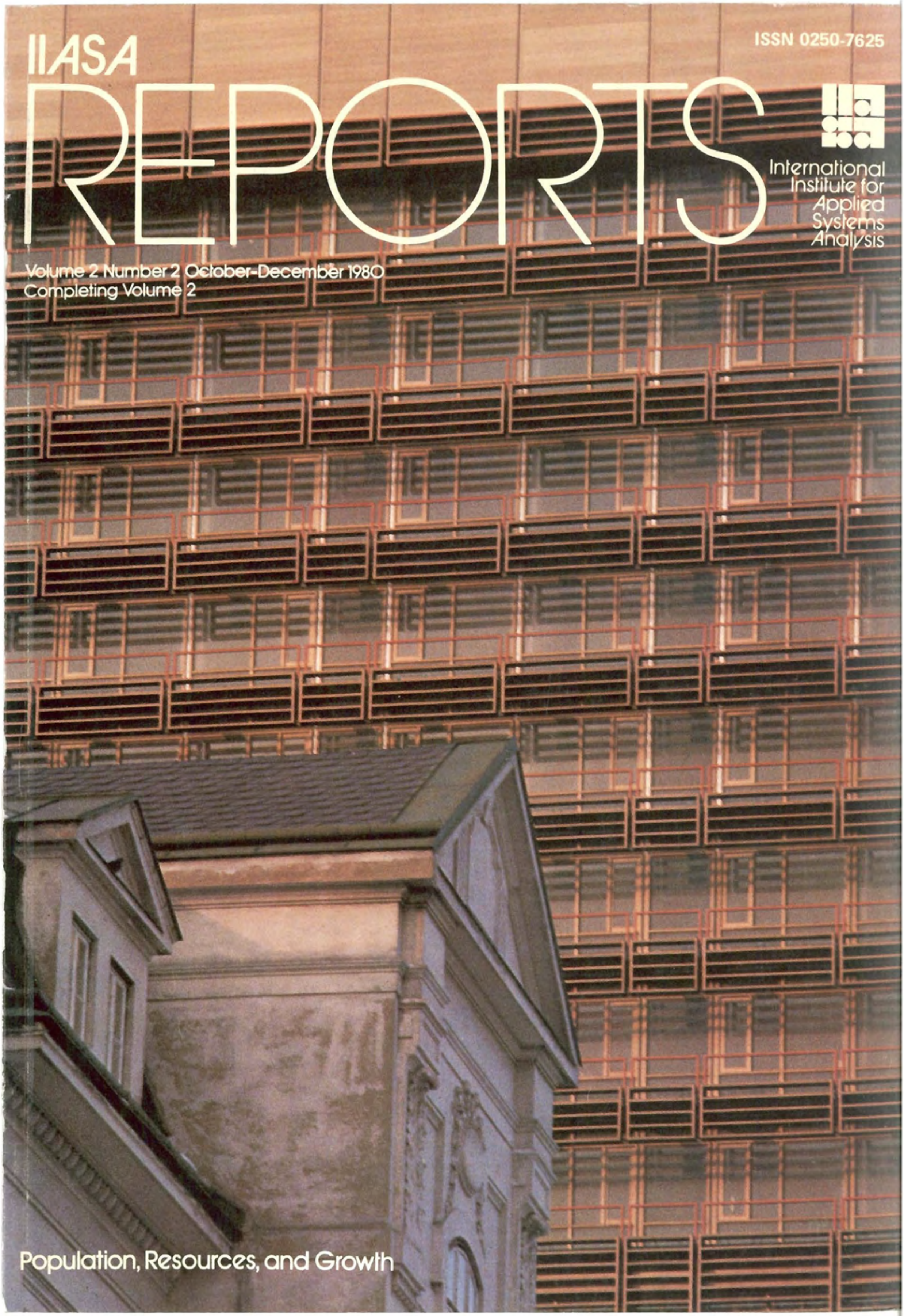

Population, Resources, and Growth

IIASA REPORTS

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Cover

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FOREWORD

Growing global economic interdependence, increasing competition for diminishing stocks of resources, and widening disparities in material welfare have made future population growth an unavoidable issue in international affairs. World population today exceeds 4 billion, and it is expected to pass the 6 billion mark before the end of this century. Conservative estimates of the total at the midpoint of the next century range from 8 to 9 billion, a doubling within the next 70 years.

Rapid population growth has important social, economic, and political consequences. It affects levels of public health and welfare, and the quality of the environment in which people live. Many of the consequences are poorly understood, yet it is clear that a reduction of population growth alone can only ease, not resolve, the diverse problems associated with economic growth and development. Thus the polarized debate between those who would stop population growth and those who believe that a continuing steady stream of human progress and well-being will accompany such growth has become unproductive. The problem is not one of growth versus nongrowth; it is, rather, the design of appropriate policies and programs for redirection and redistribution. Developing improved methods for analyzing and understanding several of the fundamental issues associated with such policies and programs is the goal of the research program in IIASA's Human Settlements and Services (HSS) Area.

Specifically, the HSS Area is concerned with the dynamics of global population growth and distribution, the consequences of these dynamics for patterns of employment generation, resource consumption, and service demand, and the design of policies and programs that respond efficiently and equitably to such issues. Within this general problem focus, the Area is analyzing national processes of structural transformation in countries evolving from rural–agrarian to urban–industrial societies. Data from several countries selected as case studies are being collected, and the research is focusing on population growth, urbanization, and economic development.

This collection of research reports reviews and summarizes the Area's recent efforts to contribute to an *interdisciplinary* analysis of the problems and a *multidimensional* (systems) understanding of the strategic options available for coping with them.

From the demographic perspective, urbanization is a consequence of urban–rural differentials in fertility and mortality patterns and of a massive net transfer of population from rural to urban areas through internal migration. To examine which of these two components is primarily responsible for this phenomenon, Jacques Ledent (France) constructs three simple demographic models of the urbanization process and examines their comparative dynamics. Setting out for each model a single differential equation that traces the impacts of different patterns of natural increase and internal migration on the urban-to-rural population ratio, Ledent concludes that, although economic development influences urbanization through both the rural–urban natural increase differential and the net migration from rural to urban areas, the impact of the latter is paramount.

The importance of rural-to-urban migration in the urbanization process leads Henry Rempel (Canada) to examine some of its fundamental determinants. Drawing on the results of a detailed sample survey carried out in Kenya in the late 1960s, Rempel seeks to unravel the influences of migrant characteristics, such as age, sex, and education, on their decisions to migrate. He finds that both age and education are important factors. The young and the more educated are the most likely to migrate, and the expectation of higher future income streams in the destination region is crucial to their decision.

The consequences of internal migration on the economy are investigated by Clark Reynolds (United States) for the case of Mexico. Assessing the effects of labor-force shifts on sectoral and regional total factor productivity growth, he argues that at the start of the 1940–1970 period substantial gains in productivity were achieved by labor transfers between sectors and regions. However, toward the end of this period, productivity increases attributable to such labor mobility apparently declined, while migration's contribution to growth in the labor force was increasing. Reynolds concludes that migration is currently dampening the growth of the leading sectors and regions of Mexico.

The central role played by economic variables in the decision to migrate and the significant impact of migration on the process of economic development underline the importance of combining demographic and economic perspectives within a single modeling framework. The last two papers in this collection effect such a marriage. Zbigniew Pawlowski (Poland) and Urban Karlström (Sweden) both construct demoeconomic models to describe and explain historical patterns of urbanization and development in their countries.

Pawlowski develops a demoeconometric simulation model that tracks Poland's past economic and demographic growth patterns; it can be subjected readily to so-called counter-factual simulations. Two are carried out by Pawlowski: Scenario A, which assumes that, during the entire 1960–1976 period, the economy was expanding at the same moderate rate it exhibited during the sixties; and Scenario B, which assumes instead that from 1960 onward the Polish economy experienced a steady, high rate of growth similar to that observed during the 1971–1976 period. Although the urban net inmigration rate increases in both scenarios, the upward trend is much faster and steadier in Scenario B.

Karlström's model of Sweden is also demoeconomic, but differs in character from Pawlowski's in a number of ways. Whereas the Polish model is in the econometric tradition, that of Sweden reflects a general-equilibrium perspective. The historical periods selected also differ markedly. The Polish case focuses on the post-World War II period; the Swedish case examines the pre-World War I period of 1870–1914. Karlström's model seeks to capture the characteristics specific to Sweden's industrializing economy during this time, especially its openness with respect to the rest of the world. As Karlström points out, the demoeconomic development of Sweden was shaped to a large extent by growing export industries and a sizable net emigration to the United States.

The five papers in this collection are a representative sample of research currently being carried out at IIASA. The work is motivated by the growing concern about the unprecedented growth of large cities in today's less-developed countries. Rapid rates of urban population growth and increased consumption arising out of growing per capita income are currently producing an annual growth rate of total urban demand for goods and services of about 9 percent, implying a staggering doubling every 7 to 8 years.

An examination of future prospects for world population growth and urbanization reveals that the twin historical developments that have combined to create the problems of human settlements today will continue for the rest of this century and beyond in most parts of the world. The rate of world population growth, though apparently declining, will still be considerable for some time to come, and rural–urban migration shows no signs of abating in most of the less-developed world. Therefore, the number of people in the world will continue to increase in the near future, as will the proportion living in urban settlements. Populations in urban centers will continue to grow at an alarming rate, particularly in the larger urban agglomerates of the less-developed world.

The problems created by this transformation are manifold and involve large private and social costs. But there are obvious benefits too, and it is important to keep these in mind when considering policies for intervening in the urbanization process. A better understanding of the dynamics and consequences of urban–rural population growth and economic development appears to be an essential ingredient of such considerations, requiring a focus on the processes of change together with their manifestations.

The improvement of this understanding is the principal goal of the HSS Area's research on migration, urbanization, and development.

Andrei Rogers
Chairman
Human Settlements and Services Area

COMPARATIVE DYNAMICS OF THREE DEMOGRAPHIC MODELS OF URBANIZATION

Jacques Ledent

Since the beginning of the last century, the world's population has grown rapidly, increasing from approximately one billion in 1800 to four billion in 1975. At the same time, urban population growth has been even more explosive: the urban population totals 1.6 billion today versus 25 million in 1800. Thus, the proportion of the world's population living in urban areas has increased from 2.5 percent in 1800 to 40 percent today. According to the latest UN projections (United Nations 1979), this past trend of population growth and urbanization is likely to continue: by the end of this century, slightly more than half the world's population will be living in urban areas.

Clearly, urbanization results from the differential growth of rural and urban areas, i.e., it depends on the rural–urban differentials in natural increase as well as the net transfer of population from rural to urban areas. In the past, there has been little analytical work done to clarify this dependence. Most of the research has concentrated on descriptive generalizations such as the demographic transition resulting from the joint and simultaneous occurrence of the vital and mobility revolutions.*

By contrast, our purpose is to examine the process of urbanization from an analytical point of view. Such an objective is performed by examining and comparing the dynamics of recently devised models of rural and urban population change. For each of the three models considered, the analysis is established on the basis of a simple differential equation – describing the evolution of the urban to rural population ratio – which is arrived at by combining the original differential equations describing the rural and urban populations.

Note that our intention here is not to test the validity of these alternative models but rather to use these models to facilitate the comprehension of the relationship between urbanization and its component factors at various stages of socioeconomic development.

*The vital revolution is the process by which societies advance from high birth and death rates to low birth and death rates. The mobility revolution is a similar process by which they move from low to high mobility rates.

This paper consists of three sections. Section I makes use of the Keyfitz model (Keyfitz 1978) in which the migration exchange between rural and urban areas is seen as a rural net outmigration flow representing a constant fraction of the rural population. Section II is based on a continuous version of a two-region components-of-change model (Rogers 1968) whose relevance in such a context was first suggested by Ledent (1978a, b). In contrast to the Keyfitz model, this model presents a symmetric treatment of the migration flows between the rural and urban areas: each sector exhibits a constant gross outmigration rate. Finally, Section III utilizes an extended version of the Rogers model that exhibits a varying regime of rural–urban migration (United Nations 1979): the gross migration flows out of each sector are introduced through a gravity model. Note that all of the aforementioned models assume constant natural increase differentials between urban and rural regions; however, the case of varying regimes of natural increase differentials is briefly examined, at the end of Section III, in relation to the third and last model.

I THE KEYFITZ MODEL

Basically, Keyfitz (1978) considers a rural–urban population system, initially entirely rural, in which the rural and urban sectors are submitted to constant rates of natural increase, denoted by r and u, respectively. In addition, he views the migration exchange between the two sectors as a net outmigration flow from the rural sector, equal to a constant fraction m of the rural population (m is assumed to be positive).

DERIVATION OF THE FUNDAMENTAL DIFFERENTIAL EQUATION

The evolution of such a rural–urban population system can be described by the following system of differential equations:

$$\frac{\mathrm{d}P_{\mathrm{r}}(t)}{\mathrm{d}t} = (r - m)P_{\mathrm{r}}(t) \tag{1}$$

and

$$\frac{\mathrm{d}P_{\mathrm{u}}(t)}{\mathrm{d}t} = mP_{\mathrm{r}}(t) + uP_{\mathrm{u}}(t) \tag{2}$$

where $P_{\mathrm{r}}(t)$ and $P_{\mathrm{u}}(t)$ are the rural and urban populations at time t.

Letting $S(t)$ denote the ratio $P_{\mathrm{u}}(t)/P_{\mathrm{r}}(t)$ of the urban to rural population, we have

$$\frac{\mathrm{d}S(t)}{S(t)\mathrm{d}t} = \frac{\mathrm{d}P_{\mathrm{u}}(t)}{P_{\mathrm{u}}(t)\mathrm{d}t} - \frac{\mathrm{d}P_{\mathrm{r}}(t)}{P_{\mathrm{r}}(t)\mathrm{d}t} \tag{3}$$

Note that if one retains $S(t)$ as the index of urbanization, this last equation can be interpreted as follows: the growth rate of urbanization is equal to the difference between the urban and rural population growth rates (United Nations 1979). Then, since the rural growth rate is constant and the urban growth rate is a simple function of $S(t)$, substituting (1) and (2) into (3) and rearranging terms leads to the following differential equation in $S(t)$

$$\frac{dS(t)}{dt} - (u + m - r)S(t) = m \tag{4}$$

EVOLUTION OF THE URBANIZATION LEVEL AND GROWTH RATE

Recalling that, by assumption, the system is initially entirely rural, we thus obtain the solution of (4) as

$$S(t) = \frac{m}{u + m - r} \{\exp[(u + m - r)t] - 1\} \tag{5}$$

Expression (5) shows that the urban to rural population ratio (or urbanization index) only depends on the rural–urban differential in natural increase $r - u$ and the rural net outmigration rate m.

Differentiating (5) with respect to time leads to

$$\frac{dS(t)}{dt} = m \exp[(u + m - r)t] \tag{6}$$

which is positive for all values of t. Consequently, the urban to rural population ratio monotonically increases as t increases.

What is the long-term behavior of $S(t)$? We must consider two cases here (Figure 1):

(a) if $u + m - r > 0$, $S(t)$ increases indefinitely at the exponential rate $(u + m - r)$;

(b) if $u + m - r < 0$, $S(t)$ tends toward a limit equal to $m/[r - (u + m)]$.

In fact, virtually all actual population systems are characterized by parameters corresponding to the first case (Ledent 1978b). Thus, we impose the following restriction

$$u + m - r > 0 \tag{7}$$

so that $S(t)$ is an *exponential function* of t. Thus, in the long run, the system becomes predominantly urban.

Then, how does the growth rate of urbanization $dS(t)/S(t)dt$ evolve? From (4), we have

$$\frac{dS(t)}{S(t)dt} = u + m - r + \frac{m}{S(t)} \tag{8}$$

Recalling the variations of $S(t)$, we thus obtain the result that the growth rate of urbanization monotonically decreases from $+\infty$ (for $t = 0$) to $u + m - r$ (as $t \longrightarrow +\infty$), a quantity which remains positive as a consequence of (7). It is

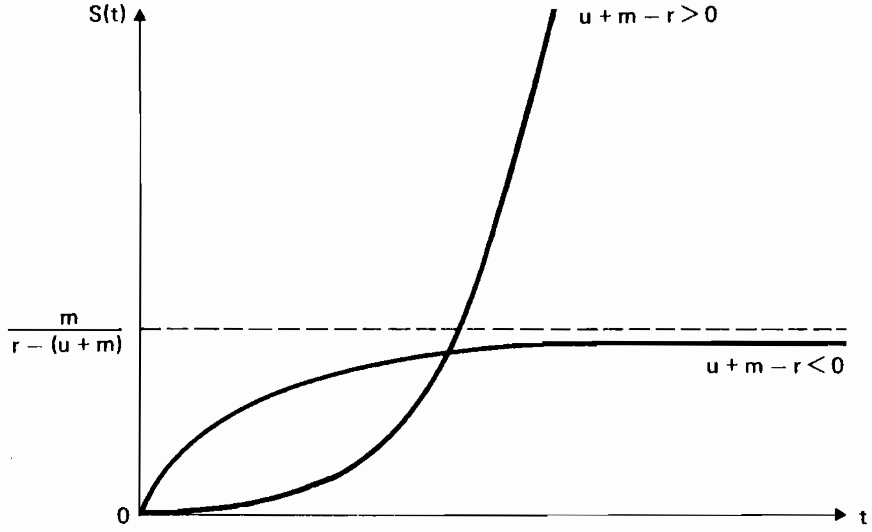


FIGURE 1 The Keyfitz model: the variations of $S(t)$.

easily established that the second derivative of $dS(t)/S(t)dt$ is always positive: the growth rate of urbanization is described by a convex curve (Figure 2).

EVOLUTION OF THE PROPORTION OF THE POPULATION THAT IS URBAN

By definition, the proportion $\alpha(t)$ of the population that is urban is such that

$$\alpha(t) = \frac{P_u(t)}{P_r(t) + P_u(t)} = \frac{S(t)}{1 + S(t)} \tag{9}$$

Differentiating $\alpha(t)$ with respect to time leads to

$$\frac{d\alpha(t)}{\alpha(t)dt} = \frac{dS(t)}{S(t)dt} - \frac{dS(t)}{[1 + S(t)]dt} = \frac{dS(t)}{S(t)[1 + S(t)]dt} \tag{10}$$

Thus, $\alpha(t)$ monotonically increases over time: from zero (for $t = 0$) to 1 (as $t \longrightarrow +\infty$). But, what is the shape of the curve describing $\alpha(t)$?

Substituting (5) into (9) leads to an explicit expression of $\alpha(t)$:

$$\alpha(t) = \frac{\exp[(u + m - r)t] - 1}{\exp[(u + m - r)t] + (u - r)/m} \tag{11}$$

which suggests the consideration of two cases.

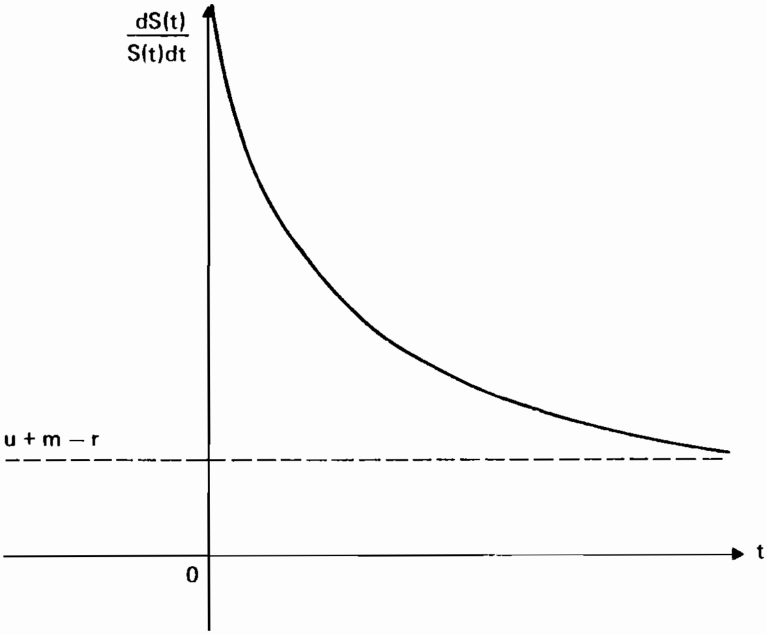


FIGURE 2 The Keyfitz model: the variations of the growth rate of urbanization.

(a) If $r \leqslant u$, the right-hand side of (11) represents a logistic function of time. Because only positive values of t are relevant to the variations of $\alpha(t)$, it is important to determine whether the point of inflection of this logistic function occurs for a negative or a positive value of t.

Differentiating the right-hand side of (11) twice with respect to time indicates that the second derivative of $\alpha(t)$ has the sign of

$$x(t) = -\frac{\exp[(u+m-r)t] - (u-r)/m}{\exp[(u+m-r)t] + (u-r)/m} \tag{12}$$

It is then readily established that the point of inflection occurs for

$$t_\alpha = \frac{1}{u+m-r} \ln\left(\frac{u-r}{m}\right) \tag{13}$$

an expression which shows that the sign of t_α depends on the respective values of r and $u - m$.

As shown in Figure 3, it follows that:

(i) if $r < u - m$, t_α is positive and the curve describing the variations of $\alpha(t)$ (the solid curve of Figure 3(a)) is S-shaped;

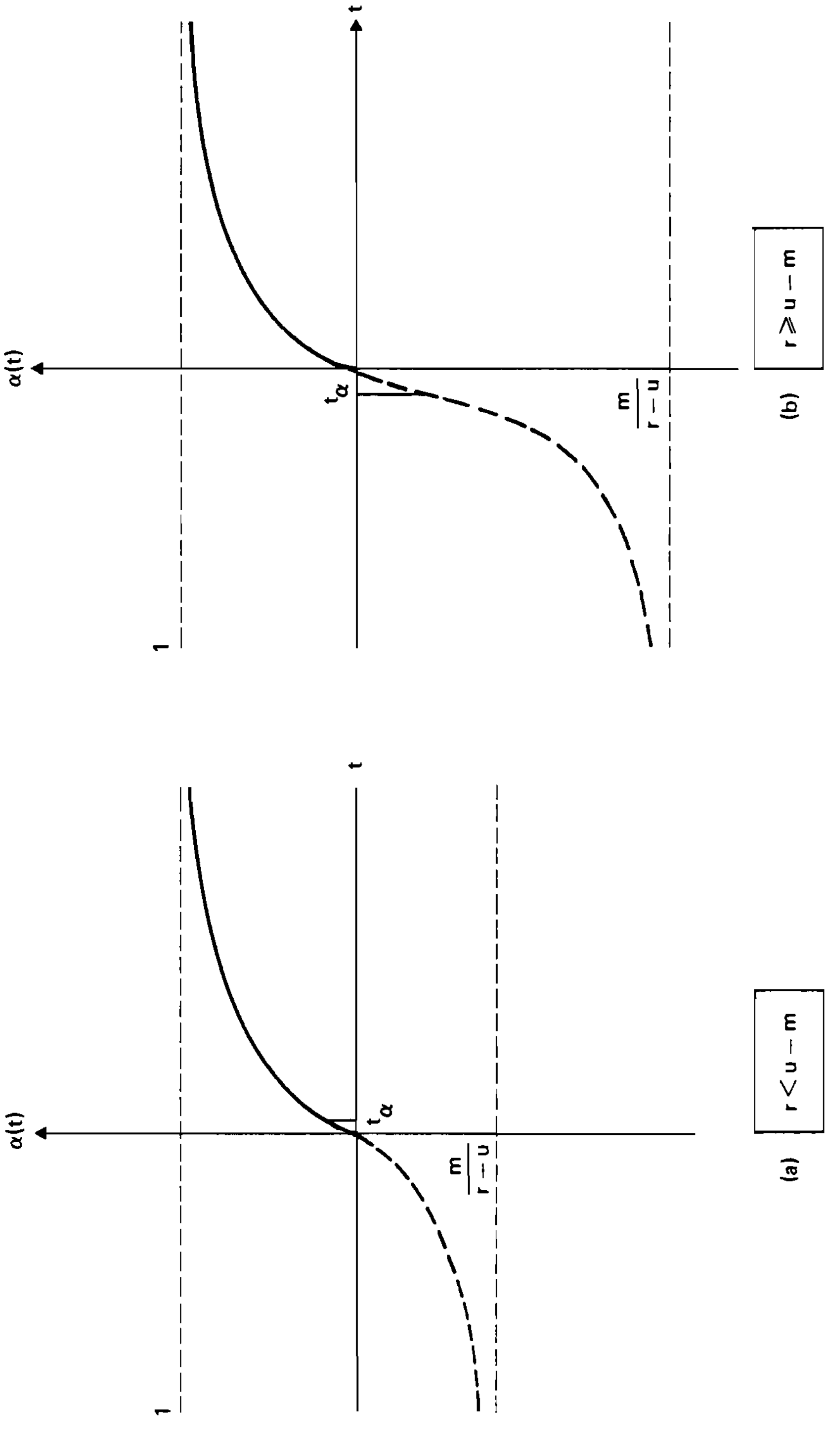


FIGURE 3 The Keyfitz model: the variations of $\alpha(t)$ for $r \leqslant u$.

(ii) if $r \geqslant u - m$, t_α is negative and the curve describing the variations of $\alpha(t)$ (the solid curve of Figure 3(b)) is shaped downward.

(b) If $r > u$, the right-hand side of (11) is no longer a logistic function of time. Its variations are slightly more complicated and are represented in Figure 4. But since $x(t)$ is negative for all values of t, the curve describing the variations of $\alpha(t)$ (the solid curve of Figure 4) is simply shaped downward.

In practice, since the rural rate of natural increase is higher or only slightly less than the urban rate of natural increase, situation (b) of Figure 3 or that of Figure 4 is typical. In other words, $\alpha(t)$ – which, in all cases, monotonically increases from zero to one – is described by a curve shaped downward (concave).

EVOLUTION OF THE RURAL AND URBAN POPULATIONS

To analyze such an evolution, the explicit derivation of expressions of $P_r(t)$ and $P_u(t)$ as functions of time (Keyfitz 1978) is not necessary. In fact, it is sufficient to look at the sign of the rural and urban population growth rates.

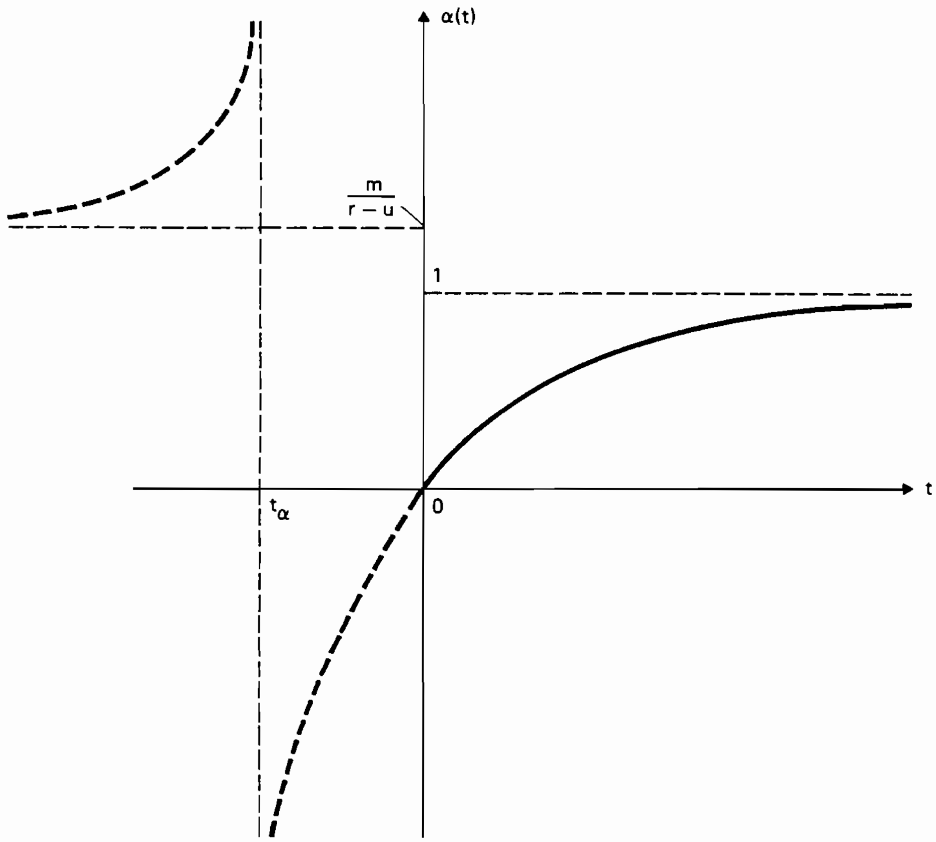


FIGURE 4 The Keyfitz model: the variations of $\alpha(t)$ for $r > u$.

Indeed, we immediately have from (1) that $P_r(t)$ varies exponentially, increasing indefinitely if $r > m$ or decreasing toward zero if $r < m$.

To obtain the variations of $P_u(t)$, we rewrite (2) as

$$\frac{dP_u(t)}{P_u(t)dt} = \frac{m}{S(t)} + u \tag{14}$$

It follows that the urban growth rate monotonically decreases from $+\infty$ (for $t = 0$) to u (as $t \longrightarrow +\infty$). Consequently,

(a) if $u > 0$, the urban population monotonically increases as $t \longrightarrow +\infty$;

(b) if $u < 0$, the urban population increases and then decreases toward zero as $t \longrightarrow +\infty$.

Hence, we impose a further restriction that the urban rate of natural increase is positive, i.e.,

$$u > 0 \tag{15}$$

From the above variations of $P_r(t)$ and $P_u(t)$, we may conclude that the fact that the system becomes predominantly urban as $t \longrightarrow +\infty$ reflects that either the rural population vanishes (if $r < m$) or the urban population becomes infinitely large with regard to the rural population (if $r > m$).

The dynamics of the Keyfitz model – a model characterized by a constant rural net outmigration rate

$$m_r(t) = m \tag{16}$$

where m is positive and subject to restrictions (7) and (15) – are summarized in Table 1.

APPLICATION TO ACTUAL RURAL–URBAN POPULATION SYSTEMS

Since $S(t)$ may take any positive value as t increases, it follows that any actual two-sector system – characterized by a ratio $\bar{S}$ of urban to rural population – appears to be identical to the subsequent state of an initially entirely rural population system subject to the same parameters r, u, and m. The time t_D at which this hypothetical population reaches the ratio $\bar{S}$ is given by the solution of $S(t) = \bar{S}$, i.e., (Keyfitz 1978),

$$t_D = \frac{1}{u + m - r} \ln\left(1 + \frac{u - m - r}{m} \bar{S}\right) \tag{17}$$

Thus, if one observes an actual population system in year y, the ratio of the urban to rural population in year $y + T$ is given by

$$S(y + T) = \frac{m}{u + m - r}\left[\left(1 + \frac{u + m - r}{m}\bar{S}\right)\exp[(u + m - r)T] - 1\right] \tag{18}$$

TABLE 1 The Keyfitz model: the variations of the main functions.

Function		t: 0	t: $+\infty$
$P_r(t)$	(a) $r < m$	$P_r(0)$ →	0
	(b) $r = m$	$P_r(0)$ →	$P_r(0)$
	(c) $r > m$	$P_r(0)$ →	$+\infty$
$P_u(t)$		0 →	$+\infty$
$S(t)$		0 →	$+\infty$
$\frac{dS(t)}{S(t)dt}$		$+\infty$ →	$u + m - r$
$\alpha(t)$		0 →	1
$m_r(t)$		m ↔	m

As an illustration, Table 2 indicates the pace of urbanization that would occur in two actual rural–urban systems on the basis of the Keyfitz model: those of India and the U.S.S.R.

Rogers and Willekens (1976) report that the urban population of India was growing at an annual rate of 37.2 per thousand during the late sixties. This rate was the sum of a rate of natural increase of 19.5 and a net migration rate of 17.7 per thousand. At the same time, the rural population was growing at an annual rate of 17.15 per thousand which was the sum of a rate of natural increase of 21.50 per thousand and a net migration rate of −4.35 per thousand. Then, in this system

$$r = 21.5 \times 10^{-3}, \qquad u = 19.5 \times 10^{-3}, \qquad m = 4.35 \times 10^{-3}, \qquad \bar{S} = 0.245$$

The left-hand side of Table 2 indicates that, if the above rates remain constant, the urbanization process of India will be slow. For example, the percentage of the population that is urban will increase, in 25 years, from 19.7 percent to only 27.1 percent. About 130 years will be necessary for the urban population to exceed the rural population.

As for the U.S.S.R. – observed in the early seventies – appropriate data can be found in Rogers (1976):

$$r = 10.0 \times 10^{-3}, \qquad u = 9.0 \times 10^{-3}, \qquad m = 20.8 \times 10^{-3}, \qquad \bar{S} = 1.291$$

TABLE 2 The Keyfitz model: application to India and the U.S.S.R.

India			U.S.S.R.	
$r = 21.5 \times 10^{-3}, u = 19.5 \times 10^{-3}$, $m = 4.35 \times 10^{-3}$			$r = 10 \times 10^{-3}, u = 9 \times 10^{-3}$, $m = 20.8 \times 10^{-3}$	
S	α (percentage)	T	S	α (percentage)
0.245	19.70	0	1.291	56.35
0.270	21.27	5	1.527	60.43
0.295	22.79	10	1.787	64.12
0.372	27.12	25	2.729	73.19
0.507	33.62	50	5.031	83.42
0.800	44.45	100	14.604	93.59
1.502	60.03	200	101.850	99.03
4.929	83.13	500	–	100.00
20.070	95.25	1,000	–	100.00

The right-hand side of Table 2 indicates that, on the basis of these rates, the urbanization process will remain strong in the future: the percentage of the population that is urban will increase from 56.4 percent to 73.2 percent in 25 years and to 83.4 percent in 50 years.

Note that there exists an important contrast between the India and U.S.S.R. cases. Whereas the rural population increases indefinitely in the former case, it decreases toward zero in the latter (since r is less than m): the rural population of the U.S.S.R., unlike that of India, vanishes in the long run.

SENSITIVITY ANALYSIS

Because eq. (5), which expresses the ratio of urban to rural population, is simple, it is easy to differentiate it with respect to the basic parameters m and $r - u$.

In particular, differentiating $S(t)$ with respect to m leads to:

$$\frac{\mathrm{d}S(t)}{S(t)\mathrm{d}m} = \frac{[u - r + tm(u + m - r)]\ \exp[(u + m - r)t] - (u - r)}{m(u + m - r)\{\exp[(u + m - r)t] - 1\}} \tag{19}$$

It is readily established that the numerator of the right-hand side of (19) is an increasing function of time taking the value zero for $t = 0$. It thus follows that $\mathrm{d}S(t)/\mathrm{d}m$ is positive so that, as expected, a higher rural net outmigration rate tends to hasten the pace of the urbanization phenomenon.

In order to assess more accurately the impact of the value of m on the urbanization level, we have simulated the growth of the Indian system for different values of the rural net outmigration rate (while keeping r and u identical to their observed values). Table 3 indicates that a 0.001 increase of the rural net outmigration rate produces a small acceleration in the pace of urbanization:

TABLE 3 The Keyfitz model: impact of the rural net outmigration rate on the percentage of the Indian population that is urban 50 years hence ($r - u = 2.0 \times 10^{-3}$).

m'	0.001	$m/2$	m	$m + 0.001$	$2m$	$3m$	$4m$
$\alpha(+50)$	22.01	26.29	33.62	36.75	46.21	56.45	64.77

TABLE 4 The Keyfitz model: the impact of the rural–urban natural increase differential on the percentage of the Indian population that is urban 50 years hence ($m = 4.35 \times 10^{-3}$).

$r - u$	−0.002	−0.001	0	0.001	0.002	0.003	0.004
$\alpha(+50)$	37.22	36.29	35.39	34.50	33.62	32.76	31.92

the urban proportion reaches 36.8 percent (versus 33.6 percent) after 50 years. Indeed, a doubling or a tripling of the rural net outmigration rate creates a dramatic speeding up of the urbanization process: after 50 years, the urban proportion reaches 46.2 and 56.5 percent, respectively.

Similarly, differentiating $S(t)$ with respect to the rural–urban natural increase differential leads to:

$$\frac{\mathrm{d}S(t)}{S(t)\mathrm{d}(r-u)} = -\frac{1 + [(u + m - r)t - 1]\exp[(u + m - r)t]}{\exp[(u + m - r)t] - 1} \tag{20}$$

It can be seen that the numerator of the right-hand side of (20) is an increasing function of time taking the value zero for $t = 0$. It follows that $\mathrm{d}S(t)/\mathrm{d}(r - u)$ is negative so that, as expected, a smaller rural–urban natural increase differential tends to speed up the urbanization phenomenon.

The impact of the value of $r - u$ on the urbanization level is assessed by simulating the growth of the Indian system for different values of $r - u$ (while keeping the rural net outmigration equal to its observed value). Table 4 indicates that a relatively small change in the natural increase differential only produces a small acceleration of the urbanization process: for example, a 0.001 decrease in the rural–urban natural increase differential causes the percentage of the population that is urban after 50 years to increase from 33.6 percent to 34.5 percent. This impact is much less than the one caused by a similar increase in the rural net outmigration rate: let us recall that a 0.001 increase in the latter causes the urban percentage to increase to 36.8 percent.

In addition, note that, because the rural and urban rates of natural increase generally take on similar values, the impact on $\alpha(+50)$ of plausible variations in the value of $r - u$ is rather small. As indicated by the figures displayed in Tables 3 and 4, the impact caused by plausible variations of m is much more important.

In the less developed countries, the rural natural increase rate r is generally higher than the urban natural increase rate u, and the difference tends to decline with economic development. In these countries, economic development promotes urbanization as a consequence of both declining rural–urban natural increase differentials and increasing net outmigration rates. However, as shown above, the influence through migration exchange is likely to be preponderant.

II THE ROGERS MODEL

As an alternative to the Keyfitz model, Ledent (1978a, b) suggests using a continuous version of a two-region components-of-change model (Rogers 1968). This model, still characterized by constant rates of natural increase in both sectors, presents a more symmetric consideration of the migration exchange between the two sectors. In each sector, a constant fraction of the population is assumed to move to the other sector.

DERIVATION OF THE FUNDAMENTAL DIFFERENTIAL EQUATION

Let o_r and o_u denote the gross migration rates out of the rural and urban sectors, respectively (o_r and o_u are positive). Then the evolution of the rural–urban population system is described by the following:

$$\frac{\mathrm{d}P_r(t)}{\mathrm{d}t} = (r - o_r)P_r(t) + o_u P_u(t) \tag{21}$$

$$\frac{\mathrm{d}P_u(t)}{\mathrm{d}t} = o_r P_r(t) + (u - o_u)P_u(t) \tag{22}$$

Since both rural and urban growth rates are simple functions of $S(t)$, substituting (21) and (22) into (3) and rearranging terms leads to the following differential equation in $S(t)$:

$$\frac{\mathrm{d}S(t)}{\mathrm{d}t} = o_r + [u - o_u - (r - o_r)]\,S(t) - o_u[S(t)]^2 \tag{23}$$

In the mathematic literature, (23) is referred to as a Riccati equation.

EVOLUTION OF THE URBANIZATION LEVEL AND GROWTH RATE

The right-hand side of (23) is a polynomial in $S(t)$ of the second order which admits two real roots since its discriminant $\Delta = [u - o_u - (r - o_r)]^2 + 4o_r o_u$ is positive. Moreover, since their product $-o_r/o_u$ is negative, these two roots have opposite signs.

Let S_A denote the positive root

$$S_A = \frac{u - o_u - (r - o_r) + [\{u - o_u - (r - o_r)]^2 + 4o_r o_u\}^{1/2}}{2o_u} \tag{24}$$

and S_B the negative one: it is identical to S_A except that the sign preceding the square root term is a minus instead of a plus. Then, one can rewrite (23) as:

$$\frac{dS(t)}{dt} = o_u[S_A - S(t)][S(t) - S_B] \tag{25}$$

Since the urban–rural population system is initially entirely rural (i.e., $S(0) = 0$), it is clear that the variations of $S(t)$ are represented by part of a *logistic* function: $S(t)$ monotonically increases from 0 to S_A over the time continuum $[0, +\infty]$, i.e.,

$$0 < S(t) < S_A \qquad \forall t > 0 \tag{26}$$

Thus, in contrast to the Keyfitz model, the Rogers model leads to a long-run stable equilibrium.

Further, rearranging terms in (25) leads to

$$\frac{\dfrac{dS(t)}{dt}}{S(t) - S_B} - \frac{\dfrac{-dS(t)}{dt}}{S_A - S(t)} = o_u(S_A - S_B) \tag{27}$$

Upon observing that (26) holds, the integration of (27) yields

$$\frac{S(t) - S_B}{S_A - S(t)} = -\frac{S_B}{S_A} \exp[o_u(S_A - S_B)t] \tag{28}$$

or, alternatively,

$$S(t) = \frac{S_A S_B\{1 - \exp[o_u(S_A - S_B)t]\}}{S_A - S_B \exp[o_u(S_A - S_B)t]} \tag{29}$$

Note that, as suggested by eq. (24), S_A – as well as S_B – are functions of the rural and urban rates of natural increase through their difference. Thus, the urban to rural population ratio only depends on the rural–urban differential in the natural increase $r - u$ and the gross migration rates out of both sectors.

As mentioned above, the variations of $S(t)$ are described by a truncated logistic curve. The question then is one of knowing whether this curve presents a point of inflection or not.

Differentiating eq. (29) with respect to time indicates that $d^2S(t)/dt^2$ has the sign of

$$y(t) = u - o_u - (r - o_r) - 2o_uS(t) \tag{30}$$

We thus obtain the following.

(a) If $u - o_u > r - o_r$, $d^2S(t)/dt^2$ is positive (negative) for all t such that

$$S(t) \underset{(<)}{>} \frac{u - o_u - (r - o_r)}{2o_u} \tag{31}$$

i.e.,

$$t \underset{(<)}{>} t_s = \frac{1}{o_u(S_A - S_B)} \ln\left(-\frac{S_A}{S_B}\right) \tag{32}$$

Then, $S(t)$ appears to be an S-shaped curve (Figure 5(a)).

(b) If $u - o_u < r - o_r$, it is clear from (30) that $d^2S(t)/dt^2$ is negative so that $S(t)$ is shaped downward (Figure 5(b)).

Since the actual values of u and r are roughly similar, the existence of a point of inflection depends, for a large part, on the comparative values of o_r and o_u. Thus in practice if the rural outmigration rate is much higher than the urban outmigration rate, the curve describing the variations of $S(t)$ exhibits a point of inflection.

Let us now turn to the examination of the evolution of the growth rate of urbanization $dS(t)/S(t)dt$. From (25), we have

$$\frac{dS(t)}{S(t)dt} = -o_u\left[S(t) - (S_A - S_B) + \frac{S_AS_B}{S(t)}\right] \tag{33}$$

The first derivative of this expression with respect to time has the sign of $-o_u\{1 - S_AS_B/[S(t)]^2\}$, which is negative for all values of t (the product S_AS_B is negative). Thus, the growth rate of urbanization monotonically decreases from $+\infty$ (for $t = 0$) to zero (as $t \rightarrow +\infty$).

Recalling the interpretation of $dS(t)/S(t)dt$ as the urban–rural growth rate difference, we conclude to the constant reduction of this difference which eventually vanishes (as a consequence of the stability result).

It is easily established that the second derivative of $dS(t)/S(t)dt$ is positive so that the variations of the growth rate of urbanization are described by a convex curve (Figure 6).

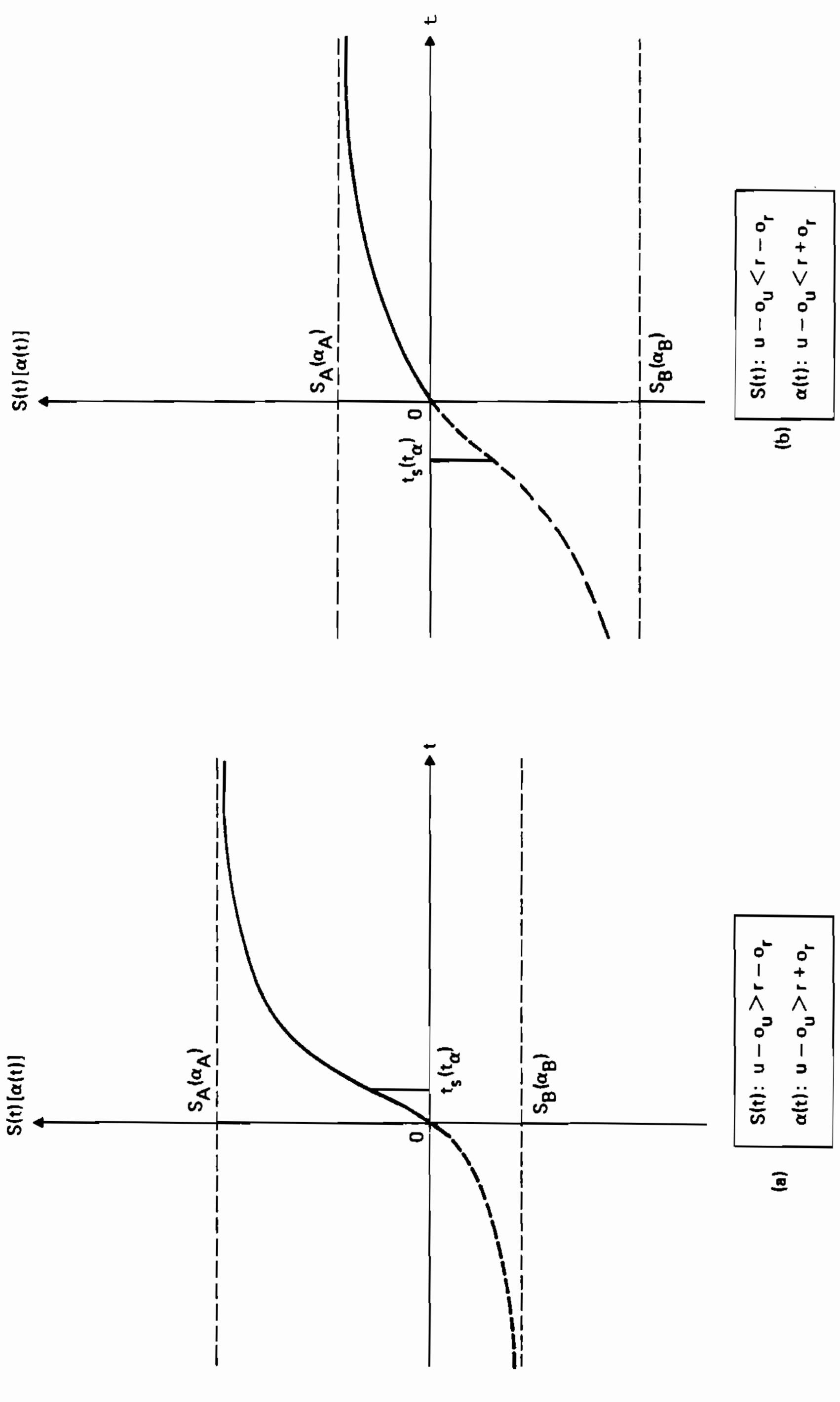


FIGURE 5 The Rogers model: the variations of $S(t)$ and $\alpha(t)$.

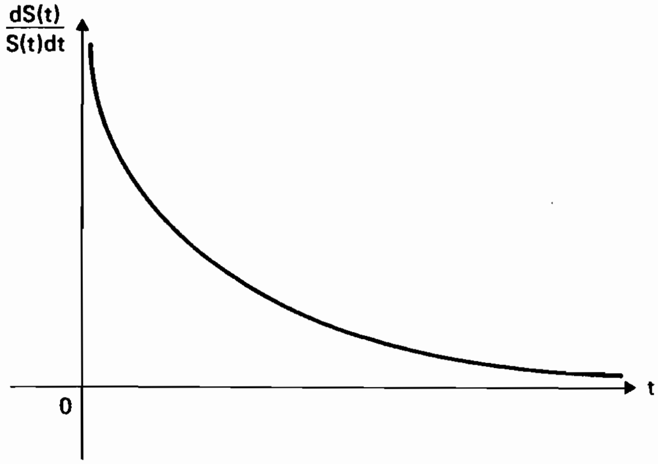


FIGURE 6 The Rogers model: the variations of the growth rate of urbanization.

EVOLUTION OF THE PROPORTION OF THE POPULATION THAT IS URBAN

Substituting (29) into (9) yields an expression of the proportion $\alpha(t)$ of the population that is urban:

$$\alpha(t) = \frac{S_A S_B\{1 - \exp[o_u(S_A - S_B)t]\}}{S_A(1 + S_B) - S_B(1 + S_A)\exp[o_u(S_A - S_B)t]} \tag{34}$$

This last expression shows that the variations of $\alpha(t)$ are also described by a truncated *logistic* curve.

Clearly, $\alpha(t)$ monotonically increases from zero (for $t = 0$) to $\alpha_A = S_A/(1 + S_A)$ (as $t \to \infty$).

Does the curve describing the variations of $\alpha(t)$ present a point of inflection or not? Differentiating $\alpha(t)$ twice with respect to time shows that $d^2\alpha(t)/dt^2$ has the sign of

$$z(t) = -\left\{\frac{1 + S_B}{S_B} + \frac{1 + S_A}{S_A}\exp[o_u(S_A - S_B)t]\right\} \tag{35}$$

an expression which is positive for all values of t less than

$$t_\alpha = \frac{1}{o_u(S_A - S_B)}\ln\left(\frac{S_A(1 + S_B)}{-S_B(1 + S_A)}\right) \tag{36}$$

There exist such values only if t_α is positive, i.e., if $-S_A(1 + S_B)/S_B(1 + S_A) > 1$

or $S_A + S_B + 2S_AS_B > 0$. Recalling the values of the sum and product of the two roots of (23), we thus obtain that:

(a) if $u - o_u > r + o_r$, $d^2\alpha(t)/dt^2$ is first positive for $t < t_\alpha$ and then negative for $t > t_\alpha$; $\alpha(t)$ then appears to be an S-shaped curve (Figure 5(b));

(b) if $u - o_u < r + o_r$, $d^2\alpha(t)/dt^2$ is negative and the curve describing the variations of $\alpha(t)$ is directed downward (Figure 5(b)).

In practice, since the rural and urban rates of natural increase are of the same magnitude, situation (b) is typical.

To summarize, the Rogers model – like the Keyfitz model – leads to a proportion $\alpha(t)$ of the population that is urban which is an increasing and concave function of time. However, there exists a major difference between the two models in the long run: the Rogers model leads to stability ($\alpha_A < 1$) unlike the Keyfitz model ($\alpha_A = 1$).

EVOLUTION OF THE RURAL AND URBAN POPULATIONS

How does the rural and urban population vary over time? For this purpose, the availability of the expressions of $P_r(t)$ and $P_u(t)$ as functions of time – which have been derived elsewhere (Ledent 1978a) – is not necessary. As with the Keyfitz model, an answer to such a question can be obtained with relatively little effort by determining the sign of the rural and urban population growth rates.

Equation (21) suggests that the rural growth rate $dP_r(t)/P_r(t)dt$ is positive (negative) if $S(t)$ is greater (less) than $(o_r - r)/o_u$. Therefore:

(a) If $S_A \geqslant (o_r - r)/o_u$, $dP_r(t)/dt$ is positive as $t \to +\infty$, i.e., $P_r(t)$ increases indefinitely. Two subcases must be considered here:

(i) if $r \geqslant o_r$, $dP_r(t)/dt$ is positive for all positive values of t so that $P_r(t)$ monotonically increases toward $+\infty$;

(ii) if $r < o_r$, $dP_r(t)/dt$ is first negative for all t less than

$$t_r = \frac{1}{o_u(S_A - S_B)} \ln\left(\frac{o_r + S_A(o_r - r)}{o_r + S_B(o_r - r)}\right) \tag{37}$$

and positive afterwards, i.e., $P_r(t)$ monotonically decreases as t increases from 0 to t_r and then monotonically increases toward $+\infty$.

(b) If $S_A < (o_r - r)/o_u$, $dP_r(t)/dt$ is negative and $P_r(t)$ monotonically decreases toward zero.

As for the variations of the urban population, eq. (22) rewritten as

$$\frac{dP_u(t)}{P_u(t)dt} = u - o_u + \frac{o_r}{S(t)} \tag{38}$$

suggests that the urban growth rate $dP_u(t)/P_u(t)dt$ monotonically decreases from $+\infty$ to its long-term value which is also the long-term rural growth rate. Thus:

(a) if $S_A \geqslant (o_r - r)/o_u$, $dP_u(t)/dt$ is positive for all t and $P_u(t)$ monotonically increases toward $+\infty$;

(b) if $S_A < (o_r - r)/o_u$, $dP_u(t)/dt$ is first positive for all t less than a certain value t_u

$$t_u = \frac{1}{o_u(S_A - S_B)} \ln\left(\frac{o_u(1 + S_A) - u}{o_u(1 + S_B) - u}\right) \tag{39}$$

and negative for $t > t_u$. Thus, $P_u(t)$ monotonically increases as t increases from 0 to t_u and then monotonically decreases toward zero.

Clearly, the case of vanishing rural and urban populations is of no interest to us, and we thus impose the restriction

$$S_A \geqslant (o_r - r)/o_u \qquad (40)^*$$

Recalling (24), which expresses S_A in terms of the basic parameters, it is readily established that (40) holds if

(i) $u + r > o_u + o_r$

or

(ii) $u + r < o_u + o_r$ and $(u - o_u)(r - o_r) - o_r o_u < 0$

EVOLUTION OF THE RURAL NET OUTMIGRATION RATE

A question of importance here is the evolution of the rural net outmigration rate implied by the Rogers model. Clearly,

$$m_r(t) = o_r - o_u \frac{P_u(t)}{P_r(t)} = o_r - o_u S(t) \tag{41}$$

an equation which shows that $m_r(t)$ is also described by a branch of a logistic curve (Figure 7): it monotonically declines from o_r (for $t = 0$) to $o_r - o_u S_A$ ($t \longrightarrow \infty$) and exhibits (does not exhibit) a point of inflection when $S(t)$ does not (does).

This property of a declining rural net outmigration rate thus seems to reduce the applicability of the Rogers model to already somewhat developed countries.

*It is easy to establish that this condition is equivalent to

$$r + uS_A \geqslant 0 \qquad (40')$$

an inequality which ensures that the population of the whole system does not vanish. Note that this condition is less restrictive than the corresponding condition (15) in the Keyfitz model (u is positive): if u is negative, the Rogers model still applies as long as r is positive and such that (40) holds.

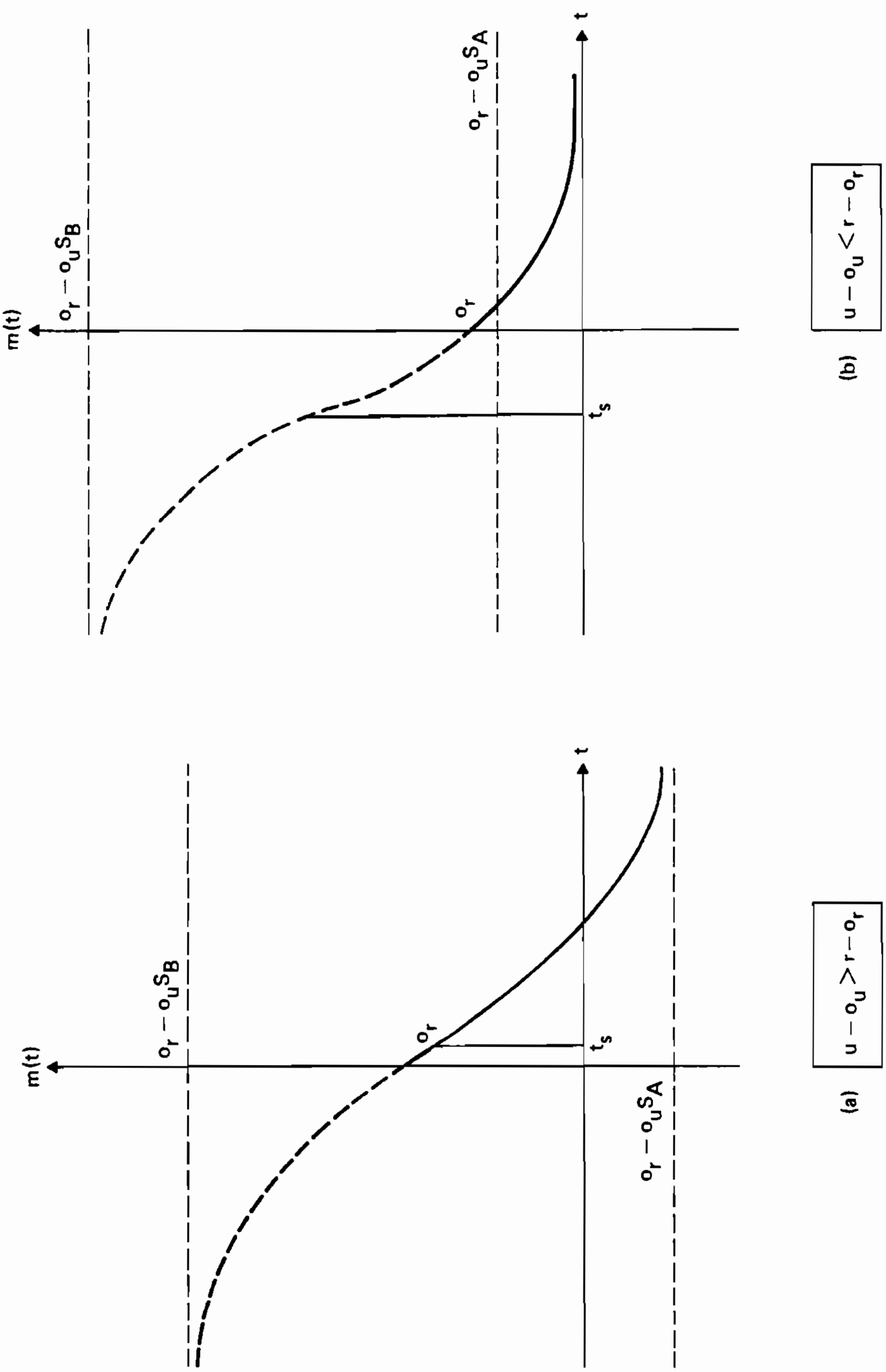


FIGURE 7 The Rogers model: the variations of $m(t)$.

How large is the drop in the rural net outmigration rate? Recalling (24) which expresses S_A in terms of the basic parameters, we have

$$m_r(\infty) = \tfrac{1}{2}\left(r + o_r + o_u - u - \{[u - o_u - (r - o_r)]^2 + 4o_r o_u\}^{1/2}\right) \quad (42)$$

Let

$$G = \tfrac{1}{2}(r + o_r + o_u - u) \quad (43a)$$

$$H = \tfrac{1}{2}\{[u - o_u - (r - o_r)]^2 + 4o_r o_u\}^{1/2} \quad (43b)$$

and let us calculate $G^2 - H^2$. After several manipulations, we obtain that

$$G^2 - H^2 = o_r(r - u) \quad (44)$$

Consequently,

$$m_r(\infty) = G - H = \frac{o_r(r-u)}{G+H} \quad (45)$$

and, since $G + H = o_r - o_u S_B$, we finally have

$$m_r(\infty) = \frac{o_r(r-u)}{o_r - o_u S_B} \quad (46)$$

This last equation suggests two interesting conclusions:

(a) If the urban rate of natural increase is higher than the corresponding rural rate, the direction of the rural–urban migration exchange is reversed at some point in time.

(b) Since S_B is negative, $o_r/(o_r - o_u S_B)$ is less than one and therefore the absolute value of the long-run rural net migration is less than the rural–urban differential in natural increase, i.e., a value generally close to zero.

To summarize, a built-in property of the Rogers model is a sharp drop in the rural net outmigration rate toward a small value (either positive or negative) less in absolute value than the rural–urban differential in natural increase.

The dynamics of the Rogers model – as defined by eqs. (21) and (22) and subject to restriction (40) – are summarized in Table 5.

APPLICATION TO ACTUAL RURAL–URBAN POPULATION SYSTEMS

Since $S(t)$ can take any value between zero and S_A as t increases, any actual two-sector system – characterized by the basic parameters r, u, o_r and o_u such that (40) holds and a ratio $\bar{S}$ of urban to rural population such that (47) holds – is identical to the subsequent state of an initially entirely rural population system subject to the same basic parameters.

$$\bar{S} < S_A \quad (47)$$

TABLE 5 The Rogers model: the variations of the main functions.

Function		t: 0	t_r	$+\infty$
$P_r(t)$	(a) $r < o_r$	$P_r(0)$ ↘	$P_r(t_r)$ ↗	$+\infty$
	(b) $r \geqslant o_r$	$P_r(0)$ ↗		$+\infty$
$P_u(t)$		0 ↗		$+\infty$
$S(t)$		0 ↗		S_A
$\frac{dS(t)}{S(t)dt}$		$+\infty$ ↘		0
$\alpha(t)$		0 ↗		$\frac{S_A}{1+S_A}$
$m(t)$		o_r ↘		$o_r - o_u S_A$

The time t_D at which this hypothetical population reaches the ratio $\bar{S}$ is given by the solution of $S(t) = \bar{S}$, i.e.,

$$t_D = \frac{1}{o_u(S_A - S_B)} \ln\left(\frac{S_A(\bar{S} - S_B)}{-S_B(S_A - \bar{S})}\right) \tag{48}$$

On the basis of this, if one observes an actual population system characterized as above in year T, the ratio of the urban to rural population in year $y + T$ is given by:

$$S(y + T) = \frac{S_B(S_A - \bar{S}) + S_A(\bar{S} - S_B)\exp[o_u(S_A - S_B)T]}{S_A - \bar{S} + (\bar{S} - S_B)\exp[o_u(S_A - S_B)T]} \tag{49}$$

Table 6 indicates the urbanization that would occur on the basis of (49) in the two actual rural–urban systems considered previously. It turns out that the long-term equilibrium is reached in about 400 years in the case of India and in less than 200 years in the case of the U.S.S.R. Note the relatively low value of the long-term percentage of the population that is urban in the case of India: 37.7 percent versus 19.7 percent initially. By contrast, the corresponding figures for the U.S.S.R. are 75.3 and 56.4 percent, respectively.

In addition, the comparison of the figures of Table 6 with those of Table 5

TABLE 6 The Rogers model: application to India and the U.S.S.R.

India				U.S.S.R.		
$r = 21.5 \times 10^{-3}$ $o_r = 6.8 \times 10^{-3}$	$u = 19.5 \times 10^{-3}$ $o_u = 10.0 \times 10^{-3}$			$r = 10.0 \times 10^{-3}$ $o_r = 35.0 \times 10^{-3}$	$u = 9.0 \times 10^{-3}$ $o_u = 11.0 \times 10^{-3}$	
S	α (percentage)	m (per thousand)	T	S	α (percentage)	m (per thousand)
0.245	19.70	4.35	0	1.291	56.35	20.80
0.269	21.21	4.11	5	1.512	60.19	18.37
0.292	22.61	3.88	10	1.721	63.24	16.07
0.353	26.10	3.27	25	2.088	67.62	12.03
0.433	30.20	2.47	50	2.745	73.30	4.81
0.528	34.54	1.52	100	3.011	75.02	1.97
0.590	37.13	0.90	200	3.045	75.28	1.51
0.605	37.68	0.75	500	3.045	75.28	1.51
0.605	37.68	0.75	1,000	3.045	75.28	1.51

indicates that, in spite of their totally differing long-term behavior, the Keyfitz and Rogers models do not show well-marked differences in the pace of urbanization over the first 25 years. For example, after 25 years, the percentage of the population that is urban, with the Rogers model, is 26.1 percent in the case of India and 67.6 percent in the case of the U.S.S.R., whereas the comparable figures obtained with the Keyfitz model are 27.1 and 73.2 percent, respectively. As expected, since the Rogers model implies a continuous decrease of the rural net outmigration rate, it leads to a slightly slower urbanization process than the Keyfitz model.

What is the shape of the curve describing the variations of the ratio $S(t)$ of the urban to rural populations? First, it is clear from the values of the basic parameters that the curve $S(t)$ associated with the actual systems considered above does not admit a point of inflection in the case of India but admits one in the case of the U.S.S.R. In the latter case, the question is then one of knowing if the point of inflection occurs before or after the time at which the hypothetical population system presents the same characteristics as the observed one. Clearly, the answer to this follows from the relative values of t_D and t_S. From a comparison of (32) and (48), it follows that t_D is smaller (greater) than t_S if $\bar{S}$ is smaller (greater) than the half sum of S_A and S_B, i.e.,

$$\bar{S} \underset{(<)}{>} \frac{u - o_u - (r - o_r)}{2o_u} \tag{50}$$

In the case of the hypothetical population system of the U.S.S.R., t_D is greater than t_S. Consequently, the urbanization process of both India and the U.S.S.R. on the basis of the Rogers model implies a continuous slowing down of the growth rate of the urbanization index $S(t)$ after the observed period.

How do the urban and rural populations evolve over time? The urban population monotonically increases toward $+\infty$ in both cases (Table 6). The rural population monotonically increases in the case of India, whereas it first decreases, passes through a minimum, and then increases indefinitely in the case of the U.S.S.R.

Finally, we note the continuous decline of the rural net outmigration rates which, as expected, take on small long-term values. In the Indian case, m decreases from 4.35 per thousand to about one-sixth of this value (0.75 per thousand), while in the case of the U.S.S.R., it decreases from 20.9 per thousand to one-thirtieth of this value (1.5 per thousand).

SENSITIVITY ANALYSIS

What is the impact of small changes in the basic parameters on the level of the long-term equilibrium? Differentiating S_A with respect to the urban outmigration rate leads to

$$\frac{dS_A}{do_u} = \frac{o_r - o_u S_A}{o_u[(u - o_u - (r - o_r)^2 + 4o_r o_u]^{1/2}} - \frac{S_A}{o_u} \tag{51}$$

an expression which, it can be shown, is always negative. As expected, a higher urban outmigration rate tends to reduce the equilibrium urbanization level. As shown in Table 7, an immediate increase of the urban outmigration rate by one point leads to a decline of the long-term percentage α_A of the Indian population that is urban from 36.7 percent to 35.6 percent. Table 7 displays values of α_A corresponding to a set of various values of o_u. A value of the urban gross migration rate as small as $o_u = 0.001$ implies a rather large value of α_A (83.7 percent) while a value of o_u, two and a half times the initial value, leads to a quasi-stationary system: α_A reaches 20.4 percent versus the initial 19.7 percent. Indeed, if there is no migration from the urban to rural areas, the model becomes the Keyfitz model as the percentage of the population that is urban tends toward a hundred percent.

A change in o_u has a sensible impact not only on the long-term urban proportion but also on the urban proportion of the years following the initial period (see Table 7 which displays the values of the urban proportion 50 years hence for various values of o_u).

Differentiating S_A with respect to the rural outmigration rate leads to:

$$\frac{dS_A}{do_r} = \frac{S_A + 1}{\{[u - o_u - (r - o_r)]^2 + 4o_r o_u\}^{1/2}} \tag{52}$$

Clearly, this derivative is always positive, which shows that a higher rural outmigration rate tends to increase the urbanization level at equilibrium. As shown in Table 8, an immediate increase of the rural outmigration rate by

TABLE 7 The Rogers model: impact of the urban outmigration rate on the percentage of the Indian population that is urban ($r - u = 2 \times 10^{-3}$; $o_r = 6.8 \times 10^{-3}$).

o'_u	0.001	$o_u/2$	o_u	$o_u + 0.001$	$3o_u/2$	$2o_u$	$5o_u/2$
$\alpha(+50)$	39.75	35.06	30.20	29.34	26.22	22.94	20.24
α_A	83.68	53.41	37.68	35.63	29.29	24.01	20.36

TABLE 8 The Rogers model: impact of the rural outmigration rate on the percentage of the Indian population that is urban ($r - u = 2 \times 10^{-3}$; $o_u = 10.0 \times 10^{-3}$).

o'_r	0.001	$o_r/2$	o_r	$o_r + 0.001$	$2o_r$	$3o_r$	$4o_r$
$\alpha(+50)$	14.16	21.28	30.20	32.59	44.63	55.50	63.72
α_A	7.79	22.75	37.68	41.11	55.63	65.62	72.04

0.001 leads to a rise in the long-term urban proportion in India from 37.7 percent to 41.1 percent. Table 8 also displays values of α_A corresponding to a set of various values of o_r; observe that the doubling of o_r leads to a 55.6 percent equilibrium while its quadrupling yields a 72.0 percent equilibrium. In the case of there being no migration from the rural to urban areas, the model would become a model polar to that of Keyfitz in that the population would become predominantly rural.

Finally, differentiating S_A with respect to the rural–urban natural increase differential yields

$$\frac{dS_A}{d(r-u)} = -\frac{S_A}{\{[u - o_u - (r - o_r)]^2 + 4o_r o_u\}^{1/2}} \tag{53}$$

so that an immediate decrease in $r - u$ brings about a higher urbanization level.

Table 9 shows the values of α_A corresponding to some likely values of $r - u$. The impact of plausible changes in $r - u$ is to remain relatively modest since a 4 per thousand decline leads to an increase of α_A from 37.7 percent to only 43.4 percent.

Thus, with regard to the relative impacts of changes in the natural increase and migration regimes, the Rogers model leads to conclusions similar to those obtained with the Keyfitz model: variations in the migration regimes have a larger influence on the pace of urbanization than variations in the fertility–mortality regimes.

TABLE 9 The Rogers model: impact of the rural–urban natural increase differential on the percentage of the Indian population that is urban ($o_r = 6.8 \times 10^{-3}$; $o_u = 10 \times 10^{-3}$).

$r - u$	−0.002	−0.001	0	0.001	0.002	0.003	0.004
$\alpha(+50)$	32.86	32.18	31.51	30.85	30.20	29.56	28.94
α_A	43.40	41.93	40.48	39.06	37.68	36.35	35.06

III THE UNITED NATIONS MODEL

Very recently, the Population Division of the United Nations (1979) proposed a model of urbanization extending the Rogers model in the direction of realism: gross outmigration rates and natural increase rates are allowed to vary. This extension is presented here in two stages: first, we introduce gravity-type migration flows and, second, we add declining urban–rural natural increase differentials.

INTRODUCING GRAVITY-TYPE MIGRATION FLOWS

As an alternative to constant outmigration rates from rural and urban sectors, the United Nations assumes that the probability of moving from one sector to the other is a linear function of the proportion of the total population that is located in that other sector, i.e.,

$$o_r(t) = i + j \frac{P_u(t)}{P_r(t) + P_u(t)} \tag{54}$$

and

$$o_u(t) = k + l \frac{P_r(t)}{P_r(t) + P_u(t)} \tag{55}$$

in which all coefficients are constants.

It follows that $o_r(t)$ and $o_u(t)$ are simple functions of the ratio of urban to rural population:

$$o_r(t) = i + j \frac{S(t)}{1 + S(t)} \tag{56}$$

and

$$o_u(t) = k + l \frac{1}{1 + S(t)} \tag{57}$$

Are there any *a priori* restrictions regarding the coefficients i, j, k, and l? First, i and k are positive so that $o_r(t)$ and $o_u(t)$ are always positive. Second, j is assumed to be positive because it is likely that the gross outmigration rate from the rural sector increases as the urban proportion increases. By contrast, there is no *a priori* sign for the parameter l in the urban gross outmigration rate equation: l is positive (negative) if $o_u(t)$ declines (increases) over time.

Note that

$$o_r(t) = i + j - j\frac{1}{1 + S(t)} \tag{58}$$

Hence, the comparison of (57) and (58) suggests that

$$j > |l| \tag{59}$$

because urban outmigration rates are generally regarded as being less sensitive to changes in socio-economic conditions than rural outmigration rates.

Recalling eqs. (21) and (22) in which o_r and o_u are now time-dependent, we obtain the result that the growth rates of the two populations are still simple functions of $S(t)$:

$$\frac{dP_r(t)}{P_r(t)dt} = r - i + kS(t) + (l - j)\frac{S(t)}{1 + S(t)} \tag{60}$$

and

$$\frac{dP_u(t)}{P_u(t)dt} = u - k + \frac{i}{S(t)} + (j - l)\frac{1}{1 + S(t)} \tag{61}$$

Substituting (57) and (58) into (3) and rearranging terms then yields the following differential equation in $S(t)$

$$\frac{dS(t)}{dt} = i + [(u - l - k) - (r - j - i)]S(t) - k[S(t)]^2 \tag{62}$$

This last equation has exactly the same functional form that was derived in the case of constant gross outmigration rates (Riccati equation). The only differences are that:

- the constant terms in $o_r(t)$ and $o_u(t)$, i and k, respectively, are substituted for o_r and o_u;
- the constant rates of natural increase r and u are replaced by $r - j$ and $u - l$, respectively.

The main consequence of this observation is that the above model leads to a pattern of urbanization similar to that of the Rogers model. The ratio of urban to rural populations $S(t)$ and the percentage $\alpha(t)$ of the population that is urban are given by formulas similar to (29) and (34) respectively. S_A and S_B are now replaced by S'_A and S'_B which also have opposite signs:

$$S'_A = \frac{(u-l-k)-(r-j-i)+\{[(u-l-k)-(r-j-i)]^2+4ik\}^{1/2}}{2k} \tag{63}$$

whereas S'_B is identical to S'_A except that the sign preceding the square root term is a minus instead of a plus. (Note that the existence of these two roots of opposite signs follows from the assumption that both i and k are positive.)

By contrast to the evolution of $S(t)$ and $\alpha(t)$, the evolution of the rural and urban populations is not easily obtained. Only in the case of the urban population can we derive interesting results. Differentiating (61) with respect to time leads to

$$\frac{d}{dt}\left(\frac{dP_u(t)}{P_u(t)dt}\right) = -\left[\frac{i}{[S(t)]^2} + \frac{j-l}{[1+S(t)]^2}\right] \tag{64}$$

Because of inequality (59), the right-hand side of (64) is negative and the urban growth rate thus monotonically decreases from $+\infty$ to its long-term value. It follows that, as in the Rogers model, the urban population either increases monotonically toward $+\infty$ or increases and then decreases toward zero. Indeed, only the first case is of interest to us: it corresponds to the situation in which substituting S'_A for $S(t)$ in (60) or (61) yields a positive value, i.e.,

$$kS'^2_A + (r+k+l-i-j)S'_A + r - i > 0 \tag{65}$$

The adoption of this restriction (65) – replacing the restriction (40) of the Rogers model – thus allows the urban population to increase monotonically toward $+\infty$. Because the model admits a long-term equilibrium, the rural population also becomes infinite as t increases but its variations are not necessarily simple over the time continuum.

Summarizing the above results, we could conclude that the United Nations model does not significantly differ from the Rogers model. However, this statement is proved wrong by the evolution of the rural net outmigration rate.

From (56) and (57), we have

$$m_r(t) = o_r(t) - o_u(t)S(t) = i - kS(t) + (j-l)\frac{S(t)}{1+S(t)} \tag{66}$$

Differentiating this expression with respect to time leads to

$$\frac{dm_r(t)}{dt} = \left[-k + \frac{j-l}{[1+S(t)]^2}\right]\frac{dS(t)}{dt} \tag{67}$$

Consequently, the rural net outmigration rate does not necessarily decrease monotonically as in the Rogers model. Its evolution is as follows, according to the parameter values:

(a) if $j - l > k(1 + S'_A)^2$, $m_r(t)$ monotonically increases;

(b) if $k < j - l < k(1 + S'_A)^2$, $m_r(t)$ increases, passes through a maximum and then decreases;

(c) if $j - l < k$, $m_r(t)$ monotonically decreases.

Thus, for some adequate parameter values (case (b)), the United Nations model may allow for an evolutive pattern of rural–urban migration which resembles the historical trend observed in today's developed nations.

The above model is also applicable to actual rural–urban systems as long as the observed urban to rural populations $\bar{S}$ is less than the quantity S'_A, calculated from the model parameters using (63). We have simulated the evolution of the two population systems of India and the U.S.S.R. assuming that the constant terms appearing in the gross migration rate equations are equal to half the value of the corresponding observed rates:

$$i = o_r/2 \quad k = o_u/2$$

As indicated in Table 10, the urban proportions tend toward larger equilibrium values than in the case of constant gross migration rates: α_A reaches 65.0 percent instead of 37.7 percent (for India) and 85.1 percent versus 75.3 percent (for the U.S.S.R.). Indeed, this larger urbanization level is due to increasing rural outmigration rates and decreasing urban outmigration rates; in the Indian case o_r rises from 6.8 to 14.6 per thousand while o_u declines from 10.0 to 7.2 per thousand.

Nevertheless, in both cases, the rural net outmigration rate monotonically decreases over the simulation period. Note that, in the Indian case, the parameters are such that, in the corresponding hypothetical population system, $m_r(t)$ increases and then decreases. However, the maximum reached after 42 years is slightly higher than the observed value: 4.58 versus 4.35 per thousand; this explains why $m_r(t)$ appears to be quasistationary over the first hundred years of the simulation period (Table 10).

The values of j and l, implied by the above assumption concerning i and k, are, in the Indian case, equal to 0.0154 and 0.0065, respectively. But how sensitive is the model to changes in these migration multipliers? For that purpose, we have simulated the Indian system by keeping j (or l) constant – and equal to the value just derived – and by letting l (or j) vary. On the one hand, Table 11 indicates that if the urban migration multiplier is kept constant, the long-term urban proportion increases from 40.8 percent (when $j = 0$) to 74.9 percent (if j is increased by 50 percent). On the other hand, Table 12 shows the dependence of the long-term urban proportion on the urban migration multiplier if the rural migration multiplier is kept constant: it decreases from 75.9 percent (when $l = 9.75 \times 10^{-3}$) to 44.5 percent (when $l = -13.0 \times 10^{-3}$).

TABLE 10 The United Nations model (stage 1): application to India and the U.S.S.R. ($i = o_r/2$; $k = o_u/2$).

India						U.S.S.R.				
S	α (percent)	o_r (per thousand)	o_u (per thousand)	m (per thousand)	T	S	α (percent)	o_r (per thousand)	o_u (per thousand)	m (per thousand)
0.245	19.70	6.80	10.00	4.35	0	1.291	56.35	35.00	11.00	20.80
0.270	21.28	7.07	9.90	4.40	5	1.524	60.38	36.25	10.49	20.26
0.296	22.83	7.34	9.81	4.44	10	1.771	63.91	37.35	10.05	19.55
0.376	27.31	8.11	9.53	4.53	25	2.567	71.96	39.85	9.03	16.66
0.518	34.14	9.29	9.10	4.57	50	3.849	79.38	42.15	8.10	10.98
0.823	45.15	11.19	8.42	4.27	100	5.286	84.09	43.62	7.50	3.95
1.361	57.64	13.35	7.64	2.96	200	5.714	85.11	43.93	7.38	1.78
1.831	64.68	14.59	7.19	1.33	500	5.729	85.14	43.94	7.37	1.70
1.853	64.95	14.61	7.18	1.30	1,000	5.729	85.14	43.94	7.37	1.70

TABLE 11 The United Nations model (stage 1): impact of variations in the rural outmigration multiplier on the long-term equilibrium of the Indian population ($l = 6.5 \times 10^{-3}$).

j ($\times 10^{-3}$)	0	3.85	7.70	11.55	15.40	19.25	23.10	26.95	30.80
α'_A	40.79	45.48	51.49	58.34	64.95	70.52	74.91	78.32	80.98
$o_r(\infty)$	6.80	7.91	9.54	11.80	14.61	17.76	21.10	24.50	27.95
$o_u(\infty)$	8.69	8.39	8.02	7.59	7.18	6.84	6.56	6.35	6.18

TABLE 12 The United Nations model (stage 1): impact of variations in the urban outmigration multiplier on the long-term equilibrium of the Indian population ($j = 15.4 \times 10^{-3}$).

l ($\times 10^{-3}$)	−13.00	−9.75	−6.50	−3.25	0	3.25	6.50	9.75
α'_A	44.52	46.47	48.86	50.27	53.69	58.29	64.95	75.94
$o_r(\infty)$	11.08	11.42	11.83	12.08	12.67	13.46	14.61	16.51
$o_u(\infty)$	12.70	12.08	11.36	10.95	10.00	8.80	7.18	4.75

The conclusion here is that the level of urbanization at equilibrium is heavily dependent on the values of the rural and urban migration multipliers, j and l, respectively. However, the urbanization path is similar in all cases and is, as shown earlier, germane to that offered by the Rogers model.

ADDING DECREASING URBAN–RURAL NATURAL INCREASE DIFFERENTIALS

In a second stage, the United Nations model allows for decreasing urban and rural rates of natural increase; however, it assumes that the urban–rural differential remains constant, in which case the urbanization process is identical to that obtained in the case of constant natural increase rates in both areas. Here, we suppose that both rural and urban natural increase rates are linearly decreasing with the ratio $S(t)$ of the urban to rural populations, but at a different rate:

$$r(t) = a - bS(t) \tag{68}$$

$$u(t) = c - dS(t) \tag{69}$$

where b and d are positive coefficients. Subtracting (69) from (68) leads to

$$r(t) - u(t) = a - c - (b - d)S(t) \tag{70}$$

TABLE 13 The United Nations model (stage 2): application to India ($i = o_r/2$; $j = o_u/2$; $f = 0.01$).

T	S	α (percent)	o_r (per thousand)	o_u (per thousand)	m (per thousand)	$r-u$ (per thousand)
0	0.245	19.70	6.80	10.00	4.35	2.00
5	0.270	21.28	7.07	9.90	4.40	1.97
10	0.296	22.83	7.34	9.81	4.44	1.95
25	0.376	27.34	8.12	9.52	4.53	1.87
50	0.522	34.28	9.32	9.09	4.57	1.72
100	0.842	45.71	11.29	8.38	4.23	1.39
200	1.463	59.44	13.66	7.53	2.63	0.76
500	2.148	68.23	15.18	6.98	0.19	0.06
1,000	2.193	68.68	15.25	6.95	0.01	0.02

TABLE 14 The United Nations model (stage 2): impact of variations in the natural increase multiplier on the long-term equilibrium of the Indian population.

f (per thousand)	0	2.0	4.0	6.0	8.0	10.0	12.0	14.0
α_A	64.95	65.64	66.35	67.10	67.87	68.68	69.53	70.42
$o_r(\infty)$	14.61	14.73	14.85	14.98	15.11	15.25	15.40	15.55
$o_u(\infty)$	7.18	7.14	7.10	7.05	7.00	6.95	6.90	6.84
$r-u(\infty)$	2.00	1.66	1.30	0.90	0.48	0.02	−0.49	−1.05

a relationship which shows that we necessarily have

$$f = b - d > 0 \tag{71}$$

if we suppose that the rural–urban differential in natural increase rates declines as the urban proportions rise.

Substituting (68) and (69) for r and u, respectively, into (62) yields

$$\frac{dS(t)}{dt} = i + [(c - l - k) - (b - j - i)]S(t) - (k - f)[S(t)]^2 \tag{72}$$

a new differential equation in $S(t)$ which still has the same functional form as the differential equation obtained with the Rogers model.

Typically, $f = b - d$ is expected to be small so that, in most current applications, the discriminant of the right-hand side of (72) is positive.

Thus, the introduction of a declining rural–urban differential in natural increase does not radically affect the pattern of urbanization which still remains similar to that of the Rogers model. Table 13 displays the evolution of the urban proportion in the Indian system; in case (a) the natural increase multiplier f is chosen equal to 0.01, and in (b) the migration flows are described by a gravity model with $i = o_r/2$ and $k = o_u/2$. The long-term urban proportion appears to be equal to 68.7 percent versus 65.0 percent for the case $f = 0$ (i.e., $r - u$ remains constantly equal to its observed value).

Selected values of α_A corresponding to various values of f between 0 and 14 per thousand appear in Table 14. Thus, as the preceding results obtained by changing $r - u$ instantaneously could suggest, declining natural increase differentials between the urban and rural sectors have a rather small impact on urbanization indices such as S_A or α_A.

CONCLUSIONS

This paper has sought to examine analytically the relation between the urbanization phenomenon and the demographic parameters which affect it. In the process, many interesting conclusions have been drawn which concern the three alternative models used in the course of our investigations.

First, we have shown that the Keyfitz model (Keyfitz 1978) implies an urban to rural population ratio which increases exponentially over time and a proportion urban which increases monotonically (with a curve of variations shaped downward); it is a logistic function of time only if the rural rate of natural increase is larger than the urban one. However, the Keyfitz model appears of limited application because of:

(a) its assumption of fixed rural net outmigration rate;

(b) its asymmetric treatment of the migration flows between the rural and urban sectors which, in the long run, leads to some undesirable features such as the preponderance of the urban region and the possible emptying out of the rural region.

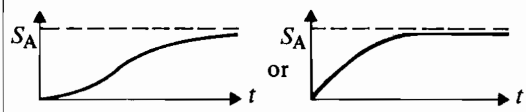
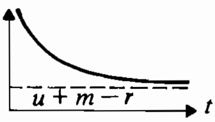
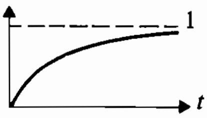
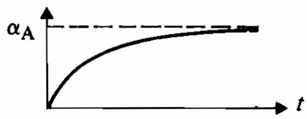
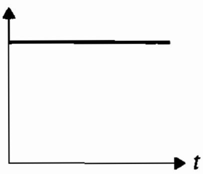
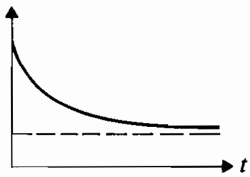
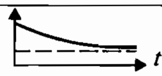
Second, we have shown that the continuous version of the two-region Rogers model (Rogers 1968) implies an urban to rural population ratio as well as a proportion urban which are described by a truncated logistic curve (with possibly the presence of a point of inflection in the case of the first index). Also, the Rogers model seems to be a more useful tool than the Keyfitz model to examine the urbanization phenomenon. Its more symmetric treatment of the rural and urban outmigration flows leads, in the long run, to more reasonable features: it admits a long-term equilibrium in which the rural and urban populations grow at the same rate. However, because it implies a continuous decline of the rural net outmigration rate (with a possible reversal in the direction of the rural–urban migration transfer), the Rogers model appears to be applicable only to nations which have already reached a certain level of economic development.

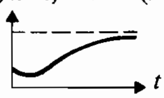
Third, we have shown that, although it relies on well-defined hypotheses (constant natural increase and gross outmigration rates in both rural and urban sectors), the Rogers model is quite general in form. As suggested by the United Nations (1979), various assumptions concerning the migration and natural increase regimes – e.g., gravity-type migration flows and natural increase rates declining linearly with the urban to rural population ratio – do not alter the pattern of urbanization stemming from the Rogers model. The only difference is that, for an adequate choice of the model parameters, the variations of the rural net outmigration rate may replicate the historical variations observed in today's developed nations: increase up to a maximum and then decrease.

The above findings concerning the comparative dynamics of the three alternative models are summarized in Table 15. Besides these findings, this paper has also permitted the derivation of interesting results about the relation between economic development and urbanization. We have shown that the former influences the latter through the rural–urban natural increase differential and the migration exchange between the two sectors, in such a way that both these factors have a direct (positive) impact on urbanization; however, the impact due to the natural increase factor is much less important. An important consequence of this is that, from a modeling point of view, a refining of the natural increase functions is not so rewarding as a realistic treatment of the migration function(s). Thus, a general strategy when building an urbanization model might be to suppose identical rural and urban natural increase rates – which considerably simplify the analytics (Keyfitz 1978) or ensure mathematical tractability (Ledent 1978c) – and to concentrate on the specification of the rural–urban migration exchange.

From a practical point of view, this paper has presented several numerical illustrations which have provided us with several interesting conclusions regarding the future urbanization process of India and the U.S.S.R. Perhaps the most significant one is that India is bound to remain a predominantly rural country for quite a while. For example, assuming an unchanged urban outmigration rate, the occurrence of a 50-percent urban proportion 50 years hence requires a sustained rural outmigration rate equal to 2.5 times its current value (see Table 8).

TABLE 15 Comparative dynamics of the three alternative models: a tabular summary.

<table>
<tr><th></th><th>The Keyfitz Model</th><th>The Rogers Model</th><th>The United Nations Model</th></tr>
<tr><td>Restrictions</td><td>$u + m - r > 0$
$u > 0; m > 0$</td><td>$S_A \geqslant \frac{o_r - r}{o_u} \; (uS_A + r \geqslant 0)$</td><td>eq. (65)</td></tr>
<tr><td>Long-term behavior</td><td>Urban population preponderant with rural population possibly vanishing</td><td colspan="2">Rural–urban equilibrium</td></tr>
<tr><td>$S(t)$</td><td>
exponential function of time</td><td colspan="2">
logistic function of time</td></tr>
<tr><td>$\frac{dS(t)}{S(t)dt}$</td><td></td><td colspan="2"></td></tr>
<tr><td>$\alpha(t)$</td><td>
logistic function of time if $r > u$</td><td colspan="2">
logistic function of time</td></tr>
<tr><td>$m(t)$</td><td></td><td></td><td>
(a) $j - l < k$

(b) $k < j - l < k(l + S_A)^2$

(c) $j - l > l(l + S_A)^2$</td></tr>
</table>

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DETERMINANTS OF RURAL-TO-URBAN MIGRATION IN KENYA

H. Rempel

In this paper, two linked aggregate models are formulated to analyze the determinants of rural-to-urban migration in Kenya. The first strives to account for patterns of rural out-migration; the second examines the decision-making process of migrants in their selection of urban destinations. The models are tested with the use of standard linear regression techniques using data from the 1969 census (Central Bureau of Statistics 1969). These data give the numbers of people born in one area but counted in another at the time of the census. Finally, the results obtained are compared with data accumulated from a 1968 survey (Rempel *et al.* 1970) of male rural-to-urban migrants residing in urban areas at the time of the survey.

As our forthcoming report indicates (Rempel 1981, chap. 1) there are two separate, but related dimensions to the analysis of migration decision making. First, there is the need to identify the probability that a member of the labor force in a particular rural district i will relocate during some defined time period to an urban location, say town j. Second, there is a need to identify the determinants of selecting a particular urban destination j from a set of m possible destinations. Here two models, which consider these questions of the migration process, are presented and tested.

DETERMINANTS OF THE PROBABILITY OF A RURAL-TO-URBAN MOVE

According to our decision-making model of labor allocation (Rempel 1981, chap. 1), households allocate their available labor, on the basis of the information available, among local and nonlocal employment opportunities in such a manner as to realize their respective income objectives. To make this model operational at a regional level of aggregation it becomes necessary to specify migration behavior in terms of "average" benefits, costs, and characteristics associated with both the sending and receiving regions.

*A Polytomous Logistic Model of Migration**

The probability P_{ij} that an individual faced with m possible urban locations, plus his current rural location i, will be residing in one of these m urban areas in any one time period can be expressed as:

$$P_{ij} = \frac{\exp[V(Z_j, D_{ij})]}{\sum_j^m \exp[V(Z_j, D_{ij})]} \qquad i = 1, \ldots, n; j = 1, \ldots, m \tag{1}$$

where

Z_j denotes the attributes associated with a particular region, in this case the receiving area j

D_{ij} reflects the "friction" of distance or intervening obstacles between a rural region i and an urban area j

V is the part of the utility function that contains the representative components of the various choices available to all prospective migrants

Similarly, the probability P_{ii} of the individual remaining in region i can be expressed as:

$$P_{ii} = \frac{\exp[V(Z_i)]}{\sum_j^m \exp[V(Z_j, D_{ij})]} \qquad i = 1, \ldots, n; j = 1, \ldots, m \tag{2}$$

In this case Z_i refers to attributes associated with the sending area only. Since staying in region i is included as an option, the sum of the two probabilities is equal to one, as is normally required for a model of choice (Grant and Vanderkamp 1976, p. 35).

The difficulty of working with this specification is that the probabilities P_{ij} and P_{ii} are constrained to the interval zero to one while the respective right-hand sides can take on arbitrary real values. This problem can be overcome by combining the two probabilities in the logit form:

$$\frac{P_{ij}}{P_{ii}} = \frac{\exp[V(Z_j, D_{ij})]}{\exp[V(Z_i)]} \tag{3}$$

This ratio of probabilities represents the chance that an individual in i will relocate to some region other than i. The denominator in eqs. (1) and (2) cancels out in the process, but is required if one needs to work out the effect of a change in attributes in some region k on the composition of migrants between i and j (Grant and Vanderkamp 1976, p. 38).

*A more detailed discussion of this model, including the utility assumptions on which it is based, can be found in Grant and Vanderkamp (1976, pp. 35–81). An alternative source is Schultz (1976, pp. 38–41).

If logarithms are taken of both sides, we obtain the estimation equation

$$\ln\left(\frac{P_{ij}}{P_{ii}}\right) = V(Z_j,D_{ij}) - V(Z_i) \tag{4}$$

It is now necessary to specify the elements of Z_j, Z_i, and D_{ij} in a manner consistent with the set of hypotheses presented at the end of chapter 1 in Rempel (1981). For this purpose we propose the following:

$$Z_j = f_1(X_j, U_j, A_j, B_j, G_{ij}, D_{ij}, I_{ij}) \tag{5}$$

and

$$Z_i = f_2(\hat{Y}_i, X_i, \tilde{X}_i, T_i, F_i, E_i, A_i) \tag{6}$$

where

- X_j is the income perceived by prospective migrants to be available in urban center j
- U_j is the probability, as perceived by prospective migrants, of obtaining X_j
- A_j is a measure of amenities perceived by prospective migrants to be available in urban center j
- B_j is a measure of the size and job diversity of the labor market in region j
- G_{ij} denotes the kin resident in region j who are available to assist prospective migrants from region i
- D_{ij} is the cost of moving from region i to region j
- I_{ij} is a measure of the information about opportunities and conditions in region j available to prospective migrants in region i
- $\hat{Y}_i$ is a measure of aspiration levels in region i
- X_i is the level of income available in region i
- $\tilde{X}_i$ is a measure of the skewness in the income distribution in region i
- T_i is a measure of the extent of commercial and social interaction between region i and external stimuli such as an urban center
- F_i is a measure of the equality of access to the productive resources in region i
- E_i is a measure of the system of land tenure and inheritance in region i
- A_i is a measure of amenities available in region i

The various personal attributes considered relevant to migration behavior, such as formal education, age, and the role of women in agricultural production, cannot be entered readily in an aggregate migration function. To allow for such factors, it becomes necessary to stratify the various elements affected by such personal attributes in Z_i and Z_j by age, education, and sex (Schultz 1976, p. 40). In this way separate estimates are obtained for the probability of a person in any one subgroup in region i relocating to some urban town j, during a specified period of time. In our case, the available data are not stratified by age and education. Therefore, stratification in our model is limited to males versus females. In addition to the dependent variable, X, U and $\hat{Y}$ will be measured with sex-specific variables.

For the dependent variable, the probability P_{ij} of migrating from i to j is measured as M_{ij}/B_i. Here M_{ij} is the total number of migrants born in i who were living in j at the time of the census; B_i is the total number of persons counted in the census as being born in region i. The probability P_{ii} of not migrating is measured as M_{ii}/B_i, where M_{ii} is the number of persons who were born in i and enumerated as resident there at the time of the census.

Therefore, the dependent variable used is

$$\ln\left(\frac{P_{ij}}{P_{ii}}\right) = \ln\left(\frac{M_{ij}/B_i}{M_{ii}/B_i}\right) = \ln\left(\frac{M_{ij}}{M_{ii}}\right) \qquad (7)$$

The nature of the data available limits the options to measuring M_{ij} in gross terms. To base the analysis on gross rather than net migration flows need not be considered a second-best option. It is likely that the urban-to-rural migration occurring in Kenya is similar to that of Sierra Leone where the simple correlation between net migration and gross urban out-migration was found to be 0.89, and between net migration and gross in-migration was −0.14 (Byerlee *et al.* 1976, p. 88). Given that the observed urban out-migration flows tend to have a disproportionate number of older persons with a below-average level of general skills, the gross urban in-migration can be considered to be a better indicator than net urban migration of the number of persons added to the urban labor force.

In specifying the urban income variable X_j in an aggregate migration model, it becomes necessary to identify the wage that can be "assumed to be perceived equally by all potential migrants." (Nelson *et al.* 1971, p. 57). *A priori* one would expect prospective migrants to aspire to the wage consistent with their respective schooling and experience. Yet, the one study which was able to stratify the sample into five occupational groupings obtained a higher coefficient of determination when using the average urban wage for all occupations than for occupation-specific wage rates (Carvajal and Geithman 1974, p. 114). This was interpreted as an indication that prospective migrants perceive their income in terms of the regional average rather than the wages paid in their current or desired occupations. Given that wage structures tend to be similar among regions even if levels differ, the average wage could serve as a good proxy measure for expected income. As a result, the average formal sector wage in each urban center is used as the measure of X_j.

For the rural areas, a weighted average of district formal sector wages and wages paid on small farms and settlement schemes is used to estimate the value of X_i. The weights used are the respective number employed in each. Given a reasonably competitive labor market in rural areas, the rural wage level can be considered a good approximation of the supply price of labor in a setting where labor allocation is decided by households rather than by individuals (Byerlee *et al.* 1976, p. 86). Because relevant data required to adjust these income levels are not available, it is necessary to assume that the income levels have comparable values in the respective locations.

The variable U_j is intended to measure the perception by rural household members of their respective probabilities of obtaining the urban wage X_j. The precise specification of this variable is difficult given the elementary development of the job-search theory as it relates to migration models.

In a survey of the literature that seeks to incorporate the concept of job search into migration theory, Miron (1978) separates those studies that are based on a dispersion of wages from those that focus on the uncertainty involved in obtaining desired employment. We concur with Miron (1978, p. 527) that the former is not particularly relevant in that prospective migrants are reasonably aware of average wages and the postulated wage illusion cannot be demonstrated empirically.

A more recent, intermediate position is that of Harris and Sabot (1976), which holds that migrants are informed of wages available within each firm and that wages vary considerably among firms.* Their model involves sequential job search, where an individual compares an existing job offer with the expected costs of searching for a "better" offer and then decides whether to accept the original offer or to search further. The decision to search further is seen to be a function of (1) the migrant's subjective evaluation of the labor market conditions, (2) his attitude toward risk and his ability to bear risk, (3) the cost of the kind of search involved, and (4) the extent of dispersion of wages among firms (Harris and Sabot 1976, pp. 40, 41). Because of imperfect information available to migrants and possibly because of a tendency to overestimate their respective "critical" (reservation) wages, migrants tend to search longer than might be considered optimal which, in turn, adversely affects urban unemployment rates.

While this approach to specifying the probability of obtaining employment for a migration model seems promising, it has not been integrated as yet into a model of migration in an operational manner (Miron 1978, p. 527; Todaro 1976a, p. 44). As a result, we confine our approach to specifying U_j to that subset of the job-search literature that focuses on the uncertainty involved in obtaining employment.

Within this subset of the relevant literature Miron (1978, pp. 529, 530) identifies three job-search mechanisms: a queuing model of job hiring, the "bingo" model, and Todaro's model. The first assumes that firms maintain

*Harris and Sabot (1976, pp. 39, 40) attribute the variation in wages among firms to rapidly expanding firms raising wages to attract more applicants, and firms with significant training and managerial costs inducing low labor turnover by paying above average wages. On the basis of an analysis of the formal sector labor market in Kenya, the latter is deemed to be the more appropriate for Kenya (House and Rempel 1976, 1978).

lists of all who apply for a position and offer a position to the person at the top of the list at the time the job becomes available. While possibly relevant for high-skill jobs in Kenya, this assumption is not realistic for the hiring mechanisms confronting the vast majority of the rural–urban migrants. The bingo model is the opposite extreme of the queuing model. Here no waiting lists are maintained and a job is offered to the first qualified person who applies after the job becomes available. The Todaro model is a special case of the bingo model which enables the probability of obtaining employment in a given time period to be specified as a function of the ratio of new openings in the labor market and the number of unemployed in that labor market at that time (Todaro 1969; Miron 1978, p. 530). In subsequent work this probability has been simplified in that it has been equated to the employment rate (Harris and Todaro 1970; Todaro 1976a, pp. 34, 35).

This last specification has several undesirable properties. First, it assumes all jobs turn over every time period (Fields 1975, p. 178). Second, it represents the special case for the bingo model where the net growth in job creation in the particular labor market is set at zero (Stiglitz 1974, pp. 223–226). Removing these unnecessarily restrictive assumptions we obtain the more general specification of U: the probability of obtaining urban employment (Tobin 1972, p. 1; Stiglitz 1974, p. 224; Barnum and Sabot 1975, pp. 13, 14; Sabot 1975, p. 12; Todaro 1976b, p. 213).* Thus,

$$U(t) = (g_t + q_t)\left(\frac{1 - u_{t-1}}{u_{t-1}}\right) \tag{8}$$

where

g is the rate of new job creation
q is the quit rate, including retirement
u is the unemployment rate
t identifies the time period

This general specification, with several modifications, is used in our regression model. Because information on q is not available, our first modification is the omission of q from the specification of U_j, which serves to bias downward the coefficient realized for U_j. Second, employment and labor force data by district and town first became available in 1964 so it is not possible to measure U_j in terms of period $t - 1$.

In addition to these measurement problems, several other shortcomings of this specification of U_j have been identified. First, the model in this form assumes that migrants have to be in town in order to be able to participate effectively in a job search. Although this is probably the case for most migrants,

*In his discussion Stiglitz (1974, p. 226) also specifies the amount of unemployment and the migrant's expected time of unemployment for the queuing model.

there are no doubt exceptions that should be allowed for in eq. (8) (Fields 1975, pp. 169–171). Second, this specification assumes that the migrant is unemployed during the job search. For some migrants, part-time employment in the informal sector while engaging in a job search is a way of remaining in town for a longer period of time (Fields 1975, pp. 171–176; Sabot 1975, pp. 11–13). The omission of these two factors serves to introduce an upward bias to our coefficient for U_j. A third factor is that the probability of being selected from a given stock of unemployed is not equal among all the unemployed. Specifically, the probability of being selected is expected to vary directly with the level of formal schooling completed (Fields 1975, pp. 176, 177; Gugler 1975, p. 194). Unfortunately, the data available do not allow us to incorporate any of these suggested modifications in the general specification.

Finally, and possibly of greatest significance for our purpose here, the manner in which this general specification of U_j is incorporated into migration models assumes that U_j is known *a priori* by prospective migrants (Miron 1978, p. 531). The Harris and Sabot (1976) approach is more realistic in that migrants are seen to act on the basis of their subjective evaluation of the conditions prevailing in a particular labor market. It is to be expected that this subjective evaluation draws more on information regarding jobs becoming available than on the rate of job creation over time. In an attempt to capture this fact, an alternative specification of U_j has been tested. In this alternative version, g in eq. (8) is defined as the number of new jobs created in town j during time period t divided by the sum of all jobs created during this period in all eight urban centers.

The urban income level X_j and the probability of obtaining employment U_j are entered in the migration model separately to avoid the restrictive assumption, typical of the Todaro migration model, that migrants are risk-neutral. We concur with Bausell (1975) that migrants are likely to be risk-averse. But we feel he is rather extreme in holding that the risk inherent in farming, relative to investing in human capital in the form of a rural-to-urban move, is so low that it can be assumed not to exist (Bausell 1975, pp. 70, 71). There is no *a priori* reason for assuming that farming is a less risky means of obtaining a desired level of income ($Y = \hat{Y}$) than the search for urban employment. Rather, the security inherent in farming is that it is a form of protection against income falling below a subsistence level. Also, we postulate that it is the young men rather than the older men who are most willing to take a risk and hence are more likely to select an urban destination. Because the precise role of risk is not known, no attempt is made to build *a priori* assumptions about risk into the specification of the migration model.

Given that our measures of amenity availability are indices only, a decision has been made to enter the two indices as one ratio ($A_{ij} = A_j/A_i$). The urban amenity index A_j is weighted by the population size of town j. The rationale here is that two towns may have the same level of amenities, but the larger town, other things being equal, would be preferred by prospective migrants because a larger quantity, and hence variety, of this level of amenities would be available there. This weighting of A_j by population size caused A_j to capture the labor market size and diversity dimension associated with the manner in which our variable B_j is normally measured (Barnum and Sabot 1975, pp. 3, 4; Grant and Vanderkamp 1976, p. 4). As a result, B_j has been dropped from the regression equation, and the interpretation of the coefficient realized for A_{ij} has to be expanded to incorporate the role of B_j.

Similarly, our sole measure for I_{ij}, the information about town j available to residents of rural area i, is the kin now resident in j, G_{ij}. As a result, I_{ij} has been dropped from the regression equation and the coefficient obtained for G_{ij} is interpreted to incorporate the effect of I_{ij}.

In most migration models the distance D_{ij} between i and j is entered as a measure of both the pecuniary costs and the various non-economic (e.g., psychic) costs of moving, such as being separated from family and friends.* In addition, a complete specification of the pecuniary costs of moving should encompass the cost of subsistence during the job-search period as well as job-search costs. For this purpose D_{ij} is split into two parts: (1) DA_{ij}, the pecuniary costs of moving – bus fare, subsistence cost during the job search and job-search costs; and (2) DB_{ij}, the extent of psychic separation between i and j measured in terms of the length of a bus trip from i to j.

For the remaining rural variables direct measures are not available so a variety of proxy measures have to be employed. In the case of aspiration levels $\hat{Y}_i$, the postulated link between the desire for formal schooling and aspirations suggests that the proportion of school-age children who have actually attended school is a means of measuring the level of $\hat{Y}_i$ in a district.

Income distribution data within districts and most towns are not available for Kenya. As a result, the dominant means of generating income in the rural areas – land – is used as a proxy measure. For the small farmers income, "beyond subsistence" is considered to be reflected by the level of production of cash crops. Therefore, the proportion of land held by smallholders and the proportion of land in settlement schemes in each district that is devoted to cash crops is used as a measure for $\tilde{X}_i$. It is postulated that the larger the proportion of smallholders growing cash crops, the more equal the income distribution within the district. In the case of F_i, equality of access to productive resources, and the proportion of land in each district (adjusted for quality) held by smallholders and in settlement schemes is considered to be an appropriate measure.

For T_i, the extent of commercial and social interaction between i and j, the length of roads per square kilometer in district i is used as a proxy measure. The reasoning here is that the more developed a road system within a district the more likely people in the district have both the interest and the means for interaction with outside areas such as a town or a city. The effect of T_i on

*For an extended discussion of this subject see Levy and Wadycki (1974a).

out-migration is not defined precisely. Improved means for commercial interaction can serve to increase local income possibilities, so out-migration may be reduced. Conversely, if increased interaction with the outside were to heighten awareness of opportunities available elsewhere but were to have no corresponding positive effect on local income possibilities, then out-migration could be expected to increase.

Finally, several local area studies in Kenya have identified the nature of local inheritance laws as having an effect on rural out-migration (Weisner 1972, p. 72; Moock 1973, p. 304).* Where only the oldest son inherits, the younger siblings must seek economic opportunities elsewhere. Similarly, if all inherit equally, the total amount of land available is small, and a strong kinship system exists. In such cases, some household members may be encouraged to seek employment elsewhere. Conversely, a claim to land which cannot be sold, because local traditions prohibit permanent alienation of land, may deter some rural residents from breaking completely from their rural home.

Given that it is impossible to measure directly variations among districts in inheritance laws and land tenure systems, a proxy measure also had to be employed for E_i, the measure of the system of land tenure and inheritance prevailing in region i. One that is considered appropriate is the proportion of land in a district available for small-holder registration that had been registered. Registration sets minimum limits on the size of farm holdings, so those with registered land are likely to have a viable farm unit which would serve to deter out-migration. Conversely, if land cannot be subdivided further, some children may not be able to inherit directly. Since registration facilitates their selling of claims to such land, registration may serve to induce more out-migration.

Given this possibility of contrary effects of both T_i and E_i on out-migration, it is not possible to postulate an expected sign for these two variables. For all the other explanatory variables a one-tail significance test is considered appropriate. The signs for X_i, U_j, A_{ij}, G_{ij}, and $\hat{Y}_i$ are hypothesized to be positive while those for DA_{ij}, DB_{ij}, X_i, $\tilde{X}_i$, and F_i are expected to be negative.

The functional form considered appropriate for this migration model is log-linear. This form avoids the problem, associated with the linear function, of assuming that the marginal utility of money income is constant (Grant and Vanderkamp 1976, p. 37). Also, in the log-linear form the marginal effect of individual explanatory variables depends on the values of the other explanatory variables in the function (Knowles and Anker 1977, p. 4).

An econometric problem associated with this specification of the migration function is the possibility of simultaneity between the dependent variable and some of the explanatory variables. Specifically, the flow of migrants into j in response to X_j can be expected to have feedback effects on the level of X_j. A simultaneous equation model would be one method of capturing this interaction between in-migration and wage levels. But, given our choice of

*Mendels (1978) makes a similar argument based on historical data for Europe.

TABLE 1 Estimates of a polytomous logistic model of migration: dependent variable is M_{ij}/M_{ii}.

Explanatory variables		1969 census – males: Coefficient	1969 census – males: t-ratio	1969 census – females: Coefficient	1969 census – females: t-ratio
	Intercept	−15.39[a]	4.47	−12.64[a]	7.44
X_j	Urban income	1.13[b]	1.86	0.64[b]	2.09
U_j	Urban employment prospects	−0.12[a]	2.70	−0.08	1.73
A_{ij}	Amenity index	0.38[a]	3.54	0.33[a]	3.64
G_{ij}	Urban-based kin	0.46[a]	15.13	0.50[a]	15.60
DA_{ij}	Cost of move	−0.01	0.10	−0.02	0.19
DB_{ij}	Extent of separation	−0.40[a]	5.99	−0.37[a]	5.28
$\hat{Y}_i$	Rural aspiration level	0.53[a]	2.88	0.31[a]	2.46
X_j	Rural income level	−0.12	0.78	−0.06	0.63
$\tilde{X}_i$	Rural income distribution	−0.06[a]	2.58	−0.08[a]	4.16
T_i	Interaction with outside	−0.09	1.02	−0.06	0.59
F_i	Access to rural resources	−0.06	1.31	−0.12[a]	2.62
E_i	Inheritance system	−0.12[a]	3.56	−0.11[a]	3.24
Coefficient of determination		0.86[a]		0.85[a]	
Degrees of freedom		243		243	

The superscripts *a* and *b* indicate that the coefficients are significantly different from zero at the 1 and 5 percent levels, respectively. The significance of R^2 was determined from the F-test.
Two-tail tests were carried out for T_i and E_i since no *a priori* expectations regarding their signs were made. One-tail tests were carried out on the remaining variables.

model, a simultaneous equation system is not practical because X_j would be affected by the in-migration from all sources, not merely from the one source, i.

Our earlier analysis of labor market pressure in Kenya indicates that the labor force is highly responsive to interregional differences in economic opportunities but wages were found to be unresponsive to growing labor-market pressure (House and Rempel 1978). Therefore, the simultaneity problem does not appear to be a major obstacle, and our proposed model is deemed appropriate for the purposes of this study.

*Regression Results**

The single-equation ordinary least-squares regression results for males and females are reported in Table 1. Table 2 contains the correlation matrix for the variables in these two equations.

*The manner in which the variables are measured, including the data sources, is given in Rempel (1981).

TABLE 2 Correlation matrix for the polytomous model of migration.

	Females													
	M_{ij}/M_{ii}	X_j	U_j	A_{ij}	G_{ij}	DA_{ij}	DB_{ij}	$\hat{Y}_i$	X_i	$\tilde{X}_i$	T_i	F_i	E_i	
	0.0008	346	0.57	7.8	79	155	7.6	21	34	2.4	92	52	13.9	Mean
M_{ij}/M_{ii}		0.60	0.09	0.60	0.84	0.31	−0.47	0.34	0.15	0.13	0.23	−0.10	0.08	M_{ij}/M_{ii}
X_j	0.67		0.13	0.89	0.40	0.54	−0.06	0.0	0.0	0.0	0.0	0.0	0.0	X_j
U_j	0.04	0.09		0.07	0.08	0.16	−0.27	0.0	0.0	0.0	0.0	0.0	0.0	U_j
A_{ij}	0.63	0.94	0.06		0.43	0.51	0.02	−0.09	−0.08	0.03	−0.03	0.11	0.01	A_{ij}
G_{ij}	0.85	0.46	0.05	0.43		0.20	−0.46	0.49	0.22	0.43	0.39	0.04	0.21	G_{ij}
DA_{ij}	0.30	0.52	0.38	0.51	0.20		0.06	−0.16	−0.05	−0.15	−0.13	0.0	−0.10	DA_{ij}
DB_{ij}	−0.45	−0.01	−0.28	0.02	−0.46	0.06		−0.30	−0.23	−0.08	−0.25	0.16	−0.15	DB_{ij}
$\hat{Y}_i$	0.33	0.0	0.0	−0.09	0.51	−0.16	−0.29		0.33	0.46	0.64	−0.32	0.55	$\hat{Y}_i$
X_i	0.18	0.0	0.0	−0.06	0.37	−0.12	−0.19	0.64		0.13	0.52	−0.32	0.27	X_i
$\tilde{X}_i$	0.17	0.0	0.0	0.03	0.43	−0.15	−0.08	0.56	0.70		0.40	0.32	0.32	$\tilde{X}_i$
T_i	0.22	0.0	0.0	−0.03	0.39	−0.13	−0.25	0.60	0.31	0.40		−0.23	0.59	T_i
F_i	−0.06	0.0	0.0	0.11	0.04	0.0	0.15	−0.31	0.0	0.32	−0.23		−0.25	F_i
E_i	0.07	0.0	0.0	0.01	0.21	−0.10	−0.15	0.54	0.26	0.32	0.59	−0.25		E_i
Mean	0.0012	413	6.8	7.8	79	155	7.6	27	90	2.4	92	52	13.9	
	M_{ij}/M_{ii}	X_j	U_j	A_{ij}	G_{ij}	DA_{ij}	DB_{ij}	$\hat{Y}_i$	X_i	$\tilde{X}_i$	T_i	F_i	E_i	
	Males													

The postulated regression model serves to explain 85 percent of the inter-regional variation in the probability that a rural resident will relocate in an urban area. The determined coefficients R^2 are significant at the 1 percent level.

The effect of economic opportunities in the destination areas, as measured by average wages in the urban modern sector, has the postulated effect on rural–urban migration. The coefficients for X_j are significant in both cases and have the expected positive sign. Urban income affects the migration of males almost twice as much as it affects females. In each of the two equations the coefficient realized for X_j is somewhat larger than the coefficient obtained for any of the other explanatory variables, indicating the prime importance of urban income prospects in migration decision making.

The other measure of urban economic opportunities, U_j, has an unexpected negative sign in both cases and is statistically significant for males.* The coefficients realized for the two alternative specifications of U_j are quite similar in magnitude and in both cases the signs are negative. Therefore, what is reported here is the specification reported in eq. (8). For the alternative specification, the coefficient for males is significant at the 5 percent level but for females it is not significant even at the 10 percent level.

Evidence that migrants are attracted to destinations having above-average unemployment is presented in other studies as well (Greenwood 1978, p. 27). One explanation for this result is that the magnitude of the rural–urban income differential is so large for some towns that rural residents move to urban areas rather independently of employment prospects (Greenwood 1971, p. 261; Carvajal and Geithman 1974, p. 118). This has some relevance for Kenya since earlier analysis has shown a correlation coefficient of 0.9 between urban modern sector wage levels and the number of modern sector jobs created in the 1964–1968 period (Rempel 1978). We expect migration to these high wage centers to be triggered by the news of new jobs available. If individual migrants failed to consider that many others would respond to the same news, then the level of unemployment evident during the height of this new surge of in-migration would hardly be representative of what rural households perceived to be the respective chances of their members obtaining a modern sector job.

Second, the knowledge that a number of unemployed were already at a particular destination need not deter individuals. Each may feel he will be more successful than others in obtaining one of these new jobs. In addition, prospective migrants may well view employment opportunities in a particular location in terms of the kin who are available there and who can provide sustenance and otherwise assist in the job search. This is the primary explanation Byerlee *et al.* (1976, pp. 95, 96) attach to the low value of the coefficient that they obtain for their unemployment variable in their Sierra Leone survey. We will consider this possibility in the analysis of our survey results in the latter part of this paper.

*Given the opposite sign, a two-tail significance test was used for U_j. The coefficient realized for females is significant at the 10 percent level.

The third measure of urban attractiveness, the amenity index A_{ij}, is statistically significant for both males and females and has the postulated positive sign. This result is obtained even though there is a high level of correlation between X_i and A_{ij}. The results obtained here stand in contrast to an earlier analysis where amenities were found to be a significant determinant of migration for females only (Rempel 1978, Table 7, p. 4). One major difference between this earlier analysis and the results reported here is our weighting of the urban amenity index by the respective population sizes of the eight towns involved.

The effect of this weighting procedure would suggest that the impact of B_j, the measure of the size and diversity of the labor market in j, is expressed prominently in our measure of amenities. An attempt will be made to separate the amenity-availability effect from the effect of B_j in our analysis of the survey results in the latter part of this paper.

In almost all migration studies, distance has been shown to be a significant deterrent to migration. The magnitude of the coefficient realized has frequently been interpreted to indicate that distance stands as a proxy for more than merely the monetary costs of moving (Greenwood 1969, pp. 285, 286; 1971, pp. 256, 257; Levy and Wadycki 1973, 1974b, p. 384; Byerlee *et al.* 1976, p. 92; Rempel 1978, House and Rempel 1978, p. 14). Our two alternative measures of the cost of moving separate explicitly the pecuniary costs DA_{ij} of the transition from rural to urban employment from the psychic costs DB_{ij} of being separated from kin. Although the two variables are not highly correlated with each other, the monetary costs of moving are correlated positively with X_j and A_{ij}. No doubt the latter reflects the importance of the length of unemployment in the urban centers with the highest incomes.

The regression coefficients obtained in this study support the conclusion of some scholars who state that psychic costs and the effect of distance on information flows are dominant concerns in migration decision making (Levy and Wadycki 1973, 1974b, p. 385). When the average one-period rural income differentials of Shs 323 (Shs = Shillings) a month for males and Shs 312 for females is projected over a time horizon of several years, the average cost per person of Shs 155 is small indeed, and it is not surprising that DA_{ij} is not significant when it no longer measures the psychic costs of a move.

Conversely, the measure of contact between the rural area and the urban center, that is, kin who have migrated previously as measured by G_{ij}, serves as a consistent, strong determinant of rural–urban migration. The size of the coefficients realized for G_{ij} are less than for X_j, but rank second for females and third for males among all the coefficients.

When considering the origin-specific determinants of migration, it is the measure $\hat{Y}_i$ of aspiration levels that has the most pronounced effect. The significant, positive effect is somewhat higher for males than for females. In contrast, the measure T_i of interaction of region i with outside areas, which has been postulated to affect aspirations as well as provide information, is not significant. A similar result for this variable was realized by Knowles and Anker (1977, Table 1, p. 15) in their analysis of interregional migration in Kenya. The correlation coefficient between T_i and $\hat{Y}_i$ was found to be 0.60 for males and 0.64 for females, so the two variables appear to be measuring similar forces. When included in a set of explanatory variables, the effect of T_i was dissipated.

With reference to the rural income variables, the results are somewhat mixed. The coefficients X_i for the level of rural income have the postulated negative sign but are not significant. In contrast, the measure $\tilde{X}_i$ of the distribution of income within a district has a significant coefficient in both equations with the postulated negative sign. Similarly, the coefficients F_i for the measure of access to the primary rural resource land have the postulated negative sign but are significant for females only. The combination of these results suggests that the distribution of income and resources within the household's immediate environment does affect migration even though differences in income levels among regions cannot be shown to have a similar effect. Within a district, the more equal the distribution of income earning possibilities and, in the case of females, the more equal the access to productive resources, the lower the odds of a rural-to-urban move.

For the final variable, E_i, significant coefficients with a negative sign have been obtained in each equation. This indicates that, given the effect of the other explanatory variables, registration of land serves to reduce rural out-migration. The variable E_i must be considered only a crude proxy for inheritance and tenure systems among districts, but the coefficients realized indicate that the precise role of these two factors on rural–urban migration needs to be explored further.

A MIGRATION ALLOCATION MODEL

Specification of the Model

The intent of this second model is quite different from the one given above even though some of the explanatory variables are common to both. First, the dependent variable is limited to migrants only: those rural residents who actually expend real resources on a move (Levy and Wadycki 1974a, p. 201). For this subset of the rural population the concern is to explain what determines the choice of one urban destination from the set of m possible destinations.

The attributes of the sending region i do not enter this aspect of the decision-making process except in the sense that rural income levels may determine the ability to select a more costly (and/or risky) destination.* This micro-effect of variations in the ability of households to finance migration is difficult to capture at an aggregate level.

*In his version of the model, as run for interdistrict migration in Brazil, Sahota (1968, Table 3, p. 232) does enter origin-region variables in the form of a ratio – the destination j variable divided by the correspondence variable for region i.

The proposed form of our migration allocation model is:

$$\frac{M_{ij}}{\sum_i M_{ij}} w_j = f_3(X_j, U_j, A_j, B_j, S_j, G_{ij}, K_{ij}, D_{ij}, X_a, U_a, A_a) \quad (9)$$

where

M_{ij} is the number of migrants who have moved from region i to urban center j

w_j is a population normalization weight that is equal to the total rural population under study divided by the product of the population size of the receiving area j

X_j is the income perceived by prospective migrants to be available in j

U_j is the probability, as perceived by prospective migrants, of obtaining X_j

A_j is a measure of the amenities perceived by prospective migrants to be available in urban center j

B_j is a measure of the size and job diversity of the labor market in j

S_j is a measure of informal sector opportunities available in j

G_{ij} is the number of kin resident in area j who are available to assist prospective migrants from region i

K_{ij} is a measure of cultural, social, and linguistic similarities in region i and area j

D_{ij} is the cost of moving from region i to area j

subscript a identifies the values of these variables in the most attractive intervening opportunities between region i and area j

The allocation of migrants among alternative destinations reflects, in part, differences in sizes among both sending and receiving areas (Beals *et al.* 1967, pp. 481, 482; Young 1975; Vanderkamp 1976; Yap 1977, pp. 245, 246). To the extent that explanatory variables to be used in the model are correlated with population size, the variation in population sizes will bias the coefficients realized in the regression model. As a result, a modified version of Young's proposed normalization procedure for the dependent variable is used to minimize this possible bias (Young 1975, p. 97). Given that the denominator in the dependent variable, the total number of out-migrants, already reflects an aspect of population size in region i, the latter is not entered in the weight used.

The specification of X_i, U_j, D_{ij}, G_{ij}, A_j, and B_j was discussed for the previous model and will not be repeated here. Both specifications of U_j, the rate of growth of urban jobs created and the proportion of all urban jobs created in time period t that were created in town j, were tested here as well. Also, the pecuniary costs DA_{ij} of moving were separated explicitly from the psychic costs DB_{ij}. Finally, B_j was again dropped from the regression model because the effect of the size and diversity of the urban labor markets was captured already in the population weights used for A_j.

In selecting a particular destination, j, the prospective migrant will have compared information available on j with the information at the migrant's disposal on the alternative possible destinations. Therefore, an attempt must be made to measure the effect of intervening opportunities that might exist between region i and town j. For this purpose we utilize the approach of Levy and Wadycki (1974a), and enter into our model the most attractive alternative for urban income, urban employment prospects and amenities, from the subset of the m possible destinations that are closer to region i than is town j. Where j is the closest town to region i, the values of these variables for j are entered. Since the relative weight that migrants attach to these three variables is not known, it is not possible to select the "most attractive" alternative. As a result, the best alternative for each variable is entered.

At least for Africa, the available literature has not documented what role, if any, the urban informal sector has on migration decision making. As a result, no information exists that could suggest the possible form the specification of S_j might take. If, for the migrant, this sector serves primarily as a point of entry to the formal sector, then it is the existence of informal sector opportunities rather than the income levels to be derived from these opportunities that is important. Therefore, the measure used for S_j is an estimate of the proportion of the urban labor force employed in the informal sector.

Finally, for the purposes of selecting a particular destination, one's ability to fit into the cultural, social, and linguistic setting in j will likely take precedence over merely the extent of information about j. As a result, Huntingdon's information index is considered an appropriate measure for K_{ij}, the index of cultural, social, and linguistic similarities (Huntingdon 1973, p. 6). This index represents a weighted average across ethnic groups in region i that are resident in town j.

As was the case in the polytomous logistic model of migration, the many relevant personal characteristics of the migrants cannot be entered readily into an aggregate migration model. Here also, we are limited by the data to stratifying the sample into males and females. In addition to the dependent variable, including the weight factor, X_j, U_j, S_j, X_a, and U_a are entered in a sex-specific form.

Similarly, for the reasons given for the previous model, a log-linear specification is considered appropriate for the migration allocation model. A one-tail significance test is considered appropriate for each explanatory variable. The postulated signs are positive for X_j, U_j, A_j, S_j, G_{ij}, and K_{ij}; they are negative for DA_{ij}, DB_{ij}, X_a, U_a, and A_a.

Regression Results

The regression coefficients for the migration allocation model, for males and females, are reported in Table 3. The corresponding correlation matrix is provided in Table 4.

TABLE 3 Log-linear regression coefficients for the migration allocation model: dependent variable is $(M_{ij}/\sum_i M_{ij})(\sum_i P_i/P_j)$.

Explanatory variables		1969 census – males		1969 census – females	
		Coefficient	*t*-ratio	Coefficient	*t*-ratio
	Intercept	9.26	1.14	−0.24	0.07
X_j	Urban income	2.99[a]	3.06	−1.54[a]	2.98
U_j	Urban employment prospects	−0.41[a]	5.53	−0.10	1.43
A_j	Urban amenity index	−0.15	1.01	0.46[a]	3.12
S_i	Urban informal sector prospects	−0.05	1.44	0.16[a]	3.12
G_{ij}	Urban-based kin	0.12[a]	9.41	0.13[a]	3.67
K_{ij}	Ethnic similarity	−0.02	0.27	−0.01	0.09
DA_{ij}	Cost of move	0.24	1.43	0.31	1.73
DB_{ij}	Extent of separation	−0.64[a]	7.01	−0.73[a]	7.31
X_a	Alternative income	−4.33[a]	3.38	2.00[a]	3.35
U_a	Alternative employment	0.39[a]	4.70	−0.01	0.12
A_a	Alternative amenities	0.10	0.43	−0.70[a]	4.38
Coefficient of determination		0.55[a]		0.49[a]	
Degrees of freedom		244		244	

The superscript *a* indicates that the coefficients are significantly different from zero at the 1 percent level. The significance of R^2 was determined from the *F*-test. One-tail tests were employed in all cases.

The explanatory capability of the migration allocation model is somewhat lower than that of the polytomous logistic model of migration. The adjusted R^2 is 0.55 for males and 0.49 for females. The set of regression coefficients, on the basis of the *F*-test, is significant in each case.

For males, the magnitude of the coefficients for urban income levels dominates the results obtained. The coefficient for X_j has the expected positive sign while that of X_a is negative as postulated. Both coefficients are significant at the 1 percent level. For females, in contrast, the signs for the two coefficients are reversed.* Clearly, females are drawn to a particular urban center by forces other than the level of modern sector income available to females at that destination.

For the urban employment variable U_j, the second specification of g in eq. (8) was used – modern sector jobs created in j during the period 1964–1968 divided by the total number of jobs created in the eight towns during this period.** The results obtained for U_j are the same as those in the polytomous

*For females, X_j and A_j are highly correlated, but the coefficient for X_j still has a negative sign (is non-significant though) even if A_j is dropped.

**The coefficients obtained were quite similar (−0.32 for males, −0.11 for females, significant at the 1 percent level in the first case and at the 10 percent level in the second case) but this specification did not cause the coefficient of X_j for males to become non-significant. The first specification of g, as reported in eq. (8), was used throughout for U_a.

TABLE 4 Correlation matrix for the migration allocation model.

	$\frac{M_{ij}}{\sum_i M_{ij}} \frac{\sum_i P_i}{P_j}$	X_j	U_j	A_j	S_j	G_{ij}	K_{ij}	DA_{ij}	DB_{ij}	X_a	U_a	A_a	
Females													
	11.4	346	0.01	200	11.1	79	0.07	155	7.6	516	5.4	763	Mean
$\frac{M_{ij}}{\sum_i M_{ij}} \frac{\sum_i P_i}{P_j}$		0.13	0.13	0.12	0.09	0.53	0.32	0.01	−0.61	−0.50	−0.51	0.55	$\frac{M_{ij}}{\sum_i M_{ij}} \frac{\sum_i P_i}{P_j}$
X_j	0.13		0.74	0.91	0.11	0.40	0.04	0.54	−0.06	−0.12	−0.25	−0.15	X_j
U_j	0.10	0.76		0.78	−0.29	0.38	0.0	0.49	−0.17	−0.21	−0.26	−0.22	U_j
A_j	0.12	0.96	0.75		−0.05	0.46	0.08	0.52	−0.01	−0.09	−0.21	−0.08	A_j
S_j	0.0	−0.05	−0.46	−0.10		−0.01	−0.01	−0.34	0.12	−0.02	−0.04	−0.04	S_j
G_{ij}	0.53	0.46	0.35	0.46	−0.04		0.44	0.20	−0.46	−0.34	−0.39	−0.35	G_{ij}
K_{ij}	0.30	0.07	−0.01	0.08	0.0	0.44		−0.10	−0.38	−0.31	−0.24	−0.27	K_{ij}
DA_{ij}	0.04	0.52	0.63	0.52	−0.46	0.20	−0.10		0.06	−0.04	−0.14	−0.04	DA_{ij}
DB_{ij}	−0.61	−0.01	−0.19	−0.01	0.14	−0.46	−0.38	0.06		0.59	0.51	0.56	DB_{ij}
X_a	−0.55	−0.12	−0.24	−0.10	0.02	−0.38	−0.27	−0.07	0.56		0.81	0.94	X_a
U_a	−0.46	−0.25	−0.25	−0.23	−0.03	−0.41	−0.28	−0.11	0.52	0.87		0.84	U_a
A_a	−0.53	−0.11	−0.22	−0.08	0.0	−0.35	−0.31	−0.04	0.52	0.98	0.85		A_a
Mean	7.1	413	0.16	200	3.2	79	0.07	155	7.6	537	10.6	763	
	$\frac{M_{ij}}{\sum_i M_{ij}} \frac{\sum_i P_i}{P_j}$	X_j	U_j	A_j	S_j	G_{ij}	K_{ij}	DA_{ij}	DB_{ij}	X_a	U_a	A_a	
Males													

logistic model. Both the coefficients of U_j have an unexpected negative sign although for females it is insignificant. Consistent with these results, the coefficient of U_a for males has an unexpected positive sign and is significant. For females it has the predicted negative sign, but again it is not significant. The only explanations we can offer for these results are the same ones provided in our interpretation of the results obtained for U in the polytomous logistic model.

Our measure of informal sector opportunities serves as a significant determinant of migration destination selection for females only.* This result is consistent with both extensive discrimination against women in modern sector employment and women who have accompanied their husbands seeking to supplement family income in a secondary labor market. The aggregate nature of the data makes it impossible to distinguish between these two plausible explanations.

Again, available urban amenities are also significant determinants of destination selection for females only. Consistent with the positive sign for the coefficient of A_j for females, the coefficient of A_a for females has the expected negative sign and is significant. For females the magnitudes of the coefficients obtained for A_j and A_a rank below the urban income variable but above that of all the other explanatory variables.

The presence of kin in a particular destination is a significant determinant of the selection of that destination. The effect of kin is similar for both males and females. In contrast, given the effect of the other explanatory variables, our measure K_{ij} of cultural, social, and linguistic similarity is not significant.

The results obtained for the two variables measuring distance are also quite similar to those obtained in the model presented previously. When the monetary costs of moving are separated from the psychic costs, we find that the former are not significant as determinants of the selection of a destination.** As was the case in the previous model, DB_{ij}, the measure of the extent of psychic separation between region i and j, varies inversely with the proportion of out-migrants from region i who select town j as a destination.

THE REASONS FOR MIGRATING GIVEN BY THE MIGRANTS

We now turn to the results of our survey of African males who voluntarily entered an urban center after Independence (December 1963). One question the men were asked was to explain why they had moved to town: "What made you decide to leave the home you had in the district before you came to this town?" (Rempel 1981, Appendix 1, Question 6). The results obtained are given in Table 5.

*For both males and females the correlation coefficient between S_j and U_j is negative yet the regression coefficients for U_j are negative. As a result, S_j can be seen as a measure of informal sector alternatives rather than merely the place where an increasing number of unemployed must seek to subsist.

**A two-tail test was used for the coefficient of DA_{ij} for females because of the unexpected negative sign. The coefficient realized is significant at the 10 percent level.

TABLE 5 The percentage distribution by education and age of the primary reasons given by the migrants for leaving their previous location.

Reasons for leaving	Education		Age		Total sample
	Primary	Secondary	15–22	23–50	
Could not find work	80	73	78	79	78
Land was not available	5	12	1	7	4
Could not enter a school	4	11	9	1	5
Lack of social amenities including schools	–	1	1	1	1
Other reasons	11	13	11	12	12
Total	100	100	100	100	100

The migrants' explanations of their own behavior indicated that economic factors were the determining forces. As can be seen by combining the first two rows in Table 5, 82 percent of the men said the primary reason for leaving their home area was because of the limited economic opportunities available there. In contrast, only 1 percent listed a lack of social amenities as a primary reason for leaving while another 5 percent listed their inability to gain entrance to the schools in their home area.

If we compare the second reason of the migrants for leaving with the primary reason, we find that of the men who listed "could not find work" as the primary reason, 73 percent did not state a second reason, 12 percent listed "land was not available," and 11 percent listed other reasons. Similarly, of the men who gave "land was not available" as a primary reason, 6 percent did not state a second reason while 93 percent gave "could not find work" as the second reason. A total of 4 percent of the men listed "could not enter a school" or "lack of social ameninies available" as a second reason for leaving their home area.

A χ^2 test of the primary reason for leaving the home area was based on the two economic reasons (rows 1 and 2 in Table 5) versus all the other reasons. The variation in the distribution of the two types of reasons for leaving among provincial migration sources was not significant. There was significant variation in the distribution of these two reasons for leaving the two education subgroups and between the two age subgroups. For the men with a secondary education the access to rural economic opportunities did not appear to rank as high as it did for the primary education group, but the former were more concerned

TABLE 6 The percentage distribution of the reasons given by the migrants in each urban center for selecting their particular migration destination.

Reasons for selection	Urban center Nairobi	Mombasa	Kisumu	Nakuru	Eldoret	Thika	Nanyuki	Nyeri	Total sample
Best employment prospects	66	42	79	66	58	62	67	72	60
Schools available	6	2	5	3	–	6	–	–	5
Social amenities available	1	1	–	–	–	–	–	–	1
I have kin here	17	43	11	28	40	25	17	6	24
It is close to my home	2	1	1	–	–	1	2	10	2
Other reasons	8	11	4	3	2	6	14	12	8
Total	100	100	100	100	100	100	100	100	100

about an inability to gain entrance to schools in their respective home areas. For the two age groups, the older men were relatively more concerned about land not being available, while the younger men were relatively more concerned about their inability to gain admission to the local schools.

The second question asked was: "Once you had decided to leave your previous home, why did you choose to come to this town?" (Rempel 1981, Question 7). The responses obtained to this question (see Table 6) were in direct contrast to the negative sign obtained for U_j, the measure of urban employment prospects used in the regression models. Sixty percent of the men indicated best employment prospects to be the primary reason for selecting their respective destinations. The only other reason of any importance given by the men was that they had kin in the destination town. There may be considerable overlap between these two reasons since the possibility of finding employment is determined in part by the existence of kin in town. We note, for example, that 27 percent of the men who indicated the possibility of finding work as their primary reason indicated the presence of kin in town as their second reason for selecting that particular town. Similarly, 36 percent of the men who indicated the presence of kin as a primary reason gave the possibility of finding employment as their second reason. In both cases, more than half of the men did not indicate a second reason for choosing a particular urban center.

TABLE 7 The percentage distribution of the primary reason given by the migrants for selecting their particular migration destination.

Reasons for selection	Education		Age		Information sources		Total sample
	Primary	Secondary	15–22	23–50	Passive	Active	
Best employment prospects	60	62	57	65	63	57	60
Schools available	3	10	7	2	5	4	5
Social amenities available	1	1	1	–	1	1	1
I have kin here	26	18	26	21	26	19	24
It is close to my home	2	1	1	3	1	3	2
Other reasons	8	8	8	9	4	16	8
Total	100	100	100	100	100	100	100

For the purposes of a valid χ^2 test, the primary reasons for choosing a particular urban center were divided into four groups: best employment prospects, schools plus social amenities available, kin in residence, and other reasons including proximity to home. The variation in the distribution of these four types of reasons among the four groupings of urban centers was significant.* Kisumu, Nyeri, Nanyuki, Nairobi, and Nakuru ranked above average with reference to best employment opportunities, while Mombasa and Eldoret ranked above average with reference to presence of kin. Availability of social amenities was important only in the case of Nairobi and Mombasa.

This variation in the distribution of the four reasons for selecting a particular destination was also significant between the two education groups, the two age groups, and between passive and active migrants (see Table 7).** For the two education groups the dominant deviation from expected values was the relative weight the secondary education group placed on the availability of schools. For the older men, in the age groups, the exact opposite was the case. For the active and passive migrants, the dominant deviation from expected values was in the "other reasons" row: active migrants placed relatively high emphasis here while the passive migrants placed below average emphasis on this factor.

*The four groupings of urban centers are: Nairobi, Mombasa, the three western towns (Kisumu, Nakuru, and Eldoret), and the three central towns (Thika, Nanyuki, and Nyeri).

**Passive migrants are defined as those men who relied on kin as their primary source of information about their respective destinations while active migrants drew on non-personalized information sources as their primary source.

Relating these responses of the migrants to the results obtained from the regression analysis, we first note the primary reason for leaving an area given by the migrants is the lack of rural opportunities, but at the same time the coefficient for the rural income level is not significant. The rural "push" into the urban scene does not appear to take the form of a desperate search for a livelihood. Rather, the significant coefficient of $\tilde{X}_i$ (the measure of the distribution of rural income-earning possibilities) has a negative sign, which suggests that the likelihood of rural–urban migration is reduced where cash crop earnings are available to a wider range of people.

Further, the survey results suggest that there is limited access to land (shown as not significant for males in the regression analysis on the basis of the coefficient for F_i) and jobs in rural areas. This raises the question: is it the poorest in the rural areas who are migrating? The regression data, at the district level, are too aggregated to enable us to answer this question. Rather, it is necessary to address this question on the basis of survey results. The evidence presented here points much more to a "push" factor than to a "pull" factor as the reason for migrating: an inability to meet household aspirations on the basis of rural opportunities open to the household. This is borne out by the positive, significant coefficient for the measure $\hat{Y}_i$ of aspiration levels. Also, the survey results reported in Table 5 can be seen to be consistent with this interpretation. A possible gap between aspiration and rural income earning opportunities is especially relevant for young men whose income earning prospects from farming would be limited at this stage in their life-cycle. The median age at the time of migration for the men in our sample is between 22 and 23 years.

The survey results and the regression results for males for urban income levels X_j and X_a obtained in both models underscore the prime importance of urban income levels as a major "pull" force. The evidence on urban employment prospects is not as consistent given the negative sign obtained for the coefficient for U_j. The argument that when selecting a particular destination the emphasis placed on employment prospects merely reflects the presence of kin, G_{ij} in the regression equations, is not fully convincing given that some men listed both good employment prospects and kin as their first and second reasons for selecting a particular destination. (The actual role played by urban-based kin is analyzed in detail in Rempel 1981, chap. 7.) The emphasis on employment as a reason for selecting a particular destination suggests that U_j is not specified correctly in our models. First, the simultaneity problem between in-migration and urban unemployment rates needs to be overcome. Second, the rural household's subjective assessment of the employment prospects in an urban town would appear to be captured inaccurately in a variable built around the rate of unemployment in the urban labor market.

The survey results do not ascribe an important role to amenity availability as a determinant in the migration process. Neither the lack of amenities in rural areas nor the existence of amenities in town is given as an important reason for migration. This is consistent with the regression results obtained for males for the amenity index in the migration allocation model but contrary to those obtained in the polytomous logistic model of migration. In the latter case the effect of B_j, the size and diversity of the urban job market, would appear to be an important element in the coefficient obtained for A_{ij}.

CONCLUSIONS

We have seen that the polytomous logistic model of migration has a relatively high predictive ability. Although the focus of the model is the probability of a rural-to-urban move occurring, rather than the rate of migration, any one coefficient can be interpreted in the normal sense of an elasticity, given the effect of the other explanatory variables. The modeling of the decision-making process of destination selection, which is captured only partially by our migration allocation model, appears to be quite complex, however.

Several summary conclusions can be drawn from the results obtained. The variation in income levels among urban centers is the dominant factor in both the decision to migrate and the selection of a particular destination. The one exception is the selection of a destination by females. Given the effect of the other explanatory variables, urban employment prospects, as specified here, cannot be seen as a significant determinant of either the decision to migrate or the selection of a particular destination. Amenity availability enters into the decision to migrate but is significant for females only in selecting a particular destination. Cumulative evidence indicates that the size and diversity of what is available in an urban town is important rather than the level of amenities the town has to offer. The variation in income levels among rural areas is not found to be a significant determinant of migration but the variation in access to rural income earning possibilities and the variation in levels of aspiration among districts is found to be significant. The extent of separation of a rural area from a given town is dominant over the monetary cost of moving when the two are considered separately. The presence of urban-based kin consistently serves as a positive factor in both the decision to move and the selection of a particular destination. Finally, while the predictive capabilities of the two models are quite similar for males and females, there are substantial differences between the two groups, both in the magnitude of the coefficients and the particular explanatory variables which are found to be significant. As a result, the rural–urban migration of women must be seen as a complex process, not one of merely accompanying husbands who have decided to move.

Given the structure of the economy – both its effect on aspiration levels and its influence on the spatial distribution of income earning possibilities – and given the dominance of urban income as an explanatory variable, rural–urban migration can be seen as a move taking place after a rational decision has been made by migrants, which, in turn, serves to reallocate resources to where they are in greatest demand. But, it does not follow that the many who have chosen not to move are therefore irrational. The evidence presented here suggests that the migration process is complex, and Amin (1974, pp. 88, 89) oversimplifies considerably when he argues that the decision to migrate is "completely predetermined." In Rempel (1981) these survey results are analyzed in detail in order to shed as much light as possible on this complex process.

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A SHIFT-SHARE ANALYSIS OF REGIONAL AND SECTORAL PRODUCTIVITY GROWTH IN CONTEMPORARY MEXICO

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A decade ago Mexico's rapid productivity growth was widely acclaimed as a "miracle." Among policy makers, questions of income distribution and social equity tended to take second place to those of productivity growth. Rapid increases in output were to provide a bounty that would assuage social pressures. Income would shift from high productivity sectors toward the poor through changes in the regional and sectoral pattern of employment. A neglected majority of workers in rain-fed agriculture would benefit from a concentration of investment in irrigated farming in newly opened regions, and urban migration would absorb the rest. (Little was said about emigration abroad.) Where the natural adjustment process might fail, through inadequate market forces, the government was expected to intervene within reason. But the very surplus needed to pay for such intervention depended, it was felt, upon the underlying growth process led by private investment in response to underlying market forces working in close cooperation with government.

The strategy prior to 1970 involved conscious government decisions to postpone fiscal reform, limit development expenditures, neglect traditional agriculture, delay land redistribution that had been promised for decades, and defer exchange rate adjustment despite evidence that the peso was becoming progressively overvalued. Although these policies served to buy time, they had an adverse impact on the long-run stability of the economy and society. One consequence was that a growing share of productive assets in Mexico was coming under the control of decision makers abroad as foreign direct investment gradually overtook that of the local elite. Another was that foreign borrowing was becoming increasingly necessary to fill the gap between investment and domestic savings.

Buying time then might have made sense if the resulting pattern of development had led to productivity growth that could eventually diffuse itself through the work force, thus raising the living standards of all Mexicans. In earlier decades there was evidence that such diffusion was gradually taking place due to the responsiveness of the work force to opportunities elsewhere and the migration in the hundreds-of-thousands of those in search of better jobs. The diffusion of productivity growth, coupled with strong demand growth, had caused an impressive shift in the regional and sectoral structure of employment. In this paper, the so-called "shift factor" is studied from 1940 to 1970. The findings are analyzed in terms of their consequences for overall productivity growth, employment, and social welfare. Placed in the context of accelerating demographic growth and subsequent growth in the number of job seekers, the study asks the question whether or not the shift factor was sufficient for Mexico's sectorally and regionally unbalanced productivity growth to become more balanced.

In 1976 the incoming administration of Lopez Portillo inherited both the problems and promises of its predecessors. The recent prospects of a petroleum export bonanza have forestalled, if not eliminated, many of the problems while greatly accelerating expectations. The success with which Mexico's goals of growth and equity may be reconciled in coming years will depend on the level and composition of future productivity growth of the economy as much as on the political skill with which the surplus of petroleum is apportioned among competing interest groups. In dealing with recent regional and sectoral trends in productivity, it is hoped that this study will contribute to the achievement of Mexico's future goals of employment, growth, and social welfare. It is also hoped that the paper sheds light on the importance to Mexico's internal stability and growth of links with the United States.

The following chapters deal respectively with (1) proximate sources of productivity growth in Mexico from 1940 to 1970; (2) the methodology used in the shift-share analysis of total factor productivity growth; (3) a shift-share analysis of total factor productivity growth in the primary, secondary, and tertiary sectors from 1940 to 1970; (4) a shift-share analysis of total factor productivity growth from 1940 to 1970 in the six main areas of Mexico: North, Gulf, North Pacific, South Pacific, Metropolitan Mexico City, and Rest of Center; (5) a shift-share analysis of productivity growth from 1940 to 1970 in the three main regions: Border, Metropolitan Mexico City, and Rest of Mexico; and (6) a shift-share analysis of the primary, secondary and tertiary sectors of the three main regions of Mexico from 1940 to 1970.

The following analysis was made possible as part of the program of the Mexico Task Force of IIASA's Human Settlements and Services Area and is believed to have relevance well beyond the Mexican case.[1]

1 PROXIMATE SOURCES OF PRODUCTIVITY GROWTH IN MEXICO FROM 1940 TO 1970

In a recent paper, Professor Ansley Coale of Princeton University in the USA commented that Mexico had astonished the world with its sustained rapid productivity growth since 1955, despite increased fertility rates and accelerating population growth. He suggested that its recent economic performance might have been even better had demographic pressures been alleviated beginning in the mid-1950s rather than two decades later. He also predicted that the wave of job seekers generated by past population growth will flow forward into the labor force for at least another generation (Coale 1978). In order to assess the impact of increased labor supply on the level and diffusion of productivity gains, an analysis is made first of net productivity growth at the national level (Chapter 1) and then of sectoral and regional productivity growth (Chapters 3–6). The findings offer striking support for Professor Coale's hypothesis and have sober implications for government policies as well as for the level and pattern of private expenditures if goals of growth and income distribution are to be made consistent with accelerated expansion of the work force.

MEASURING TOTAL FACTOR PRODUCTIVITY GROWTH

In this section we present new calculations of total factor productivity growth in Mexico from 1940 to 1975 based on the most recent available information on output and input of labor, capital, and land. The objective is to determine how total factor productivity has grown during periods of quite different patterns of employment and investment, government policy, and land use. The stress is on productivity growth as an essential element in the improvements of standards of living. The relationship between total factor productivity, labor productivity, and employment is crucial to the distribution of gains throughout the work force. But the first step is to determine whether output has continued to rise relative to *all* factor inputs, including capital and land. The basis of the calculations is a simplified "Denison production function" (Denison 1962) in which output is expressed as a function of labor (L), capital (K), land (R), and a total factor productivity term (e^T). Thus, $Y = e^T L^a K^b R^c$ such that the logarithmic relationship $\hat{Y} = T + a\hat{L} + b\hat{K} + c\hat{R}$ permits one to use information on observed growth of the respective inputs of labor, capital, and land and on observed growth of output to derive the "unexplained residual" of total factor productivity (T), such that

$$\hat{Y} - a\hat{L} + b\hat{K} + c\hat{R} = T$$

Inputs L, K, and R are weighted according to the assumptions of a Cobb–Douglas production function[2] in which case the constant returns to scale property ensures that the output elasticity coefficients with respect to each input (a, b, and c, respectively) sum to unity. Each coefficient represents the respective share of that factor in value added. Hence, we can use observed shares of value added in gross domestic product (GDP) accruing to each factor to represent that factor's elasticity of output a, b, or c. For example, if the share of labor income represents 60 percent of GDP, then the coefficient for labor inputs is assumed to be 0.6. For purposes of the following calculations, the factor shares applied to the Mexican case are[3]

$$a = \text{labor share} = 0.60$$

$$b = \text{capital share} = 0.35$$

$$c = \text{land rent share} = 0.05$$

Growth of output is taken from the Bank of Mexico's GDP estimates expressed in constant prices. These figures are published in Bank of Mexico (1960–1976).[4]

Growth of the labor force is based on man-years of labor uncorrected for age, sex, skill, or degree of unemployment or underemployment, drawing upon census figures for the economically active population over 12 years of age (PEA) for the years 1940, 1950, and 1970. For 1960 major adjustments to the census figures were made by Altimir (1974), reducing the PEA by slightly over one million workers.[5]

The capital stock indexes for 1960 onward are calculated as follows. An initial capital stock is assumed, a hypothetical rate of depreciation is applied, and current gross investment (in constant) prices are added in order to derive the capital stock (K) at the end of the year (Table 1).[6]

In Table 2, proximate sources of productivity growth in the national economy are estimated in order to determine the residual attributable to increased total factor productivity.[7] Productivity gains at the national level, after rising steadily from the 1940s through the mid-1960s, have since sharply reversed their trend. The unexplained residual, which is a surrogate for net productivity growth in the economy, fell from a high of 3.4 percent per annum in the period 1960–65 to 2.9 percent per annum in the second half of the decade and further declined to 1.6 percent per annum in the 1970–75 period. This trend primarily reflects higher growth rates of labor and capital inputs in

TABLE 1 Capital stock estimates for the relevant years used in the productivity calculations.

	Gross investment (million current pesos)[a]	Gross investment[b] I (million 1960 pesos)	Capital stock K (million 1960 pesos)	Gross domestic product Y (million 1960 pesos)	Capital/ output K_{t-1}/Y_t
1959			331 124		
1960	33 123	33 132	347 700[d]	150 511	2.2
1961	32 829	31 750		157 931	
1962	32 344	30 370		165 310	
1963	(34 426)[c]	31 353[c]		178 516	
1964	(36 642)[c]	31 588[c]	399 208	199 390	
1965	39 000	32 856	412 103	212 320	1.9
1966	50 400	40 843		227 037	
1967	59 600	46 929		241 272	
1968	65 700	50 538		260 901	
1969	72 500	53 664	514 707	277 400	
1970	81 100	57 436	546 407	296 600	1.7
1971	75 500	51 254		306 800	
1972	98 874	63 503		329 100	
1973	123 300	70 456		354 100	
1974	175 759	80 995	694 236	375 000	
1975	210 189	81 977	741 501	390 300	1.8

[a] At the official exchange rate a current peso in 1978 was worth about US$0.045. On a purchasing power parity basis a 1960 peso would be worth about US$0.25 (1978) value and a 1950 peso would be worth about US$0.50 today.
[b] Converted from current values using implicit GDP inflator. Figures for 1972 to 1975 are from Fitzgerald (1977b) expressed as percentages of GDP, applied to 1960 value GDP estimates of the Bank of Mexico for the same years.
[c] Interpolated for 1963, 1964.
[d] Raymond Goldsmith (1966) estimated the physical capital stock ("structures and equipment") for 1960 to be 250 000 current pesos (cited in Reynolds 1970, Appendix Table D.8, 0.383).
SOURCES: The initial capital stock figure as well as the current value figures for gross investment 1960–62 were taken from Reynolds (1970, p. 7.9). Gross investment figures for 1965–71 in current values are from Fitzgerald (1977a) Table II. For 1972–75 (from Fitzgerald 1977a), investment percentages of GDP are applied to GDP figures from Bank of Mexico official estimates to derive gross investment estimates. The method of calculation of K is described in the text.

contrast to slower growth rates of output in recent years. Since both the economic constraints on the ability of government to respond to social pressures and the capacity of the market to transmit productivity gains from leading to lagging sectors depend on net productivity growth, this is an alarming trend. It suggests that the Mexican economy may have reached a watershed in the mid-1960s, such that the previous pattern of development described earlier (Reynolds 1970) is now giving way to a new set of structural forces that will

TABLE 2 Proximate sources of productivity growth in the Mexican economy, 1940–70 (compound annual rates of growth).

	1940–50	1950–60	1960–70	1960–65	1965–70	1970–75
OUTPUT						
1. Gross Domestic Product[a]	5.8	5.9	6.8 (7.2)[b]	6.9	6.7	5.5
INPUT						
2. Man years of Labor[c]	3.5	2.0	2.4	(2.4)[d]	(2.4)[d]	(2.5)[d]
3. Stock of Fixed Reproducible Assets	2.8	5.5	6.0	5.3	6.7	6.7
4. Hectares of Land in Cultivation	3.6	1.0	2.1	3.2	− 0.5	(2.0)[d]
5. Rate of Growth Attributable to Inputs 2, 3 and 4 above[e]	3.3	3.2	3.6	3.5	3.8	(3.9)[d]
6. Rate of Growth Unexplained by Above Inputs ("Unexplained residual")	2.5	2.7	3.2	3.4	2.9	(1.6)[d]

[a] The compound rates of growth of gross domestic product (GDP) for the periods 1940–50 and 1950–60 are based on GDP estimates used by Unikel (1976) and Appendini (1974 and private communication) in million 1950 pesos (1940: 22 889; 1950: 41 060; 1960: 74 215). These are taken from Solis (1970) and may be compared with other Bank of Mexico estimates used in Reynolds (1970) for 1940 in 1950 pesos: 21 658; 1950: 41 060; 1960: 74 317.

[b] Unikel's figure for 1970 is 152 341 which implies a rate of growth for 1960–70 of 7.2 percent per annum. However, the latest Bank of Mexico data (in million 1960 pesos) as cited in Table 1, imply a lower growth rate for 1960s of 6.8 percent per annum. Note that regional and national shift-share estimates of subsequent sections employ the Unikel–Appendini GDP estimates (in 1950 pesos), so that they almost certainly bias upward productivity growth during that decade.

[c] Based on economically active population (PEA) reported in the census for those 12 years of age and over for 1940: 5858×10^3; 1950: 8345×10^3; 1970: $12\,955 \times 10^3$. The 1960 census figure for PEA ($11\,253 \times 10^3$) was rejected in favor of the downward adjustment by Altimir: $10\,213 \times 10^3$. The growth of PEA for 1950–60 based on Altimir's adjustment is 2.0 percent per annum and that for 1960–70 is 2.4 percent per annum. On the basis of the official 1960 census figures for PEA the growth for the 1950s rises to 3.1 percent per annum and that of the 1960s falls to 1.4 percent per annum (too low and too high respectively, see text).

[d] Estimate based on extrapolation of trends (land and labor, 1975) or interpolation (labor, 1965).

[e] The weights used were labor (0.60), capital (0.35), and land (0.05), compared to Reynold's (1970) weights 0.66, 0.29, and 0.05 respectively which would give residuals of 1940–50: 2.5 percent per annum; 1950–60: 2.9 percent per annum; and 1960–70: 3.4 percent per annum. For the form of production function used see page 4. The factor shares applied in Table 2 reflect subjective considerations of underlying factor productivities in the absence of distortions in relative prices, subsidies, and other policies which bias upward the share of profits, interest, and quasi-rent. The actual labor share of GDP during the period was probably closer to 30 percent, while the capital share, including mixed income of owner-operated farm and nonfarm enterprises and depreciation allowances, was about 65 percent of GDP. The

imply slower output growth per unit of input.[9] Since this process of deceleration is occurring precisely at the time when pressures are mounting for wage increases, greater social outlays, more equitable agrarian policies, and other reform measures, an analysis of the factors underlying productivity growth is especially timely. Also the acceleration in demographic growth and urbanization in recent decades places a growing demand on the economy to absorb new entrants into the work force, exacerbating the problems caused by declining rates of output growth.

The preceding examination of productivity trends suggests that rapid expansion of the work force may have begun to place a significant drag on productivity growth as early as the mid-1960s. The turnaround in the "residual" reflecting net factor productivity growth may be due to the onset of diminishing marginal productivity of labor as growth in the supply of available workers began to outstrip demand growth. This is supportive of the suggestions by Coale (1978) that acceleration in population growth since 1940 would, with a lag, lead to a lower rate of productivity growth and social progress than would have been obtained under more moderate demographic conditions. The more detailed shift-share analysis of the following chapters provides additional evidence to support this conclusion.

Although both output and productivity growth have decelerated in the past decade, Mexico's rate of investment has continued to expand as shown in Table 3.

The investment share of GDP has risen progressively since 1940 as has the internal rate of savings, which in the 1970s was almost double that of the 1940s. Investment opportunities appear to have increasingly outstripped domestic savings capacity, leading to a growth of foreign borrowing. External borrowing (imports minus exports) has risen sharply as a share of GDP, from 0.2 percent in the 1940s to 1.8 percent and 3.1 percent in the 1960s and 1970s, respectively. As a share of total investment, external borrowing rose from under 2 percent in the 1950s to 10 percent in the 1960s and 15 percent in the 1970s. This is consistent with evidence that net productivity growth is decelerating, implying that the domestic surplus available for saving and investment is expanding at a lower rate, forcing increased dependence on foreign borrowing and foreign direct investment.

In Latin America total government expenditure has risen as a share of GDP in recent years. Mexico remains below the average as shown in Table 4 below.

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land rent share was about 5 percent of GDP. If these observed shares were used to weight inputs, productivity residuals would be 2.8 percent per annum for the 1940s, 1.7 percent per annum for the 1950s, and 2.1 percent per annum for the 1960s. For the period 1960–65 productivity growth would be 2.6 percent per annum, 1965–1970 would be 1.7 percent per annum, and 1970–75 would be 0.3 percent per annum, sharpening the downtrend in productivity growth observed in recent years.

Notes on sources and methods: Land inputs are derived from figures in Hewitt (1976) for total cropland of Mexico for 1960 and 1970.[8] Earlier years are from Reynolds (1970). The figures from Hewitt (1976) for total hectares cultivated are 7934 $\times 10^3$ for 1940, 10 753 $\times 10^3$ for 1950, 12 239 $\times 10^3$ for 1960, and 15 128 $\times 10^3$ for 1970.

TABLE 3 Rates of investment and saving in Mexico (as a percentage of GDP).

	Gross fixed capital formation			Gross saving		
Average	public	private	total	internal	external	total
1940–49	4.4	4.8	9.2	9.0	0.2	9.2
1950–59	5.4	10.8	16.2	15.0	1.2	16.2
1960–69	7.0	10.6	17.6	15.8	1.8	17.6
1970–76	8.4	12.0	20.4	17.3	3.1	20.4

SOURCE: Fitzgerald (1977a, p. 50).

TABLE 4 Public sector expenditure in Latin America, 1960–70 (as percentage of GDP).

Country	1960–61	1969–70
Mexico	16.7	21.9
Argentina	21.4	25.2
Brazil	25.3	33.3
Chile	29.3	34.6
Colombia	11.2	17.3
Peru	15.9	18.9
All Latin America[a]	20.7	25.7

[a] Average weighted by GDP in 1960.
SOURCE: Economic Commission for Latin America, cited in Fitzgerald (1978, p. 9).

TABLE 5 Consolidated federal government account, 1940–76 (as percentage of GDP).

	1940–49	1950–59	1960–68	1969–72	1973–76
Current income	6.5	7.7	7.5	8.2	9.8
Current expenditure	4.6	5.4	6.1	6.5	8.9
Current account surplus	1.9	3.2	1.3	1.6	0.9
Capital expenditure: GDCF[a]	1.7	2.0	2.0	2.2	3.2
Other	0.5	1.3	1.2	0.6	0.7
Total capital expenditure	2.2	3.3	3.2	2.8	3.9
Total expenditure	6.8	7.8	9.3	9.0	12.8
Total deficit	0.3	0.1	1.8	1.2	3.0

[a] Gross Domestic Capital Formation.
SOURCE: Fitzgerald (1978, p. 14).

The federal government, by far the dominant fiscal entity, has progressively increased both its current and capital expenditure shares, while the current account surplus is declining (Table 5). Although tax shares of GDP have risen, they have not grown as fast as current expenditures. Thus burgeoning capital formation of the public sector has increasingly been financed out of government borrowing from the financial sector, foreign credits, and an "inflation tax" on the private sector, reflecting Central Bank discounting of otherwise unfunded fiscal deficits.

CONCLUSIONS

This chapter indicates that in terms of total factor productivity growth at the national level, Mexico was losing ground by the 1970s with consequences for both private and public sector savings and investment. While increased rates of investment would be required to sustain the rate of output growth, the surplus needed to finance that investment was decelerating, even as social pressures for income redistribution increased. In the following chapters, an analysis is made of the underlying patterns of productivity growth by sector and region in order to determine some of the proximate causes of declining productivity growth.

2 METHODOLOGY USED IN THE SHIFT-SHARE ANALYSIS OF TOTAL FACTOR PRODUCTIVITY GROWTH

An important share of overall productivity growth in Mexico has been associated with a continuing shift of the labor force from lower to higher productivity occupations. This shift has occurred within production sectors, among sectors, and between regions of the economy, as well as from rural to urban areas. In an earlier work (Reynolds 1970), a measurement was made of the relative contribution of shifts of labor among the three main sectors of the economy – primary (agriculture, cattle, forestry, fishing), secondary (manufacturing, mining, petroleum, electricity), and tertiary (transport, communications, commerce, government, other services), – for the two decades since 1940. Subsequently, these calculations at the national level were updated to include the 1960s (Reynolds 1977). It is now possible to extend this analysis to the regional level permitting productivity growth to be linked to internal migration. To do this, shift-share analysis is applied to the main regions of the economy as well as to intra-regional shifts among the three production sectors for the three decades from 1940 to 1970. This permits one to determine the secular pattern of output, employment, and total factor productivity growth (increase in value added per worker) in response to changing market conditions and government policy. Extending the shift-share analysis to the regional level, first to six areas (North, Gulf, North Pacific, South Pacific, Metropolitan Mexico City, and Rest of Center), then to three regions (the Border States, Metropolitan Mexico City, and Rest of Mexico), substantially increases the usefulness of the analysis since major migratory trends can be taken into consideration. Trends in agricultural and tertiary sector productivity show sharp regional differentials as do related patterns of migration and employment.[10]

The method of estimating the shift-share component of total factor productivity growth is relatively straightforward. It takes advantage of the fact that growth in value added per worker in the economy as a whole (or in any region of the economy) is the sum of increases in output per worker multiplied by initial employment in the subsectors, plus the increase in sectoral employment multiplied by initial output per worker in the subsectors, plus the cross products.

The model is as follows:[11]

$$Y_T = Y_1 + Y_2 + \ldots + Y_n \tag{1}$$

$$Y_T/N_T = Y_1/N_T + Y_2/N_T + \ldots + Y_n/N_T \tag{2}$$

$$Y_T/N_T = (Y_1/N_1)(N_1/N_T) + (Y_2/N_2)(N_2/N_T) + \ldots + (Y_n/N_n)(N_n/N_T) \tag{3}$$

where $Y_{ij} \equiv$ value added in sector or region i in period j, where $i = 1, \ldots, n$; $N_{ij} \equiv$ employment in sector i in period j, where $i = 1, \ldots, n$; and $T \equiv$ total economy. Let

$$A \equiv Y_1/N_1; \quad a \equiv N_1/N_T$$

$$B \equiv Y_2/N_2; \quad b \equiv N_2/N_T$$

$$\vdots$$

$$Z \equiv Y_n/N_n; \quad z \equiv N_n/N_T$$

and let $t \equiv$ period t; and let $t + j$ be the period t plus j periods; and let $\Delta \equiv$ change from period t to period $t + j$; then

$$\frac{Y_{Tt}}{N_{Tt}} = A_t a_t + B_t b_t + \ldots + Z_t z_t \tag{4}$$

$$Y_T(t+j)/N_T(t+j) = (A_t + \Delta A)(a_t + \Delta a) + (B_t + \Delta B)(b_t + \Delta b) + \ldots + (Z_t + \Delta Z)(z_t + \Delta z) \tag{5}$$

$$Y_T(t+j)/N_T(t+j) = A_t a_t + \Delta A a_t + A_t \Delta a + \Delta A \Delta a + B_t b_t + \Delta B b_t + B_t \Delta b + \Delta B \Delta b + \ldots + Z_t z_t + \Delta Z z_t + Z_t \Delta z + \Delta Z \Delta z \tag{6}$$

therefore

$$Y_T(t+j)/N_T(t+j) - Y_{Tt}/N_{Tt} = \Delta Y_T/N_T = \Delta A a_t + A_t \Delta a + \Delta A \Delta a + \Delta B b_t + B_t \Delta b + \Delta B \Delta b + \ldots + \Delta Z z_t + Z_t \Delta z + \Delta Z \Delta z \tag{7}$$

This change can be divided into the own sectoral (or regional) productivity growth component, the intersectoral (or interregional) shift component, and the combined elements as follows:

$$A(Y_T/N_T) = \overbrace{\Delta A a_t + \Delta B b_t + \ldots + \Delta Z z_t}^{\text{own sectoral (or regional) factors}} \overbrace{+ \Delta a A_t + \Delta b B_t + \ldots + \Delta z Z_t}^{\text{shift factors}} \overbrace{+ \Delta A \Delta a + \Delta B \Delta b + \ldots + \Delta Z \Delta z}^{\text{combined factors}} \tag{8}$$

The model may be used to estimate the effects on productivity of the country as a whole from shifts in labor among sectors with different average productivities (shift factor) as distinct from the changes in total output per worker resulting from productivity growth within each sector (own factor). The term "total factor productivity" reflects the fact that the numerator (value added) represents the return to all factors of production, though only labor appears in the denominator. Hence, the increases in output due to factors such as physical capital, average hours worked per man-year, age, sex, and skill composition of the work force, and technological change are all included in the measure. Index number problems may bias output estimates owing to changes in relative prices and product mix. None of these factors is expressly considered here.

A simplifying assumption in the model is that changes in output per worker occur independently from employment changes. Hence, a once-and-for-all shift in average productivity of labor from period t to $t + j$ is implied in ΔA, ΔB, . . . , ΔZ, assuming average productivity to be invariant to subsequent changes in the quantity of employment in the sector (or region). This implicitly supposes that complementary factor inputs adjust in proportion to labor inputs under conditions of constant returns to scale for each sector and region.

One might alternatively assume that labor is subject to diminishing marginal productivity so that ΔA would be a declining function of Δa and similarly for other sectors. There is evidence that investment growth has increased more rapidly than the demand for labor since the capital-labor ratio is rising in the economy as a whole. However, it is likely that capital deepening was disproportional among sectors and regions in Mexico and that the capital-labor ratio grew more slowly in the tertiary sector than in the secondary or primary sectors. It is also likely that capital deepening was more pronounced in the Border region and the Metropolitan Mexico City region than in the Rest of Mexico region. Unfortunately, comparable investment figures are unavailable at the sectoral or regional level, making it impossible to estimate the pure marginal productivity of labor by region and sector for the three decades studied. Hence, the total factor productivity model presented above is used for the analyses in Chapters 3–5.

3 A SHIFT-SHARE ANALYSIS OF TOTAL FACTOR PRODUCTIVITY GROWTH IN THE PRIMARY, SECONDARY AND TERTIARY SECTORS FROM 1940 TO 1970

The pattern of total factor productivity growth among the three principal sectors of the economy is presented in Table 6 for four benchmark years, 1940, 1950, 1960, and 1970. It is evident that growth in output per worker was not balanced among the sectors nor did the same rank order of growth apply over time. In the 1940s the tertiary sector led with absolute productivity growth of 626 pesos per worker, followed by the primary sector with 550 pesos per worker.[12] The fact that 22 percent of overall growth was attributable to the primary sector (Table 7) and 44 percent to the tertiary sector was extremely important in permitting the economy to expand at the rate it did in the 1940s. In contrast, the secondary, which might have been expected to take the lead, fared least well despite its recovery from several decades of revolution and depression during the boom years of World War II. Productivity grew by only 148 pesos per worker in the secondary sector, though it accounted for one-third of total productivity growth in the economy. This is partially explained by the fact that capital deepening in manufacturing only began after World War II when machinery and equipment imports again became available. The lagged effects of these investments are seen in the data for the 1950s (Table 6) when the secondary sector took the lead, accounting for almost 40 percent of the nation's productivity growth (Table 7).

The primary sector, which had been given substantial injections of public infrastructure investment since the late 1930s, also showed increased productivity growth during the 1950s, though it lagged behind the rest of the economy. Its share of total productivity growth declined to one-half of the former rate or 11 percent in the 1950s. The relatively large and growing share of the labor force in the tertiary sector caused it to account for an ever-increasing share of national productivity growth reaching 50 percent in the 1950s and 64 percent in the 1960s (Table 7).

These data point to the key role of labor migration in Mexico's total factor productivity growth. They suggest that a "pull" factor operated

TABLE 6 Output, employment, and total factor productivity growth in Mexico, 1940–70.

		1940	1950	1960	1970
Primary sector[a]					
Y_A	Output (value added in million 1950 pesos)	5 171	9 242	13 917	17 712
N_A	Labor Force (PEA[b] × 10^3)	3 832	4 867	5 048	5 293
Y_A/N_A	Output per worker (1950 pesos)	1 349	1 899	2 757	3 346
$\Delta(Y_A/N_A)$	Change in output per worker over past decade (1950 pesos)		550	858	589
Secondary sector[c]					
Y_B	Output	6 788	12 466	24 603	52 198
N_B	Labor Force	826	1 490	2 175	3 439
Y_B/N_B	Output per worker	8 218	8 366	11 312	15 178
$\Delta(Y_B/N_B)$	Change in output per worker		148	2 946	3 866
Tertiary sector[d]					
Y_C	Output	10 930	19 352	35 695	82 431
N_C	Labor Force	1 200	1 988	2 990	4 223
Y_C/N_C	Output per worker	9 108	9 734	11 938	19 517
$\Delta(Y_C/N_C)$	Change in output per worker		626	2 204	7 579
Total GDP					
Y_T	Output	22 889	41 060	74 215	152 341
N_T	Labor Force	5 858	8 345	10 213	12 955
Y_T/N_T	Output per worker	3 907	4 920	7 267	11 759
$\Delta(Y_T/N_T)$	Change in output per worker		1 013	2 347	4 495

[a] Primary sector: agriculture, cattle, forestry, fishing.
[b] PEA stands for economically active population over 12 years of age.
[c] Secondary sector: manufacturing, mining, petroleum, construction, electricity.
[d] Tertiary sector: transport, communications, commerce, government, other services. (Banking services are included in the value added of the respective user sectors including services. Hence their inclusion in the tertiary sector is net of an adjustment for banking services in the primary and secondary sectors.)

Notes on sources and methods: GDP estimates in million 1950 pesos are taken directly from Unikel (1976) and Appendini (1974 and private communication) both of which refer to Solis (1970). There are now more recent estimates by the Bank of Mexico for years since 1960, reported in 1960 pesos. These later estimates may be compared to those of Solis (1970) by converting the former into 1950 pesos using the implicit GDP deflator between 1950 and 1960 of 0.477. This deflator is based on earlier official Bank of Mexico GDP series presented in Reynolds (1970, pp. 368–373). In that series, GDP for 1960 in current prices was 155 867 and in constant 1950 prices 74 317, giving an implicit deflator of 0.477.

continually from 1940 into the 1960s, drawing labor from primary into secondary and tertiary occupations and sustaining strong absolute and relative productivity gains in both sectors. A number of scholars have pointed to the potential for increases in output per worker in certain key tertiary activities due to capital deepening, technological progress, learning by doing, and the rising skill content of labor. Still the enormous upward productivity trend for the tertiary sector (Table 7) seems exaggerated. For this reason some alternative calculations were made for the present study based on more recent GDP estimates by the Bank of Mexico. While these updated data differ from those used for the regional estimates in the following chapters (the Unikel (1976)–Appendini (1974) breakdown of GDP at the state level is linked to earlier GDP estimates as shown in Table 6), the updated data are useful for checking possible biases in aggregate productivity growth estimates due to previous GDP estimates.

In Table 8, an alternative set of total factor productivity figures (Estimate B) is presented for all sectors, using the more recent GDP estimates. These data show somewhat more productivity growth in the tertiary sector during the 1950s and much less in the 1960s than those of Estimate A. The secondary sector, on the other hand, shows opposite changes, productivity growth being less in the 1950s and greater in the 1960s in Estimate B. Evidence of impressive growth in the manufacturing subsector during the 1960s is sustained by the new data, as is evidence of acceleration of productivity in the secondary sector.

	Bank of Mexico (1977)				Unikel*	
Sector	1960		1970		1960	1970
	(Million pesos) 1960 prices	1950† prices	(Million pesos) 1960 prices	1950 prices	(Million pesos) 1950 prices	
Primary	23 970	11 433	34 535	16 473	13 917	17 712
Secondary	43 933	20 956	102 154	48 727	24 603	52 198
Tertiary	82 608	39 404	159 911	76 278	35 695	82 431
Total GDP	150 511	71 793	296 600	141 478	74 215	152 341

* Used in Table 6.

† Converted by a factor of $\frac{1950}{1960}$ peso = 0.477.

There is probably a wide margin of error in GDP whatever the estimates adopted. For reasons of consistency with the Unikel–Appendini statewide breakdowns of GDP, which we employ in later sections of the paper, the Unikel series was chosen. Hence, growth in output for both the 1950s and 1960s is slightly higher in Table 6 than would have been obtained using the more recent revisions of GDP, see Table 6. The latter gives a compound annual rate of growth for 1960 to 1970 of 6.8 percent. The later estimates imply much less relative productivity growth in the tertiary sector in the 1960s, though it still leads in absolute terms.

Labor force estimates are for PEA from the censuses of 1940, 1950, and 1970, as presented in Unikel (1976). Data on PEA for 1960 are revised downward based on Altimir (1974), as discussed earlier. Data on PEA for 1970 are based on Altimir (1974). The author is indebted to Peter Gregory for calling attention to the adjustments required in the 1970 labor force estimates.

TABLE 7 Sectoral and shift elements underlying growth in output per worker, 1940–70. (All nonpercentage figures represent 1950 pesos per worker.)

	1940–50(%)		1950–60(%)		1960–70(%)	
Primary sector						
ΔAa (Sectoral)	360		500		291	
ΔaA (Shift)	− 95		− 169		− 234	
$\Delta a \Delta A$ (Combined)	− 39		− 76		− 50	
Weighted growth of output per worker	226	22	255	11	7	0
Secondary sector						
ΔBb	21		527		823	
ΔbB	312		284		588	
$\Delta b \Delta B$	6		100		201	
Weighted growth of output per worker	339	33	911	39	1612	36
Tertiary sector						
ΔCc	128		525		2221	
ΔcC	300		535		394	
$\Delta c \Delta C$	21		121		250	
Weighted growth of output per worker	449	44	1181	50	2865	64
Total Mexico						
ΔYn	509		1552		3335	
ΔnY	517		650		748	
$\Delta n \Delta Y$	− 12		145		401	
Total $\Delta(Y/N)$ growth of output per worker	1014	100	2347	100	4484	100
Shift (%)						
ΔYn estimated change in productivity with no shift in labor force	509		1552		3335	
Share of productivity attributable to the shift factor	$\frac{1014 - 509}{1014} = 0.50$		$\frac{2347 - 1552}{2347} = 0.34$		$\frac{4484 - 3335}{4484} = 0.26$	

Notes: Definitions of sectors are given in Table 6. ΔA, ΔB, and ΔC refer, respectively, to changes in output per worker in the primary, secondary, and tertiary sectors based on data in Table 6. a, b, and c refer to the share of the labor force in the primary, secondary, and tertiary sectors in the base year of each period. Δa, Δb, and Δc refer to changes in the sectoral share of the labor force over each decade based on labor force data in Table 6.

A 1950 peso valued at the exchange rate in that year of 8.64 pesos to the US dollar, was then worth about US$0.11.6, which owing to US inflation would be equal to US$0.30 in 1977. Raising the 1950

But perhaps most notable is that the tertiary sector, which led the rest in productivity growth in the 1940s and 1950s, now lags behind the secondary sector. This provides important evidence that service employment may be beginning to place a drag on Mexico's overall productivity growth, helping to account for a turnaround in the "residual" as reported in Chapter 1. One might expect this, given the rush of job seekers to the urban sector, which reflects earlier demographic trends, recent lags in agricultural productivity growth, and a steady shift toward more capital-intensive cropping since the 1930s. Indeed, the primary sector has made a shockingly small contribution to national productivity, falling to 11 percent in the 1950s and to zero in the 1960s (Table 7). Even by more recent GDP estimates, which bias upward agricultural output growth in the 1960s to 3.7 percent per annum (compared to Unikel's figures of 2.4 percent in Table 8), the primary sector only accounted for 1 percent of national productivity growth in the 1950s and 4 percent in the 1960s (Table 9).[13]

Based on the data in Table 6, total factor productivity growth in Mexico increased steadily since 1940: from 2.3 percent per annum in the 1940s to 3.9 percent and 4.8 percent respectively in the 1950s and 1960s. These figures agree with the general trend of *net* productivity growth through the mid-1960s presented in Chapter 1 (Table 2), which also takes into account capital and land inputs. In absolute terms the increase in output per worker in the 1960s was four times that of the 1940s, or almost 4500 (1950) pesos in the course of the decade. This is equivalent to between 1200 and 2400 current US dollars, depending on the conversion factor used. In principle such growth should have greatly enlarged the economic "policy space" permitting higher rates of savings and investment together with improvements in real incomes of the work force. However, more recent GDP estimates show slower growth in the 1960s of about 3900 (1950) pesos per worker, or between $1000 and $2000 (1978 US dollars). (See Table 8 for a comparison of the two sets of estimates.) Of course these estimates do not take into consideration the turning point in the mid-1960s indicated by the analysis in Chapter 1.

Especially interesting is the contribution to overall productivity growth made by shifts in employment from lower to higher productivity occupations. This is one important element in the "unexplained residual" presented in Table 2. To the extent that there has been a shift of the work force toward more productive occupations, significant gains in national productivity growth could have been experienced without net gains in any specific sector. In Reynolds (1970) the shift element was estimated as a residual after deducting from total

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peso to its 1960 peso value, based on the Mexican implicit GDP deflator (1/0.477) and then converting to US dollars at the 1960 purchasing power parity rate of 8 pesos to the dollar would give a 1950 peso value of US$0.26 in 1960. At the US GDP deflator between 1960 and 1977 of 2.057, this would represent over US$0.50 today in terms of purchasing power (Reynolds 1970; US Government Council of Economic Advisors 1978). Hence one may estimate the value of 100 (1950) pesos to be between US$30 and US$50 in 1977.

TABLE 8 Alternative output and total factor productivity growth, Estimates A and B, 1960 and 1970.

	1950	1960				1970			
	Est. A	Est. A	%[a]	Est. B	%[a]	Est. A	%[a]	Est. B	%[a]
Primary sector									
Y_A Output (value added in million 1950 pesos)	9 242	13 917	4.1	11 433	2.1	17 712	2.4	16 473	3.7
N_A Labor force (PEA $\times 10^3$)	4 867	5 048		5 408		5 293		5 293	
Y_A/N_A Output per worker (1950 pesos)	1 899	2 757		2 265		3 346		3 112	
$\Delta(Y_A/N_A)^b$ Change in output per worker over past decade (1950 pesos)		858		366		589		847	
Secondary sector									
Y_B	12 466	24 603	6.8	20 959	5.2	52 198	7.5	48 727	8.4
N_B	1 490	2 175		2 175		3 439		3 439	
Y_B/N_B	8 366	11 312		9 636		15 178		14 169	
$\Delta(Y_C/N_C)^b$		2 946		1 270		3 866		4 533	
Tertiary sector									
Y_C	19 352	35 695	6.1	39 404	7.1	82 431	8.4	76 278	6.6
N_C	1 988	2 990		2 990		4 223		4 223	
Y_C/N_C	9 734	11 938		13 179		19 517		18 063	
$\Delta(Y_C/N_C)^b$		2 204		3 445		7 579		4 884	
Total GDP									
Y_T	41 060	74 215	5.9	71 794	5.6	152 341	7.2	141 478	6.8
N_T	8 345	10 213		10 213		12 955		12 955	
Y_T/N_T	4 920	7 267		7 030		11 759		10 921	
$\Delta(Y_T/N_T)^b$		2 347		2 110		4 495		3 891	

[a] Rate of growth per annum.

[b] Total factoral productivity.

Notes: Definitions of sectors are given in Table 6. Estimate A corresponds to Tables 6 and 7; the GDP figures for 1960 and 1970 are taken from Unikel (1976) using as sources Appendini (1974) and Bank of Mexico (1977), and the labor force data for 1970 are from Unikel (1976). For 1960 the Unikel figures are adjusted based on Altimir (1974). Estimate B uses more recent GDP estimates for 1960 and 1970 from the Bank of Mexico expressed in constant 1960 pesos and converted for this study using the implicit GDP deflator of 0.477 (1960) pesos = 1 (1950) peso as in Reynolds (1978). The Altimir and Unikel labor force figures for 1960 and 1970 are used in both Estimates A and B (see footnotes to Table 6 for details) whereas in Reynolds (1978) the adjusted 1960 and 1970 census figures were used.

TABLE 9 Alternative sectoral and shift elements in productivity growth, Estimate B, 1950–70. (All nonpercentage figures represent 1950 pesos per worker.)

Sector and total Mexico	1950–60	%	1960–70	%
Primary sector				
ΔAa (Sectoral)	213		418	
ΔaA (Shift)	– 169		– 193	
$\Delta a \Delta A$ (Combined)	– 33		– 72	
Total growth of output per worker	11	1	153	4
Secondary sector				
ΔBb	227		966	
ΔbB	284		501	
$\Delta b \Delta B$	43		236	
Total growth of output per worker	554	26	1703	44
Tertiary sector				
ΔCc	820		1431	
ΔcC	535		435	
$\Delta c \Delta C$	189		169	
Total growth of output per worker	1544	73	2027	52
Total Mexico				
ΔYn	1260		2815	
ΔnY	650		742	
$\Delta n \Delta Y$	200		326	
Total $\Delta(Y/N)$ growth of output per worker	2110	100	3883	100
Shift component				
$\frac{\Delta(Y/N) - \Delta Yn}{\Delta(Y/N)} \times 100 =$		40		28

Note: Definitions of sectors are given in Table 6.

productivity growth in each sector the component that could be attributed to own sectoral increases in output per worker ($a\Delta A, b\Delta B, \ldots, z\Delta Z$). The remainder represents the sum of the pure shift ($\Delta aA, \Delta bB, \ldots, \Delta zZ$) and combined components ($\Delta a\Delta A, \Delta b\Delta B, \ldots, \Delta z\Delta Z$). It was found that the shift factor fell from 41 percent of national productivity growth in the 1940s to 24 percent in the 1950s (Reynolds, 1970: 66–68), indicating that although the movement of labor between sectors was extremely important in the first decade of rapid growth, it was much less so in the 1950s. It is now possible to carry this analysis forward due to more recent estimates of output and employment through 1970. The shift component, based on Estimate A (Table 7), appears to have been even more important than was earlier believed. It is now seen to have accounted for 50 percent of productivity growth in the 1940s, falling to 34 percent in the 1950s and 26 percent in the 1960s. Estimate

B (Table 9) also shows the trend declining in the 1950s when the shift component was 40 percent of productivity growth, after which it fell to 28 percent in the 1960s. However, the contribution of the secondary sector to the shift factors (shift and combined) relative to the tertiary sector increased significantly in the 1960s, its share of the shift factor rising from 38 percent in the 1950s to 69 percent in the 1960s (Table 9).

The implications of these results are that as much as half of the total factor productivity growth in the 1940s was associated with labor force shifts from lower to higher productivity occupations. However over the next two decades, the shift factor fell to one-fourth of total productivity growth. Hence, there is strong evidence that the shift contribution to Mexican productivity growth is declining. Also the relative importance of the tertiary sector for transmission of productivity growth through labor absorption is diminishing, notwithstanding sustained increases in income per worker within that sector. For future productivity growth to continue, greater stress must be placed on investments that are complementary to labor and on labor-absorbing technological progress in the primary and secondary sectors as well as in the tertiary sector since the shift factor cannot be expected to take up the slack as before. Data at the national level indicate that the gains from labor diffusion and internal migration are dwindling and that more attention must be directed to investment and innovations in those localities and occupations where labor is most redundant.

4 A SHIFT-SHARE ANALYSIS OF TOTAL FACTOR PRODUCTIVITY GROWTH IN THE SIX MAIN AREAS OF MEXICO FROM 1940 TO 1970

In order to determine the impact on productivity of internal migration of the labor force, shift-share analysis has been applied to output and employment data for the six major areas of Mexico.[14] The results are presented in Tables 10 and 11. They indicate that the regional shift factor does not appear to be of major importance in explaining productivity growth, especially when compared with sectoral elements as analyzed in Chapter 2. For example, the regional shift component in the 1940s was no higher than 16 percent, falling to 11 percent in the 1950s, and recovering to 14 percent in the 1960s (Table 11). This implies that at the most only one-seventh to one-tenth of the growth in output per worker could have been explained by movement of the work force from lower to higher productivity areas, with that share falling over the course of the three decades.

These figures also permit one to examine the effect of regional relocation of the work force on regional inequality in output per worker. The rank ordering of total factor productivity for the six areas remains almost unchanged over the four benchmark years, with the Metropolitan Mexico City area well ahead in each year followed by the North Pacific (Table 10). The North area, also including primarily border states with the USA, is third in all years except 1950, when it was temporarily displaced by the Gulf area (which includes the city of Veracruz and a major traditional oil producing region). In all other years the Gulf ranked fourth. The rest of the Center (which excludes Mexico City and the state of Mexico) ranked next to last in all years, followed finally by the Pacific South.

There is some evidence that the gap between richest and poorest regions is gradually narrowing since output per worker in the Metropolitan Mexico City area was 6.8 times that of the Pacific South in 1940. This multiple declined to 4.6 in 1950, rose again to 5.9 in 1960, and ultimately fell back to 5.0 in 1970. In the 1940s Metropolitan Mexico City accounted for only 24 percent of national productivity growth, but its share doubled to 56 percent in the 1950s

TABLE 10 Output, employment, and total factor productivity by area, 1940–70.

Region		1940	1950	1960	1970
North[a]					
Y_N	Output (value added in million 1950 pesos)	5 276	9 001	14 978	30 653
N_N	Labor force (PEA x 10^3)	1 121	1 631	1 954	2 350
$N = Y_N/N_N$	Output per worker (1950 pesos)	4 706	5 519	7 665	13 044
$\Delta(Y_N/N_N)$	Change in output per worker over past decade (1950 pesos)		813	2 146	5 379
$n = N_N/N_T$	Labor force share	0.191	0.195	0.191	0.181
Gulf[b]					
Y_G	Output	2 556	5 483	8 400	13 477
N_G	Labor force	711	973	1 174	1 496
$G = Y_G/N_G$	Output per worker	3 595	5 635	7 155	9 009
$\Delta(Y_G/N_G)$	Change in output		2 040	1 520	1 854
$g = N_G/N_T$	Labor force share	0.121	0.117	0.115	0.115
North Pacific[c]					
Y_P	Output	1 710	3 730	6 774	16 358
N_P	Labor force	362	549	748	1 034
$P = Y_P/N_P$	Output per worker	4 724	6 794	9 056	15 820
$\Delta(Y_P/N_P)$	Change in output		2 070	2 262	6 764
$p = N_P/N_T$	Labor force share	0.062	0.066	0.073	0.080
South Pacific[d]					
Y_S	Output	998	2 142	3 164	5 543
N_S	Labor force	769	1 088	1 295	1 375
$S = Y_S/N_S$	Output per worker	1 298	1 969	2 443	1 375
$\Delta(Y_S/N_S)$	Change in output		671	474	1 588
$s = N_S/N_T$	Labor force share	0.131	0.130	0.127	0.106
Metropolitan Mexico City[e]					
Y_D	Output	8 329	13 959	30 538	65 491
N_D	Labor force	946	1 545	2 111	3 223
$D = Y_D/N_D$	Output per worker	8 804	9 035	14 466	20 320
$\Delta(Y_D/N_D)$	Change in output		231	5 431	5 854
$d = Y_D/N_T$	Labor force share	0.162	0.185	0.207	0.249
Rest of Center[f]					
Y_C	Output	4 018	6 746	10 361	20 810
N_C	Labor force	1 948	2 558	2 922	3 478
$C = Y_C/N_C$	Output per worker	2 062	2 637	3 546	5 983
$\Delta(Y_C/N_C)$	Change in output		575	909	2 437
$c = N_C/N_T$	Labor force share	0.333	0.307	0.286	0.268

TABLE 10 *Continued*

Region		1940	1950	1960	1970
Total Mexico					
Y_T	Output	22 889	41 060	74 215	152 341
N_T	Labor force	5 858	8 345	10 213	12 955
$T = Y_T/N_T$	Output per worker	3 907	4 920	7 267	11 759
$\Delta(Y_T/N_T)$	Change in output		1 013	2 346	4 491
$t = N_T/N_T$	Labor force share	1.00	1.00	1.00	1.00

[a] *North*: Coahuila, Chihuahua, Durango, Nuevo Leon, San Luis Potosí, Tamaulipas, Zacatecas.
[b] *Gulf*: Campeche, Quintana Roo, Tabasco, Veracruz, Yucatán.
[c] *North Pacific*: Baja California N., Baja California S., Nayarit, Sinaloa, Sonora.
[d] *South Pacific*: Colima, Chiapas, Guerrero, Oaxaca.
[e] *Metropolitan Mexico City*: Federal District (Mexico D.C.), State of Mexico.
[f] *Rest of Center*: Aguascalientes, Guanajuato, Hidalgo, Jalisco, Michoacán, Morelos, Puebla, Querétaro, Tlaxcala.

SOURCES: GDP and labor force by region are aggregated from state level data estimated by Unikel (1976) and Appendini (1974).

and remained high at 46 percent in the 1960s (Table 11). It appears that labor absorption by Metropolitan Mexico City in the 1940s was accompanied by relatively slow productivity growth. One may presume that had agricultural policy been delayed during that crucial decade, causing urbanization to have been even greater than it was, the resulting drag on productivity growth would have seriously undermined political and economic stability and have increased pressure for migration to the USA. The timing of public investment policy, in agriculture first, then in manufacturing, was of the utmost importance in preventing premature urbanization.

Hence, there was a reduction in the gap of regional income inequality between 1940 and 1950, a widening during the 1950s, and a narrowing again in the 1960s. Despite the small regional shift factor, some of this reduction in inequality may well be due to internal migration as suggested by Unikel (1976: 182). He refers to Mexico's possible confirmation of the Williamson model (Williamson 1965) in which urbanization may widen income gaps in the short run but will narrow them in the long run. Unikel notes that migration was from lower productivity regions to those with higher incomes per capita, and still the productivity growth in the leading areas continued to outstrip the in-migration of labor. This finding is supported by shift-share analysis for the six areas since those areas with a negative shift factor (due to declining labor force shares) tended to be the poorest, namely the South Pacific and Rest of Center. The behavior of the North and Gulf areas is ambiguous since both had negative shift factors in two of the three periods, the Gulf in the 1940s and 1950s and the North in the 1950s and 1960s.

The following are the means and standard deviations of output per worker in the six areas for the four benchmark years. The ratio of the mean to the standard deviation indicates the inverse of the degree of dispersion of productivity.

TABLE 11 Sectoral and shift elements underlying growth in output per worker by area, 1940–70. (All nonpercentage figures represent 1950 pesos per worker.)

Region	1940–50	%	1950–60	%	1960–70	%
North						
Regional	155		418		1027	
Shift	19		− 22		− 77	
Combined	3		− 9		− 54	
Total	177	18	387	17	896	20
Gulf						
Regional	247		178		213	
Shift	− 14		− 11		0	
Combined	− 8		− 3		0	
Total	225	22	164	7	213	5
North Pacific						
Regional	128		149		494	
Shift	19		48		63	
Combined	8		16		47	
Total	155	15	213	9	604	13
South Pacific						
Regional	88		62		202	
Shift	− 1		− 6		− 51	
Combined	− 1		− 1		− 33	
Total	86	9	55	2	118	3
Metropolitan Mexico City						
Regional	37		1005		1212	
Shift	202		199		608	
Combined	5		119		246	
Total	244	24	1323	56	2066	46
Rest of Center						
Regional	191		279		697	
Shift	− 54		− 55		− 64	
Combined	− 15		− 19		− 44	
Total	122	12	205	9	589	13
Total Mexico						
Regional	847		2091		3845	
Shift	171		153		479	
Combined	− 8		103		162	
Total	1010	100	2347	100	4486	100

TABLE 11 *Continued*

Region	1940–50	%	1950–60	%	1960–70	%
Estimated change in productivity with no shift in labor force	847		2091		3845	
Share of productivity attributed to shift factor	$\frac{1010-847}{1010}=0.16$		$\frac{2347-2091}{2347}=0.11$		$\frac{4486-3845}{4486}=0.14$	

Note: Definitions of areas are given in Table 10.
SOURCE: Figures in this table are calculated from data in Table 10.

		1940	1950	1960	1970
μ	Mean productivity of the six areas (1950 pesos per worker)	4 200	5 265	7 390	11 370
σ	Standard deviation of productivity of the six areas (1950 pesos per worker)	1 193	860	1 921	2 771
$\frac{\mu}{\sigma}$	Ratio of mean to standard deviation; indication of narrowing of productivity differentials among regions	3.5	6.1	3.8	4.1

These ratios evidence a sharp reduction in regional inequality between 1940 and 1950, after which the earlier pattern was recovered. Between 1960 and 1970 there is evidence that regional disparities narrowed again, providing modest support for the Williamson hypothesis. In order to test the results still further, GDP is broken into rural and urban income shares in Table 12. The results are then compared with rural and urban population shares to estimate trends in relative income shares associated with rapid urbanization since 1940 (Table 13).

One would expect from the importance of the shift effect in gradually leveling area incomes that there might have been a narrowing of the gap of productivity (and income) between the rural and urban sectors of Mexico over the same period. This would hold if the pull factors were dominant in urban migration, such that labor drawn out of the rural sector by higher income possibilities in the cities would cause the rural marginal productivity of labor to rise together with capital- and land-labor ratios. This then would have been reflected in the relative growth of rural income shares. However, there is an additional element, namely, the demand for rural output. If rural physical productivity rose but demand for farm output lagged, the rural terms of trade

TABLE 12 Rural/urban income shares, 1960–75 (%).

	1960	1965	1970	1975
Shares of gross domestic product imputed to rural areas	28	27	22	20
1. Agriculture				
Share of total GDP	15.9	14.2	11.6	9.6
Rural GDP share	14.3	12.8	10.4	8.6
2. Extractive industries				
Share of total GDP	4.9	4.9	5.2	5.5
Rural GDP share	1.7	1.7	1.8	1.9
3. Commerce and transportation				
Share of total GDP	34.5	34.8	35.0	35.1
Rural GDP share	6.2	5.6	4.7	4.2
4. Manufacturing, construction, and electricity				
Share of total GDP	24.3	26.4	29.2	30.3
Rural GDP shares	0	0	0	0
5. Government				
Share of total GDP	4.9	5.6	5.8	7.2
Rural GDP share	0	0	0	0
6. Other sectors				
Share of total GDP	15.5	14.1	13.1	12.2
Rural GDP share	7.6	6.4	5.4	4.9

Sources and methods: Distribution of shares is as in Reynolds (1970, Table 2.7), where

1. Agriculture: 90 percent rural.
2. Extractive Industries: 35 percent rural based on 1950 input–output table for Mexico.
3. Commerce and transport $= \frac{(3)}{10\%\ \text{GDP}\ (3)} \times 1/2$ rural share of GDP in other sectors.
4. Manufacturing, construction, electricity: all urban.
5. Government: all urban.
6. Rent and other: proportional to population share in rural sector 1960: 0.493; 1965 (est.): 0.452; 1970: 0.414; 1975 (est.): 0.400.

Derived shares are from GDP estimates of Bank of Mexico (1977) (1960 pesos) corresponding to those in Estimate B. For this reason the 1960 shares for agriculture and rural GDP are well below those in Reynolds (1970, p. 72), which were 18.9 (c.f. 15.9) and 32 (c.f. 28), respectively.

(prices of farm products relative to goods and services) might decline, thus offsetting this favorable trend of growth of rural income shares. In the estimates in Table 12 constant value indexes of rural and urban GDP have been used so as to minimize the terms of trade effects.

With this adjustment the real output of the rural sector per rural dweller fell relative to that of the urban areas in all periods except for the 1940s and the interval from 1960 to 1965 (Table 13). Indeed, the situation as of 1975

TABLE 13 The distribution of GDP and population rural and urban, 1940–75 (%).

Share	1940	1950	1960	1965	1970	1975
1. Rural share of GDP	40	36	28	27	22	20
2. Urban share of GDP	60	64	72	73	78	80
3. Rural share of population	65	57	49	45	41	40
4. Urban share of population	35	43	51	55	59	60
5. Rural share of GDP/Rural share of population (Row 1/Row 3 = Row 5)	0.62	0.63	0.57	0.60	0.53	0.50

SOURCE: Table 12 for 1960–75 and Reynolds (1970, p. 74) for 1940–50. Owing to the latest GDP estimates used for 1960–75, the 1960 ratio of rural GDP to population falls from 0.65 (Reynolds 1970) to 0.57.

indicates that relative rural per capita output was only half that of the urban sector, compared to over 60 percent in 1940.

Clearly, the process of migration of the work force has failed to narrow the relative rural-urban income gap. Of course, since real income in both rural and urban areas has multiplied several times, the absolute gap has widened even more. To the extent that migration decisions are made on the basis of expected income, the absolute rather than relative gap may be more relevant to a study of the relationship between productivity growth and migration. Output per capita rose from 3600 (1960) pesos in 1960 to almost 5000 (1960) pesos in 1970, a gain of between 575 and 800 current US dollars, depending on the conversion factor used. However, the gap between Mexico's rural per capita output and real wages in US agriculture paid to temporarily migrating Mexican workers remains double or triple that amount.

In order to determine the relative importance of migration to the regional pattern of employment, a hypothetical regional labor supply estimation was made for which it was assumed that there had been no migration. In the absence of migration it was assumed that the economically active population over 12 years of age (PEA) in each region would have grown in direct proportion to its initial labor force at the beginning of each of the three decades from 1940 to 1970. The difference between this hypothetical growth of labor supply and observed increases in active population in each region gives a crude indicator of net regional migration of labor. Of course, this indicator is sensitive to errors in the underlying assumptions of proportional changes in demographic factors among regions and proportional shifts in labor participation rates. However, the results are suggestive of general trends in labor force migration and hence are used to estimate the relative importance of such shifts in regional patterns of productivity growth.

It can be seen from Table 14 that total internal migration estimated in these terms has amounted to a steadily increasing share of labor force growth.

TABLE 14 Estimates of labor force growth assuming no net migration among the six areas, 1940–70 [labor force (× 10^3)].

Region	1940	1950			1960			1970		
	Observed labor force[a]	Observed labor force[a]	Estimated labor force[b]	Estimated migration	Observed labor force[a]	Estimated labor force[b]	Estimated migration	Observed labor force[a]	Estimated labor force[b]	Estimated migration
1. North	1 121	1 631	1 594	+ 37	1 954	1 990	− 36	2 350	2 477	− 127
2. Gulf	711	973	1 010	− 37	1 174	1 194	− 20	1 496	1 491	+ 5
3. North Pacific	362	549	517	+ 32	748	673	+ 75	1 034	947	+ 87
4. South Pacific	769	1 088	1 093	− 5	1 295	1 327	− 32	1 375	1 647	− 272
5. Metropolitan Mexico City	946	1 545	1 352	+ 193	2 111	1 888	+ 223	3 223	2 685	+ 538
6. Rest of Center	1 948	2 558	2 779	− 221	2 922	3 133	− 211	3 478	3 709	− 231
Total labor force Mexico	5 858	8 344	8 344		10 204	10 204		12 956	12 956	
Net migration				± 263			± 299			± 630
Net migration/growth in labor force (%)				11			16			23

Note: Definitions of areas are given in Table 10.

[a] Observed labor force is from Table 10.

[b] Estimated labor force for region A in year $t + j = N_{A_t}/N_{T_t} \times N_{T_{t+j}}$.

That share, which was only 11 percent in the 1940s, increased to 16 and 23 percent respectively in the 1950s and 1960s. Without going into the underlying causes of this labor movement, it is evident that regional patterns of productivity growth have been closely associated with increased internal migration. The most notable relationship is the strong apparent link between labor force migration and regional productivity growth. Two of the three leading areas in overall productivity growth, Metropolitan Mexico City and the North Pacific, also showed net labor in-migration in each of the three decades (Table 11). However the North, which was second in productivity growth in both the 1950s and 1960s, had a net outflow of labor in both periods. This is almost certainly associated with impoverished agriculture in the arid regions throughout the North, which caused rural out-migration to outstrip urban growth in Monterrey and the border cities. On the other hand, in the 1940s the North was a net attracting area for emigration. Third place shifted to the Gulf, which after losing labor at decreasing rates in the 1940s and 1950s, became an area of net in-migration by the 1960s. With the recent petroleum boom, this pattern continues.

In no case did permanent internal labor migration represent an important share of the total work force, the percentage actually falling between the 1940s and 1950s from 3.2 percent to 2.9 percent. However, the share of migration in labor force growth has steadily increased to almost one-fourth of net growth in the 1960s. By that decade the absolute share of migration (1960–1970) had risen to 5 percent of the 1970 labor force. The amount of temporary migration is of course missing from these figures since they are based on decennial census data. However, there is strong evidence that seasonal migration is very important, especially, in the rural labor market. Thousands of workers move back and forth, many of them hundreds of miles, during the harvest seasons, and many of them also travel across the border on a seasonal basis as temporary migrant workers in the USA.

5 A SHIFT-SHARE ANALYSIS OF PRODUCTIVITY GROWTH IN THE THREE MAIN REGIONS – METROPOLITAN MEXICO CITY, BORDER, AND REST OF MEXICO – FROM 1940 TO 1970

In view of the large and growing importance of migratory relations between Mexico and the United States, it was decided that the shift-share effects of regional output and employment changes for Mexico's two major regions of in-migration, the Border states plus Metropolitan Mexico City, vis à vis the rest of the country, should be estimated. The breakdown is justified by the findings in Chapter 4 which indicated that the North and Pacific North have disproportionately large increases in output per worker and that the Pacific North together with Metropolitan Mexico City consistently experiences net in-migration. One may expect that the greater the imbalance in regional output growth, the more migration (shift factor) will serve to diffuse productivity gains through the work force. On the other hand, the more proportional the growth among regions, the more regional productivity factors will dominate. Where the "pull factor" is relatively strong, initial differentials in regional output growth will be maintained despite rapid shifts of the labor force from lower to higher growth regions. Where the "push factor" dominates, labor force migration could dampen potential regional inequalities in productivity growth by forcing down the marginal productivity of labor in the receiving regions while allowing it to rise in the sending regions.

The gravity model of labor force movement, together with trade in goods and services and capital flows, suggests that the shift factor will work to equalize factor incomes. Given the fact that the United States enjoys much higher output per worker than Mexico and is relatively accessible to Mexican labor, the gravity model would imply that the Mexican work force should gradually displace itself northward and shift into the sphere of influence of the US labor market. Indeed, there is strong evidence from the data on the Border region that labor force growth in areas adjacent to the Border has been much greater than elsewhere. Some of this movement has been within the Border states, from rural areas to urban centers located on the frontier, which are connected to US service economy through tourism and which have recently established a number of Border industry assembly plants (*maquiladoras*). These plants are linked with US manufacturers, and duty is charged only on the value-added components for re-export. Since the North also serves as a staging area for migration into the USA, it (especially the North Pacific) has had a net attraction effect on migration from the center and south of Mexico only exceeded by that of Metropolitan Mexico City.

This chapter presents a cursory view of the implications of North/South regionalization in terms of shift-share analysis. Table 15 reorganizes earlier data

TABLE 15 Output, employment, and total factor productivity by region, 1940–70.

Region		1940	1950	1960	1970
Border[a]					
Y_B	Output (in million 1950 pesos)	4 755	9 127	16 838	37 482
N_B	Labor force (PEA x 10^3)	778	1 225	1 630	2 120
$B = Y_B/N_B$	Output per worker (1950 pesos)	6 112	7 451	10 330	17 680
ΔB	Change in output per worker over past decade (1950 pesos)		1 339	2 879	7 350
$t = N_B/N_T$	Labor force share	0.133	0.147	0.160	0.164
Metropolitan Mexico City[b]					
T_M	Output	8 329	13 959	30 538	65 491
N_M	Labor force	946	1 545	2 111	3 223
$M = Y_M/N_M$	Output per worker	8 804	9 035	14 466	20 320
ΔM	Change in output per worker		231	5 431	5 854
$m = N_M/N_T$	Labor force share	0.161	0.185	0.207	0.249
Rest of Mexico[c]					
Y_R	Output	9 803	17 975	26 839	49 359
N_R	Labor force	4 134	5 575	6 471	7 612
$R = Y_R/N_R$	Output per worker	2 371	3 224	4 148	6 484
ΔR	Change in output per worker		853	924	2 336
$r = N_R/N_T$	Labor force share	0.706	0.668	0.634	0.588
Total Mexico					
Y_T	Output	22 887	41 061	74 215	152 332
N_T	Labor force	5 858	8 345	10 212	12 955
$T = Y_t/N_t$	Output per worker	3 908	4 921	7 267	11 758
ΔT	Change in output per worker		1 013	2 346	4 491
$t = N_T/N_T$	Labor force share	1.00	1.00	1.00	1.00

[a] Border: Baja California N., Baja California S., Coahuila, Chihuahua, Nuevo Leon, Sonora, Tamaulipas.
[b] Metropolitan Mexico City: Federal District (Mexico D.C.) and State of Mexico.
[c] Rest of Mexico: All other states.
SOURCE: Figures are calculated from data in Table 10.

so as to permit an examination of the three major regions: Border, Metropolitan Mexico City, and Rest of Mexico. One can quickly see the immense and growing gap between output per worker in the Border region and that of the Rest of Mexico. The difference in labor productivity rose from 3741 (1950) pesos in 1940 to 11 196 pesos in 1970, notwithstanding the fact that the productivity growth rate in the Rest of Mexico was 3.4 percent per annum over the 30 year period, almost equal to that of the Border, which was 3.5. This is due to the simple mathematics of growth, whereby even though values subject to wide absolute differentials grow at almost the same rates, their absolute gap may widen substantially over time. The gravity process may be working in Mexico, however, since Metropolitan Mexico City has grown at a slower rate than the Rest of Mexico in productivity terms (2.8 percent per annum) between 1940 and 1970. However, here again a disturbing element is that the absolute productivity gap, which was wide between the Border and Rest of Mexico (11 196 pesos in 1970), was even greater between Metropolitan Mexico City and the Rest of Mexico, rising from 6433 (1950) pesos in 1940 to 13 836 (1950) pesos in 1970. Since the purchasing power parity of a 1950 peso is today (1978) about US$0.50, the comparable value of this differential in productivity between the Border and the Rest of Mexico in 1970 is about $5600 in 1978 US dollars and between Metropolitan Mexico City and the Rest of Mexico about US$7000.

Most noteworthy about the evidence from Table 15 is that the gravity process appears to be narrowing the absolute productivity gap between the Border and Metropolitan Mexico City from 2672 (1950) pesos in 1940 to 2640 (1950) pesos in 1970. This has resulted from a much faster migration of labor over the 30-year period to the Metropolitan Mexico City region (4.1 percent per annum), while output growth was about the same in both regions (6.9 percent per annum). The spillover of labor from the Border region into the US labor market is not measured. There is no place for migrants to Metropolitan Mexico City to go but back home or northward. Hence it is likely that the gravity effect is more successful in leveling income between Metropolitan Mexico City and the Rest of Mexico than between the Border and the Rest of Mexico. This will continue as long as income differentials between the Border and the USA remain so much greater in absolute terms. Since output and productivity in the US economy are growing much more slowly than in Mexico, and especially in Mexico's two major regions of attraction, it would not be surprising if the gravity process eventually began to show a leveling effect between the two countries. However, as we have seen, where absolute income differentials remain so large it will take decades before growth rate differentials will narrow absolute income gaps. Until this happens, wide gaps in earnings will drive the forces of migration. Indeed, the findings presented in this chapter indicate that the lure of Metropolitan Mexico City may well begin to give place to that of major Border areas and the USA as

TABLE 16 Sectoral and shift elements underlying growth in output per worker by region, 1940–70. (All nonpercentage figures represent 1950 pesos per worker.)

Region	1940–50	%	1950–60	%	1960–70	%
Border						
Regional Productivity Growth	178		423		1176	
Shift	86		97		41	
Combined	18		37		29	
Total	282	28	557	24	1246	28
Metropolitan Mexico City						
Regional	37		1005		1212	
Shift	202		199		608	
Combined	5		119		246	
Total	244	24	1323	56	2066	46
Rest of Mexico						
Regional	602		617		1481	
Shift	− 90		− 110		− 191	
Combined	− 32		− 31		− 107	
Total	480	48	476	20	1183	26
Total Mexico						
Regional	817		2045		3869	
Shift	198		186		458	
Combined	− 9		125		168	
Total	1006	100	2356	100	4495	100
Share of productivity growth attributed to shift factor between regions	0.19		0.13		0.14	

Note: Definitions of regions are given in Table 15.
SOURCE: Figures are calculated from data in Table 10.

Metropolitan Mexico City's productivity gap begins to decline vis à vis that of the Border. Hopefully, if new centers of growth are fostered within Mexico, this could considerably alter the path of migration.

How much has migration mattered in terms of overall productivity growth? In Table 16 the own regional productivity growth and interregional shift factors are measured for the three decades. Here again, as in the analysis of the six areas of Mexico in Chapter 4, there is evidence that the interregional shift factor declined as a share of total productivity growth from 19 percent in the 1940s to 13 percent in the 1950s and remained at 14 percent in the 1960s. In short, the role of regional labor movement was important in raising overall productivity in the 1940s but has played a smaller role since then. In regional terms the contribution of Metropolitan Mexico City to the overall shift factor has risen substantially from 70 percent of the positive shift component in the

1940s to 93 percent in the 1960s (the remainder being attributed to the Border). Hence while the Border region continues to exhibit "pull" tendencies, the Metropolitan Mexico City region may well begin to be dominated by "push" forces as labor moves there in a desperate search for release from rural poverty and underemployment in other regions. In terms of its contribution to total productivity growth in Mexico, Metropolitan Mexico City has risen from one-fourth in the 1940s to over one-half in the 1950s, though this share declined somewhat to 46 percent in the 1960s, while the Border recovered its earlier 28 percent share. Interestingly, the Rest of Mexico with 70 percent of the work force in 1940 contributed one-half of total productivity growth in that decade, while its contribution declined to only 20 percent in the 1950s as Metropolitan Mexico City mushroomed in terms of both population and output. However, by the 1960s the Rest of Mexico's productivity share began to rise again, increasing to 26 percent, while its labor share fell to 58 percent. This augurs favorably for the continuation of the diffusion of Mexican productivity growth from the center to the periphery. The process is consistent with the gravity model of migration since output per worker in the Rest of Mexico grew by 3.4 percent per annum since 1940 compared with only 2.8 percent in Metropolitan Mexico City. Indeed the Rest of Mexico did almost as well as the Border region (3.5 percent per annum). Notwithstanding this performance, pockets of poverty and stagnation remain throughout the countryside and particularly in the northern desert regions, the central plateau, and the eroded areas of the south. Most of the rural areas are subject to erratic rainfall, and many small- and medium-sized urban centers have long since lost their comparative advantage for growth and will remain so in the absence of major new state development efforts, which include incentives for investment and technical progress suited to the special conditions of the regions.

While the analysis throughout this monograph has related migration to output and productivity rather than to income, it is recognized that among economic incentives labor movement is primarily responsive to expected wages and that wages are not necessarily related to total factor productivity, especially in a country in which the supply of labor from impoverished areas is so abundant. Indeed, it is possible for output per worker to rise considerably while real wages remain low or even decline (especially during periods of inflationary growth). However, total factor productivity gives some idea of the output per employed worker capable of supporting improvements in infrastructure, eduction, and other investments, which will eventually permit income to be diffused more broadly. This may occur through private expenditures by the recipients of profit and rental income as well as through increased capacity of the government to tax and spend on activities favoring social and economic progress. Moreover, the availability of urban amenities and other nonwage benefits, which attract labor to new locations, tends to be highly correlated with total factor productivity, even though real wages of unskilled labor may lag. Furthermore, the ability of workers to organize and

TABLE 17 Estimates of labor force migration, 1940–70 [labor force (× 10^3)].

Region	1940	1950			1960			1970		
	Observed labor force[a]	Observed labor force[a]	Estimated labor force[b]	Estimated migration (1940–50)	Observed labor force[a]	Estimated labor force[b]	Estimated migration (1950–60)	Observed labor force[a]	Estimated labor force[b]	Estimated migration (1960–70)
Border	778	1 225	1 110	+ 115	1 630	1 501	+ 129	2 120	2 070	+ 50
Metropolitan Mexico City	946	1 545	1 344	+ 201	2 111	1 889	+ 222	3 223	2 680	+ 543
Rest of Mexico	4 134	5 575	5 891	− 316	6 471	6 822	− 351	7 612	8 205	− 593
Total Mexico	5 858	8 345			10 212			12 955		
Net migration growth in labor force (%)		13			19			22		

[a] Observed labor force from Table 15.

[b] Estimated labor force – see Table 14 and text referring to Table 14. Estimates do not agree due to rounding.

Note: Definitions of regions are given in Table 15.

bargain collectively is directly related to the surplus (rental income including excess profits) earned per worker that is available to be bargained between labor and capital. Hence labor incomes may be increased in those subsectors of the labor market where such "economic rents" (broadly defined) are generated, and the increase in labor income tends also to be directly related to sectoral productivity growth (more appropriately, to "net" sectoral productivity growth after subtracting a normal return to capital).

Finally, in Table 17, estimated net labor force migration among the three regions is shown for the three decades. Here again, as in Chapter 4, migration is shown to have steadily increased as a share of labor force growth even after the net flows are restricted to the three main regions. Indeed, the shares remain about the same as those among the six areas (Table 14) since most net regional migration has been toward the Border and Metropolitan Mexico City. (The North Pacific is the only other main region of net in-migration and then only since the 1950s.) Most net labor migration in the 1960s was to Metropolitan Mexico City (92 percent), though in earlier decades the Border accounted for about 36 percent. Again, this may be due to increasing evidence of under-employment in the border towns, notwithstanding their rapid growth in output, as well as to the desperate poverty of agriculture in most border regions and finally to the "passing on" of regional migration to the USA.

The rank correlation is weak between growth in productivity and growth in migration among the three regions since the Border and Rest of Mexico show much faster productivity growth than Metropolitan Mexico City over the three decades, though the latter experienced the major share of in-migration. However, when one looks at absolute productivity differentials, the correlation becomes more perfect since Metropolitan Mexico City has led throughout the period in both absolute income per capita and in-migration, followed by the Border, which is catching up in income per capita. The Rest of Mexico, which still lags behind the other two regions by over 10 000 (1950) pesos per worker, continues to register an important rate of out-migration amounting to almost 600 000 workers between 1960 and 1970, or one-third of the increase in its labor force.

6 A SHIFT-SHARE ANALYSIS OF THE PRIMARY, SECONDARY, AND TERTIARY SECTORS OF THE THREE MAIN REGIONS OF MEXICO FROM 1940 TO 1970

In this chapter the same regionalization is used (Border, Metropolitan Mexico City, and Rest of Mexico) to determine those intraregional shifts that caused the respective growth patterns of the main sending and receiving regions. For this purpose, the change in output and employment of the main production sectors – primary, secondary, and tertiary – is analyzed for each region. Tables 18 to 20 present the underlying data on output, employment, and total factor productivity, and Tables 21 to 23 provide estimates of the sectoral and shift components of productivity growth for each of the three regions. The results are as follows.

In the Border region there is important evidence that the internal shift factor as a share of the region's productivity growth fell from almost one-half (48 percent) in the 1940s to one-third (33 percent) in the 1950s and to less than one-tenth (9 percent) in the 1960s (Table 21). Hence, the Border region has been increasingly unable to generate overall productivity growth simply by moving its work force from an impoverished agriculture to more productive employment in manufacturing and services. Migration among sectors has continued (Table 18) but the sectoral productivity component has grown from one-half to 90 percent of growth in output per worker. In the 1960s the Border states' manufacturing sector (secondary) accounted for most of the relative increase, its share rising from 28 to 37 percent of productivity growth, which is a very healthy sign (Table 21). This contrasts sharply with the Metropolitan Mexico City region where the share of productivity growth from the secondary sector fell from 57 percent in the 1950s to 27 percent in the 1960s (Table 22). The establishment of border industries linked to the US economy plus growth of industry in Monterrey almost certainly had much to do with this impressive performance of the Border region. Industry in Metropolitan Mexico City, on the other hand, grew on the basis of production through tariffs and quotas. Oriented toward import substitution, industry in Metropolitan Mexico City showed much less productivity growth in the 1960s

TABLE 18 Output, employment, and total factor productivity growth in the Border region, 1940–70.

		1940	1950	1960	1970
Primary sector					
Y_A	Output (value added in million 1950 pesos)	1 052	2 102	3 437	5 916
N_A	Labor force (PEA x 10^3)	448	614	629	642
$Y_A/N_A = A$	Output per worker (1950 pesos)	2 348	3 423	5 464	9 215
$\Delta(T_A/N_A)$	Change in output per worker over past decade (1950 pesos)		1 075	2 041	3 751
$N_A/N_T = a$	Labor share in sector	0.574	0.501	0.386	0.303
Secondary sector					
Y_B	Output	1 501	2 935	5 208	12 521
N_B	Labor force	143	265	409	594
$Y_B/N_B = B$	Output per worker	10 497	11 075	12 733	21 079
$\Delta(Y_B/N_B)$	Change in output per worker		578	1 658	8 346
$N_B/N_T = b$	Labor share	0.183	0.216	0.251	0.280
Tertiary sector					
Y_C	Output	2 204	4 089	8 195	19 045
N_C	Labor force	189	346	592	884
$Y_C/N_C = C$	Output per worker	11 661	11 818	13 843	21 544
$\Delta(Y_C/N_C)$	Change in output per worker		157	2 025	7 701
$N_C/N_T = c$	Labor share	0.242	0.282	0.363	0.417
Total region					
Y_T	Output	4 757	9 126	16 840	37 482
N_T	Labor force	780	1 225	1 630	2 119
Y_T/N_T	Output per worker	6 098	7 450	10 331	17 689
$\Delta(Y_T/N_T)$	Change in output per worker		1 352	2 881	7 358

Note: Definitions of sectors are given in Table 6. Definition of the Border region is given in Table 15.

than did industry in the Border region (Tables 18 and 19). Earlier, in the 1950s, Metropolitan Mexico City's import substituting manufacturing had taken a temporary lead in productivity growth after having shown a net *decline* in the 1940s (Tables 18 and 19).[15]

The Border region's primary sector labor share steadily declined, most importantly in the 1950s, so that its rural employment share in 1970 was only 30 percent compared to 57 percent for the Rest of Mexico (Tables 18 and 20). Hence it is not surprising that the primary sector contribution to productivity growth in the Border region fell from 27 percent in the 1940s to 9 percent in the 1960s. However, output per worker in the primary sector of the Border region grew by twice that of the Rest of Mexico in the 1940s, three times more in the

TABLE 19 Output, employment, and total productivity growth in the Metropolitan Mexico City region, 1940–70.

		1940	1950	1960	1970
Primary sector					
Y_A	Output (value added in million 1950 pesos)	385	486	590	673
N_A	Labor force (PEA x 10^3)	302	372	331	369
$Y_A/N_A = A$	Output per worker (1950 pesos)	1 275	1 306	1 782	1 824
$\Delta(T_A/N_A)$	Change in output per worker over past decade (1950 pesos)		31	476	42
$N_A/N_T = a$	Labor share in sector	0.319	0.241	0.157	0.115
Secondary sector					
Y_B	Output	2 680	4 005	11 952	23 298
N_B	Labor force	226	470	810	1 206
$Y_B/N_B = B$	Output per worker	10 858	8 521	14 756	19 318
$\Delta(Y_B/N_B)$	Change in output per worker		−2 337	6 235	4 562
$N_B/N_T = b$	Labor share	0.239	0.304	0.384	0.374
Tertiary sector					
Y_C	Output	5 204	9 468	17 996	41 520
N_C	Labor force	418	703	970	1 647
$Y_C/N_C = C$	Output per worker	12 593	13 468	18 553	25 209
$\Delta(Y_C/N_C)$	Change in output per worker		875	5 085	6 656
$N_C/N_T = c$	Labor share	0.442	0.455	0.459	0.511
Total region					
Y_T	Output	8 329	13 959	30 538	65 491
N_T	Labor force	946	1 545	2 111	3 222
Y_T/N_T	Output per worker	8 804	9 035	14 466	20 326
$\Delta(Y_T/N_T)$	Change in output per worker		231	5 431	5 860

Note: Definitions of sectors are given in Table 6. Definition of the Metropolitan Mexico City region is given in Table 15.

1950s and 20 times as much in the 1960s (Tables 18 and 20). Clearly, the Northern states have retained the lead in rural output per worker by pursuing capital- and land-intensive techniques or irrigated farming. As such they could be regarded as southerly extensions of "Sunbelt" agriculture in the USA, using much the same technology and cropping patterns and exporting a considerable share of their output to the USA. Hence, this pattern of Border productivity growth in the primary sector, as in the secondary sector, is closely linked to the US economy.

In the tertiary sector, the Border region has also shown major productivity growth rising from 38 percent in the 1940s, to 59 percent in the 1950s, and to 54 percent in the 1960s of the region's growth in output per

TABLE 20 Output, employment, and total factor productivity growth in the Rest of Mexico region, 1940–70.

		1940	1950	1960	1970
Primary sector					
Y_A	Output (value added in million 1950 pesos)	3 734	6 654	4 890	11 123
N_A	Labor force (PEA x 10^3)	3 082	3 881	4 089	4 318
$Y_A/N_A = A$	Output per worker (1950 pesos)	1 212	1 715	2 419	2 576
$\Delta(T_A/N_A)$	Change in output per worker over past decade (1950 pesos)		503	704	157
$N_A/N_T = a$	Labor share in sector	0.746	0.696	0.632	0.567
Secondary sector					
Y_B	Output	2 608	5 526	7 443	16 379
N_B	Labor force	457	755	956	1 398
$Y_B/N_B = B$	Output per worker	5 706	7 319	7 786	11 716
$\Delta(Y_B/N_B)$	Change in output per worker		1 613	467	3 930
$N_B/N_T = b$	Labor share	0.111	0.135	0.148	0.184
Tertiary sector					
Y_C	Output	3 462	5 795	9 505	21 866
N_C	Labor force	593	939	1 428	1 897
$Y_C/N_C = C$	Output per worker	5 838	6 171	6 656	11 527
$\Delta(Y_C/N_C)$	Change in output per worker		333	485	4 871
$N_C/N_T = c$	Labor share	0.144	0.168	0.221	0.249
Total region					
Y_T	Output	9 804	17 975	26 838	49 368
N_T	Labor force	4 132	5 575	6 473	7 613
Y_T/N_T	Output per worker	2 373	3 224	4 146	6 485
$\Delta(Y_T/N_T)$	Change in output per worker		851	922	2 339

Note: Definitions of sectors are given in Table 6. Definition of the Rest of Mexico region is given in Table 15. For Total Mexico see Table 6, which is the sum of Tables 18, 19, and 20.

worker (Table 21). Its employment share has also risen from 24 percent in 1940 to 42 percent in 1970. This is strong evidence that the sector has exerted a demand pull on employment sufficient to prevent steady increases in employment from swamping productivity growth. The most interesting contrast is with tertiary sector productivity in the other main receiving region (Metropolitan Mexico City) which grew more rapidly than that of the Border in the 1940s and 1950s but which lagged behind the Border region in the 1960s (Tables 18 and 19). Here again, the Border region, which is heavily engaged in service-related trade (tourism) with the USA, now leads the whole nation in its growth of output per worker. Over half of that leadership stems from productivity growth in the tertiary sector. (See Table 18 and Chapter 4).

TABLE 21 Sectoral and shift elements underlying growth in output per worker in the Border region, 1940–70. (All nonpercentage figures represent 1950 pesos per worker.)

	1940–50	%	1950–60	%	1960–70	%
Primary sector						
ΔAa (Sectoral)	617		1023		1448	
ΔaA (Shift)	− 171		− 394		− 454	
$\Delta a \Delta A$ (Combined)	− 78		− 235		− 311	
Total growth of output per worker (1950 pesos)	368	27	394	14	683	9
Secondary sector						
ΔBb	106		358		2095	
ΔbB	346		388		369	
$\Delta b \Delta B$	19		58		242	
Total growth of output per worker (1950 pesos)	471	35	804	28	2706	37
Tertiary sector						
ΔCc	38		571		2795	
ΔcC	466		957		748	
$\Delta c \Delta C$	6		104		416	
Total growth of output per worker (1950 pesos)	510	38	1632	59	3959	54
Total region						
$\Sigma \Delta Yn$	761		1952		6338	
$\Sigma \Delta nY$	641		951		663	
$\Sigma \Delta n \Delta Y$	− 53		− 13		347	
Total regional growth of output per worker (1950 pesos)	1349	100	2890	100	7348	100
Share of regional productivity growth attributable to shift factor	0.48		0.33		0.09	

Note: Definitions of sectors are given in Table 6. Figures are calculated from data in Table 18. Methods are discussed in Chapter 3 and in Table 7.

The second region in productivity growth and the leader in labor absorption is Metropolitan Mexico City (Tables 19 and 22). This region is by definition almost 90 percent urban, and its service sector has accounted for most of its productivity growth in the 1940s (over 100 percent) and 1960s (75 percent). In the 1950s the growth of import-substituting industries led the way with 57 percent as mentioned above. The pattern of growth in this region provides support for the hypothesis that "push" factors are beginning to have a retarding effect on Mexico's productivity growth as labor is forced

TABLE 22 Sectoral and shift elements underlying growth in output per worker in the Metropolitan Mexico City region, 1940–70. (All nonpercentage figures represent 1950 pesos per worker.)

	1940–50	%	1950–60	%	1960–70	%
Primary sector						
ΔAa (Sectoral)	10		115		7	
Δ (Shift)	− 99		− 110		− 75	
$\Delta a \Delta A$ (Combined)	− 2		− 40		− 2	
Total growth of output per worker (1950)	− 91	− 40	− 35	− 1	− 70	− 1
Secondary sector						
ΔBb	− 798		1895		1752	
ΔbB	771		682		− 148	
$\Delta b \Delta B$	− 217		499		− 46	
Total growth of output per worker (1950)	− 244	− 107	3076	57	1558	27
Tertiary sector						
ΔCc	387		2314		3055	
ΔcC	164		54		965	
$\Delta c \Delta C$	11		20		346	
Total growth of output per worker (1950 pesos)	562	247	2388	44	4366	75
Total region						
$\Sigma \Delta Yn$	− 401		4324		4814	
$\Sigma \Delta nY$	836		626		742	
$\Sigma \Delta n \Delta Y$	− 208		479		298	
Total regional growth of output per worker	227	100	5429	100	5854	100
Share of regional productivity growth attributable to shift factor	3.68		0.12		0.13	

Note: Definitions of sectors are given in Table 6. Figures are calculated from data in Table 19. Methods are described in Chapter 3 and in Table 7.

into the tertiary sector which, after remaining at a fairly constant 45 percent of employment in the first two decades, rose to 51 percent in the 1960s (Table 19). Still output per worker in the tertiary sector continued to grow in the 1960s, though evidence from Chapter 1 would suggest that if the decade could have been divided into 5-year intervals, that trend might well have been declining. The probable slowdown is likely to have continued into the 1970s as a flood of immigrants failed to find adequate employment opportunities in the overcrowded Valley of Mexico. The drastic deceleration in productivity

TABLE 23 Sectoral and shift elements underlying growth in output per worker in the Rest of Mexico region, 1940–70. (All nonpercentage figures represent 1950 pesos per worker.)

	1940–50	%	1950–60	%	1960–70	%
Primary sector						
ΔAa (Sectoral)	375		490		99	
ΔaA (Shift)	− 60		− 110		− 156	
$\Delta a \Delta A$ (Combined)	− 25		− 45		− 10	
Total growth of output per worker (1950 pesos)	290	34	335	36	− 67	− 3
Secondary sector						
ΔBb	179		63		580	
ΔbB	139		90		280	
$\Delta b \Delta B$	39		6		141	
Total growth of output per worker (1950 pesos)	357	42	159	17	1001	43
Tertiary sector						
ΔCc	48		82		1075	
ΔcC	142		322		190	
$\Delta c \Delta C$	8		25		139	
Total growth of output per worker (1950 pesos)	198	23	429	46	1404	60
Total region						
$\Sigma \Delta Yn$	602		635		1754	
$\Sigma \Delta nY$	221		305		314	
$\Sigma \Delta n \Delta Y$	22		− 14		270	
Total regional growth of output per worker	845	100	926	100	2338	100
Share of regional productivity growth attributable to shift factor	0.26		0.33		0.13	

Note: Definitions of sectors are given in Table 6. Figures are calculated from data in Table 20. Methods are described in Chapter 2 and in Table 7.

growth in manufacturing and agriculture almost certainly will have repercussions on income and job multipliers in the service sector of this region, exacerbating relative pressures for migration to the Border and other growth centers. Hence if policies were adjusted to favor decentralized growth, they might well find a favorable labor response, though as shown in Chapter 5 absolute gaps in output per worker still favor Metropolitan Mexico City.

Finally, the Rest of Mexico (Tables 20 and 23) deserves attention since the 23 states that make up this region account for almost two-thirds of the

TABLE 24 Regional and sectoral shifts as a share of Mexican productivity growth (%). (Based on the division of Mexico into 3 regions.)

Shift	1940–50	1950–60	1960–70
1. Regional shift as a share of productivity growth in Mexico	20	8	10
2. Sectoral shift as a share of productivity growth	51	28	16
3. Internal migration among the 3 regions as a share of growth in the economically active population	13	19	22

SOURCE: Tables 18–23 and Chapters 5 and 6.

Mexican labor force (1970). Here too the pattern is disturbing. Although 57 percent of the labor force remained in the primary sector in 1970, that sector's share of regional productivity growth, which had been one-third in the 1940s and 1950s, became negative in the 1960s (Table 23). Manufacturing on the other hand showed signs of regional dispersion, as its share of employment rose from 11 percent in 1940 to 18 percent in 1970. Here again, however, the tertiary sector took the lead with a 60 percent contribution to overall productivity growth in the 1960s. It is likely that without significant labor emigration from the Rest of Mexico to the Metropolitan Mexico City and the Border regions, the productivity growth in the Rest of Mexico would have lagged still more. The output per worker in agriculture in that region was only about one-fourth that of the Border region, though its service sector productivity was one-half that of the Border. Clearly, it is the tertiary sector in which productivity "leveling" is occurring, and it is this sector that deserves much more research than it has received, given its patterns of employment, distribution of output, and income trends.

In conclusion, the shift factor is declining as a contributor to productivity growth, both regionally and sectorally. Meanwhile, the share of migration among regions, as a proportion of growth in the labor force, is on the increase (Table 24). This indicates that while workers are increasingly moving to higher productivity regions in search of employment, those regions are less capable of sustaining their role as transmitters of growth through shifts in the labor force. A squeeze is coming between migratory pressures for higher income and the potential of leading regions to provide jobs. Indeed, it is likely that rather than passing on productivity gains, migration is now dampening such growth in the leading sectors and regions. Mexico is in danger of becoming a low income and low productivity "service economy" in contrast to the USA which is attempting to maintain its position as a high income "service economy". The consequences are a sharpening of the disparities in the standards of living and quality of life between the two countries, disparities that exacerbate pressures for migration northward to bridge the gap that has not yet been narrowed through trade and investment flows or technology transfers. The emerging pattern is different from the 1940s, when according to our data, there was more hope. During the 1940s the internal shift factor accounted for one-half of productivity growth. Migration within Mexico offered promise of a better life, and the regional shift accounted for up to one-fifth of national productivity growth (Table 24). But by the 1960s sectoral shifts were at most responsible for only one-sixth and regional shifts for one-tenth of national productivity growth. The new petroleum windfall may provide an economic surplus that could be allocated to favor basic regional and sectoral productivity growth. This might reverse historical trends. But to do so, every effort must be made to assure that the new oil rents are not simply redistributed as consumption subsidies, artificially causing service sector employment to rise still further, nonpetroleum exports to decline, and imports of consumer goods to expand disproportionately. Fundamental changes are needed in the incentive structure of the economy. These changes should favor true productivity growth in the nonpetroleum primary sector, in manufacturing, and in agriculture, together with expansion of wage good production to serve the mass of the Mexican population.

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NOTES

1. The Human Settlements and Services Area's research in urbanization and development is concerned with simulation modeling and counterfactual analysis of alternative patterns of demographic and economic growth, urbanization, and regional migration under conditions of alternative rural technologies, income distribution, and demand patterns, and implications of the foregoing for the provision of social services (Rogers 1978). This research is inspired by the importance of issues underlying current debates between those criticizing alleged "over-urbanization" of developing countries and those supporting present patterns of urbanization and migration as means of improving social welfare. Demographic influences on migration are of course of considerable importance to economic growth, and the outcome will, in an iterative fashion, affect the future growth of population, welfare, and migration. By breaking into this sequence of behavior to look at the structure of output and employment and its changes over time at the national level and by sector and region, for a single important case, the Mexican Case Study seeks to provide empirical evidence on both costs and benefits of rapid demoeconomic changes. The resettlement of important segments of the work force has been an essential element in this study.
2. A more explicit statement of the theoretical framework used follows. The foundation of the section is taken from production theory and uses the implicit production function

$$Y = A_{(t)} f(K, L, R) \tag{1}$$

where Y is the total value added or GDP; f is a function having the neoclassical properties of being homogeneous of degree one and twice differentiable; and $A_{(t)}$ is the so-called efficiency term which is a function of time and independent of the factors of production. Changes of this term are considered to reflect the effects of technological change, and they serve to shift the production function without altering its basic structure. Therefore the term is considered as neutral technological change. The term can adopt the form

$$A_{(t)} = A_{(0)} e^{\lambda t}$$

where λ is a parameter. Explicitly what we have in the paper is

$$Y = e^{T} L^{a} K^{b} R^{c} \tag{2}$$

Therefore, the following observations are in order

(a) $A_{(0)} = 1$
(b) $\lambda T = t$
(c) f adopts the form of a Cobb–Douglas production function. The purpose of this section is to determine by means of equation (2) the percentage of change in output attributed to variation in the quantity and quality of inputs. To illustrate, we can differentiate equation (1) totally with respect to time and obtain

$$\frac{\partial Y}{\partial t} = \frac{\partial A}{\partial t} f + A_{(t)} \frac{\partial f}{\partial K}\frac{\partial K}{\partial t} + \frac{\partial f}{\partial L}\frac{\partial L}{\partial t} + \frac{\partial f}{\partial R}\frac{\partial R}{\partial t} \tag{3}$$

or

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + A_{(t)} \frac{\partial f}{\partial K}\frac{\dot{K}}{Y} + A_{(t)} \frac{\partial f}{\partial L}\frac{\dot{L}}{Y} + A_{(t)} \frac{\partial f}{\partial R}\frac{\dot{R}}{Y} \tag{4}$$

We know that under competitive conditions (one of the implicit assumptions in the analysis)

$$\frac{\partial f}{\partial K}\frac{K}{Y} = b; \quad \frac{\partial f}{\partial L}\frac{L}{Y} = a; \quad \frac{\partial f}{\partial R}\frac{R}{Y} = c$$

Therefore

$$\frac{\dot{Y}}{L} = \frac{\dot{A}}{A} + a\frac{\dot{L}}{L} + b\frac{\dot{K}}{K} + c\frac{\dot{R}}{R} \tag{5}$$

or in discrete terms

$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + a\frac{\Delta L}{L} + b\frac{\Delta K}{K} + c\frac{\Delta R}{R} \tag{6}$$

Since A is not observable, it is found as a residual

$$\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - a\frac{\Delta L}{L} - b\frac{\Delta K}{K} - c\frac{\Delta R}{R} \tag{7}$$

3. These factor shares are based on estimates for the period 1940–65 taken from the author's earlier study (Reynolds 1970) in which the labor share includes mixed income ("ingresos mixtos") of small business and farm households. There is some likelihood that in the years since 1965 the labor share has declined serving to lower this coefficient.
4. It should be noted that the post-1960 GDP series was somewhat revised since the Reynolds (1970) volume was published, and the present study incorporates these changes, causing the results for earlier years to be slightly different from earlier estimates.
5. The 1960 census PEA (economically active population over 12 years of age) was reported to be $11\,235 \times 10^3$. Altimir adjusted this figure to $10\,213 \times 10^3$. The agricultural population was most affected by this downward adjustment: the census PEA in agriculture for 1960 of 6086×10^3 being reduced by Altimir to 5048×10^3. If the census figures for 1960 (6086×10^3) and 1970 (5329×10^3) are compared, it appears that the rural PEA declined sharply in absolute terms. Yet as Altimir shows, this is not consistent with sample surveys taken in 1963, 1964, and 1965 that showed rural labor participation rates to be close to the 1970 levels and much below those of 1960. Clearly, Altimir's adjustments for 1960 when disaggregated are crucial, regionally, to the analysis of migration and sectoral and regional labor absorption in Mexico between 1950 and 1970. On the basis of the uncorrected 1960 census data, the degree of labor flow from rural to urban areas is seriously understated for the

1950s and overstated for the 1960s. The Altimir adjustments resulted from a thoroughgoing examination of coverage, definition, measurement and other problems of the population censuses of 1950, 1960, and 1970. His research was done under the auspices of the United Nations Economic Commission for Latin America and the Regional and Urban Development Project at El Colegio de Mexico. Altimir argues convincingly that the PEA reported in the 1960 census was seriously overestimated, the upward bias being concentrated in the rural labor force through over counting of unrenumerated family workers and agricultural wage labor in 1960 relative to that of the 1950 and 1970 censuses. His conclusions are supported by a comparison of the respective population censuses of 1950 and 1960 (which also report rural employment) and by an El Colegio de Mexico reestimate of the 1960 PEA based on a 1.5 percent sample of 1960 census cards. As mentioned above, his major adjustment was to reduce the PEA in the agricultural sector (which includes cattle, forestry, and fishing) in 1960 from 6089×10^3 to 5048×10^3. Altimir does not give statewide breakdowns for these adjustments by sector, but he does report the adjusted PEA by state for 1960. Since the overall total downward adjustment was concentrated in the primary sector, I applied the difference in state PEA from the census and Altimir's estimates entirely to the primary sector of the respective state. Only in the case of the state of Mexico and the Federal District of Mexico did this method lead to spurious results (negative employment in the rural sector). In those two cases instead of using the above method, I reduced primary sector employment by the same proportion as that of the Rest of Mexico allocating the remainder as a proportioned reduction to the rest of the states.

6. The capital stock in 1959 was assumed to be 331 124 million pesos (at constant 1960 values) to which an assumed 5 percent depreciation rate was applied. To this figure were added gross investment flows in 1960 of 33 132 million pesos, producing an estimated capital stock at the end of 1960 of 347 700 million pesos (this would have meant a capital/output ratio (K_{t-1}/Y_t) for 1960 of 2.2.
7. Continual revisions of the national accounts make it difficult to get a secure fix on the level or trend of income and product in Mexico. For example, earlier data implied trends in GDP for the 1940s of 6.4 percent to 6.7 percent per annum (Reynolds, 1970) compared to 5.8 percent in Table 2 (Solis 1970; Unikel 1976). Official revisions that have appeared since the Unikel study lower the growth rate for the 1960s from 7.2 percent to 6.8 percent per annum. In order to keep estimates in this chapter as close as possible to those in the following chapters (which rely on Appendini (1974)–Unikel (1976) regional gross product estimates that are linked to the Solis (1970) GDP data at the national level), I have retained the Solis figures for GDP growth in the 1940s and 1950s. However, estimates for 1960–1976 provided by the Bank of Mexico in 1977 differ significantly from Solis's earlier figures. Thus, it is necessary to adopt the Bank of Mexico's data for the 1960s, despite the fact that they lower the growth rate (and residual) during that decade by 0.4 percent per annum. The turnaround in productivity growth since the mid-1960s is independent of the choice of GDP estimates for the 1960s.
8. Hewitt's 1960 figure (Hewitt 1976) is derived from CIDA (1964: Vol. 1), and the source of the 1960 figure is not clearly cited. Her figures for growth of cultivated land between 1940 and 1960 are comparable to those presented in Reynolds (1970), justifying a linking of her 1960 to 1970 figures to the earlier index.

	1940–50 (%)	1950–60 (%)	1960–70 (%)
Hewitt (1976)	3.0	1.0	2.1
Reynolds (1976)	3.6	1.0	N.A.

9. In my 1970 volume, estimates of the unexplained productivity residual showed a decline between the 1940s and 1950s, from 3.3 percent per annum to 2.5 percent per annum, respectively, as compared with the reverse trend in Table 2 (from 2.5 percent to 2.7 percent). The later results are due primarily to a downward revision of output growth in the 1940s (GDP in constant 1950 pesos) based on the GDP estimates (Solis 1970) presented in Appendini (1974)–Unikel (1976). Labor force growth in the 1950s has also been sharply reduced in the present study drawing on the more recent downward revision of the 1960 census figures by Altimir (1974). The growth in PEA based on official census data between 1950 and 1960 was 3.1 percent per annum (Reynolds 1970: 50, Table 1.7).
10. The primary sector receives emphasis as a source of out-migration. Regional differences in agricultural productivity, which in Mexico reflect severe contrasts between irrigated agriculture in the North and Pacific North (or Border states) and rain-fed agriculture (principally in the Center, Gulf, and South, i.e., Rest of Mexico states), leading to different paths of employment and income among the regions of Mexico. The tertiary sector is focused on as a buffer that absorbs labor displaced from rural areas. In Mexico the tertiary sector also evidences wide differences in employment and productivity growth by region. The tertiary sectors of the Border and Metropolitan Mexico City regions absorb much labor displaced from the primary sector both in those regions and in the Rest of Mexico region.
11. This is a generalized version of the shift-share model for three sectors presented in Reynolds (1970: 64ff) designed to accommodate any number of sectors and regions. Its characteristics are discussed in detail in that study.
12. The sustained high value of output per worker in the tertiary sector, exceeding that of the secondary sector in all four years (Table 6), deserves comment. Since this sector aggregates a number of activities of very different productivity, from banking and finance to domestic services and street vendors, it disguises a large and growing dualism in Mexico as elsewhere. While productivity is growing in the modern tertiary sector, reflecting a high and growing rate of capital formation and technological progress in modern commerce, transport, and services, it is almost certainly stagnating or perhaps even declining in the traditional tertiary sector, which serves as a major buffer for workers migrating from the rural areas of Mexico. Hence, further analysis of this problem should attempt to differentiate between tertiary activities that are capital intensive and those that are labor intensive. It is likely that some of the shift factor attributable to the tertiary sector is in fact own productivity growth in the modern tertiary sector rather than increased employment as in the traditional tertiary sector. In addition the methodology used for estimation of value added in some of the tertiary sector activities, such as commerce and services, is extremely crude (application of a coefficient to value added in other production sectors) and leads to possible biases in either direction, while employment figures are taken from the decennial censuses and bear no relation to the value added estimates in the national accounts. It is quite possible that value added is overestimated for these components of the tertiary sector. Also, value added for the large and growing public sector is a simple reflection of government wages and salaries and bears no necessary relationship

to physical productivity. It has been suggested, on the other hand, that the nature of highly protected manufacturing in Mexico has led to a lower level of productivity and slower rate of productivity growth in the secondary sector than would have been obtained under a more internationally competitive system. This should be offset by the consideration that value added in manufacturing is distorted upward by the degree of effective protection of its products, while value added in the primary and tertiary sectors is subject to a proportional downward bias. In short, it is not possible to net out the effects on output per worker in the three sectors of statistical and policy-related (price) distortions. For that reason the value added estimates from the national accounts are used without adjustment.

13. In subsequent chapters regional patterns of productivity growth in the service (tertiary) sector are examined. It is shown that the regional performance of this sector is quite diverse, and that the shift element is an important contribution *within* the tertiary sector as well as between it and the primary sector. These initial findings support the need for far more detailed research on the service sector, with special attention to its role in labor absorption in Mexico (Souza and Tokman 1976; Reynolds and Leiva 1978). It is quite likely that the pattern of productivity growth within the tertiary sector is even more unbalanced than between it and other activities. Growth in output per worker in services tends to occur in the more capital- and skill-intensive subsectors, which are least likely to absorb job seekers displaced in increasing numbers from the rural areas. Unfortunately, the data used in this paper do not easily accommodate disaggregation of the tertiary sector. A more detailed study of the output and population censuses might permit such an analysis to be made at both the national and regional levels for at least some of the subsectors. This research could then be combined with a sectoral analysis of budget study data plus interviews of small businesses and other activities in the informal sector. The rarely characterized "urban informal sector" is a nontrivial consideration and may be said to include self-employed, workers and owners of small businesses, workers receiving relatively low incomes and those outside of the social security system, or other categories, depending upon the choice of criteria of the observer. There seems to be a strong overlap between conventionally defined informal sector employment and that of subsectors of the tertiary sector, but all sectors of production have been found to have important elements of informal sector employment (Souza and Tokman 1976).

14. This study draws on the statewide breakdown of GDP data in Unikel (1976), which is based on work by Appendini for the years 1940, 1950, and 1960. It also draws on estimates by the Secretaria de Hacienda y Crédito Público, Dirección de Programación y Descentralizacion Administrativa, Subdirección de Programación Fiscal, for 1970, which appear in Unikel (1976). Labor force data for 1940, 1950, and 1970 are estimated on the basis of the respective population censuses as described in Unikel and Torres (1970). The data for 1960 have been further adjusted by Altimir's agricultural labor force estimates for 1960 (Altimir 1974).

15. The figures in Table 19 show a significant decline in output per workers in the Metropolitan Mexico City region during the 1940s. If correct, they suggest that labor absorption dominated the growth of secondary production in that period, while capital-intensive growth characterized the 1950s and 1960s.

A DEMOECONOMETRIC MODEL OF POLAND AND ITS APPLICATION TO COUNTERFACTUAL SIMULATIONS

Zbigniew Pawlowski

1.1 THE GENERAL AIM OF THE RESEARCH

The aim of the research described in this report is to understand the quantitative behavior of the growth of the Polish economy and to discover to what extent this growth is interrelated with demographic phenomena, especially migration from rural to urban areas.

The research has led to the construction of an econometric model explaining the variations of a number of key economic and demographic variables pertaining to Poland during the sixties and seventies. As will be seen later in this report, there is indeed a strong interdependence between demographic factors, particularly the population totals and their distribution among rural and urban areas, and economic factors.*

Once the model had been built and estimated, its equations were used to obtain the reduced form, which in turn made it possible to perform some counterfactual simulations and forecasts. The counterfactual scenarios were designed to show the impact that a change in the economic situation would have on demographic phenomena. Our experiments show that different economic policies can affect many of the demographic variables introduced into the model, in significantly different ways.

Since the model discussed in this report takes into account both economic and demographic factors and is basically of the econometric type from the point of view of its construction and estimation, it is referred to as the DemoEconometric Model of Poland (DEMP-1).

* The reciprocal impact of demographic variables and the state and dynamics of the Polish economy will be more fully reflected by a second version of the model, whose construction is now largely complete.

1.2 SOME CHARACTERISTIC FEATURES OF THE POLISH NATIONAL ECONOMY

Although we do not propose to give a detailed exposition of all the characteristic features of the Polish economy, it seems worthwhile to stress some basic points. It is hoped that this will help the reader to follow the rationale used in building the model, i.e., to understand the definitions of the variables and the reasons for including them in specific equations of the model.

The following 13 points are worth bearing in mind:

1. Poland is a country with a centrally planned national economy. This means that economic growth and many social phenomena are regulated by appropriate long-, medium-, and short-term plans, while market mechanisms play a small role or are totally excluded.
2. The industrial sector exhibits a steady, high rate of growth (an average annual rate of 8% for 1960–1970, and 12% for 1970–1978) and is almost totally composed of state and cooperative units.
3. The agricultural sector is predominantly private (about 85% of arable land is owned by peasants who operate private farms), is composed of rather small private farms (average area less than 7 hectares), and uses family labor.
4. The whole agricultural sector – both socialized and private – is heavily dependent on weather conditions. Inadequate rainfall, or rainfall concentrated in the wrong period of the year, can cause the yield of crops to be as much as 20% lower than under normal conditions. Moreover, it should be noted that the frequency of occurrence of years with adverse weather conditions is high (for instance, 8 such years out of the last 20).
5. The service sector is considered as unproductive, i.e., as adding nothing to the volume of national income, thus implying that it is subordinate to the industrial and agricultural sectors.
6. Prices of consumer, intermediate, and investment goods are to a large extent determined by the appropriate state authorities. Since there is virtually no market mechanism, prices are not necessarily equilibrium prices, and it may take some time before a price change occurs which puts demand and supply into equilibrium.
7. During the whole post-war period, Poland has been experiencing not only a situation of full employment but also a shortage of manpower in the socialized sectors. Total employment figures have been steadily rising.
8. The industrial sector, especially, has been drawing the labor force away from the agricultural and household sectors.
9. There has been a steady outflow of people – especially the young – from rural to urban areas. The reasons for these migrations are not so

much wage differentials (in fact during some periods the average income of farmers has been higher than the average wage in industry) but are connected more with seeking new ways of life, shorter working hours, and access to better services, culture, and education. The limit to out-migrations from rural to urban areas is set by the existing shortage of housing facilities in the urban areas.

10. Because of this limit to out-migrations there exists in Poland a special group, the peasant-workers. These are people who own and work on private farms, and simultaneously take full-time jobs in state firms, especially in industry, construction, or transportation. The peasant-workers provide a mainly unskilled or semiskilled labor force for these sectors.
11. The standard of living has been steadily increasing in real terms over the period studied.
12. Directly after 1945 and up to the late fifties, Poland experienced a high rate of population growth due to a high birth rate and a decreasing death rate. Since the early sixties the rate of population growth has significantly declined, primarily because of a decrease in birth rate, not only in urban but also in rural areas.
13. In the post-war period, a visible process of urbanization, especially in middle-sized towns, has occurred as a result of migrations and general population growth. In 1950 the number of towns in Poland with a population greater than 100,000 was 16, whereas now there are more than 30 such towns.

1.3 THE HISTORY OF ECONOMETRIC MACROMODELING IN POLAND

Before presenting DEMP-1 it seems worthwhile to devote a few lines to the history of econometric modeling of the Polish economy. This history goes back as far as 1964, when Pawlowski *et al.* (1964) published a paper presenting a small, six-equation model describing the existing interrelations between employment, investments, national income, foreign trade, and standard of living (as represented by the wage rate).* Four years later the same group of authors published a book (Pawlowski *et al.* 1968) in which they described a new and larger model. The new model contained 17 endogenous variables. The types of economic phenomena were roughly the same as those dealt with in the earlier model, except that the employment, investment, and national-income variables were disaggregated into two types, namely, the agricultural and nonagricultural productive sectors.**

*It is fair to say that the first attempt in Poland to use econometric methods for macroanalysis was that of Pajestka (1961), who tried to fit a Cobb–Douglas–Tinbergen production function to Polish data on national income, employment, and fixed productive assets. It is doubtful, however, if such an approach can be labeled as econometric modeling for the national economy.

**It is interesting to add that four years ago an analysis of the predictive power of that model was made by Artwig (1976) who found, surprisingly enough, that for some of the variables the model still provided fairly good predictions.

While the contributions in the field of macromodeling made during the sixties could be considered mainly as academic experiments, in the seventies models designed for the practical purpose of application in national planning began to appear. In this respect, mention should be made of the work of Kanton (1975) and, especially, that of Maciejewski and Zajchowski (1974) and Maciejewski (1976). A research group at the State Planning Commission built a couple of econometric models which were then used in practice, either for short-term prediction or for evaluation of expected effects induced by different envisaged variants of a medium-term economic plan. The econometric macromodels used by planners in the seventies contained more than 50 variables, and were thus much larger than those of the sixties. Maciejewski's models included as endogenous variables employment, man-hour inputs of labor, sectoral outputs (on the basis of classical econometrics, and not the input–output approach), national-income formation, production fixed assets, foreign trade, balance of payments, income flows, and consumer demand.

Finally, a large econometric model of the Polish economy is being built by Welfe and his team at the University of Lodz. Since the complete model has not yet been published it is difficult to say much about its character. From some of the papers published to date, which present different aspects of the model (see for instance Welfe and Debski 1976), it can be inferred that this model will assume a much higher degree of disaggregation and that it will combine the classical econometric approach with input–output analysis.

None of the models mentioned, however, have made provision for demographic variables. Consequently no analysis of the existing intercorrelations between the sphere of economics and that of demography has been made. To our knowledge, DEMP-1 is the first Polish econometric macromodel to approach this problem.

2 THE ENDOGENOUS VARIABLES

2.1 THE REALM OF THE MODEL

The extent to which DEMP-1 covers the realm of economic and demographic phenomena in Poland rests on two assumptions. First, the model must contain endogenous variables that reflect the process of economic growth of the country and make it possible to study the impact of the economic factors on the demographic factors and *vice versa*. Second, the whole model must be quantifiable (i.e., its parameters must be given numerical values stemming from the statistical estimation of the model) and the estimation must be based on officially published data (in this case data from the Statistical Yearbooks and other publications of the Polish Central Statistical Office).

While the first assumption makes it possible to ignore some phenomena which – although of an economic or demographic nature – are not crucial for the main area of analysis, the second assumption is a more stringent one. As happens in many countries, the system of Polish official statistical data is not wholly consistent with the real needs of econometric modeling and, therefore, data may not be available for some important variables. This precludes the introduction into the model of some of the variables which otherwise should be accounted for.

The various economic and demographic phenomena whose behavior and time variation have been accounted for and analyzed in the framework of the model, i.e., those that represent the endogenous sphere of the model, can be summarized by means of the following blocks of endogenous variables:

1. Employment variables
2. Investment variables
3. National income variables
4. Consumption variables
5. Demographic variables

As can be seen from this list, DEMP-1 does not consider a number of economic phenomena that are usually accounted for in quantitative macromechanism models. First, one should note that the model does not make provision for foreign trade; second, the model does not deal with price formation; and third, there are no financial-flow variables in the model. Thus, the model represents the "real-term" approach and provides no facilities for analysis of any eventual impact on the economy of changing price structures or inflationary trends.

There are three main reasons for this limitation of DEMP-1. The first is the desire to keep the size of the model (as measured by the number of its endogenous variables) within reasonable limits. The second is the problem of gaps in the data (especially for foreign trade). Finally, and perhaps most important, the reason for keeping strictly to the real-term approach is that, in a system of centrally planned economies with no (or almost no) market mechanism, prices do not usually follow a well-defined pattern or even exhibit a stochastic regularity. This is because administrative decisions determine the majority of prices.

While discussing the "real-term" approach it must be noted that DEMP-1 makes one exception to the rule of leaving out price variables. Among the endogenous variables of the model there is one variable that is defined as the consumer price index. Since the level of many individual prices largely determines the level of the standard of living, it was thought advisable to include the equation for this variable in the model. We should note, however, that this equation is only meaningful when the regularity of consumer price formation in the past is considered. Since the majority of prices are state-determined, the correlations observed in the past have no meaning for the future and, therefore, the consumer price index equation has no predictive meaning. In other words, there is nothing to guarantee that future price decisions will be based on considerations similar to those used in the past.*

2.2 THE LEVEL OF DISAGGREGATION

Although DEMP-1 is a highly aggregative model, it nevertheless makes provision for the partitioning of its endogenous variables. There are three main types of disaggregation used in the model; one refers to sectoral composition, another to territorial distribution of inhabitants of the country, and the third to the division of investment data into exogenous and endogenous components.

The sectoral disaggregation leads us to distinguish three separate sectors:

1. Nonagricultural – Sector I
2. Agricultural – Sector II
3. Services (non-productive sector of national economy) – Sector III

*This is a problem which we shall treat more fully in a later section. When modeling a national economy with centrally directed planning, one finds that some endogenous variables are, to a large extent, influenced by administrative decisions, and hence the corresponding model equations are not autonomous in the sense of providing reasonable insight into the future behavior of the given endogenous variable.

This classification follows the material-product concept used in planning and in the collection of statistics in the socialist countries. Thus, the first sector includes industry, construction, transportation, and some other minor components, while the third sector embraces such activities as administration, health services, education, culture, and personal services.

The second type of disaggregation used in the model applies to all demographic and employment variables and considers the rural and urban populations separately.

The model also makes provision for a third, rather special type of disaggregation. This applies to the investment variables which, besides being split according to the sectoral criterion, are also presented as the sum of their endogenous and exogenous parts, each part being statistically measured. This third type of disaggregation stems from a long-standing difficulty which has been present ever since the first attempts at the modeling of centrally planned economies. In some of the models constructed to date, investment has been treated as an endogenous variable, and in some other models as an exogenous variable. While the argument for the first approach is that, to a large extent, the present level of investment is determined by the past level and that, therefore, it is interesting to find out what is the relevant relationship, one cannot discount lightly the argument for the second approach: namely that, in a planned economy, investment is a major decision variable. Since there is much truth in both arguments, a method was found to split total investment data into two components, one representing the endogenous part and one the exogenous part of investment level; this method will be discussed in detail in Chapter 5.

2.3 THE LIST OF ENDOGENOUS VARIABLES OF DEMP-1

We now present the complete list of endogenous variables of the model, together with the corresponding symbol for each variable. These symbols will be used consistently throughout the report.

- Y_1 – national income (computed according to the material-product concept) from Sector I, in billion zlotys, constant prices
- Y_2 – employment (i.e. number of persons employed) in Sector I (excluding peasant-workers), in millions
- Y_3 – employment of peasant-workers in Sector I, in millions
- Y_4 – employment in Sector II, in both private and socialized farms, including estimated part-time work on private farms by family members, in millions
- Y_5 – urban population, in millions on January 1st of each year
- Y_6 – rural population, in millions on January 1st of each year
- Y_7 – total employment in Sector I ($Y_7 \equiv Y_2 + Y_3$), in millions
- Y_8 – national income from Sector II, in billion zlotys, constant prices
- Y_9 – employment in Sector III, in millions

Y_{10} – total employment ($Y_{10} \equiv Y_2 + Y_3 + Y_4 + Y_9$), in millions
Y_{11} – endogenous investment in Sector I, in billion zlotys, constant prices
Y_{12} – endogenous investment in Sector II, in billion zlotys, constant prices
Y_{13} – endogenous investment in Sector III, in billion zlotys, constant prices
Y_{14} – total investment in Sector I, in billion zlotys, constant prices
Y_{15} – total investment in Sector II, in billion zlotys, constant prices
Y_{16} – total investment in Sector III, in billion zlotys, constant prices
Y_{17} – total investment in the whole national economy ($Y_{17} \equiv Y_{14} + Y_{15} + Y_{16}$)
Y_{18} – total national income ($Y_{18} \equiv Y_1 + Y_8$), in billion zlotys, constant prices
Y_{19} – labor productivity in Sector I, in thousand zlotys value-added output per person, constant prices
Y_{20} – labor productivity in Sector II, in thousand zlotys value-added output per person, constant prices
Y_{21} – average labor productivity in Sectors I and II, in thousand zlotys value-added output per person, constant prices
Y_{22} – consumption out of private funds, in billion zlotys, constant prices*
Y_{23} – overall index of consumer prices
Y_{24} – urban birth rate, per 1000 inhabitants
Y_{25} – rural birth rate, per 1000 inhabitants
Y_{26} – urban death rate, per 1000 inhabitants
Y_{27} – rural death rate, per 1000 inhabitants
Y_{28} – net urban in-migration rate, per 1000 inhabitants**

In addition, when considering the reduced form of the model and simulations based upon it, it is useful to introduce yet another auxiliary endogenous variable Y_{29}, the net rural out-migration rate. Variables Y_{28} and Y_{29} have the same numerators while the denominators are different: in the case of Y_{28} the denominator is the urban population total while for Y_{29} the denominator is the rural population total.

Whenever a variable is expressed in constant prices the price system of 1971 has been used. Furthermore, all the endogenous variables which refer to employment levels or indicate demographic rates are measured as yearly averages.

DEMP-1 has altogether 28 endogenous variables. Of these, 9 variables (namely $Y_2, Y_3, Y_4, Y_7, Y_9, Y_{10}, Y_{19}, Y_{20}, Y_{21}$) belong to the employment block, 7 variables form the investment block ($Y_{11}, Y_{12}, Y_{13}, Y_{14}, Y_{15}, Y_{16}, Y_{17}$), 3 variables express national income (Y_1, Y_8, and Y_{18}), 2 variables refer to the

*That is, consumption financed by private financial funds resting in the hands of the population. Variable Y_{22} thus does not include the so-called "social consumption", which is financed directly by the state (education, health care, etc.).

**This is net in-migration in the sense of a surplus of people moving from rural to urban areas over those who move from towns to the countryside.

standard of living (Y_{22} and Y_{23}), and, finally, 7 variables belong to the demographic block. Since 4 variables (Y_7, Y_{10}, Y_{18}, and Y_{21}) are definition totals or averages of other endogenous variables, this eventually reduces the size of the model to 24 autonomous endogenous variables. Thus, the model is of a moderate size.

3 THE EXPLANATORY VARIABLES OF THE MODEL

3.1 THE CHOICE OF EXPLANATORY VARIABLES

Having explained the endogenous variables of the model, something must now be said about the way the structural equations* for these variables were constructed. The approach adopted was to include in a single equation all the explanatory variables that – in the light of existing economic theory – influence the corresponding endogenous variable. Although logically sound, this approach usually yielded too few explanatory variables for an adequate fit of the model to the statistical data used for its estimation.

In order to improve the fit, the following procedure was adopted. For every endogenous variable whose variation was inadequately explained by the variables suggested by economic theory, a tentative list of possible alternative explanatory variables was compiled, the "candidates" in this list being chosen either on the basis of common sense and as working hypotheses or on the grounds of observed high correlation (in absolute value) with the endogenous variable concerned. To illustrate the next stages in the procedure, we will consider in detail the treatment of the list of additional explanatory variables for the national income from Sector I, Y_1.

Let $\{X_i\}$ denote the set of candidates collected to serve as additional explanatory variables for the national income (Y_1). The $\{X_i\}$ variables are chosen by a procedure, first described by Pawlowski (1973), which assumes that the following conditions must be obeyed:

1. All the variables suggested by economic theory must be included as explanatory variables in the equation explaining the behavior of variable Y_1.
2. The equation must provide an adequate fit with the statistical data; therefore if the variables referred to under condition 1 do not give such

*The terminology first introduced by Koopmans (1950) is used throughout this report.

a fit, additional variables from $\{X_i\}$ must be used to ensure the required degree of fit.
3. The explanatory variables which will finally be included in the equation must be as independent of one another as possible.
4. The number of explanatory variables included in the equation must be small. This leads to the conclusion that, from all the possible subsets of explanatory variables from $\{X_i\}$, together with the variables suggested by economic theory, a subset of explanatory variables will be finally adopted which – besides obeying conditions 2 and 3 –contains the minimum number of elements.

With reference to condition 2, let us note that the requirement of adequate fit will usually be a constraint on the coefficient of multiple correlation or on the value of the standard error of the equation. Condition 3, on the other hand, requires all the explanatory variables to be as independent as possible. These requirements are present for two reasons: to avoid multicollinearity and to maximize the amount of information provided by the explanatory variables.* Together with condition 4, condition 3 leads us to consider correlation matrices, e.g. P_j, whose elements consist of correlation coefficients of two types of variables. The first type are variables belonging to a chosen subset of the set $\{X_i\}$, and the second type are explanatory variables suggested by economic theory.

Since the condition of least correlation among the explanatory variables is equivalent to maximizing the determinant of the corresponding matrix of correlation coefficients, it is immediately found that this algorithm leads to the choice of a vector of explanatory variables, e.g. j_0, that satisfies the relation

$$|P_{j_0}| = \max_{\{X_i\}} |P_j| \tag{3.1}$$

To conclude our remarks on the method of choosing the explanatory variables, it should be noted that condition 4, which requires that the number of such variables should be minimized, is especially important when the statistical sample-size is small. This is due to the fact that when statistical data are scarce and the number of explanatory variables (and parameters to be estimated) is large, the standard errors of estimation of these parameters will usually be high, thus endangering the correctness of any inference made from the model.

The approach described in this section applies to all the stochastic equations of the model except when the variables suggested by economic theory provide a sufficiently good fit; this is, however, seldom the case. It should also be noted that, for a number of equations, the set $\{X_i\}$ of possible additional explanatory variables contains only one or two elements, mainly due to the lack of relevant statistical data.

*The impacts of two highly correlated variables are almost parallel, and therefore give little additional information about the mechanism of formation of the dependent variable in the equation.

3.2 THE MAIN TYPES OF EXPLANATORY VARIABLE IN THE MODEL

The explanatory variables appearing in different stochastic equations of the model belong to six distinct groups:

1. Lagged endogenous variables
2. Quantitative, purely exogenous variables
3. Quantitative decision variables
4. Dummy variables of purely exogenous character
5. Dummy variables intricately connected with planning processes
6. Other nonlagged endogenous variables of the model

The lagged endogenous variables are mostly investment variables, and they are extensively used because the investment cycles in the Polish economy are rather long; hence, the effects of investment outlays are delayed. The maximum time-lag used in the model is three years, and this applies to investment in Sector I, i.e., in nonagricultural productive activity. As can be seen from the list of all the predetermined variables of the model (Section 3.4), DEMP-1 also makes use of other lagged endogenous variables, with lags of one or two years.

The group of quantitative, purely exogenous variables has only four members, namely the unit variable, the time variable, the square-of-time variable, and the balance of payments. On the other hand, there are many variables in the third group: the quantitative decision variables. Without enumerating all of them here we shall focus our attention on some which are of special interest. Those of primary importance are the variables representing the level of exogenous investment, either in Sector I or in Sector II. As will be seen later, in the section discussing the results of the estimation of the model, these two "classical" decision variables exert their influence on a number of phenomena, of both an economic and a demographic nature.

Another decision variable of interest is the construction of flats in urban areas.* Such flats are constructed either directly by the state or through cooperatives, and the finance for such activities comes finally from the national budget. This variable was found to have some impact both on the birth rate and on employment levels. New flats in urban areas attract people who have been working only on their private farms and who have decided to take jobs in Sector I, hoping eventually to move permanently to the towns.

DEMP-1 makes extensive use of dummy variables. Since, however, the reasons for introducing such variables are to a large extent connected with the economic system of the country, some of them need to be carefully explained. For this reason we will examine the problem of dummy variables in more detail in the next section.

*As may be easily seen, this variable, if expressed in monetary terms, would represent a part of total investment outlay in Sector III. To avoid the cumbersome problem of price changes in residential construction the variable in question is measured in the model in a quantitative way – in units of 10^3 rooms.

3.3 THE PROBLEM OF DUMMY VARIABLES

The system of centralized economic planning presupposes direct state intervention in economic processes in order to achieve long-term and short-term economic and social policy targets. This means that not all the economic variables are autonomous, in the sense of being free to vary according to regular patterns established in the past. On the contrary, since deviations from planned trajectories occur, the economic system is subject to various interventions, which consist not only of changes of decision variables but also of restrictions or limitations (or encouragements) of particular activities. The consequences of these interventions are that the economic processes (variables) thus affected do not follow a regular pattern over time but instead exhibit some discontinuities.

The easiest and best parameter-saving approach in such a case is to introduce into the model an appropriately defined dummy variable.* During the period 1960–1976 which is covered by the model there occurred various such discontinuities in the growth pattern, so DEMP-1 makes use of a number of appropriate dummy variables.

Two of these variables call for special attention. The first one, X_{22}, is a variable which assumes the value 1 for the years 1971–1976, and zero for all earlier years. The reason for introducing this variable (which, as can be seen from the results of the estimation of the model, proved to be very important) is that in 1971 and subsequent years a special economic and social policy was pursued in Poland. This policy was markedly different from the one followed during the sixties, and consisted, broadly speaking, of fast economic growth coupled with a substantial rise in the standard of living of the population. This new policy not only generated higher investment outlays and a higher consumption level – which could be dealt with in the model by assuming appropriate changes in such variables – but also caused a number of other effects of a more quantitative character (greater efficiency of management, better work motivation, new consumption patterns, attaching new value to family life, etc.). To account summarily for all these changes and discontinuities in the former pattern of economic (and also demographic) processes, it was thought best to introduce into the model a special dummy variable. As will be seen later, the variable X_{22} affects a major part of the endogenous variables of the model. For the sake of easy reference, X_{22} will henceforward be referred to as the "fast economic growth" variable.

Another interesting dummy variable of a similar type is X_{21}, which is the heavy investment variable. For a number of years, heavy investment was pursued as the underlying economic policy. This in turn caused several repercussions that are important enough to be taken into account when modeling the economy; hence the use of X_{21}. This variable is equal to 1 for the years when especially heavy investment outlays were made and equal to 0 for all other

*Dummy variables can also be used if it is thought that policy shifts affect the coefficients of the explanatory variables. See, for instance, Pawlowski (1977).

years. (Note that $X_{22} = 1$ for years when there was both heavy investment and a fast rise in the standard of living, whereas only the first condition is necessary for $X_{21} = 1$.)

The reader must be warned, however, that equations containing such dummy variables as X_{21} or X_{22}, while adequately explaining the past, have only a restricted predictive power. The coefficient of the dummy variable expresses the size of the impact of qualitative factors which are concealed by the dummy variable, but there is nothing to guarantee that similar policy measures will have the same result in the future. Therefore an equation of the model can only be considered as "safe" for predictive purposes if the user predicts that the future will be such that the dummy variables can be set equal to zero.

Finally, let us note that DEMP-1 also has two dummy variables of a purely exogenous character. These are connected with the fact that Polish agriculture is highly sensitive to adverse weather conditions, i.e., to droughts or to heavy rainfalls occurring in the wrong season. Since such bad weather conditions may cause the yield of crops to be as much as 20% lower than their expected level and since low agricultural production usually has far-reaching repercussions, it was thought necessary to introduce appropriate dummies; these later proved to be significant.

3.4 THE LIST OF PREDETERMINED VARIABLES

We now present the complete list of the predetermined variables of the model together with their corresponding symbols.

- X_1 – fixed assets in agriculture, in billion zlotys, constant prices
- X_2 – real wage index in socialized nonagricultural sectors
- X_3 – use of artificial fertilizers in agriculture (100 kg/ha)
- X_4 – difference between X_2 and the index of real per capita income in private agriculture
- X_5 – exogenous investment in Sector I, in billion zlotys, constant prices
- X_6 – exogenous investment in Sector II, in billion zlotys, constant prices
- X_7 – exogenous investment in Sector III, in billion zlotys, constant prices
- X_8 – flats constructed in urban areas, in units of 10^3 rooms
- X_9 – balance of foreign trade (exports – imports), current zlotys
- X_{10} – unit variable
- X_{11} – time variable, assuming the value 1 for 1960, the value 2 for 1961, etc.
- X_{12} – square-of-time variable
- X_{13} – variable Y_1 lagged one year
- X_{14} – variable Y_{14} lagged two years
- X_{15} – variable Y_{14} lagged three years
- X_{16} – variable Y_{15} lagged one year
- X_{17} – variable Y_{15} lagged two years

X_{18} – variable Y_{19} lagged one year

X_{19} – weather dummy variable, assuming the value 1 for years when agricultural yields suffered greatly from exceptionally dry or wet weather, and equal to zero for other years

X_{20} – bad agricultural output dummy variable, assuming the value 1 for years when $Y_{8,t} < Y_{8,t-1}$, and equal to zero for other years

X_{21} – heavy investment dummy variable, assuming the value 1 for years when the policy of especially heavy productive investment was pursued, and equal to zero for other years

X_{22} – fast economic growth dummy variable, assuming the value 1 for the period 1971–1976, and equal to zero for other years

X_{23} – demographic echo dummy variable, assuming the value 1 for years when large generations, born during the post-World War II baby boom, came to maturity and started reproducing; for other years this variable is equal to zero

X_{24} – variable Y_5 lagged one year

X_{25} – variable Y_6 lagged one year

As can be seen, this list contains 25 predetermined variables. Eight of them are lagged endogenous, four are of a purely exogenous character, eight are exogenous to the model but are, at the same time, decision variables, and five are dummy variables.

In Section 5.2, where the method of splitting total investment into its endogenous and exogenous components is presented, some additional predetermined variables will be used. However, since these variables only appear in that section, they are not listed here among the predetermined variables in use for the whole model.

4 THE SAMPLE PERIOD AND THE STATISTICAL DATA

One of the basic assumptions made at the start of this research was that the model would be based on the data which are officially published by the Central Statistical Office of Poland in its Statistical Yearbooks of Poland.

The time-series data used for the estimation of the model cover the period 1960–1976; when the research leading to DEMP-1 started in 1978, statistical data for 1977 and 1978 were not yet available. Although the length of this period is not excessive and a sample of 17 observations is not large, it was thought better to keep to such a restricted sample than to extend it by using the data pertaining to the fifties. The first five or six years of the decade 1950–1959 were still part of the period of post-war reconstruction. The economic and demographic structural parameters at that time may have had substantially different values from the present ones, not only for technological reasons but also due to the significantly different system of economic management that then existed. The last years of the fifties were perhaps not so strikingly different from the present, but, for a number of variables, data were either missing or were compiled on the basis of totally different systems of classification, thus making it necessary to exclude them on comparability grounds. In some cases it was necessary to rework even the data for the period 1960–1976, to ensure either a consistent classification system or a uniform price system.

In the pages which follow, Figures 1–13 illustrate some characteristic features of a number of the model variables, most of which are endogenous in character. In order to show their variation more clearly, all the variables have been expressed as indexes, based on a 1960 index level of 100. Moreover, particular figures usually show indexes of two or three variables which are either logically related or are otherwise of interest for simultaneous analysis.

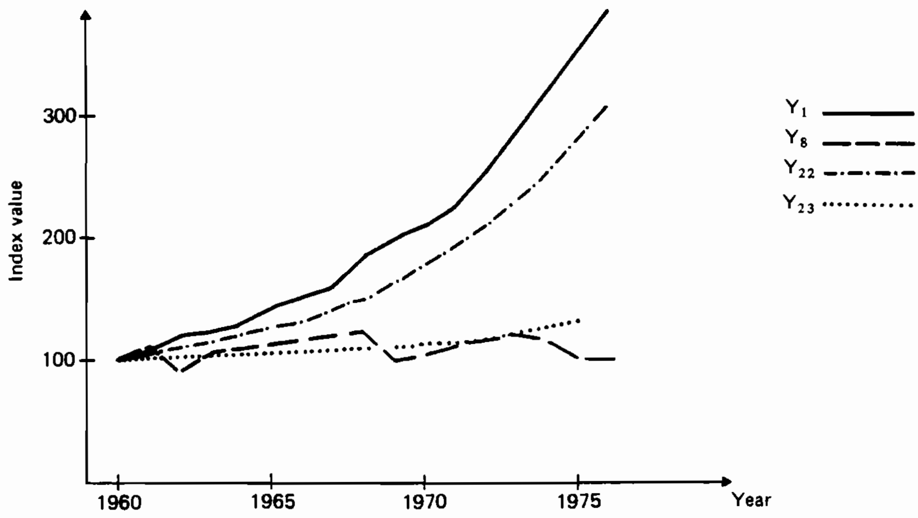

FIGURE 1 National income and consumption variables.

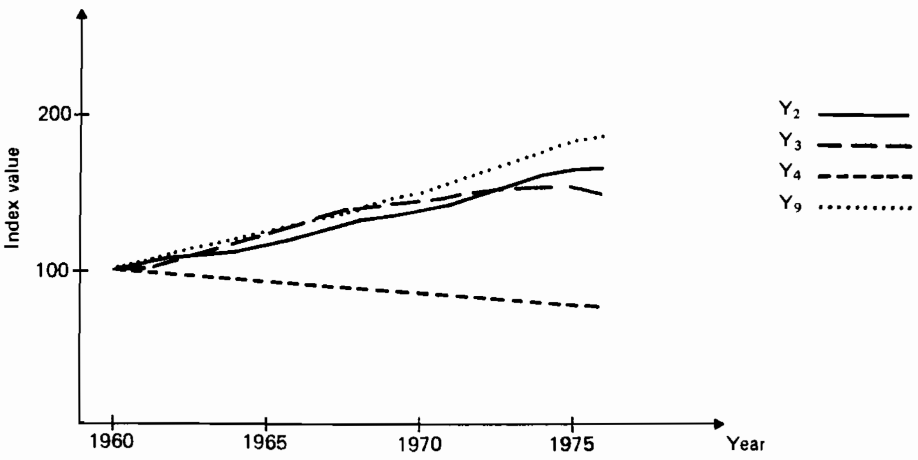

FIGURE 2 Employment variables.

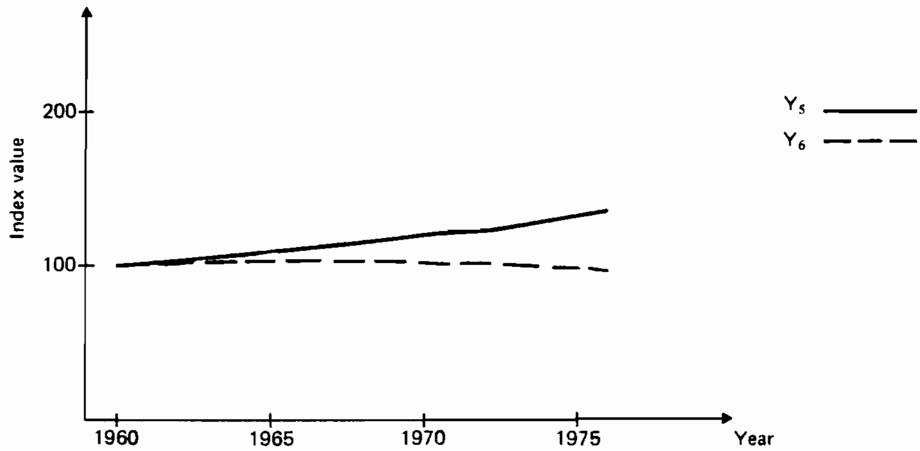

FIGURE 3 Population variables.

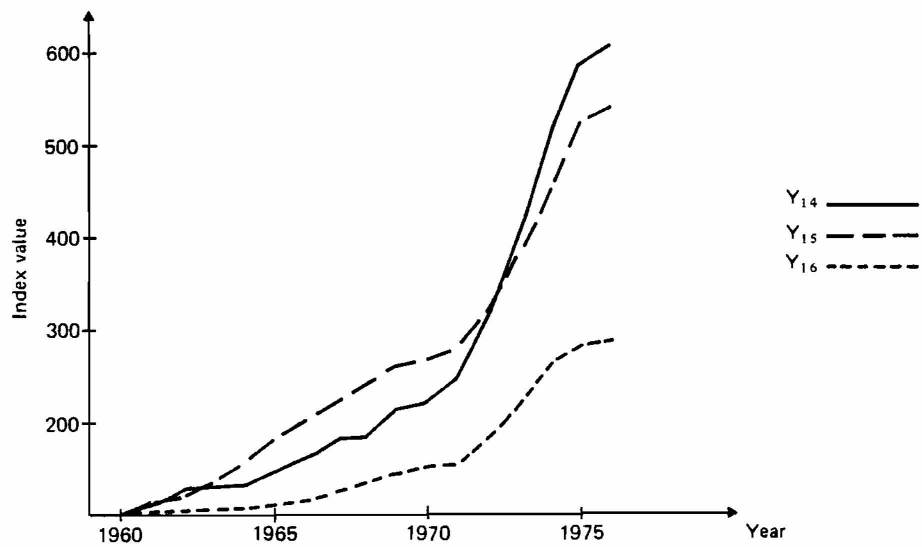

FIGURE 4 Total investment variables.

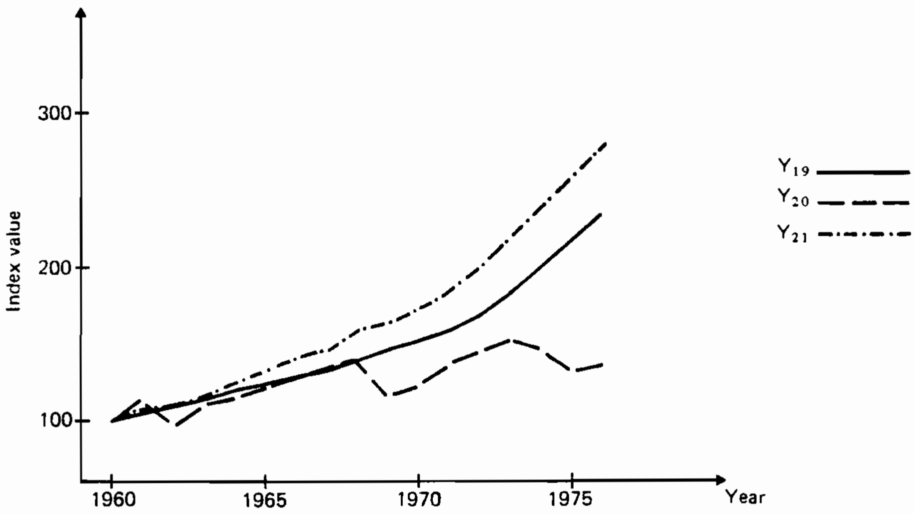

FIGURE 5 Labor productivity variables.

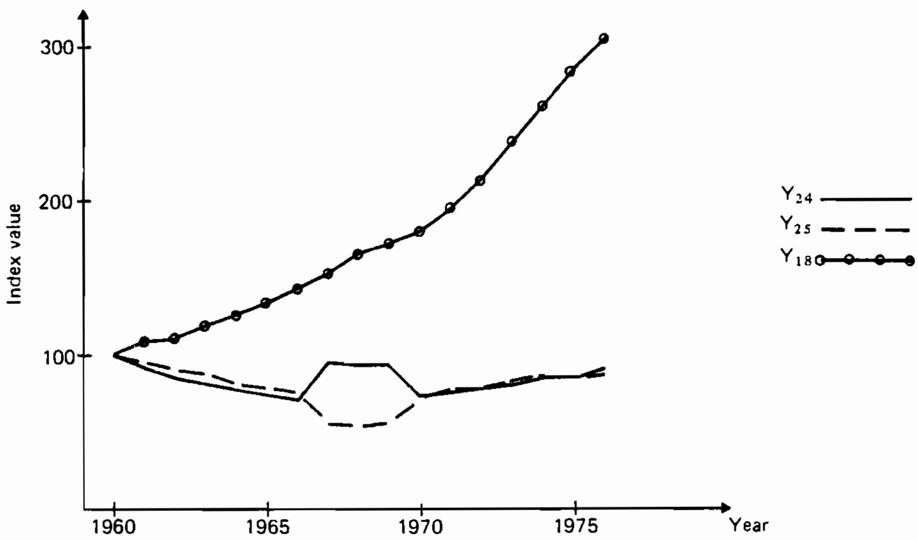

FIGURE 6 Birth rate variables and total national income.

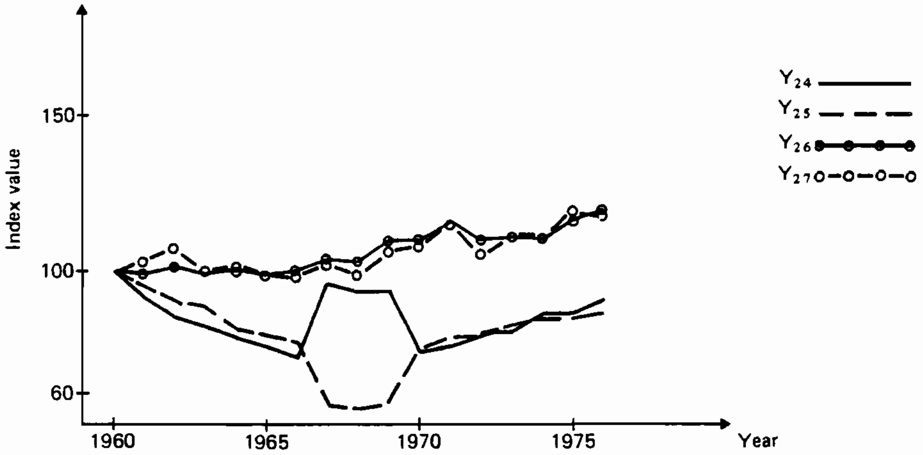

FIGURE 7 Birth rate and death rate variables.

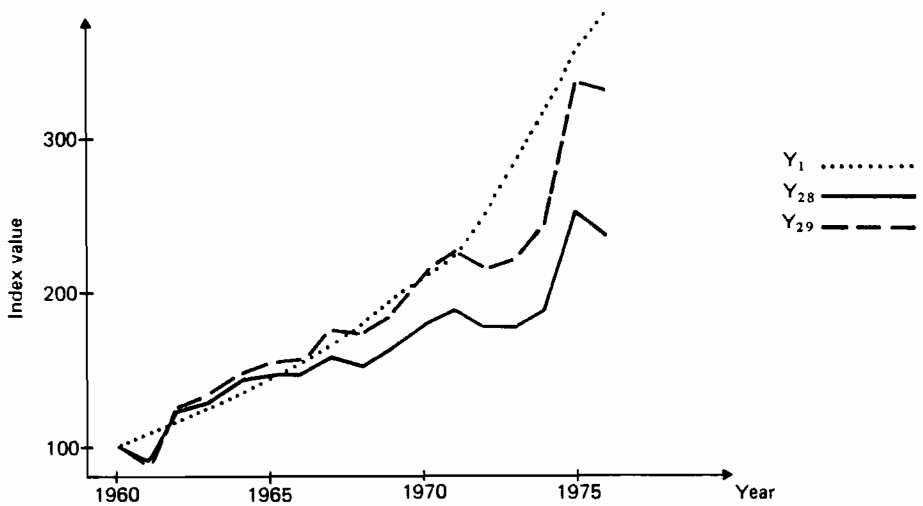

FIGURE 8 National income from Sector I and rates of rural out-migration and urban in-migration.

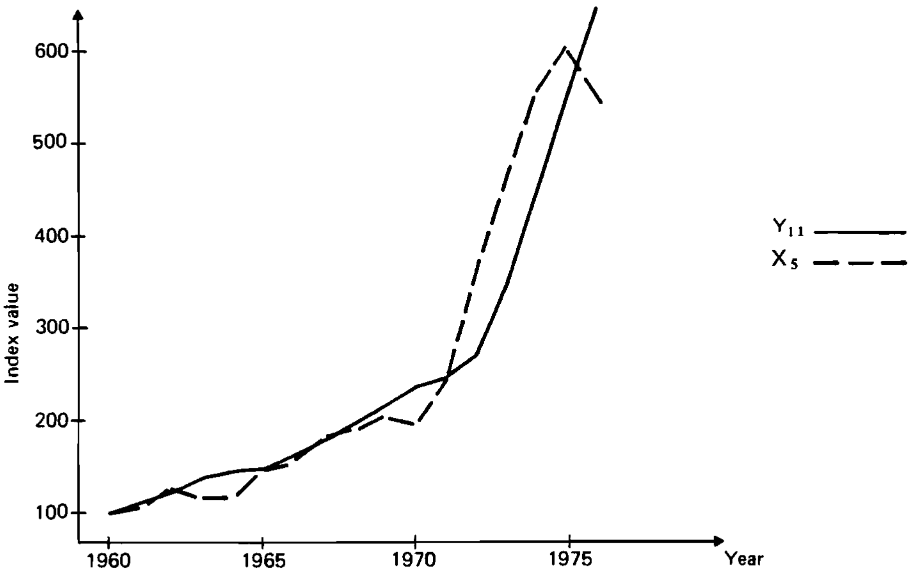

FIGURE 9 Endogenous and exogenous investment in nonagricultural productive sectors.

FIGURE 10 Endogenous and exogenous investment in agriculture.

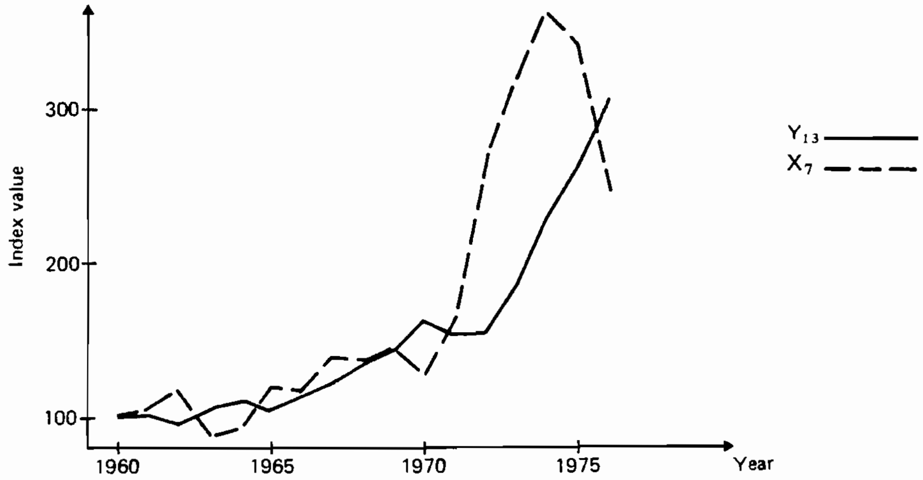

FIGURE 11 Endogenous and exogenous investment in services.

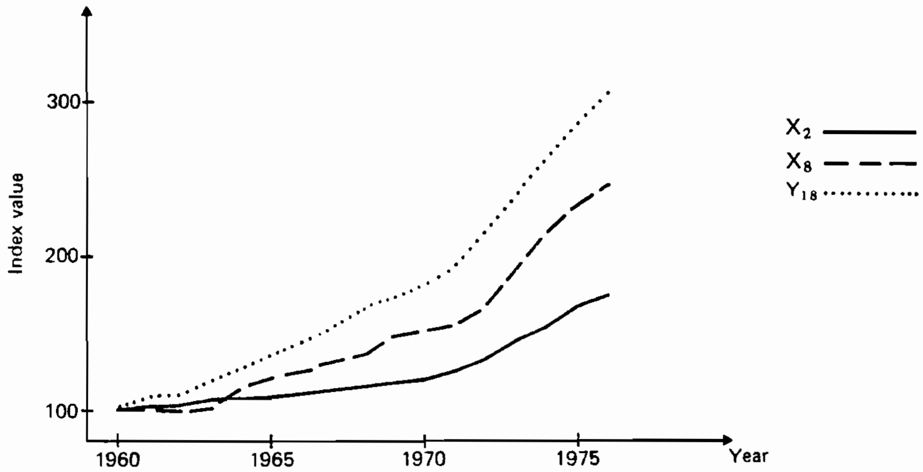

FIGURE 12 Real wages, construction of flats, and national income.

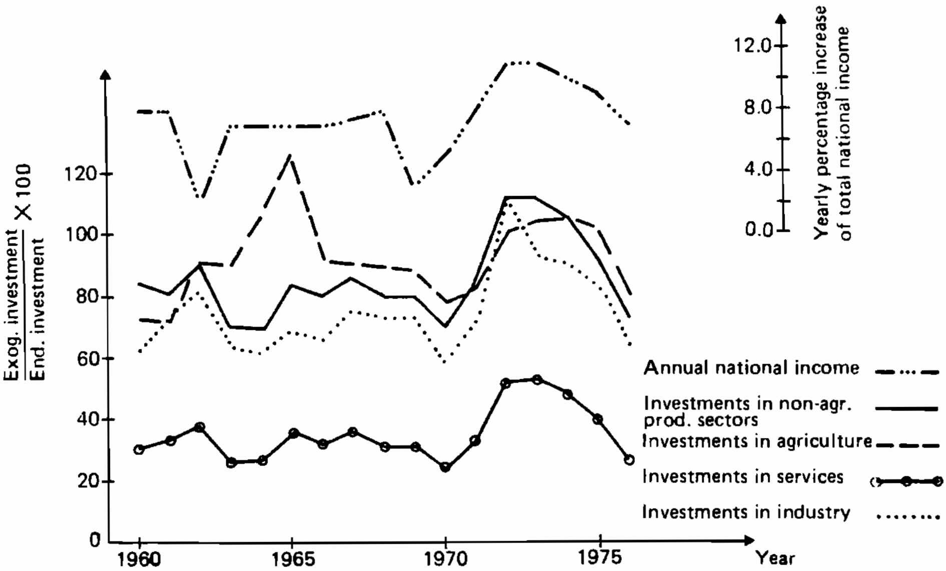

FIGURE 13 Percentage ratio of sectoral exogenous investment to sectoral endogenous investment.

5 ENDOGENOUS AND EXOGENOUS INVESTMENT

5.1 THE PROBLEM

When the various disaggregations used in the model were discussed in Section 2.2, it was pointed out that the sectoral total investment variables were split into two components: endogenous and exogenous investment.

The rationale underlying such an approach is twofold. First, one must take into account the fact that, in every country with a centrally planned economy, investment is one of the key decision variables. Every year, large financial outlays are made by the state to finance investment. The level and the distribution of these outlays depend on the economic policy which, in turn, is assumed to achieve optimal targets stemming from long-range economic and social policies and not from current needs. On the other hand, not all investment outlays are exogenous. Some are influenced by previous investment outlays. Since the average length of the investment cycle is significantly longer than one year, investment activities started in the past are not all finished before the beginning of the current year. This means that if such investments are not being discontinued (which would usually involve some serious loss) they must still be financed. Thus we arrive at the concept of the endogenous part of total investment as that which is induced by previous investment outlays:

$$\text{Total investment} = \text{endogenous investment} + \text{exogenous investment} \tag{5.1}$$

The statistical data published by official authorities, however, make no such distinction and always refer to the total investment. A method, therefore, had to be found to perform the disaggregation shown in Eq. (5.1), and our solution to this problem is presented in the next section.

5.2 THE METHOD OF ESTIMATING THE ENDOGENOUS INVESTMENT

From the discussion above, the model for determining the endogenous part of investment in year t should have the following general form:

$$J_{\text{end},t} = f(J_{\text{total},t-1}, J_{\text{total},t-2}, \ldots, J_{\text{total},t-c}) \tag{5.2}$$

where $J_{\text{end},t}$ denotes endogenous investment in year t, $J_{\text{total},t-i}$ denotes total investment i years prior to year t, and c is a positive integer such that investment cycles of length greater than c occur extremely infrequently. The practical difficulties connected with this model are not negligible. The integer c is usually not known and, even if it were, the number of variables on the right-hand side of Eq. (5.2) would normally be so large that a problem would still exist. For this reason it was necessary to look for other models which, although simpler, would still provide a good approximation for the estimation of endogenous investment.

After experimenting with the data, a more simple one-year-lag model was found. This simpler model assumes that there is a relation between total investment shares in national income during two consecutive years and that, eventually, such shares also depend on an exogenous variable. Such a model can be written as

$$\frac{J_{\text{total},t}}{Y_{18,t}} = \alpha_1\left(\frac{J_{\text{total},t-1}}{Y_{18,t-1}}\right) + \alpha_2 X_t + \alpha_3 \tag{5.3}$$

where Y_{18} denotes total national income (see Section 2.3), X stands for the auxiliary exogenous variable, and $\alpha_1, \alpha_2, \alpha_3$ are constant parameters. Once the model has been estimated, i.e., once the numerical estimates a_1, a_2, a_3 of α_i parameters are known, the endogenous part of the investment in year t can be computed as

$$J_{\text{end},t} = \alpha_1 J_{\text{total},t-1}\left(\frac{Y_{18,t}}{Y_{18,t-1}}\right) \tag{5.4}$$

After the endogenous investment has been estimated, one can then deduce the level of exogenous investment from the total investment, by using Eq. (5.1).

5.3 ESTIMATION OF INVESTMENT RELATIONS

Total investment figures were divided into their endogenous and exogenous parts for all three sectors studied. Furthermore, and just for curiosity's sake, the same experiment was performed with the statistical data referring to total investment allocated in industry (note that industry is a subsector of Sector I in DEMP-1). The results of the estimation of the model shown in Eq. (5.3) for these four cases were as follows:

For Sector I:

$$\frac{J_{\text{total},t}}{Y_{18,t}} - 0.229 = 0.6063\left(\frac{J_{\text{total},t-1}}{Y_{18,t-1}} - 0.222\right) + 0.0435(X_{22} - 0.294) \tag{5.5}$$

where X_{22} is the fast economic growth dummy variable defined in Section 3.3.

For Sector II:

$$\frac{J_{\text{total},t}}{Y_{18,t}} - 0.045 = 0.5758\left(\frac{J_{\text{total},t-1}}{Y_{18,t-1}} - 0.0434\right) + 0.001174\, X'_{11} \tag{5.6}$$

where X'_{11} is a time variable defined in a slightly different way from that in Section 3.4: X'_{11} is equal to –7.5 in 1961, –6.5 in 1962, etc., and finally $X'_{11} = +7.5$ in 1976.

For Sector III:

$$\frac{J_{\text{total},t}}{Y_{18,t}} - 0.236 = 0.3272\left(\frac{J_{\text{total},t-1}}{Y_{18,t-1}} - 0.226\right) + 0.0042(X_{26} - 0.3125) \tag{5.7}$$

where X_{26} is a dummy variable assuming the value 1 in the years 1970–1976 and equal to zero for other years; thus X_{26} differs from X_{22} in only one respect, namely that for 1970 $X_{26} = 1$ while $X_{22} = 0$. Variable X_{26} reflects a shift in economic policy connected with encouraging increased employment in Sector III.

For the industrial sector alone:

$$\frac{J_{\text{total},t}}{Y_{18,t}} - 0.143 = 0.6371\left(\frac{J_{\text{total},t-1}}{Y_{18,t-1}} - 0.137\right) + 0.0338(X_{22} - 0.3125) \tag{5.8}$$

where, again, X_{22} is the fast economic growth dummy variable.

Under the assumption that the rate of growth of national income is approximately constant over a period of time, one can easily use Eq. (5.4) to estimate the average length of the sectoral investment cycle. For instance, if we put $Y_{18,t}/Y_{18,t-1}$ numerically equal to 1.06, we can rewrite Eq. (5.4) as

$$J_{\text{end},t} = 1.06 \cdot a_1 \cdot J_{\text{total},t-1} \tag{5.9}$$

where a_1 stands for the estimate of α_1. By using the geometric series sum formula and substituting the value of a_1 from Eqs. (5.5)–(5.8), we find that the average length of investment cycle in Sector I is almost 2.75 years, in Sector II it is 2.6 years, in Sector III it is as great as 8.1 years, and in the industrial sector taken separately it is 3.1 years.

6 THE ESTIMATION OF THE MODEL

6.1 THE STRUCTURAL FORM OF THE MODEL

Before going into details of the estimation results for all the equations of DEMP-1, it seems advisable to describe first the general shape of the model. The equations presented below correspond to the subsets of explanatory variables which were thought most appropriate in view of the procedure adopted when building the equations (see Section 3.1).

The model is predominantly linear, with only two exceptions: the variables Y_5 and Y_6. The fact that the majority of the equations are linear does not stem from a personal belief that the various interrelations are in fact linear, but rather it is a necessary result of the small size of the statistical sample (time-series data referring to only 17 yearly observations). When presenting the structural form, the symbol L is used for a linear relation, whereas the non-linear relations have been explicitly written down. The symbol ξ denotes the random component of each stochastic equation. As usual, ξ has been assumed to be a random variable with zero expectation and finite variance for every such equation.

If straightforward identities are excluded, the model contains 15 equations to be estimated. Of these, 7 are interdependent linear equations, and 8 are either linear recursive or are such that the endogenous variable explained by the equation depends only on the predetermined variables.

$$Y_1 = L(Y_7, X_{10}, X_{13}, X_{14}, X_{15}, X_{22}, \xi)$$
$$Y_2 = L(Y_1, Y_5, X_{10}, X_{11}, \xi)$$
$$Y_3 = L(Y_1, Y_{14}, X_2, X_8, X_{10}, \xi)$$
$$Y_4 = L(Y_6, Y_{15}, X_{10}, X_{22}, \xi)$$
$$Y_5 \equiv \left(1 + \frac{Y_{24} - Y_{26} + Y_{28}}{1000}\right) X_{24}$$
$$Y_6 \equiv \left(1 + \frac{Y_{25} - Y_{27} - Y_{29}}{1000}\right) X_{25}$$

$$
\begin{aligned}
Y_7 &\equiv Y_2 + Y_3\\
Y_8 &= L(X_1, X_3, X_{10}, X_{19}, X_{22}, \xi)\\
Y_9 &= L(Y_1, Y_5, Y_{22}, X_{10}, \xi)\\
Y_{10} &\equiv Y_2 + Y_3 + Y_4 + Y_9\\
Y_{14} &\equiv Y_{11} + X_5\\
Y_{15} &\equiv Y_{12} + X_6\\
Y_{16} &\equiv Y_{13} + X_7\\
Y_{17} &\equiv Y_{14} + Y_{15} + Y_{16}\\
Y_{18} &\equiv Y_1 + Y_8\\
Y_{19} &= L(X_{10}, X_{13}, X_{18}, \xi)\\
Y_{20} &= L(X_{10}, X_{16}, X_{17}, X_{19}, \xi)\\
Y_{21} &\equiv \alpha(t)Y_{19} + [1 - \alpha(t)]Y_{20}\\
Y_{22} &= L(Y_8, Y_{20}, Y_{23}, X_{10}, X_{20}, X_{22}, \xi)\\
Y_{23} &= L(Y_8, Y_{10}, X_9, X_{10}, \xi)\\
Y_{24} &= L(Y_{22}, X_{10}, X_{22}, X_{23}, \xi)\\
Y_{25} &= L(Y_{22}, X_{10}, X_{22}, \xi)\\
Y_{26} &= L(Y_1, X_{10}, X_{11}, X_{12}, \xi)\\
Y_{27} &= L(Y_8, X_{10}, X_{11}, X_{12}, \xi)\\
Y_{28} &= L(Y_{14}, X_4, X_{10}, X_{21}, \xi)
\end{aligned}
$$

The equations for the variables Y_{11}, Y_{12}, and Y_{13} do not appear here since these variables (sectoral endogenous investments) have been dealt with using the method described in Sections 5.2 and 5.3. It should also be noted that the variable Y_{21} is defined by means of an identity which assumes the form of a weighted average with the weights changing over a period of time. This is because Y_{21} represents the average level of labor productivity, and this level depends on the relative (variable over a period of time) shares of Sector I and Sector II.

6.2 THE METHODS OF ESTIMATION OF STRUCTURAL EQUATIONS

Because of the system of interrelations among the nonlagged endogenous variables dictated by the structural form of the model, two different methods of parameter estimation had to be used. For the recursive equations and for the equations with only predetermined endogenous variables, the ordinary least-squares method was used. As can be seen from the shape of the structural equations presented in Section 6.1, this procedure was appropriate for variables $Y_8, Y_{19}, Y_{20}, Y_{22}, Y_{24}, Y_{25}$, and Y_{28}.

All the remaining nonlagged endogenous variables form the interdependent part of the model, so that use of the ordinary least-squares method would yield biased estimates. It was therefore decided to use the double-least-squares method instead (see, for example, Theil 1961).

However, one further remark must be made in this context. Since the 17-observation sample size is smaller than the total number of predetermined variables appearing in the model, the moment matrix $X_K' X_K$ of these predetermined variables would be singular, and consequently, it would not be possible to obtain estimates of the parameters of the interdependent structural relations.

For this reason the size of the matrix $X_K'X_K$ was reduced with respect to the number of predetermined variables. This resulted in the use of a submatrix in order to express the explanatory endogenous nonlagged variables as a function of the model's predetermined variables. This submatrix, denoted for example by $\hat{X}_K'\hat{X}_K$, was obtained as follows:

1. All the lagged endogenous variables were omitted from $X_K'X_K$.
2. Submatrix $\hat{X}_K'\hat{X}_K$ was assumed to be a 10×10 matrix composed of exogenous variables that had a large variance and had little correlation with each other.*

Besides calculating the values of the parameter estimates by both methods of estimation, two goodness-of-fit parameters were computed. The first one was the standard error of the equation – denoted by s – and the second was the so-called coefficient of random variation, defined as the percentage ratio of s to the observed arithmetic mean value of the variable whose variations were explained by the equation in question. This coefficient of random variation will be denoted by C.

Standard errors of estimation of structural parameters were also computed, and these are given in Section 6.3, as values in parentheses under the corresponding parameter estimates. These standard errors, however, are of only limited informative value since they were computed by using the classical formulas which assume a lack of autocorrelation between the random components. In fact, for almost half of the estimated equations the value of the Durbin–Watson statistic was found to be less than 2.0, a fact which suggests the existence of positive first-order autocorrelation of ξ_t.

6.3 THE RESULTS OF THE ESTIMATION

In this section we present the results of the estimation of the stochastic structural equations of the model, for each equation in turn. For the sake of simplicity, the symbol representing the random component has been omitted from each equation. These results are as follows:

$$\begin{aligned} Y_1 = &\underset{(102.6)}{-61.097} + \underset{(22.2)}{9.274}Y_7 + \underset{(0.29)}{1.147}X_{13} + \underset{(0.74)}{0.516}X_{14} - \underset{(0.51)}{1.217}X_{15} \\ &+ \underset{(12.4)}{21.496}X_{22} \end{aligned} \tag{6.1}$$

*The choice of 10 as the number of exogenous variables forming the submatrix $\hat{X}_K'\hat{X}_K$ was somewhat arbitrary. On the other hand, with the total number of such variables in the model being almost twice as large (17), this restriction leads to the construction of a submatrix $\hat{X}_K'\hat{X}_K$ which is numerically well-behaved, i.e., nonsingular.

$$\begin{aligned} Y_2 = {} & \underset{(4.5)}{13.287} + \underset{(0.007)}{0.0024}Y_1 + \underset{(0.33)}{0.557}Y_5 + \underset{(0.07)}{0.326}X_{11} \end{aligned} \tag{6.2}$$

$$Y_3 = \underset{(0.62)}{1.024} + \underset{(0.0005)}{0.0013}Y_1 + \underset{(0.0013)}{0.0015}Y_{14} - \underset{(0.007)}{0.0092}X_2 + \underset{(0.0066)}{0.0005}X_8 \tag{6.3}$$

$$Y_4 = \underset{(4.4)}{27.080} - \underset{(0.28)}{0.974}Y_6 - \underset{(0.005)}{0.044}Y_{15} - \underset{(0.20)}{0.538}X_{22} \tag{6.4}$$

$$Y_8 = \underset{(18.5)}{140.826} + \underset{(0.006)}{0.076}X_1 + \underset{(0.13)}{0.391}X_3 - \underset{(3.9)}{21.224}X_{19} - \underset{(6.8)}{12.473}X_{22} \tag{6.5}$$

$$Y_9 = \underset{(0.43)}{-1.694} + \underset{(0.0007)}{0.00045}Y_1 + \underset{(0.03)}{0.209}Y_5 + \underset{(0.0009)}{0.00051}Y_{22} \tag{6.6}$$

$$Y_{19} = \underset{(8.5)}{26.492} + \underset{(0.02)}{0.079}X_{13} - \underset{(0.33)}{0.115}X_{18} \tag{6.7}$$

$$Y_{20} = \underset{(0.48)}{10.079} - \underset{(0.13)}{0.088}X_{16} + \underset{(0.12)}{0.220}X_{17} - \underset{(0.51)}{1.914}X_{19} \tag{6.8}$$

$$\begin{aligned} Y_{22} = {} & \underset{(491.3)}{-1711.2} + \underset{(0.04)}{0.076}Y_8 - \underset{(36.4)}{13.084}Y_{20} + \underset{(4.8)}{24.253}Y_{23} - \underset{(2.4)}{7.125}X_{20} \\ & + \underset{(29.4)}{112.314}X_{22} \end{aligned} \tag{6.9}$$

$$Y_{23} = \underset{(14.3)}{-30.493} - \underset{(0.04)}{0.070}Y_8 + \underset{(0.8)}{6.431}Y_{10} - \underset{(0.2)}{0.235}X_9 \tag{6.10}$$

$$Y_{24} = \underset{(1.7)}{16.266} + \underset{(0.00004)}{0.00019}Y_{22} + \underset{(0.8)}{0.042}X_{22} + \underset{(1.1)}{2.446}X_{23} \tag{6.11}$$

$$Y_{25} = \underset{(3.3)}{24.339} - \underset{(0.08)}{0.0122}Y_{22} + \underset{(3.2)}{5.407}X_{22} \tag{6.12}$$

$$Y_{26} = \underset{(0.7)}{8.287} - \underset{(0.002)}{0.0041}Y_1 - \underset{(0.004)}{0.0053}X_{11} + \underset{(0.007)}{0.0175}X_{12} \tag{6.13}$$

$$Y_{27} = \underset{(0.9)}{10.244} - \underset{(0.008)}{0.018}Y_8 - \underset{(0.007)}{0.0132}X_{11} + \underset{(0.003)}{0.0058}X_{12} \tag{6.14}$$

$$Y_{28} = \underset{(0.6)}{5.587} + \underset{(0.005)}{0.020}Y_{14} + \underset{(0.003)}{0.006}X_4 - \underset{(0.72)}{0.139}X_{21} \tag{6.15}$$

TABLE 1 Parameters of goodness-of-fit.

Endogenous variable	Parameters of fit s	C(%)	Endogenous variable	Parameters of fit s	C(%)
Y_1	10.92[a]	1.7	Y_{22}	24.27[a]	4.5
Y_2	0.13[b]	2.3	Y_{23}	1.67[c]	1.7
Y_3	0.03[b]	4.5	Y_{24}	1.56[d]	9.3
Y_4	0.20[b]	2.0	Y_{25}	2.08[d]	10.5
Y_8	5.69[a]	4.4	Y_{26}	0.18[d]	2.3
Y_9	0.04[b]	2.0	Y_{27}	0.28[d]	3.3
Y_{19}	0.82[e]	1.2	Y_{28}	1.11[d]	12.0
Y_{20}	0.83[e]	6.5			

[a]Billions of zlotys, 1971.
[b]Millions of persons.
[c]Index points, based on 1960 value = 100.
[d]Persons per 1000 inhabitants.
[e]Thousands of zlotys per person.

The parameters s and C, which summarize the goodness-of-fit of the estimated equations, are presented in Table 1.

6.4 SOME COMMENTS ON THE ESTIMATION RESULTS

Although the estimated structural equations themselves provide the most precise information about the quantitative relations which exist between the variables representing economic and demographic phenomena in Poland, it seems, nevertheless, worthwhile and necessary to comment further upon some of them.

As shown by Eq. (6.1), which explains the variations of Y_1, national income stemming from Sector I is strongly dependent on labor inputs and on lagged investments in that sector. The negative sign of the coefficient of X_{15} (the variable representing investments lagged three years) can probably be explained by frequent shifts of economic policy on the intensity of investments and the rate of growth of output. Also of interest is the positive coefficient of the fast economic growth dummy variable X_{22}. Its relatively high value shows that the new economic and social policy pursued in the years 1971–1976 produced visible results and helped to speed up economic growth in the area of nonagricultural productive activity. To conclude our comments on the Y_1 equation, it should be noted that, since X_{13} denotes Y_1 lagged one year and since the coefficient of X_{13} is very near to 1.0, Eq. (6.1) can explain *changes* in nonagricultural national income rather than its absolute value.

In Eq. (6.2), which explains the behavior of Y_2, all the estimated coefficients have the correct signs. There is obviously a positive feed-back from the level of production (represented here by Y_1) to employment and, in fact, the corresponding coefficient is positive. The positive coefficient of Y_5 can be interpreted as reflecting the policy of full employment pursued in Poland. This policy is found to influence about 55% of the urban population increase to take up employment in Sector I; the remaining 45% are either employed in Sector III or are not formally employed (e.g., students, married women with children). Out-migration from the towns to rural areas is negligible. Finally, it should be noted that the equation for Y_2 contains also a time trend which has been introduced because, over the period studied, the work participation coefficient of women has been steadily increasing.

The equation explaining Y_3, Eq. (6.3), is interesting because it illustrates the specifically Polish phenomenon of peasant-workers. The inflow of such people to Sector I is found to depend positively on three factors. As evidenced by the estimated equation, the number of peasant-workers is regulated not only by the level of economic activity in Sector I but more particularly by the level of investment in this sector.* The third factor to affect the number of peasant-workers is the level of housing construction in urban areas. This can be explained by the fact that many peasants start working in nonagricultural firms, having in mind the future possibility of leaving their farms, and emigrating to urban areas (this applies especially to young people). Obviously, the fact that housing construction is more intensive increases the chances that potential migrants will be able to obtain urban housing, and therefore encourages them to take such steps. Less obvious is the interpretation of the negative sign connected with variable X_2. Perhaps this arises because the periods of fast growth in wage-rates have coincided with the periods when private farming enjoyed prosperity and its outlook for the future was also bright. These good prospects for private farming may have been a factor reducing the willingness to emigrate to urban areas.

Variable Y_4 was defined as employment in agriculture. As can be seen from Eq. (6.4), the level of employment in this sector is influenced by the amount of investment in the sector and by the general level of economic activity. The establishment of the new policy of fast and intensive economic growth at the beginning of 1971 created many new jobs, particularly in the industrial and building sectors. Owing to the lower birth rate, the size of new generations in towns has always been noticeably smaller than in rural areas, and, since there were no reserves in manpower in urban areas (except for the natural reserves due to new generations reaching maturity), the additional workers for Sector I had to be found in rural areas. The negative coefficient of variable Y_6 provides an insight into the autonomous mechanism of emigration to the towns. With improved investment policies, agriculture now does not need as many people to work in the fields and raise cattle as it did in previous years.

The next stochastic equation to be estimated, Eq. (6.5), is that for variable Y_8, which represents national income generated in Sector II. As may be expected, such income depends positively on fixed assets and on the amount of fertilizer used. On the other hand, Y_8 depends negatively on X_{19} and X_{22}. The first of

*It should be noted that a large proportion of the peasant-workers are hired by construction firms for which they provide the unskilled labor force, still very much in demand.

these variables is a dummy, taking the value 1 in the years of unfavorable weather conditions, so it is no surprise that its coefficient is negative. The second, X_{22}, is the fast economic growth dummy variable and therefore one should expect its coefficient to be positive. Unfortunately, however, this dummy variable only proved to be significant as far as Sector I is concerned. For half of the years, when $X_{22} = 1$, the variable X_{19} also assumed the value 1, which means that while the policy of fast growth was pursued, adverse weather conditions for agriculture were very often present. Hence the relevant coefficient proved to be negative.*

As may be seen from Eq. (6.6), the variable Y_9, i.e., employment in services, depends on Y_1, Y_5, and Y_{22}. The first of these variables has a positive coefficient, and this is justified by the fact that economic planners consider services as a sector subordinate to industrial and related activities. This means that services are supposed to expand in relation to the overall level of nonagricultural activity. The coefficient of Y_5 shows that about 20% of the urban population increase is used as an addition to the labor force in Sector III. Finally, the positive coefficient of Y_{22} reflects the situation arising when an increase in the private consumption fund is coupled with an increase in that part of Sector III that provides direct services to individuals.

The equation explaining Y_{19}, Eq. (6.7), is of a simple, autoregressive character. Labor productivity in Sector I is seen to depend on its previous level, but since the corresponding coefficient is negative, one infers that this productivity tends to oscillate when all other factors remain constant. The other explanatory variable is X_{13}, which is really a proxy for one-year lagged investments in Sector I. The positive and statistically significant coefficient of X_{13} shows that such investment plays an active role and causes labor productivity to increase.

The level of labor productivity in agriculture is also found to be dependent on investment [Eq. (6.8)]. Attention should be paid, however, to the negative sign of the coefficient of X_{19} which is the bad weather dummy variable. In fact, the impact of adverse weather conditions – as we have already mentioned in Section 1.2 – is very serious.

The equation reflecting the mechanism of Y_{22}, Eq. (6.9), is of interest. We find that the level of private consumption is very sensitive to the agricultural production level, i.e., to the level of the domestic food supply. The large and positive coefficient of X_{22} reflects the fact that 1971–1976 was a period when much was done to increase private consumption. On the other hand, it is more difficult to explain the positive dependence of Y_{22} on the level of consumer prices. However, one is tempted to advance the opinion that the results of the estimation reflect a specific phenomenon. The substantial increase in the population's income, which occurred during a period when the supply of consumer

*This, by the way, is a good example of what has already been pointed out, namely that equations with dummies specific to central planning are seldom of a predictive character. In fact, there is no reason to suppose that a future policy of fast economic growth in Sector I would result in the level of national income derived from agriculture declining.

goods did not increase enough to satisfy demand, was coupled with price increases. Because of a strong desire to increase their levels of consumption, the consumers spent more (in real terms) even when the level of prices rose.

The level of consumer prices Y_{23} [described by Eq. (6.10)] depends on agricultural production, on the balance of foreign trade, and on variable Y_{10}. In the first two cases the coefficients are negative as expected. An improved home supply of food provides no stimulus for price increases and a better foreign trade situation means that price increases to cut consumption are not necessary. A more detailed explanation is needed with respect to Y_{10}, i.e., total employment. This variable can be considered as a proxy for the total amount of income earned by the population, which – in the existing situation of limited supply of consumer goods – is an important price-inflating factor. Thus, the whole equation for variable Y_{23} can be thought of as reflecting the mechanism used for equilibrating the purchasing power of the population with the supply of consumer goods, with food always being the most important item of private consumption.

Eqs. (6.11)–(6.15), that pertain to variables $Y_{24}-Y_{28}$, explain the observed variations of the demographic variables of DEMP-1. It is fair to say that, although these variables do show some degree of dependence on economic factors, one might have hoped that they would show a stronger dependence and thus a lower level of random variation.

It is interesting to note that the birth rates in urban and rural areas react in different ways to a rise in private consumption. While in towns an increase in private consumption is found to stimulate births, the opposite effect occurs in rural areas where a better standard of living means less babies. Both Y_{24} and Y_{25} depend positively on the variable X_{22}. This can be explained by the fact that the new economic and social policy started in 1971 has had, among other targets, the aim of attaching more value to family life and larger families.

The equations pertaining to urban and rural death rates (variables Y_{26} and Y_{27}), Eqs. (6.13) and (6.14), show these rates to depend negatively on economic growth (variables Y_1 and Y_8, respectively). This seems logical since better economic conditions induce better living conditions and more sophisticated health care. It should not be overlooked, however, that in both equations there is a quadratic trend and the coefficient of variable X_{12}, i.e., of the square-of-time variable, is positive. This means that, in spite of the favorable influence of economic growth on death rates, there is a tendency for these rates to increase in the future. This long-term upward trend may be due to at least two factors. One is the aging of the population, causing the proportion of old people (for whom the probabilities of death are obviously higher) to increase with time. The second may be connected with air pollution and other industrial side effects.

The last stochastic equation of the model, Eq. (6.15), pertains to migrations from rural to urban areas (involving variable Y_{28}). Here again, the coefficients connected with the explanatory variables have the correct signs. Migration is found to be positively correlated with the level of investments in Sector I:

it has already been pointed out that increasing the level of investments creates an incentive for migration, both because in-migrants from rural areas find many jobs in the building sector and because investments mean new, larger-scale non-agricultural productive activity. The migration variable is also found to depend positively on the urban–rural wage differential (variable X_4). This, it should be pointed out, is in strong contrast to the behavior of peasant-workers, whose decisions to take a second job do not depend on wage considerations. Perhaps the reason is that while peasant-workers can still count on the income derived from their farms, emigrants from rural areas must rely solely on the monetary income derived from their work in the towns. Finally, variable Y_{27} is found to depend negatively on variable X_{21}, i.e., on the heavy investment dummy variable. This is quite understandable. In past years when heavy investment outlays in productive sectors (and especially in Sector I) were made, the construction of housing facilities was noticeably slowed down and this – by cutting down the supply of potential new accommodation – induced a decrease in the level of migration.

7 THE REDUCED FORM OF THE MODEL

7.1 THE LIMITED REDUCED FORM

Once the estimation of the structural form has been performed it becomes possible to find the reduced form of the model. From the application point of view this latter form is even more important, since it makes possible a number of different inferences, such as straightforward prediction,* multiplier analysis, or counterfactual simulation.

Solving the set of equations (6.1)–(6.15), together with the relevant identities concerning the nonlagged endogenous variables, gives us the reduced form of the linear part of the model. If, for the time being, we also omit from our considerations the investment variables,** we obtain the limited reduced form of DEMP-1. The matrix of the coefficients of this limited reduced form is presented in Appendix A.

Since the numerical values of the parameters can be directly seen – as presented in Appendix A – there is no need to discuss them further. The qualitative side of the limited-reduced-form problem is much more interesting, namely, the information concerning the predetermined variables that enter into the different equations of the reduced form. Such information is provided by Table 2, in which the rows correspond to the various nonlagged endogenous variables while the columns indicate the predetermined variables. Whenever the coefficient of the reduced-form equation is different from zero, the symbol + appears at the intersection of the appropriate row and column. If, however, the coefficient is equal to zero then the symbol 0 appears in Table 2. Thus, the number of +

*A distinction is made here between the two types of econometric inference about the future, namely prediction, which consists of inference from a causal-type model, and forecasting, based on any noncausal model (trend, autoregressive, adaptive, etc.).

**Because the investment variables form a special block of the model, which is very different from the remaining equations in terms of the method of splitting total investments and the form of investment equations, which take the form of definition identities (see Section 6.1).

TABLE 2 Zero and non-zero coefficients of the limited reduced form.

Endogenous variable	Predetermined variables of DEMP-1																					
	X_1	X_2	X_3	X_4	X_5	X_6	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}
Y_1	0	+	0	0	+	0	+	0	+	+	0	+	+	+	0	0	0	0	0	0	+	0
Y_2	0	+	0	0	+	0	+	0	+	+	0	+	+	+	0	0	0	0	0	0	+	0
Y_3	0	+	0	0	+	0	+	0	+	+	0	+	+	+	0	0	0	0	0	0	+	0
Y_4	0	0	0	0	0	+	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0
Y_7	0	+	0	0	+	0	+	0	+	+	0	+	+	+	0	0	0	0	0	0	+	0
Y_8	+	0	+	0	0	0	0	0	+	0	0	0	0	0	0	0	0	+	0	0	+	0
Y_9	0	+	0	0	+	0	+	0	+	+	0	+	+	+	0	0	0	0	0	0	+	0
Y_{10}	0	+	0	0	+	+	+	0	+	+	0	+	+	+	0	0	0	0	0	0	+	0
Y_{18}	+	+	+	0	+	0	+	0	+	+	0	+	+	+	0	0	0	+	0	0	+	0
Y_{19}	0	0	0	0	0	0	0	0	+	0	0	+	0	0	0	0	+	0	0	0	0	0
Y_{20}	0	0	0	0	0	0	0	0	+	0	0	0	0	0	+	+	0	+	0	0	0	0
Y_{22}	+	+	+	0	+	+	+	+	+	+	0	+	+	+	0	0	0	+	0	0	+	0
Y_{23}	+	+	+	0	+	+	+	+	+	+	0	+	+	+	0	0	0	+	0	0	+	0
Y_{24}	+	+	+	0	+	+	+	+	+	+	0	+	+	+	0	+	0	+	+	0	+	+
Y_{25}	+	+	+	0	+	+	+	+	+	+	0	+	+	+	+	+	0	+	+	0	+	0
Y_{26}	0	+	0	0	0	0	+	0	+	+	+	+	+	+	+	0	0	+	0	0	+	0
Y_{27}	+	0	+	0	0	0	0	0	+	+	+	0	0	0	0	0	0	+	0	0	+	0
Y_{28}	0	0	0	0	+	0	0	0	+	0	0	0	0	0	0	0	0	0	0	+	0	0

symbols in a row indicates the total number of predetermined variables influencing the endogenous variable, and the location of the + symbols shows which ones these variables are. On the other hand, the 0 symbols indicate that a predetermined variable has no impact on the endogenous variable.*

A closer look at Table 2 reveals that there are three blocks of endogenous variables that are dependent upon similar predetermined variables. These blocks are: (Y_{22}, Y_{24}, Y_{25}), $(Y_1, Y_2, Y_3, Y_7, Y_9, Y_{10}, Y_{18}, Y_{26})$, and (Y_8, Y_{27}); other endogenous variables exhibit specific individual patterns. It should be noted that the variables forming the first block depend on the largest number of predetermined variables, and that Y_4 depends on the smallest number (2) of them.

Perhaps it is even more interesting to note those particular predetermined variables which most often have an impact on the endogenous variables of the model. In doing this we shall, however, exclude from our considerations the unit variable, since it obviously must appear in all linear equations.

There are 8 predetermined variables which appear to have an impact on a large number of endogenous variables. These are variables $X_2, X_5, X_8, X_{11}, X_{13}$, X_{14}, X_{15}, and X_{22}. Checking their definitions we find that three of them, namely X_{13}, X_{14}, and X_{15}, are lagged endogenous variables, three are exogenous decision variables (X_2, X_5, and X_8), one is the fast economic growth dummy variable X_{22}, and the last is the time variable X_{11}. This particular pattern of the most often-recurring predetermined variables has important and far-reaching implications. We should note that the three exogenous decision variables are very crucial since they refer to wage level, to construction of flats, and to exogenous investment in Sector I. This inference is further strengthened by the widespread influence of variable X_{22}, which summarizes the effects of the 1971–1976 shift in economic policy, aimed at fast economic growth coupled with a rise in the standard of living.

On the other hand, one must not overlook the importance of the time element, which manifests itself in two ways. First, it acts directly through the variable X_{11} which – as may be seen from Table 2 – influences quite a number of endogenous variables. Second, time enters the economic mechanism by means of lagged endogenous variables. As has been pointed out earlier, three such variables, namely X_{13}, X_{14}, and X_{15}, appear frequently as influencing factors. While X_{13} has a lag of one year, X_{14} is lagged two years, and X_{15} incorporates the even longer lag of three years. When one notes that, in the reduced form, other lagged variables, namely X_{16}, X_{17}, and X_{18}, also appear (though not often) and that one of them has a two-year lag, then it becomes apparent that time is a factor that really plays a major role in the quantitative mechanism of the Polish economy.

The existence of lags, and especially of the long ones, implies that it is quite likely that the results of economic decisions undertaken by appropriate

*Had the structural form of the model been fully interdependent, the nonlagged endogenous variables would be dependent on all the predetermined variables. In fact this is not so because some of the structural form equations are of the recursive or simple form; in the latter case, the endogenous variable is dependent on only some of the predetermined variables.

planning and other institutions will not always be felt immediately but will rather be spread over a period of time, sometimes with quite substantial delays.

As can be seen from Table 2, more than half of the endogenous variables of the model are subject to such time-delayed impacts. This applies to variables $Y_1, Y_2, Y_3, Y_7, Y_9, Y_{10}, Y_{18}, Y_{22}, Y_{25}$, and Y_{26}, all of which depend on the lagged variables X_{13}, X_{14}, and X_{15}, and on the time variable X_{11}. Variable Y_{20} also shows a time-delayed response to stimuli since it depends (among other factors) on variables X_{16} and X_{17}, which are investments in Sector II with lags of one and two years, respectively.

7.2 THE EXTENDED REDUCED FORM

This section will be devoted to a brief exposition of how one could find the reduced form for all the endogenous variables of DEMP-1. This would involve adding to Table 2 (or to a generalized version of Table 2, presenting not only the symbols 0 and + but also numerical values of the coefficients) an appropriate number of rows corresponding to the variables omitted thus far. These variables are $Y_5, Y_6, Y_{11}, Y_{12}, Y_{13}, Y_{14}, Y_{15}, Y_{16}, Y_{17}$, and Y_{21}. The additional rows of the table must be constructed according to the specific way in which an endogenous variable enters the model and the structural form of the model.

Let us consider first the variables Y_5 and Y_6. In Section 6.1, where the structural form was described, the equations for these two variables were written as

$$Y_5 = \left(1 + \frac{Y_{24} - Y_{26} + Y_{28}}{1000}\right) X_{24} \tag{7.1}$$

and

$$Y_6 = \left(1 + \frac{Y_{25} - Y_{27} - Y_{29}}{1000}\right) X_{25} \tag{7.2}$$

If we now substitute for $Y_{24} - Y_{29}$ their limited-reduced-form expressions (see Appendix A) we obtain the reduced-form expressions for Y_5 and Y_6, respectively. Let us note in this context that, because of the non-linearity of Eqs. (7.1) and (7.2) due to the multiplication of the terms in parentheses by X_{24} and X_{25}, the reduced-form coefficients will not be constant but will vary in time. The reduced-form coefficients for the variables Y_5 and Y_6 are given in Appendix B.

Next we turn our attention to the variable Y_{21}, defined as the average labor productivity in Sectors I and II. This may be expressed as

$$Y_{21} \equiv \alpha(t) \cdot Y_{19} + [1 - \alpha(t)] Y_{20} \tag{7.3}$$

where

$$\alpha(t) = \frac{Y_2 + Y_3}{Y_2 + Y_3 + Y_4} \tag{7.4}$$

TABLE 3 Values of $\alpha(t)$ coefficients.

Year	$\alpha(t)$	Year	$\alpha(t)$	Year	$\alpha(t)$
1960	0.38	1966	0.45	1972	0.53
1961	0.39	1967	0.46	1973	0.54
1962	0.40	1968	0.48	1974	0.56
1963	0.41	1969	0.49	1975	0.56
1964	0.42	1970	0.50	1976	0.57
1965	0.44	1971	0.51		

Hence, in order to derive the reduced-form coefficients for the equation pertaining to Y_{21}, one must find (from Appendix A) the reduced-form coefficients for Y_{19} and Y_{20}, and then weight them with $\alpha(t)$ and $1 - \alpha(t)$, respectively. Table 3 gives the values of $\alpha(t)$ for all years within the period 1960–1976, and it can be seen that $\alpha(t)$ is not constant over time. Hence, the reduced-form coefficients for Y_{21} will also vary with time in correspondence with the changing share of employment in Sector I.

Finally, one could also envisage the construction of the reduced-form equations for the investment variables. It was shown in Chapter 5 that the investment structural equations are essentially used for splitting total sectoral investments into their endogenous and exogenous parts, and that, in fact, they do not enter the proper structural form of the model. In spite of this, an approximation to the reduced-form relations for either total or endogenous investment variables can be found.

As was shown in Section 5.2, the endogenous part of investment was computed by means of the following formula

$$J_{\text{end},t} = \alpha_1 J_{\text{total},t-1} \cdot \frac{Y_{18,t}}{Y_{18,t-1}} \tag{7.5}$$

Taking into account the fact that total investment equals endogenous plus exogenous investment, Eq. (7.5) can be written as

$$J_{\text{end},t} = \alpha_1 (J_{\text{end},t-1} + J_{\text{exog},t-1}) \cdot \frac{Y_{18,t}}{Y_{18,t-1}} \tag{7.6}$$

Now $J_{\text{end},t-1}$, $J_{\text{exog},t-1}$, and $Y_{18,t-1}$ are all predetermined variables and, as such, they should enter the reduced-form equation. The variable $Y_{18,t}$ is, by definition, equal to $Y_{1,t} + Y_{8,t}$. The reduced-form coefficients for these variables are known and can be found in Appendix A. By summing the coefficients of each predetermined variable one can easily obtain the reduced form for $Y_{18,t}$. This completes the task since all the variables appearing on the right-hand side of Eq. (7.6) will be of predetermined character, thus providing the reduced-form equation for the sectoral endogenous investment variable. Note that because of the nonlinearity of Eq. (7.6) the coefficients of the reduced form will not be constant in time, but will vary depending on the variations of $J_{\mathrm{end},t-1}$ and $J_{\mathrm{exog},t-1}$.

To conclude this section it should be noted that the solutions presented here are of an approximate character. This is because the approach adopted made no provision for the feed-back effects between Y_5, Y_6, and the endogenous investment variables on the other endogenous variables of the model. For this reason we have used the term "extended reduced form" in the title of this section, thus implying that the resulting coefficients do not reflect the full impact of the predetermined variables, i.e., the impact corresponding to the situation when all the interrelations and feed-backs have been accounted for.

In classical linear models, when all the equations have been consistently estimated, the reduced form obtained by the standard formula* obviously reflects the full impact of the predetermined variables of the model.

7.3 THE RANGE OF POSSIBLE PRACTICAL USES OF THE MODEL

Once its reduced form has been obtained, the model is ready for practical applications. Since the main objective of the research which lead to the construction of DEMP-1 was to analyze the existing interrelations between economic and demographic factors in Poland, our analysis of the model's results must provide answers to the following questions:

1. Do economic factors have any impact on demographic variables, and if so, of what kind and intensity?
2. Are demographic factors important to economic growth?

The solutions to these problems can be obtained in a number of different ways. So far, the author has concentrated mostly on counterfactual simulation procedures. If the counterfactual simulations are performed over a sufficiently long period of time and the underlying scenarios are carefully chosen in order to make them differ significantly from each other with respect to the decision variables, the results usually prove to be fruitful. These results give a clear insight into the mechanism of existing interrelations and the role of the different decision variables.

Counterfactual simulation, however, is not the only possible method of inference. Much information can also be derived from analyzing single coefficients of the reduced-form equations, since such coefficients are direct multipliers, expressing the expected change in the endogenous variable given an assumed change in a particular predetermined variable.

*That is, by computing matrix P, defined as $P = B^{-1} \cdot C$, where B is the matrix of coefficients of nonlagged endogenous variables and C is the matrix of coefficients of predetermined variables.

It should be pointed out, moreover, that DEMP-1 can also be used for straightforward predictions of the future behavior of its endogenous variables. So far, however, the author's research in the applications of the model has concentrated on the counterfactual simulation procedures; these procedures and the resulting inferences will be presented in the next section.

8 COUNTERFACTUAL SIMULATION OF THE MODEL

8.1 THE SCENARIOS

The model in its present form is constructed to show primarily the existing interrelations of economic factors and their impact on such demographic phenomena as demographic coefficients and population totals for urban and rural areas. The counterfactual scenarios are designed to show the results of the impact of different economic policies on economic growth and on demography. Starting with two or more sets of basically different initial assumptions about the economic policy, and looking at the results obtained from the counterfactual simulation, it is possible to judge whether the demographic phenomena are really conditioned by economic factors and, if so, in which direction and to what extent.

For the purpose of such an analysis two different simulation scenarios have been designed, and these are referred to as Scenario A and Scenario B. In agreement with what was said earlier about the necessary divergence of scenarios, the two scenarios decided upon represent two extreme situations in the history of the Polish economy during the years 1960–1976.* Scenario A reflects the hypothetical assumption that, during the entire period, the economy was growing at the same moderate rate as it actually was during the sixties. On the other hand, Scenario B assumes that, from 1960 onward, Poland experienced a steady, high rate of economic growth similar to that observed in the years 1971–1976, and that this high rate of growth was coupled with a significant rise in the standard of living of the population.

In order to design such scenarios the values of the predetermined variables of the model had to be set at levels corresponding to the basic assumptions made for the two situations. Table 4 contains the values assumed for Scenario A while Table 5 refers to the levels of predetermined variables corresponding to

*Since DEMP-1 has been built using time-series data referring to the period 1960–1976, it seems logical that any counterfactual simulation based on it should refer to the same period.

TABLE 4 Values of predetermined variables assumed for Scenario A.[a]

	Year					
Variable	1971	1972	1973	1974	1975	1976
X_1	565	580	595	610	625	640
X_2	122	124	126	128	130	132
X_3	133	142	151	160	169	178
X_4	0	0	0	0	0	0
X_5	68	71	74	77	80	83
X_6	17	18	19	20	21	22
X_8	650	670	690	710	730	750
X_9	−0.2	0	0	0	0	0
X_{10}	1	1	1	1	1	1
X_{11}	12	13	14	15	16	17
X_{12}	144	169	196	225	256	289
X_{13}	650	685	730	770	810	860
X_{14}	130	137	144	151	158	165
X_{15}	120	130	137	144	151	158
X_{16}	38.5	41.0	43.5	46.0	48.5	50.1
X_{17}	36.2	38.5	41.0	43.5	46.0	48.5
X_{19}	0	0	0	0	0	0
X_{20}	0	0	0	1	1	1
X_{21}	0	0	0	0	0	0
X_{22}	0	0	0	0	0	0
X_{23}	0	0	0	0	0	0

[a]For the years 1960–1970, the values assumed for Scenario A are the same as the observed data reported in Table 6.

Scenario B. Assuming that Scenario B represents not only a much faster economic growth but also a higher standard of living, the data pertaining to the two scenarios differ, not only with respect to variables inducing economic growth (such as investments), but also with respect to variables connected with the standard of living (wages, housing construction). For easier comparison with the *real* behavior of predetermined variables over the period studied, Table 6 presents the relevant observed statistical data.

The counterfactual simulations performed were of the deterministic type, i.e., the random components of the stochastic equations of the model were all put equal to zero. The choice of the deterministic variant was made entirely by considering the computing time and facilities available. It must be remembered, however, that stochastic simulation yields much more valuable information, since it provides not only the expected values of endogenous variables but also gives insight into the distribution of individual observations. Moreover – when there is a strong autocorrelation between the random components present – the stochastic variant of simulation gives information about the behavior of

TABLE 5 Values of predetermined variables assumed for Scenario B.

Variable	Year 1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
X_1	385	415	445	475	505	535	565	595	625	655	685	715	745	775	805	835	865
X_2	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180
X_3	36	48	60	72	84	96	108	120	132	144	156	168	180	192	204	216	228
X_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X_5	28	32	37	43	50	57	65	75	85	99	114	131	153	176	202	233	268
X_6	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37
X_8	414	474	534	600	660	720	880	840	900	960	1020	1080	1140	1200	1260	1320	1380
X_9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X_{10}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
X_{11}	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
X_{12}	1	4	9	16	25	36	49	64	81	100	121	144	169	196	225	256	289
X_{13}	300	330	363	400	440	484	532	585	644	710	781	860	944	1038	1142	1256	1380
X_{14}	50	60	64	72	80	90	100	110	125	150	176	210	270	335	400	470	550
X_{15}	45	50	60	64	72	80	90	100	110	125	150	176	210	270	335	400	470
X_{16}	12	13	14	16	20	25	29	32	27	50	53	58	60	65	70	76	82
X_{17}	10	12	13	14	16	20	25	29	32	37	50	53	58	60	65	70	76
X_{19}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X_{20}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X_{21}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
X_{22}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
X_{23}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 6 Observed values of predetermined variables (for selected years).

Variable	Year 1960	1962	1964	1966	1968	1970	1972	1974	1976
X_1	385	401	421	451	491	539	588	671	791
X_2	100.0	103.0	107.7	111.3	115.5	119.5	134.4	155.7	175.5
X_3	36.5	44.1	49.1	66.4	93.4	123.6	149.1	173.6	193.3
X_4	0	8	1	−10	−14	7	−14	13	30
X_5	28.2	36.2	32.7	43.2	52.9	55.0	101.0	157.0	152.6
X_6	5.7	7.8	10.9	13.0	15.3	15.9	21.7	30.8	32.5
X_8	414.8	411.1	475.2	517.1	569.5	630.0	697.5	895.4	1009.4
X_9	−0.7	−1.0	0.1	−0.9	0.0	−0.2	−1.5	−7.2	−9.5
X_{10}	1	1	1	1	1	1	1	1	1
X_{11}	1	3	5	7	9	11	13	15	17
X_{12}	1	9	25	49	81	121	169	225	289
X_{13}	297.8	335.0	384.9	449.8	518.5	619.2	704.0	885.5	1116.3
X_{14}	48.3	60.6	76.5	80.1	97.1	119.4	133.9	191.3	306.2
X_{15}	43.4	57.5	66.4	78.8	88.9	109.6	130.2	148.7	246.0
X_{16}	12.0	15.0	17.9	24.7	29.9	35.5	37.8	51.0	70.1
X_{17}	10.0	13.5	16.5	21.2	27.2	32.5	36.2	43.5	60.2
X_{18}	43.0	45.9	49.3	54.6	57.6	64.5	69.7	80.5	96.2
X_{19}	0	1	0	0	0	1	0	1	1
X_{20}	0	1	0	0	0	0	0	0	1
X_{21}	1	0	0	0	1	0	1	1	1
X_{22}	0	0	0	0	0	0	1	1	1
X_{23}	0	0	0	0	1	0	0	0	0

individual growth paths. This is especially important when there is a possibility of some paths of an endogenous variable going astray, i.e., in the direction opposite to that shown by the expected values of the given variable.* Notwithstanding these advantages, it has only been possible, to date, to run the deterministic variant of the counterfactual simulation, because of the lack of an efficient computer.

8.2 THE ANALYSIS OF COUNTERFACTUAL SIMULATION RESULTS

Using the two scenarios described in Section 8.1, counterfactual simulation was performed with respect to all the endogenous variables of the model and for all the years of the period 1960–1976. However, to keep this report reasonably brief, we shall restrict ourselves to discussing the results which refer to national income, employment, and demographic variables.

*The frequency of occurrence of such stray paths of growth provides information about the possibility that random causes will completely disturb the pattern of behavior of an endogenous variable and make it significantly diverge from what might be "reasonably" expected.

The counterfactual simulations performed on the basis of Scenarios A and B provided, for every endogenous variable considered, two sets of "theoretical" values, each set being composed of 17 consecutive figures, one for each year in the period 1960–1976. The first set represents the expected values of the particular endogenous variable if Scenario A were true, and the second set gives the corresponding figures on the basis of the assumptions of Scenario B.

Tables 7–11 present the results of the counterfactual simulations of variables $Y_1, Y_8, Y_{18}, Y_2, Y_3, Y_4, Y_9, Y_{24}, Y_{25}, Y_{26}, Y_{27}, Y_{28}, Y_5$, and Y_6. For the sake of clarity, simulation results have been grouped so that each table contains the results pertaining to similar types of variables (national income, employment, etc.). Also, to avoid presenting too many data, which would obscure the general trends of the results, only those data referring to even-numbered years have been included in the tables.

When both sectoral and total national income are considered (see Table 7) we find that the pattern of growth corresponding to Scenario B leads to substantially higher figures (in constant prices!) than in the case of Scenario A. This is not surprising, though, since the basic difference between the two scenarios lies mainly in the assumption that the stimuli of economic growth are much stronger for Scenario B. The nontrivial observation, however, is that in 1976 the total national income figure is about 43 percent higher for Scenario B than for Scenario A. The obvious inference to be drawn is that if the policy of fast economic growth had been started as early as 1960 and pursued in all the subsequent years, the country's economic potential would now be significantly improved. Another striking conclusion that can be drawn from the data in Table 7 is that, even under the growth-pattern assumptions of Scenario B, we do not observe a substantial rise in the agricultural sector, which is lagging well behind the other productive sector.

When analyzing the results of counterfactual simulations applied to employment variables, we notice for both scenarios that the level of employment of full-time, one-job workers and employees in Sector I (variable Y_2) increases very substantially – and at almost the same rate for both scenarios. A slightly different pattern is seen with respect to the peasant-workers, who also increase in number; however, the magnitude of this increase is different for each simulation. While under Scenario A the expected number of peasant-workers (variable Y_3) in 1976 is almost 2.5 times greater than in 1960, under Scenario B the corresponding factor is only 2.2. Whatever its magnitude, the appearance of this difference is not surprising. Scenario B leads to a larger overall employment in Sector I than does Scenario A (the figures being 14.1 and 13.1 millions, respectively) and also to a more intensive construction of flats in urban areas. Thus, new workers attracted to Sector I from Sector II would –under Scenario B – not only easily find new jobs but could also, and in larger numbers, move permanently to the towns to settle because adequate accommodation would be available.

TABLE 7 Counterfactual simulation of national income.

Variable	Scenario	Year 1960	1962	1964	1966	1968	1970	1972	1974	1976
Y_1	A	307	346	409	478	562	674	741	838	940
Y_1	B	331	400	491	594	721	866	1039	1192	1390
Y_8	A	126	107	128	133	140	127	153	136	141
Y_8	B	113	118	123	128	133	138	142	147	152
Y_{18}	A	433	453	537	611	702	801	894	974	1081
Y_{18}	B	444	518	614	722	854	1004	1181	1339	1542

TABLE 8 Counterfactual simulation of productive employment.

		Year								
Variable	Scenario	1960	1962	1964	1966	1968	1970	1972	1974	1976
Y_2	A	5.1	5.9	6.7	7.5	8.4	9.3	10.1	11.0	11.9
Y_2	B	5.2	6.0	6.9	7.8	8.7	9.7	10.8	11.8	12.8
Y_3	A	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.1	1.2
Y_3	B	0.6	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3
Y_4	A	10.8	10.7	10.6	10.5	10.4	10.2	9.8	9.7	9.6
Y_4	B	10.3	10.1	10.0	9.8	9.6	9.4	9.3	9.1	8.9
Total	A	16.4	17.2	18.0	18.7	19.6	20.4	20.9	21.8	22.7
Total	B	16.1	16.7	17.6	18.4	19.2	20.1	21.2	22.1	23.0

TABLE 9 Counterfactual simulation of employment in services.

		Year								
Variable	Scenario	1960	1962	1964	1966	1968	1970	1972	1974	1976
Y_9	A	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.9	1.9
Y_9	B	1.6	1.7	1.7	1.8	1.8	1.9	2.0	2.1	2.2

TABLE 10 Counterfactual simulation of demographic coefficients.

Variable	Scenario	Year 1960	1962	1964	1966	1968	1970	1972	1974	1976
Y_{24}	A	16.2	16.3	16.4	16.6	18.6	16.8	17.0	17.0	17.0
Y_{24}	B	16.6	16.6	16.6	16.7	18.7	16.8	16.9	16.9	17.0
Y_{25}	A	37.3	35.1	32.7	30.3	27.8	25.4	23.0	20.5	17.0
Y_{25}	B	24.9	22.4	20.5	20.0	19.5	18.8	18.0	15.0	13.0
Y_{26}	A	7.2	7.1	7.0	7.0	7.2	7.7	7.8	8.4	9.0
Y_{26}	B	6.6	6.4	6.3	6.0	6.3	6.4	6.5	6.8	7.2
Y_{27}	A	8.3	8.1	8.0	8.0	7.9	8.0	8.2	8.8	9.1
Y_{27}	B	8.1	8.1	8.0	8.0	8.1	8.2	8.3	8.5	8.7
Y_{28}	A	6.0	6.2	6.4	6.7	6.7	6.9	7.0	7.0	7.1
Y_{28}	B	6.0	6.2	6.4	6.7	7.1	7.7	8.4	9.5	10.7

TABLE 11 Counterfactual simulation of urban and rural population totals.

Variable	Scenario	Year 1960	1962	1964	1966	1968	1970	1972	1974	1976
Y_5	A	14.2	14.8	15.2	15.8	16.5	17.0	17.5	18.1	18.6
Y_5	B	14.0	14.4	14.9	15.4	16.0	16.6	17.2	17.9	18.6
Y_6	A	15.8	16.5	17.2	17.8	18.2	18.6	18.8	18.9	18.8
Y_6	B	15.4	15.6	15.8	15.9	15.8	15.7	15.7	15.7	15.6
Total population	A	30.0	31.3	32.4	33.6	34.7	35.6	36.3	37.0	37.4
Total population	B	29.4	30.0	30.7	31.3	31.9	32.3	32.9	33.6	34.2

As far as agricultural employment is concerned, both scenarios show a decrease in the number of persons working in Sector II. In the case of Scenario B this decrease is slightly more pronounced (1.4 instead of 1.2 million persons). This is due to the fact that Scenario B induces a stronger "drain" of labor force away from agriculture, both because of the demand for new workers in Sector I and because of the high investment outlays in agriculture, thus making such an exodus to urban areas possible without a corresponding loss of agricultural output.

A counterfactual simulation was also run for the variable Y_9, i.e., employment in the service sector. Here we find that employment would rise faster under Scenario B than under Scenario A, and this difference in employment levels is especially visible in the seventies. However, it is somewhat surprising to note that the historically observed data for 1975 and 1976 are in fact even higher than the results for Scenario B, not to mention those for Scenario A. This is perhaps due to government decisions taken in the mid-seventies that aimed to expand small trades and the crafts, which provide direct services to the population. These government decisions were not accounted for explicitly in the model.

When viewing the results of counterfactual simulations performed for the demographic coefficients represented by the variables $Y_{24}-Y_{28}$, it can be seen that one of these variables, Y_{24} (urban birth rate), is practically unaffected by the different assumptions underlying the two scenarios. In both cases, the urban birth rate shows a very slow upward trend which, however, is less evident during the last years of the simulation period.

All the other demographic coefficients considered show different trends, depending on whether Scenario A or Scenario B is applied. These differences, however, seem to be of a quantitative and not a qualitative character, because the general characteristics of their variation are the same for both scenarios.

In contrast to the behavior of the urban birth rate, the rural birth rate visibly decreases in time, the speed of this decrease being faster for Scenario B. This is because the birth rate in rural areas depends inversely on consumption, which is steadily rising throughout the simulation period.

An interesting conclusion can be derived from the figures pertaining to death rates. The urban and rural death rates are lower for Scenario B, which is probably due to the fact that having a higher national income makes it possible to spend more money on health care. A still more interesting feature of these death rates is that, after a temporary decline, they start rising again, the minimum level occurring in the late sixties. The present version of the model does not permit us to ascertain the real cause of such a variation pattern, but we may speculate that the effect is due either to the aging of Poland's population or to the worsening of natural environmental conditions.

Finally, some points are worth noting with respect to the variable Y_{28}, defined as the urban net in-migration rate. Under both scenarios this rate increases, but there is a marked difference in the patterns of growth. If a moderate growth of the national economy is assumed, the simulated values of the urban in-migration rate rise, but this trend slows down remarkably in the later years of the period studied. On the other hand, for Scenario B the variable Y_{28} exhibits a much faster and steadier upward trend, even in the last years of the simulation period. This is not surprising, since among other factors, Scenario B assumes intensive construction of flats in urban areas, so that people who wish to move to towns find not only job possibilities but also suitable accommodation.

To conclude this overview of the counterfactual simulation results, Table 11 shows urban, rural, and total population levels computed on the basis of each scenario. The general pattern of urban population growth is the same, as regards its upward trend, and the computed population figures tend to coincide for the two scenarios in the last years of the simulation period.

In spite of out-migration, the rural population is found to be growing until 1970. From then on its level stabilizes. This is due to the declining birth rate and to the rising death rate. Possibly, if the simulation had also been performed for later years, one might observe a substantial decline in the rural population figures.

To provide a better overview of the results of the counterfactual simulations performed, the behavior of each variable under Scenarios A and B is shown in Figures 14–21, which follow. In each figure, the continuous line refers to Scenario A and the broken line to Scenario B.

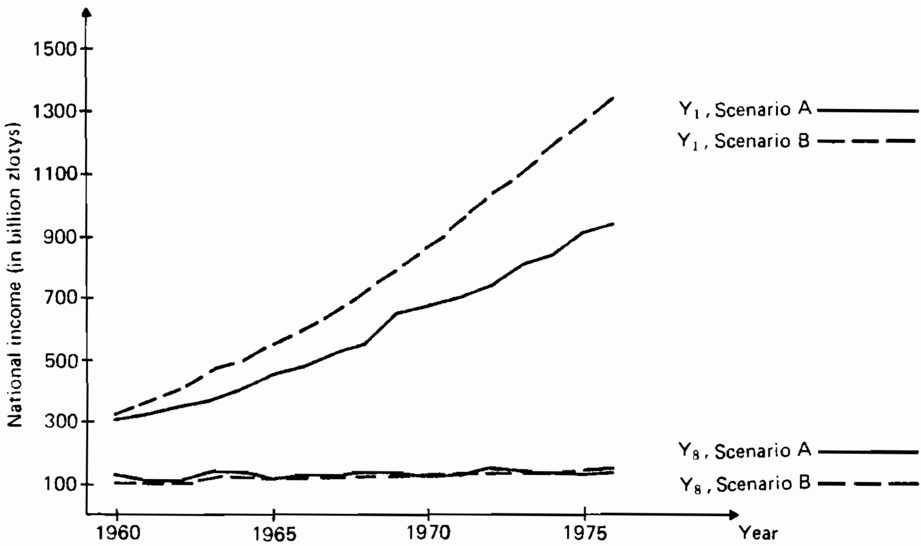

FIGURE 14 National income (sectoral), counterfactual simulation.

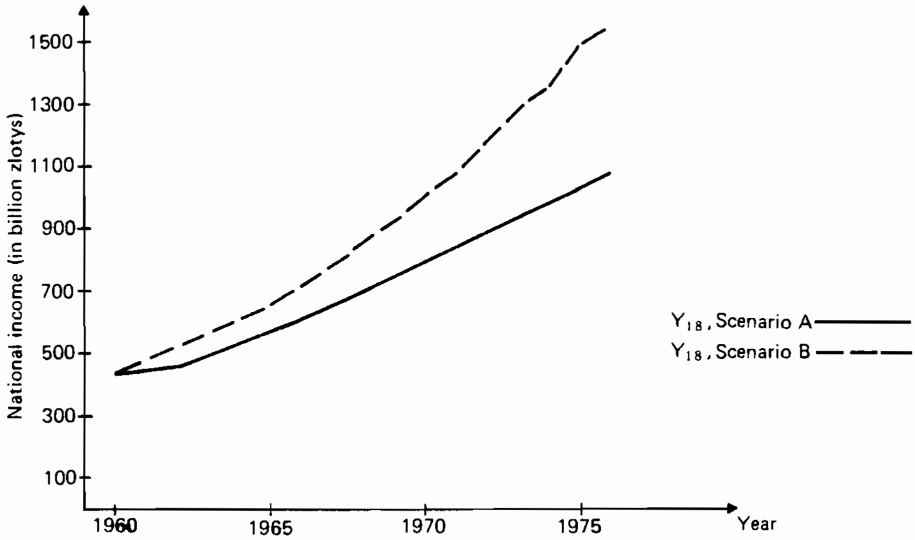

FIGURE 15 Total national income, counterfactual simulation.

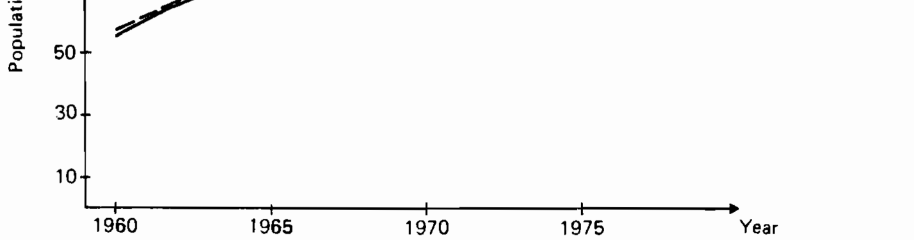

FIGURE 16 Productive employment in Sector I and Sector II, counterfactual simulation.

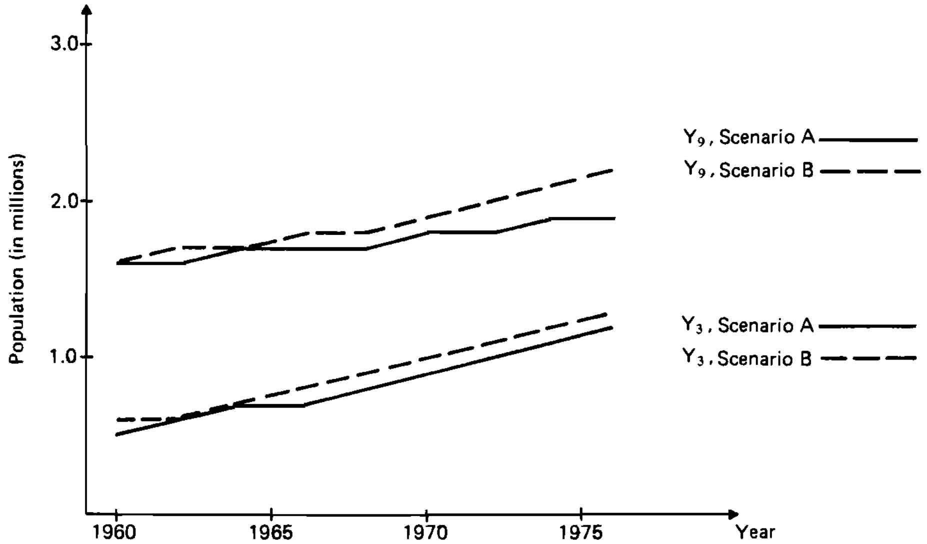

FIGURE 17 Employment in services and employment of peasant-workers, counterfactual simulation.

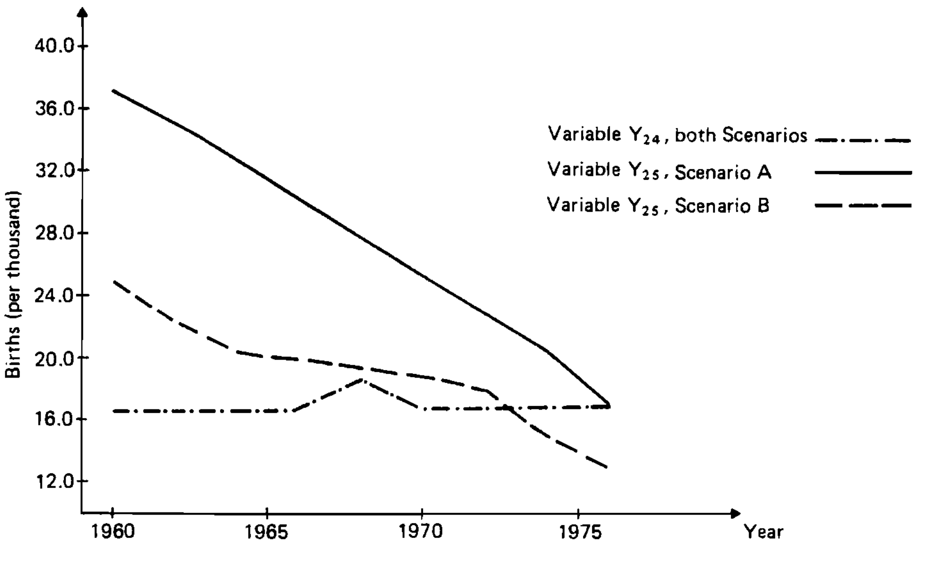

FIGURE 18 Urban and rural birth rates, counterfactual simulation.

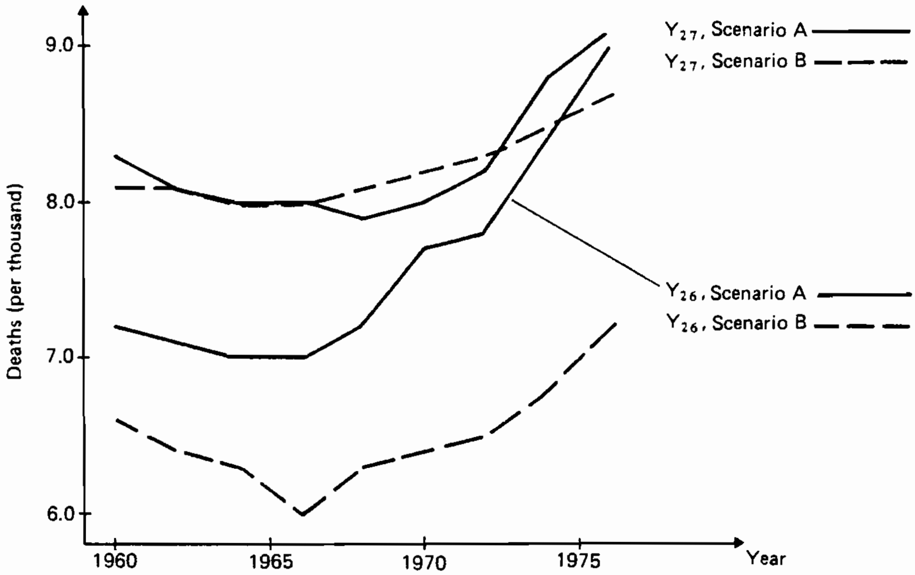

FIGURE 19 Urban and rural death rates, counterfactual simulation.

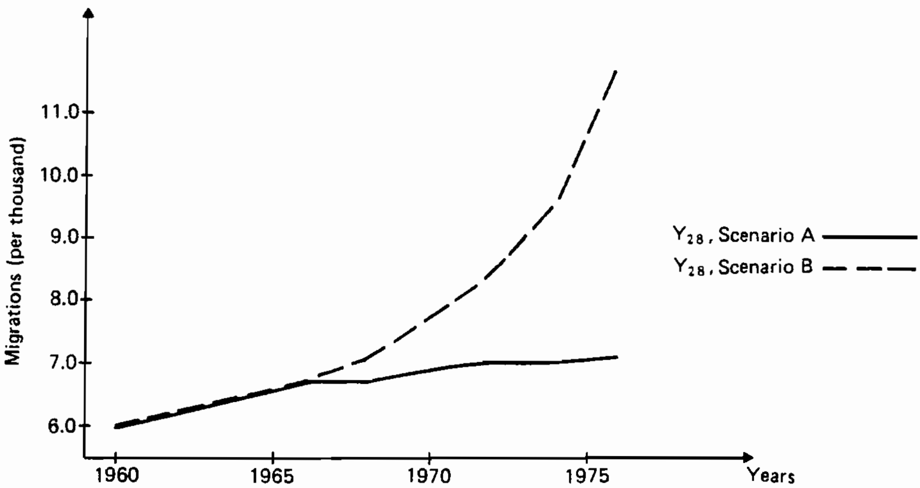

FIGURE 20 Net migration rate to urban areas, counterfactual simulation.

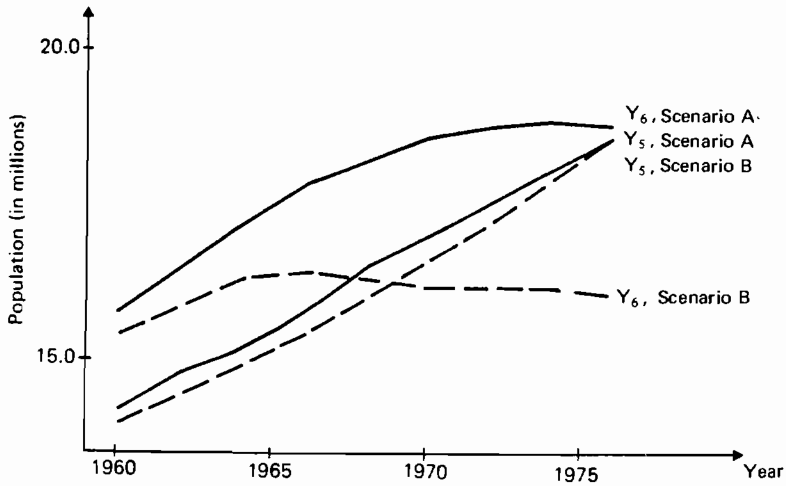

FIGURE 21 Urban and rural population, counterfactual simulation.

8.3 CONCLUDING REMARKS

DEMP-1, as presented and discussed in this report, may contain a number of shortcomings and approximations which preclude its practical application to large-scale and long-term analyses. In fact, a new version of the model (DEMP-2) is almost finished, and, from the results of the estimation of its structural relations, it seems that this newer version of the model provides more insight into the realm of quantitative interrelations between economic and demographic phenomena.

However, some important conclusions can already be drawn using the DEMP-1 version of the model. These conclusions may be summarized as follows:

1. In the light of our experience to date, it can be stated that it *is* possible to build demoeconometric models of countries that have a central economic planning system.
2. While some of the equations of such models may have a different interpretational and operational (predictive) meaning as compared to models of market economies, they nevertheless provide a basis for drawing inferences about the mechanism of economic growth and the mechanism of demographic behavior.
3. The demographic variables of Poland show a degree of dependence on economic factors which, although not excessively high, can be observed, especially when reference periods longer than 10 years are used for comparison.
4. Migration from rural to urban areas is not only influenced by such purely economic factors as income differentials, but also depends to a

large extent on social policy, particularly the intensity of housing construction in urban areas.

5. Because of the full employment policy consistently pursued during the whole post-war period, employment figures have been steadily rising in Poland. A further rise in the labor force may be constrained because of insufficient growth in the working-age population. Thus, the demographic factor may initiate a brake on economic growth, unless this growth is coupled with an adequate labor–capital substitution, and, consequently, higher labor productivity.

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APPENDIX A Matrix of limited-reduced-form coefficients (elements multiplied by − 1).

Variable	Column 1	Column 2	Column 3
Y_1	+0.000000000 / 0	+0.883525104 / − 1	+0.000000000 / 0
Y_2	+0.000000000 / 0	+0.212046025 / − 3	+0.000000000 / 0
Y_3	+0.000000000 / 0	+0.931485326 / − 2	+0.000000000 / 0
Y_4	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_7	+0.000000000 / 0	+0.952690429 / − 2	+0.000000000 / 0
Y_8	+0.755000000 / − 1	+0.000000000 / 0	−0.391000000 / 0
Y_9	+0.000000000 / 0	+0.441762552 / − 4	+0.000000000 / 0
Y_{10}	+0.000000000 / 0	+0.957108054 / − 2	+0.000000000 / 0
Y_{18}	+0.755000000 / − 1	+0.883525104 / − 1	−0.391000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	−0.121544630 / 0	+0.149279295 / + 1	+0.629456296 / 0
Y_{23}	−0.524725000 / − 2	+0.615516190 / − 1	+0.271745000 / − 1
Y_{24}	−0.243089260 / − 4	+0.298558590 / − 3	+0.125891259 / − 3
Y_{25}	+0.148234449 / − 2	−0.182120740 / − 1	−0.767936681 / − 2
Y_{26}	+0.000000000 / 0	−0.362245293 / − 3	+0.000000000 / 0
Y_{27}	−0.139675000 / − 2	+0.000000000 / 0	+0.723350000 / − 2
Y_{28}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0

Variable	Column 4	Column 5	Column 6
Y_1	+0.000000000 / 0	+0.144053006 / − 1	+0.000000000 / 0
Y_2	+0.000000000 / 0	+0.345727214 / − 4	+0.000000000 / 0
Y_3	+0.000000000 / 0	+0.151872689 / − 2	+0.000000000 / 0
Y_4	+0.000000000 / 0	+0.000000000 / 0	+0.436000000 / − 1
Y_7	+0.000000000 / 0	+0.155329961 / − 2	+0.000000000 / 0
Y_8	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_9	+0.000000000 / 0	+0.720265030 / − 5	+0.000000000 / 0
Y_{10}	+0.000000000 / 0	+0.156050226 / − 2	+0.436000000 / − 1
Y_{18}	+0.000000000 / 0	+0.144053006 / − 1	+0.000000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	+0.000000000 / 0	+0.243390155 / 0	+0.680025336 / + 1
Y_{23}	+0.000000000 / 0	+0.100355901 / − 1	+0.280391600 / 0
Y_{24}	+0.000000000 / 0	+0.486780310 / − 1	+0.136005067 / − 2
Y_{25}	+0.000000000 / 0	−0.296935989 / − 2	−0.829630910 / − 1
Y_{26}	+0.000000000 / 0	−0.590617325 / − 4	+0.000000000 / 0
Y_{27}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{28}	−0.610000000 / − 2	−0.195000000 / − 1	+0.000000000 / 0

Variable	Column 7	Column 8	Column 9
Y_1	+0.000000000 / 0	−0.480176687 / − 2	+0.000000000 / 0
Y_2	+0.000000000 / 0	−0.115242405 / − 4	+0.000000000 / 0
Y_3	+0.000000000 / 0	−0.506242297 / − 5	+0.000000000 / 0
Y_4	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_7	+0.000000000 / 0	−0.517766537 / − 3	+0.000000000 / 0
Y_8	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_9	+0.000000000 / 0	−0.240088343 / − 5	+0.000000000 / 0
Y_{10}	+0.000000000 / 0	−0.520167421 / − 3	+0.000000000 / 0
Y_{18}	+0.000000000 / 0	−0.480176687 / − 2	+0.000000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	+0.000000000 / 0	−0.811300516 / − 1	+0.570130977 / + 1
Y_{23}	+0.000000000 / 0	−0.334519668 / − 2	+0.235100000 / 0
Y_{24}	+0.000000000 / 0	−0.162260103 / − 4	+0.114036195 / − 2
Y_{25}	+0.000000000 / 0	+0.989786630 / − 3	−0.695620792 / − 1
Y_{26}	+0.000000000 / 0	+0.196872447 / − 4	+0.000000000 / 0
Y_{27}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{28}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0

Variable	Column 10	Column 11	Column 12
Y_1	−0.741731123 / + 2	−0.312691058 / + 1	+0.000000000 / 0
Y_2	−0.134653155 / + 2	−0.333104585 / 0	+0.000000000 / 0
Y_3	−0.112062505 / + 1	−0.406498376 / − 2	+0.000000000 / 0
Y_4	−0.270799000 / + 2	+0.000000000 / 0	+0.000000000 / 0
Y_7	−0.145859405 / + 2	−0.337169569 / 0	+0.000000000 / 0
Y_8	−0.140825200 / + 3	+0.000000000 / 0	+0.000000000 / 0
Y_9	+0.165631344 / + 1	−0.156345529 / − 2	+0.000000000 / 0
Y_{10}	−0.670093271 / + 2	−0.602333024 / 0	+0.000000000 / 0
Y_{18}	−0.214998312 / + 3	−0.312691058 / + 1	+0.000000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	−0.100788000 / + 2	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	−0.764212957 / + 4	−0.939453480 / + 2	+0.000000000 / 0
Y_{23}	−0.390657131 / + 3	−0.387360368 / + 1	+0.000000000 / 0
Y_{24}	−0.162140259 / + 2	−0.187890696 / − 1	+0.000000000 / 0
Y_{25}	+0.344946808 / + 2	+0.114613325 / + 1	+0.000000000 / 0
Y_{26}	−0.799249024 / + 1	+0.181203334 / − 1	−0.175000000 / − 1
Y_{27}	−0.763863380 / + 1	+0.132000000 / − 1	−0.580000000 / − 2
Y_{28}	−0.558740000 / + 1	+0.000000000 / 0	+0.000000000 / 0

Variable	Column 13	Column 14	Column 15
Y_1	–0.118754933 / + 1	–0.534438620 / 0	+0.125982954 / + 1
Y_2	–0.285011839 / – 2	–0.128265269 / – 2	+0.302359089 / – 2
Y_3	–0.154381413 / – 2	–0.694770206 / – 3	+0.163777840 / – 2
Y_4	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_7	–0.439393252 / – 2	–0.197742289 / – 2	+0.466136929 / – 2
Y_8	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_9	–0.593774665 / – 3	–0.267219310 / – 3	+0.629914769 / – 3
Y_{10}	–0.498770719 / – 2	–0.224464220 / – 2	+0.529128406 / – 2
Y_{18}	–0.118754933 / + 1	–0.534438620 / 0	+0.125982954 / + 1
Y_{19}	–0.791000000 / – 1	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	–0.777928269 / 0	–0.350024855 / 0	+0.825276886 / 0
Y_{23}	–0.329759449 / – 1	–0.144352940 / – 1	+0.340232478 / – 1
Y_{24}	–0.153585654 / – 3	–0.700189710 / – 4	+0.165055377 / – 3
Y_{25}	–0.949072489 / – 2	+0.427115723 / – 2	–0.100683780 / – 1
Y_{26}	+0.486895225 / – 2	+0.219119834 / – 2	–0.516530111 / – 2
Y_{27}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{28}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0

Variable	Column 16	Column 17	Column 18
Y_1	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_2	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_3	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_4	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_7	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_8	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_9	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{10}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{18}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0	+0.115200000 / 0
Y_{20}	+0.878000000 / – 1	–0.219800000 / 0	+0.000000000 / 0
Y_{22}	–0.114874886 / + 1	+0.287579726 / + 0	+0.000000000 / 0
Y_{23}	+0.000000000 / 0	+0.000000000 / 1	+0.000000000 / 0
Y_{24}	+0.229749772 / – 3	+0.575159452 / – 3	+0.000000000 / 0
Y_{25}	+0.140147361 / – 1	–0.350847266 / – 1	+0.000000000 / 0
Y_{26}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{27}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{28}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0

Variable	Column 19	Column 20	Column 21
Y_1	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_2	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_3	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_4	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_7	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_8	+0.212235000 / + 2	+0.000000000 / 0	+0.000000000 / 0
Y_9	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{10}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{18}	+0.212235000 / + 2	+0.000000000 / 0	+0.000000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	+0.191350000 / + 1	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	−0.592025799 / + 2	+0.712540000 / + 1	+0.000000000 / 0
Y_{23}	−0.147503325 / + 1	+0.000000000 / 0	+0.000000000 / 0
Y_{24}	−0.118405160 / − 1	+0.142508000 / − 2	+0.000000000 / 0
Y_{25}	+0.722271475 / 0	−0.869298800 / − 1	+0.000000000 / 0
Y_{26}	+0.000000000 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{27}	−0.392634750 / 0	+0.000000000 / 0	+0.000000000 / 0
Y_{28}	+0.000000000 / 0	+0.000000000 / 0	+0.138500000 / 0

Variable	Column 22	Column 23
Y_1	−0.222595083 / + 2	+0.000000000 / 0
Y_2	−0.534228200 / − 1	+0.000000000 / 0
Y_3	−0.289373608 / − 1	+0.000000000 / 0
Y_4	+0.537600000 / 0	+0.000000000 / 0
Y_7	−0.823601808 / − 1	+0.000000000 / 0
Y_8	+0.124726000 / + 2	+0.000000000 / 0
Y_9	−0.111297542 / − 1	+0.000000000 / 0
Y_{10}	+0.444110065 / 0	+0.000000000 / 0
Y_{18}	−0.978690832 / + 1	+0.000000000 / 0
Y_{19}	+0.000000000 / 0	+0.000000000 / 0
Y_{20}	+0.000000000 / 0	+0.000000000 / 0
Y_{22}	−0.631255197 / + 2	+0.000000000 / 0
Y_{23}	+0.198922613 / + 1	+0.000000000 / 0
Y_{24}	+0.290748961 / − 1	−0.244550000 / + 1
Y_{25}	−0.463646866 / + 1	+0.000000000 / 0
Y_{26}	+0.912639841 / − 1	+0.000000000 / 0
Y_{27}	−0.230743100 / 0	+0.000000000 / 0
Y_{28}	+0.000000000 / 0	+0.000000000 / 0

APPENDIX B Reduced-form coefficients[a] for equations of Y_5 and Y_6.

Endogenous variable	Predetermined variables appearing in the reduced-form equation									
Y_5	X_1	X_2	X_3	X_4	X_5	X_6	X_8	X_9	X_{11}	X_{12}
	−0.000024	0.000063	0.000126	0.006100	0.019510	−0.001360	0.000040	−0.001140	0.000663	0.017500
	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}
	−0.004715	−0.002121	0.004998	0.000230	−0.000575	0.011841	−0.001425	−0.138500	−0.120339	2.445000
Y_6	X_1	X_2	X_3	X_4	X_5	X_6	X_8	X_9	X_{11}	X_{12}
	−0.002085	0.018210	0.000446	−0.000085	0.033469	0.082963	−0.000990	0.069562	1.159333	0.005800
	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}
	0.009491	−0.004272	0.010068	−0.014015	0.035065	−0.329636	0.086929	−0.027000	4.867211	

[a]Note that the coefficients in the table which refer to Y_5 must be multiplied by the correct value of variable X_{24} for the year in question; similarly, the coefficients referring to Y_6 must be multiplied by the appropriate value of X_{25}.

URBANIZATION AND INDUSTRIALIZATION: MODELING SWEDISH DEMOECONOMIC DEVELOPMENT FROM 1870 TO 1914

Urban Karlström

One of the most challenging problems in Third World countries is the rapid growth of metropolitan areas. The two most important questions are: Is urbanization a necessary and desirable consequence of the process of development, or is it a constraint on further development? In order to understand the interaction between economic growth and urbanization in the developing world today, there has been increasing interest in the analysis of the historical experiences of developed countries. This is the purpose of the Swedish case study. Through an analysis of the crucial factors in Swedish demoeconomic development, it is hoped that further insights into the interactions of economic and demographic variables can be gained.

The prewar period, 1870–1914, is chosen for this study in order to follow the conventional view that considers the 1870s as the starting decade for the industrialization era in Sweden and a dramatic political event, the outbreak of the First World War, as the terminal year (Heckscher 1957). To consider 1914 as a watershed terminal year seems reasonable even from the economic point of view: the war caused dramatic changes on the world market, thus influencing in a positive way the conditions for industrialization in Sweden. One of the most striking changes was the alteration of Sweden's status from a capital importing to a capital exporting nation. A second dramatic change was the ending of the great migration to America. The emigration started in the 1860s and played a vital role during Sweden's industrialization. For an examination of the industrial breakthrough in Sweden, see Gårdlund (1942), Jörberg (1961, 1970), and Montgomery (1947). The beginning of the First World War, therefore, is the terminal point of this study. The influence that the war had on Sweden's demoeconomic development is not our concern here; the 44 years between 1870 and 1914 are challenging enough as a subject of study.

During these 44 years the per capita income of Sweden grew at an annual rate of 2 percent, a rate exceeded only by Japan and the United States. As

Kuznets has pointed out, it was the rather low increase in the population that gave Sweden this leading position (Kuznets 1956, p. 13). The Swedish population grew from almost 4.2 million in 1870 to slightly more than 5.6 million by the outbreak of the war, showing an annual growth rate of only 0.7 percent. (These figures have been derived from the tables in Appendix A.) This low rate was largely due to emigration, which drained the population of roughly 1.1 million people.

Not only the demographic but also the economic consequences of Sweden's migration patterns were far-reaching. The heavy emigration has been regarded as beneficial in its increasing effect on real wages even though it is rather difficult to estimate its total consequences for the economy (Henricsson 1969). Internal migration was also considerable during this period and was reflected to some extent in the rate of urbanization. The proportion of the population living in towns and cities increased from 13 to 31 percent between 1870 and 1914. This reallocation of the labor force from a low-productivity agricultural sector to a modern industrial sector with higher productivity contributed positively to the economic growth. These gains from labor force reallocation have been estimated and the results can be seen in Appendix Table A3. The gains differ among the decades, but over the whole period nearly 24 percent of the increase in total labor productivity was due to urbanization. [Åberg (1969) calculated almost the same figures using older data.]

These general remarks on Swedish development show the potential magnitude of demographic and economic interrelations. This interplay is especially critical for a study that highlights urbanization. In particular, the analysis of migration requires taking into account the existence of causality in both directions, which in turn affects the choice of methodology for this study. Many migration studies employ the underlying assumption that

> . . . while the various explanatory factors influence migration, migration does not in turn influence these factors. If this assumption does not in fact hold, the parameter estimates of the various models possess a simultaneous equations bias that may be great enough to vitiate the findings. (Greenwood 1975, p. 412)

When one considers how important economic variables (for example, wages) seem to be in the migration decision, and how the reallocation of the labor force between sectors works as an equilibrating factor on wages, one finds that a general equilibrium approach is most suitable for the problem. Only within such a framework can the complicated relations between the various demographic and economic variables be satisfactorily analyzed (Rogers 1977).

Thus the model that this paper deals with is of the general equilibrium type. It is within the tradition of the so-called multisectoral growth (MSG) models, first developed by Leif Johansen (see, for example, his 1974 revised book on the subject) and later extended by Bergman, among others (Bergman

1978; Bergman and Pór 1980). The models also draw from the theory of dualistic economic growth formulated in a general equilibrium framework by Kelley and Williamson (Kelley, Williamson, and Cheetham 1972; Kelley and Williamson 1974 and 1980).

The general equilibrium model presented in this report is designed to fit the Swedish prewar development for the purpose of undertaking counterfactual analysis. If the actual demoeconomic development between 1870 and 1914 corresponds closely to the model simulations, it will be possible to place some confidence in counterfactual studies. Through changes in one or more of the exogenous variables or parameters in the model, the importance of the variables or parameters on the economy can be explored through a comparison between the actual development and the counterfactual history. Some of the aspects that will be analyzed are the following:

1. What role did emigration play in Sweden's development? Its consequences have been discussed since Wicksell pointed out in the 1880s that emigration solved the proletarianization problem in Swedish agriculture (Wicksell 1882). But what were the long-run consequences of emigration? Would a larger population have increased the economic growth because of its enlargement of the home market? Was emigration a substitute for internal migration?
2. How crucial were the effects of the growth of world trade and the changes in terms of trade on the performance of economic growth? Were the trade tariffs stipulated in the 1880s important for the development of the Swedish consumer-goods industry? What was the impact of the participation of the agricultural sector in foreign trade on out-migration from rural areas?
3. Was the import of foreign capital a prerequisite for economic growth? What would have been the consequences for industrial growth and urbanization if there had been more borrowing? Was the saving generated in the agricultural sector to any substantial extent transferred to industry or was it absorbed by the investments within the sector?
4. How important were capital formation and technical progress in agriculture to development? And moreover, what effect did capital formation have on out-migration and urbanization?
5. How important to growth was internal demand? How did differences in consumption patterns between rural and urban households influence industrial growth?

The list of questions can easily be extended. These and other aspects of Swedish development will be analyzed with the help of the model. The study not only may be of some historical interest, but also, it is hoped, may increase our understanding of the forces behind the urbanization process as well as its implications in a small and open economy such as that of Sweden.

TABLE 1 The production sectors in the model and their empirical counterparts.

Sector subscripts	Sector[a]
1	Agriculture, forestry, and fishing
2	Export-oriented industry (mining and metal, wood products, pulp, paper, and printing)
3	Home-market-oriented industry (textile and clothing, leather, hair and rubber, chemical industries, power stations, waterworks and gasworks, stone, clay, glass, and food products)
4	Service (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, the urban sector (U), as opposed to the agricultural sector (A).

THE SECTOR DIVISION

The structure of the model is based on the duality between a traditional agricultural sector and a more modern industrial sector. But in order to capture the specific mechanisms that have driven Swedish economic growth, it is necessary to extend the model beyond the simple two-sector analysis. Therefore, the modern sector has been subdivided into four different sectors.*

The five production sectors and their empirical counterparts are displayed in Table 1. This division is based on two aspects: the relationship of each sector to the world market, and the importance of investments in railways and housing. The continuing industrialization in Europe increased foreign demand on Swedish exports, especially iron, steel, and sawmill products. Exports can, therefore, be considered a driving force in the economic development of Sweden (Jörberg 1961; Ohlsson 1969). Exports accounted for 19 percent of the GNP in 1871–1875, 22 percent in 1891–1895, and 27 percent in 1911–1915 (see Table 2). The industrial sectors have been divided into three groups according to their dependence on foreign trade: export-oriented industries, home-market-oriented industries, and branches of industries sheltered from international competition. Table 2 also shows exports and imports in relation to gross production in the various sectors (the main criteria for the grouping of sectors) and in the economy as a whole.

*Agricultural activities are treated within one sector in the model. For a model where agriculture is disaggregated, see Colosio (1979).

TABLE 2 The shares and ratios of exports (EX) and imports (IM) by sector and period in Sweden.

Sector number	Sector	Export share (EX_i/EX)			Export ratio (EX_i/gross output[a])			Import share (IM_i/IM)			Import ratio (IM_i/gross output[a])		
		1871–1875	1891–1895	1911–1915	1871–1875	1891–1895	1911–1915	1871–1875	1891–1895	1911–1915	1871–1875	1891–1895	1911–1915
1	Agriculture, forestry, and fishing	22	10	4	8	4	3	27	27	28	9	12	16
2	Mining and metal	21	14	22	38	27	34	12	12	17	22	22	22
	Wood products	27	28	17	80	71	59	1	1	1	3	2	3
	Pulp, paper, and printing	2	5	14	33	51	59	1	2	1	17	17	4
3	Food products	4	16	10	6	17	13	26	15	12	35	17	13
	Textiles and clothing	1	2	1	4	8	6	20	18	10	86	72	33
	Leather, hair and rubber	–	1	–	–	6	10	2	4	4	25	39	24
	Chemical industries	2	3	4	16	27	26	7	11	13	56	86	100
	Power stations, waterworks, and gasworks	–	–	–	–	–	–	–	–	–	–	–	–
	Stone, clay, and glass	1	3	3	14	41	23	7	10	14	229	120	110
4	Commerce and other services	6	7	8	5	4	8	–	–	–	–	–	–
	Public administration	–	–	–	–	–	–	–	–	–	–	–	–
	Transport and communication	14	14	15	58	43	41	–	–	–	–	–	–
	Services of dwellings	–	–	–	–	–	–	–	–	–	–	–	–
5	Building and construction	–	–	–	–	–	–	–	–	–	–	–	–
	Total	100	100	100	19[b]	22[b]	24[b]	100	100	100	19[b]	22[b]	21[b]

[a]Gross output is the domestic production of commodity i, including intermediate goods.
[b]Total exports and total imports as shares of gross domestic production.
SOURCE: Adapted from Johansson (1967).

The strategic role that building and construction activities have played in the economy has motivated a division of the trade-sheltered sector into a service sector and a building and construction sector. The building industry produced railways and housing, both of which played a crucial role in the Swedish development. A further argument for disaggregating this sector is that it is quite "population sensitive." Swings in emigration and urbanization can have substantial effects on building (see Wilkinson 1967).

When it is important, however, to stress the dualism between agriculture and industry, the four nonagricultural sectors are treated as one sector and designated as "urban."

PRODUCTION AND TECHNOLOGY

The dualism between Swedish agriculture and industry during the 19th century was to a large extent a question of differences in production conditions which resulted in a much lower productivity within the agricultural sector than the industrial sector.

The sources of productivity growth are not exactly the same in agriculture as in industry. In agriculture, productivity can be divided into two parts

$$\frac{X}{L} \equiv \frac{X}{R} \quad \frac{R}{L}$$

where X/L refers to the agricultural output per worker, X/R measures the agricultural output per unit area, and R/L equals land area per worker. The identity is another way of stating that an increase in output per worker can come about through an improved yield per unit area, through a larger area per worker, or through a combination of both.

Between 1870 and 1912 the output per worker grew at an annual rate of 1.19 percent. Of this growth 62 percent was due to an increase in output per unit area and the rest to an increase in land per worker.* In the 1880s the labor force started to decline, but cultivated acreage increased during the whole prewar period. Holgersson has estimated its growth to be 12–15 percent between 1870 and 1914.

It is worth noting that the processes of bringing more land under cultivation and increasing agricultural productivity had gone on for a long time before industrialization began. During the 100-year period between 1750 and 1850, the net population increase was 1.3 million. Roughly 80 percent of the population was dependent on agriculture, and since the rate did not change during

*The figures underlying the estimates are taken from the following sources: *output*, Krantz and Nilsson 1975, p. 172: *employment*, Jungenfelt 1966, p. 224; and *cultivated acreage*, Holgersson 1974, p. 47. The new data for cultivated acreage which have been estimated by Holgersson indicate that the agricultural output is 10 percent too low in the 1860s (see Krantz and Nilsson 1975, p. 35). Therefore, we have used figures for X in 1870 that have been increased by 10 percent.

that period, slightly more than 1.0 million people were absorbed by the agricultural sector. Through increased acreage of cultivated land, introduction of new production techniques, and land reform, the agricultural sector managed to absorb its growing population (Thomas 1941, p. 49). However, this trend did not continue after 1850.

Population pressure in the agricultural sector increased during the second part of the century due to an augmented natural population increase in the 1870s and 1880s. Despite an increased transformation of agriculture this sector was no longer totally able to absorb its growing population. The growth in agricultural production during the prewar period was a consequence not only of increased acreage but also of technological development and capital investments. The combine-harvester was an example of production technology becoming more and more capital intensive.

Against this background it has been decided to use three factors of production when modeling agricultural production: land, labor, and capital. The conventional Cobb–Douglas production function is not appropriate unless one is able to justify a unitary elasticity of substitution between each pair of production factors. Instead of assuming this, more flexibility is introduced by using a so-called nested production function.

Labor and capital are considered to be functionally separable from land. This means that growth in the amount of cultivated land results in a proportional increase in the marginal productivity of labor and capital.* Labor and capital are combined by a constant-elasticity-of-substitution (CES) production function into a composite production factor (H). Land and H are then combined in a Cobb–Douglas function. There is some empirical support for not choosing a Cobb–Douglas specification for labor and capital. In a study by Jungenfelt (1966), it was shown that labor's share of value added in agriculture decreased before the First World War (Table 3). Jungenfelt has also estimated the elasticity of substitution between labor and capital to be 0.6.** A Cobb–Douglas specification for these two production factors, therefore, appears to be inappropriate.

The CES production function is used for each nonagricultural sector. Even in these sectors, the development of the labor's share of value added and the elasticity of substitution have been the bases on which the choice has been made. As can be seen in Table 3, neither transport nor industry exhibits constant shares of labor. It is true that the sectors in the present model differ from those of Jungenfelt's, which are displayed in Table 3, but the model's sectors 2 and 3 – the export-oriented and the home-market-oriented industries – compose Jungenfelt's industry sector, and his transport sector constitutes an increasing proportion (6 percent in 1871–1875 and 17 percent in 1911–1915) of the

*For a discussion of the specification of production technology in agriculture see Kaneda (1979, pp. 11–23).

**See Jungenfelt (1966, p. 22). These estimates cover the whole 1870–1950 period, but to our knowledge they are the only ones available that cover the prewar period.

TABLE 3 The labor's share of value added in the Swedish economy as a whole and in agriculture, industry, and transport, 1870–1914.

Period	The whole economy	Agriculture	Industry	Transport
1870–1879	72	84	67	41
1880–1889	72	82	75	46
1890–1899	70	83	71	43
1900–1909	66	80	63	45
1910–1914	64	75	60	47

SOURCE: Jungenfelt (1966) p. 42.

model's sector 4 – the service sector. The elasticities of substitution in industry and transport are estimated to be 0.6 (Jungenfelt 1966, p. 202).

Thus, the production functions in the model have the following form. (The complete mathematical statement of the model can be found in Appendix B. Equation numbers correspond with the mathematical statement.) For agriculture

$$X_1 = A_1 R^{\alpha} H^{1-\alpha} \tag{5}$$

$$H = \left\{ \delta_1 \left(g_1 K_1\right)^{-\rho_1} + \gamma_1 \left(h_1 L_1\right)^{-\rho_1} \right\}^{-1/\rho_1} \tag{6}$$

and for the remaining four sectors

$$X_j = A_j \left\{ \delta_j \left(g_j K_j\right)^{-\rho_j} + \gamma_j \left(h_j L_j\right)^{-\rho_j} \right\}^{-1/\rho_j} \qquad j = 2, \ldots, 5 \tag{7}$$

$$X_{ij} = a_{ij} X_j \qquad \begin{matrix} i = 1, \ldots, 5 \\ j = 1, \ldots, 5 \end{matrix} \tag{8}$$

X_j are gross output in sector j, K_j the capital stock, and L_j the employment in sector j. A_j, α, δ_j and γ_j are constants. The formulation allows for different values of these parameters in the different sectors. The substitution parameter is ρ, and it is defined as

$$\rho = \frac{1}{\epsilon_s} - 1$$

where ϵ_s is the elasticity of substitution. The technological parameters are g_j and h_j. And $g_j K_j$ and $h_j L_j$ can be referred to as "efficiency capital" and "efficiency labor," respectively. Deliveries of intermediate goods from sector i to sector j are denoted by X_{ij}, and the input coefficients by a_{ij}.

Technological development is one of the dynamic features of the model. There is historical evidence that technological progress had an extensive growth-creating effect on the economy in Sweden. Åberg has estimated that 42 percent of the growth in productivity between 1870 and 1913 can be explained by technological progress (Åberg 1969, p. 38). It has also been shown that the growth in technology was not neutral but was labor saving (Jungenfelt 1966; Åberg 1969). Moreover, the labor-saving bias was a characteristic not only for the industrial sectors but also for the agricultural sector.

The model formulation captures these characteristics. The technological parameters in the production functions, g_j and h_j, change over time (t) according to exogenously determined growth rates:

$$g_j(t) = g_j(t-1)\exp(\lambda_j^g) \qquad j = 1, \ldots, 5 \tag{54}$$

$$h_j(t) = h_j(t-1)\exp(\lambda_j^h) \qquad j = 1, \ldots, 5 \tag{55}$$

The growth rate λ differs among the different sectors and when $\lambda^h > \lambda^g$ the model exhibits a labor-saving bias in technological growth.

Reflecting the historical situation, the area of cultivated land, R, is enlarged over time in the model

$$R(t) = R(t-1)\exp(r) \tag{53}$$

where r is the annual rate of growth in land acreage.

The different factors of production are assumed to be combined in a way that will maximize profits in each sector. Before the necessary conditions are presented it is worthwhile to point out three specific features of the model.

(1) Because of low agricultural wages, a reallocation of the labor force from agriculture to other sectors took place during the 1870–1914 period. But, as can be seen in Figure 1, the wages were not equalized. For a discussion of the sectorial wages see Bagge, Lundberg, and Svennilson (1933). In a pure general equilibrium model without wage-structure or labor-mobility constraints, the labor force is allocated in each period in such a way as to equalize wages. In our model, which has to reflect the Swedish stylized facts, it is necessary to incorporate such constraints. This is done in two ways: through the specification of an explicitly formulated migration function for rural–urban migration as well as emigration, and through the introduction of a wage structure among urban sectors. Migration is a function of the relative levels of wages in the sending and receiving regions, and the urban wage structure is exogenously determined. Thus there will be a reallocation of labor among the sectors, but not to the extent that wages will be equalized in each period of time.

(2) Total savings in the model make up total gross investments. Investments are divided between rural and urban areas according to an exogenously determined share. Difficulties in modeling the imperfect capital market, which

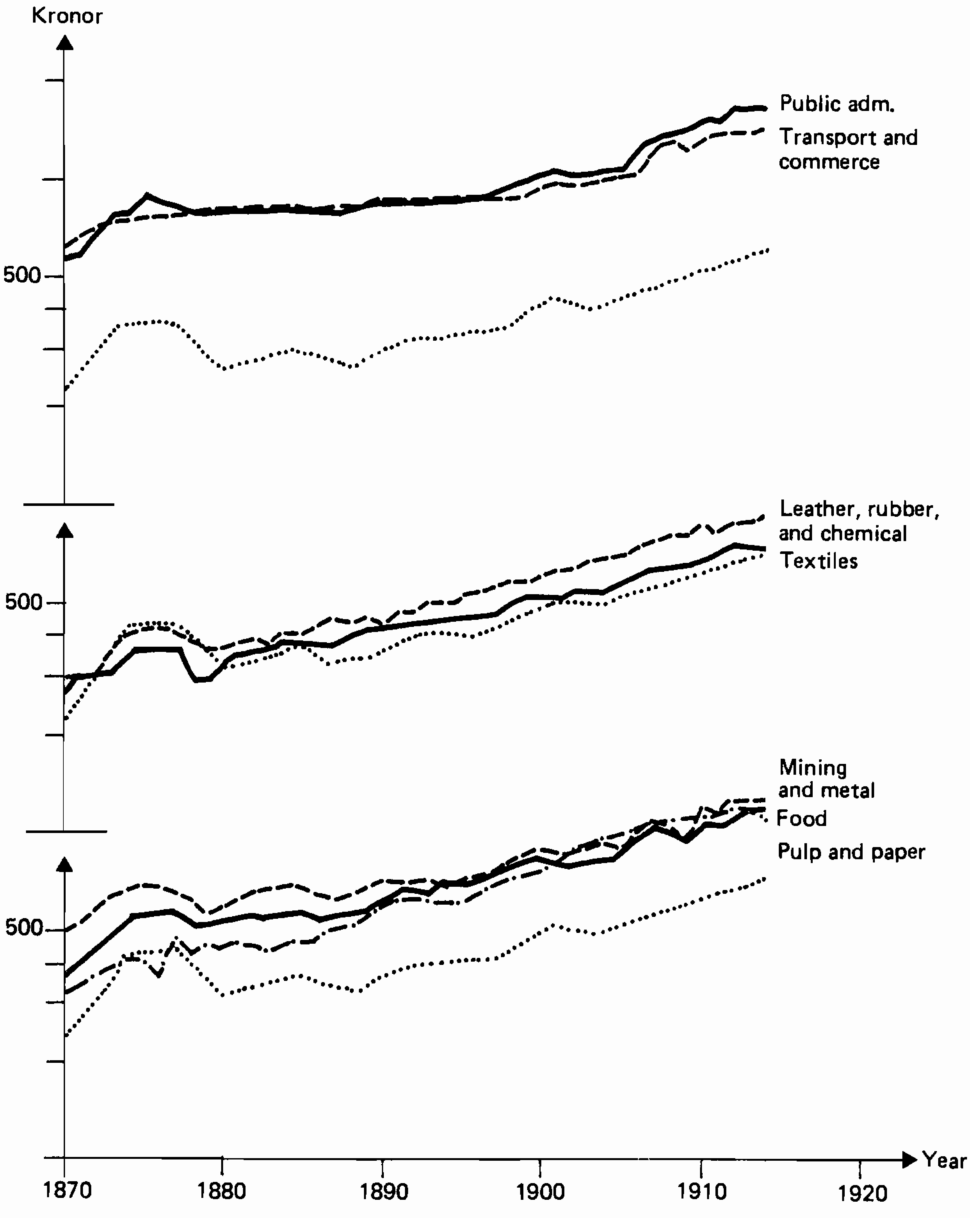

FIGURE 1 Wages in different sectors as compared to the agricultural sector (·····), 1870–1914. Source: adapted from Jungenfelt (1966).

prevailed in Sweden during the prewar period, have made it necessary at this stage to treat this share as exogenous. Within the urban sector the entire "urban" capital stock, not just new investments, is assumed to be completely mobile. The capital stock in the urban sector is thus of the "putty-putty" type. Between the four urban sectors the capital is allocated so that an exogenously given structure of the sectorial rate of returns will be fulfilled in each period of time.

(3) There are three sets of prices in the model. The first two sets are domestic production costs (P_i) and domestic prices (P_i^D) of commodity i. Domestic prices are distinguished from domestic production costs through the influence of the world market in the three sectors where foreign trade occurs*

$$P_i^D = \frac{im_i}{1 + im_i} \left(1 + \phi_i\right) P_i^W + \frac{1}{1 + im_i} P_i \qquad i = 1, 3 \tag{1}$$

where $im_i = IM_i/(X_i - EX_i)$, ϕ is an *ad valorem* custom duty on imports, and P_i^W measures world market prices expressed in Swedish currency (kronor). The export-oriented sector is assumed to be a price-taker on the world market, and the world market price has a total price penetration on the Swedish market. Thus, the domestic price in sector 2 is exogenous in the model

$$P_2^D = P_2^W \tag{2}$$

And in sectors 4 (service) and 5 (building and construction) there are no imports so no differences will occur between domestic production costs and domestic prices

$$P_i^D = P_i \qquad i = 4, 5 \tag{3}$$

The third set of prices in the model is introduced to simplify the treatment of intermediary goods. A set of so-called value-added prices, P_i^*, is defined as the production cost of one unit of a commodity after deduction of the cost for the necessary intermediaries to produce that commodity

$$P_i^* = P_i - \sum_{j=1}^{5} P_j^D a_{ji} \qquad i = 1, \ldots, 5 \tag{4}$$

With these three basic features of the model in mind, the necessary conditions for profit maximization can be presented. First we have the agricultural sector. Because capital stock and available land are exogenous, the profit function is formulated as

$$\Pi_1 = P_1^* X_1 - W_1 L_1 \tag{10}$$

*The treatment of foreign trade will be more fully discussed in the following section. See also Bergman and Pór (1980).

where Π_1 represents profit in agriculture and W_1 refers to the wage rate. Included in Π_1 are not only remittances to the owners of capital and land, but also the necessary depreciation of the capital stock. Labor is paid in correspondence with its marginal productivity, and this results in the following conditions for profit maximization:

$$\frac{W_1 L_1}{P_1^* X_1} = (1-\alpha)\gamma_1 \left(\frac{H}{h_1 L_1}\right)^{\rho_1} \tag{9}$$

In the four urban sectors profit is defined as

$$\Pi_j = P_j^* X_j - W_j L_j - RC_j(P_2^D K_j^M + P_5^D K_j^B) - \left[P_5^D \kappa^B \zeta_j + P_2^D \kappa^M (1-\zeta_j)\right] K_j$$

The total wage sum ($W_j L_j$), the returns on the capital stock (RC_j), and depreciation are deducted from the "revenues" $P_j^* X_j$. [Observe that the cost for intermediary goods has already been deducted; see eq. (4).] The capital stock is divided into buildings, B, and other capital equipment, M. The annual rate of depreciation of these two types of capital stock is represented by κ^B and κ^M. The share of buildings and plants out of the total capital stock in sector j is ζ_j. If the concept "user cost" of capital, Q_j, (Johansen 1974) is defined as

$$Q_j = P_2^D (RC_j + \kappa^M)(1-\zeta_j) + P_5^D (RC_j + \kappa^B)\zeta_j \qquad j = 2, \ldots, 5 \tag{10a}$$

then the profit function can be rewritten as

$$\Pi_j = P_j^* X_j - W_j L_j - Q_j K_j$$

The resulting necessary conditions derived from this profit function are

$$\frac{W_j L_j}{P_j^* X_j} = \gamma_j \left(\frac{X_j}{h_j L_j A_j}\right)^{\rho_j} \qquad j = 2, \ldots, 5 \tag{11}$$

$$\frac{Q_j K_j}{P_j^* X_j} = \delta_j \left(\frac{X_j}{g_j K_j A_j}\right)^{\rho_j} \qquad j = 2, \ldots, 5 \tag{12}$$

The export sector is assumed to be the sector that leads the way in wages. The wage increases in that sector are followed by increases in other urban sectors and result in a rather fixed wage structure over time. The actual levels of different wages over time, plotted in Figure 1, seem to justify such an assumption. The wages in the branches of industry that form sector 2, are rather close to each other and are also higher than in the home-market-oriented sectors. However, the public administration and the transport subsector have the highest wages. This may be explained by a higher share of skilled labor in these sectors.

The fluctuations in the wages also seem to support the hypothesis that the export sector is wage determining.

Against this background it seems difficult to assume the same wage for all the urban sectors. Instead, the observed wage differences among the urban sectors are built into the model through an assumption of a constant sectorial structure

$$W_j = \omega_j W_U \qquad j = 2, \ldots, 5 \tag{14}$$

Wages in the different sectors are thus assumed to remain at certain constant proportions, ω_j, of the average wage level, W_U, across the entire urban area. In the solution of the model the average wage is normalized to one, and therefore, ω_j values refer to observed wage rates at the base point of time. The supply of labor in the urban sector will be allocated so that this relationship prevails over time and thus implicitly captures such differences between the urban sector as, for example, the share of the skilled worker. This formulation has not changed the assumption of a mobile labor force. Instead of assuming equalization of wages in each period of time, however, the relative increase in wages between two years is equalized.

Because of the lack of data it is more difficult to know the sectorial structure of the rates of return. To make the model flexible, however, we make similar assumptions for these rates as for wages. There are also many reasons to expect sectorial differences in the rate of return on capital, i.e., different risks connected with investments in the sectors, degree of monopolization in various branches, average size of firms, etc. The allocation of the capital stock among the urban sectors is thus determined by the rate of return in such a way as to maintain a certain sectorial structure over time

$$RC_j = q_j RC_U \qquad j = 2, \ldots, 5$$

where RC_U is the average rate of return in the urban sector, normalized to unity in the base year, and q_j are constants that reflect the sectorial structure of capital remuneration.*

THE FACTOR MARKET

Different characteristics of the factor markets have been discussed in the previous sections. It is, therefore, enough to present the equations which close the capital and labor markets.

The urban capital market is simply closed by summing the capital stocks in the four urban sectors, and setting the sum equal to the total capital stock

*It is unlikely that the sectorial structure of the rate of return on capital would remain stable over a long period of time, especially the 43 years between 1871–1914. Johansen discusses this formulation of sectorial structure of factor returns (Johansen 1974, p. 259). In the model simulation it will be shown just how realistic the assumptions are.

available to them, K_U

$$\sum_{j=2}^{5} K_j = K_U \tag{18}$$

To complete the labor market picture the supply of labor has to be formulated. The supply is assumed to be a certain share of the total population. But this share (total aggregated labor participation rate) differs between the two labor markets (urban and rural), as well as showing an increase during the industrialization period. The difference between urban and rural participation can be partly explained by different age structures. During the entire 1870–1914 period, the share of the population below the age of 15 was higher in the rural areas. For example, during the 1870s 35 percent of the rural working population was under 15 years of age as compared to 30 percent of the urban population (Thomas 1941, p. 47). This does not, however, explain all the differences between the rural and urban labor participation rates. Even the rate within the working-age group (defined as the part of the population over 15 years of age) differs. How important the age distribution above 15 is for this difference cannot be displayed because of the lack of information about age-specific participation rates. Part of the explanation can be found in the different sex-specific labor participation ratios. Among men, no significant difference existed between urban and rural areas (around 80 percent in both areas in the 1870s). However, for women in the rural areas the rate remained constant at 17 percent during the prewar period while in urban areas it increased from 28 percent in the 1870s to 43 percent in 1920 (Silenstam 1970, p. 103).

To capture these demographic differences affecting the aggregated labor participation rate, the rate is decomposed in the model and supply of labor in the two regions is described by the following conditions

$$L_A = \left[p_A^{\Gamma} z_A^{\Gamma} l_A + p_A^{\Omega} z_A^{\Omega} (1 - l_A)\right] N_A \tag{15}$$

$$L_U = \left[p_U^{\Gamma} z_U^{\Gamma} l_U + p_U^{\Omega} z_U^{\Omega} (1 - l_U)\right] N_U \tag{16}$$

where p is the labor participation rate within the working ages, z is the working-age share of the total population (N), and l is the share of females in the total population. All these rates are sex-specific and are indicated by the superscripts Γ for female and Ω for male. The demographic parameters (z, l) remained almost stable over the period studied but the sex- and age-specific labor participation ratios did not. They increase in the model with an exogenously determined growth rate

$$p_j^h(t) = p_j^h(t-1)\exp(\nu_j^h) \qquad \begin{matrix} j = A, U \\ h = \Gamma, \Omega \end{matrix} \tag{56}$$

In order to close the urban labor market, the employment in the different urban sectors must add up to the supply of labor

$$\sum_{j=2}^{5} L_j = L_U \tag{17}$$

The population grows by migration as well as by natural increase; migration is a function of the relative wages between urban and rural areas. The labor supply in the urban sector is, through migration, sensitive to relative wage differences and the labor-supply curve thus slopes upward.

HOUSEHOLD DEMAND AND INCOME

Consumption demand and its pattern have long been suppressed in the explanation of the long-run economic growth process, at least in theoretical studies. The supply condition has always been the primary focus. In some empirical studies, however, the importance of the final demand and its structure has been stressed (Kelley 1968 and 1969).

In a simple two-sector simulation model by Kelley, Williamson, and Cheetham, the effect on the growth process from the demand side was analyzed. The conclusion was that

> . . . demand does play a pervasive and important role in the model through changes in consumer tastes. Indeed, in a simulation experiment we find that the sensitivity of the economy to shifts in tastes toward urban goods may be as stimulatory to structural change in the long run as alterations in savings parameters, the variable of traditional focus in the development literature. Thus, the "demonstration effect," commonly a villain in descriptive analyses of growth and development, may turn out to be as much a hero as the touted puritan ethic regarding high savings and spending prudence. (Kelley, Williamson, and Cheetham 1974, p. 241)

Did demand play a similar role in the Swedish development? In the simulations of the model this question can be answered. From different studies it is clear that there has been a shift in consumption patterns. In a study of the cost of living in Sweden between 1860 and 1930, Myrdal composed two typical household budgets, one for the middle and one for the end of the 19th century (Myrdal 1933, pp. 116 and 138). He found that during this time the consumption pattern changed considerably. For example, the share of the family income spent on food decreased from 65 to 55 percent. In a study by Allen (1955, p. 91) comparing household budgets for industrial and agricultural workers for the year 1913/1914, the same conclusion was drawn. As expected, the share of food expenditure was highest among the lower paid rural workers. These changes in budget shares for different types of commodities are due to both price and income effects. Changes in relative prices affect the allocation of expenditure. When the per capita income grows, the marginal increase in demand for luxuries (industrial goods) is larger than that for necessities (agricultural goods). This so-called Engel effect has been a typical feature of the growth process in various types of countries on different development levels (Houthakker 1957), and Sweden is no exception (Parks 1969, p. 648). The typical relationship between income elasticities of different commodities seems to be that the income elasticity for primary products is lower than for industrial goods, which is, in turn, lower than for services.

Besides these demand-structure characteristics, duality in the demand pattern is sometimes stressed (Kelley, Williamson, and Cheetham 1972, p. 76). The consumers in urban areas disclose a different consumption pattern from the population in the traditional agricultural sector, even for given incomes and prices. Thus urbanization also plays an important, indirect role in the development process through its influence on the pattern of final demand.

Against this background the household demand in the model is captured by two expenditure systems, one for the urban areas (U) and one for the agricultural areas (A). The selected form is the Linear Expenditure System (LES). [A detailed treatment of LES can be found in Powell (1974) where the derivation from underlying utility functions is also discussed.] We use this formulation in the following way:

$$\frac{P_i^D D_{ij}}{N_j} = b_{ij}P_i^D + \beta_{ij}\left(\frac{C_j}{N_j} - \sum_{i=1}^{5} b_{ij}P_i^D\right) \qquad i = 1, \ldots, 5 \quad j = A, U \tag{19}$$

$$C_j = (1 - s^l)\left(Y_j^{Dl} - \sum_{i=1}^{5} b_{ij}P_i^D N_j\right) + (1 - s^c)Y_j^{Dc} + \sum_{i=1}^{5} b_{ij}P_i^D N_j \qquad j = A, U \tag{20}$$

where D_{ij} is consumption of commodity i in sector j, b_{ij} is a parameter which represents the per capita subsistence consumption of commodity i in sector j, and β_{ij} stands for the marginal propensity to consume commodities after subsistence expenditures are satisfied. The consumption expenditure C_j is the remaining disposable income (Y_j^D) after deduction for savings. Different savings rates (s^l and s^c) are assumed for labor and capital income. The labor forces are assumed to save only from their "supernumerary" incomes, i.e., after basic-needs consumption is satisfied.

Already in the 1870s a large range of different taxes and duties existed in Sweden: different property taxes, a proportional income tax, a personal tax for adults independent of income, and so on (Lundsjö 1975, p. 41). In the model, the 19th-century taxation system is roughly described by a proportional tax on capital income, τ^c (including factor returns on land in agriculture), and on wages, τ^l. In eqs. (21)–(24), the disposable incomes are defined as gross income minus taxes

$$Y_A^{Dl} = (1 - \tau^l) W_1 L_1 + RE \tag{21}$$

The term *RE* in eq. (21) refers to remittances from emigrants, which the agricultural labor force receives in addition to income from wages. These remittances have often been neglected in studies of this period, but they are of a substantial magnitude. The amount fluctuates around an average of 1 percent of the Swedish national product (Lindahl, Dahlgren, and Koch 1937, p. 588). In the model it is assumed that these remittances are sent to people living in the rural areas since these are the main origins of the emigrants. The remittances are exogenously determined in the model. The capital income in the agricultural sector

$$Y_A^{Dc} = (1 - \tau^c)\Pi_1 \tag{22}$$

consists of income from land and capital. In the urban sector, labor income comes only from employment in industries

$$Y_U^{Dl} = (1 - \tau^l) \sum_{j=2}^{5} W_j L_j \tag{23}$$

and capital income comes from returns on capital investments

$$Y_U^{Dc} = (1 - \tau^c) \sum_{j=2}^{5} Q_j K_j \tag{24}$$

EXPORTS AND IMPORTS

As has already been pointed out in the sectorial division discussion of the model, exports have played a crucial role in Swedish economic development. They have affected economic growth in two ways: through an increase in the demand for Swedish products and through an increase in productivity because of competition with foreign supply.

The effects of exports on Swedish economic growth were especially important during the prewar period. Ohlsson (1969, p. 60) has estimated that the direct and indirect effects of foreign trade contributed 56 percent of the growth in the national product between 1870 and 1890 and 29 percent between 1890 and 1913. He also concluded that a large part of the technical progress made during this time can be explained by foreign trade through its positive effect on productivity.

These stimulating effects on the Swedish economy, made possible by a quick adaptation to new world market conditions, altered the structure of Swedish foreign trade.

> At the outbreak of the First World War, about one third of Sweden's exports consisted of goods that 25 years earlier had not, broadly speaking, existed in the Swedish export statistics. The expansive powers in the exports had thereby been usurped by quite other groups of goods than earlier. (Fridlizius 1963, p. 30)

Two characteristic features of this structural change should be stressed. The first is the decline in agricultural exports, as has been shown in Table 2. In the 1870s, agricultural exports made up more than 20 percent of Sweden's total exports. Oats were the most important export product until 1890 when butter took this position. The stagnation in grain exports was due to sharpened competition. Russia and America became strong competitors because of improved transportation facilities. Toward the end of the century grain exports from Sweden almost ended.

The second characteristic feature is the change from exporting raw materials and less refined commodities to more manufactured products. Technical innovations and organizational changes altered this structure. Pig iron had traditionally been the main export product of the iron and steel industry, but due to new ingot-steel processes, steel exports markedly increased. The mining sector changed its character as well. The old mining industries in central Sweden began to concentrate on manufactured products, and phosphorus iron ore in the north became worth mining. Furthermore, in the 1890s, the engineering industry started to expand on the basis of two early Swedish innovations: the separator, originally a Swedish invention, and the telephone. Also, the timber industry began to reflect the typical export pattern – a transition to manufactured products. In the 1880s this industry held a 43 percent share of the world market, but this share decreased considerably by the end of the 1890s. During the same period, however, the pulp and paper industry began to expand.

Initially, imports concentrated on only a few products, as did exports, but as the economy grew imports became more and more diversified (see Table 2). The main import groups were agricultural products (more than 25 percent during the entire period), food products, and textiles and clothing. As can be seen in Table 2, imports existed in sector 2, the export-oriented industry.

In order to allow for both exports and imports in the sectors, one has to assume a finite elasticity of substitution between domestically produced commodities and those supplied by foreign producers. Relying on this assumption separate export and import functions are fomulated for each of the trade-participating sectors. Four different export functions are included in the model and should capture the important export-determining factors. The increase in world trade, as well as the development of productivity and production costs in Sweden in relation to the rest of the world, has been pointed out as the important factor behind the growth of Swedish exports (Ohlsson 1969, p. 83). Thus these factors will influence exports in the model.

In sectors 1 and 3, the agricultural sector and the home-market sector, the export functions have an identical formulation

$$EX_i = EX_i^{\circ} (P_i/P_i^W)^{\epsilon_i} \exp(\sigma_i t) \qquad i = 1, 3 \tag{25}$$

Exports from sector i, EX_i, are determined by the relation between Swedish production costs P_i and the world market prices P_i^W, as well as the growth of the world market, σ. The price elasticity parameter, ϵ_i, captures the response between changes in relative prices and exports. EX_i° is constant.

All the main Swedish export industries are put together into one sector in the model: sector 2, export-oriented industry. Thus one feature of the Swedish export pattern cannot be captured in the model, that is the transition from raw-material exports to the export of manufactured products. (We have not divided this sector into a base-industry sector and a refining-industry sector in order to capture this transition because, to our knowledge, the necessary data are not available.) More than three-fourths of the industrial exports are covered by this sector. In 1899, the total share of Swedish industrial products in the world market was 0.97 percent and in 1913 it was 1.25 percent (Ohlsson 1969, p. 79). It seems reasonable to assume from this that the export industry was a price-taker in the world market, and that these products sold at world market prices in the home market (i.e., $P_2^D = P_2^W$). The export-limiting factor is, therefore, the growth of the capacity of the industry (i.e., productivity increases and capital formation). Against this background the export function in our model cannot be of the same type as it is for sectors 1 and 3. Instead, the exports from sector 2 are determined as a residual in the balance of payments. This means, for instance, that the growth capacity of the export industry will implicitly be the limiting factor on exports through the development of other economic variables in the model

$$P_2 EX_2 = P_1^W IM_1 + P_2^W IM_2 + P_3^W IM_3 - P_1 EX_1 - P_3 EX_3 - P_4 EX_4 - F - RE \tag{29}$$

where IM measures imports; F, the net capital inflow from abroad; and RE, the remittances from emigrants.

The exports from sector 4, the service sector, originate from the subsectors of transportation and commerce. The export revenues from commerce are the trade markups on exported goods, and from transportation they are the income earned by Swedish ships in foreign trade (more exactly net income, see Johansson 1967, p. 182). In the model, exports from sector 4 are assumed to be determined as a fixed share of the total exports from sectors 1–3

$$EX_4 = \upsilon \sum_{i=1}^{3} EX_i \tag{26}$$

The import share in the model is a function of the relationship between domestic production costs and world market prices (plus any custom duty, ϕ, that may occur)

$$im_i \equiv \frac{IM_i}{X_i - EX_i} = im_i^{\circ} \left[\frac{P_i}{(1 + \phi_i)P_i^W} \right]^{\mu_i} \qquad i = 1, 3 \qquad (27)$$

where im_i° is a constant and μ_i is the price elasticity parameter.

Since, by assumption, no price differences exist in sector 2, prices cannot have an impact on the import share. Instead it is assumed, in correspondence with the figures in Table 2, that the share diminishes over time

$$im_2 \equiv \frac{IM_2}{X_2 - EX_2} = im_2^{\circ} \exp(-\psi t) \qquad (28)$$

SAVINGS AND INVESTMENTS

The domestic savings pattern during the 1870–1914 period displayed two different tendencies, as can be seen in Figure 2. During the 1870s and the 1880s, the savings rate diminished from almost 11 percent to around 7 percent. The rate showed a rapid increase, however, at the beginning of the 1890s.

The investment rate exhibited a similar pattern, but the reduction in the 1870s and 1880s was not as pronounced as the decline in the savings rate. The difference between these two rates (when the investment rate is higher than the savings rate) is the net capital borrowing from abroad. From Figure 2 it is obvious that there was an important inflow of foreign capital to Sweden during the industrialization period. The borrowing from abroad, mainly from France, was undertaken primarily by the government (Sundbom 1944). Economic historians have found that foreign capital played a crucial role in Sweden's economic development process. Through capital inflow, Sweden was able to build "cities, railways, and factories at the same time" (Gårdlund 1942, p. 194). Investment in the infrastructure (housing and transportation) made up over 50 percent of total investments during the prewar period. The housing share fluctuated between 30–40 percent and investment in transportation was around 20 percent. Industry's share increased from 16 percent in the 1870s to 25 percent before the First World War and agricultural investments declined from 22 percent to 9 percent of the total investment (Lundberg 1969, p. 142).

During the beginning of the industrial era hardly any financial market existed. The need for industrial capital was to a great extent met by internal sources through retained profits, and the external credit facilities were mainly supplied by private persons with a close connection to the companies. [For a description of the financing of the Swedish industry during the industrial breakthrough, see Gårdlund (1947)]. Toward the end of the century private

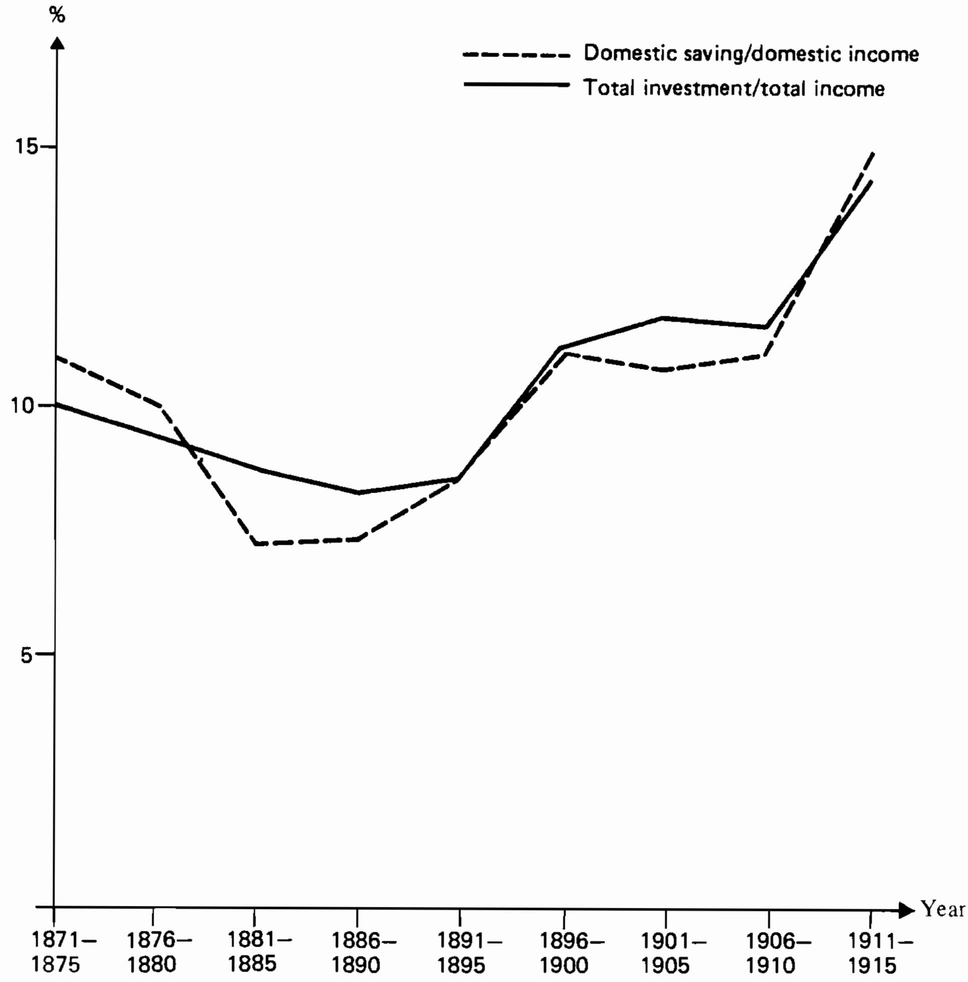

FIGURE 2 Savings and investment rates, 1870–1914. Source: adapted from Krantz and Nilsson (1975) Table 2.2.3, pp. 163, 164.

banks became more and more important as collectors of private savings and suppliers of credit. The growth of financial intermediaries made the capital market less imperfect, but nevertheless by the end of the period, the market was still far from efficient. Thus capital formation in Sweden was characterized by large government investment, foreign borrowing, and a growing but imperfect financial market.

Therefore, to assume a perfect capital market and rate of return equalization among all the sectors seems to be an incorrect way to describe the real situation. The ideal model, of course, should have investment functions that capture this imperfect market. But, at this stage it appears to be too difficult a task. Instead a simpler treatment is chosen as previously described.

Total investments in the economy, I, are allocated between agriculture and the rest of the economy, the four urban sectors, by an exogenously chosen parameter

$$I_1 = \xi I \tag{33}$$

$$I_U = (1 - \xi)I \tag{34}$$

where ξ is simply the share of total investment that went into agriculture, and I_1 and I_U the investments in the two sectors. The capital stock in period t consists of the stock in period $t - 1$ plus gross investments minus depreciations

$$K_j(t) = K_j(t-1) + I_j(t-1) - \left[\kappa^B \zeta_j + \kappa^M (1 - \zeta_j)\right] K_j(t) \qquad j = A, U \tag{50}$$

where κ^B and κ^M are different depreciation rates of the two types of physical capital of which the capital stock is assumed to consist: namely, buildings and plants, superscript B, and other capital equipment, superscript M. The sector's share of buildings and plants in the capital stock is denoted by ζ_j. The reason for this formulation is that the investments are produced in two different sectors: buildings and plants in sector 5, and other capital equipment in sector 2.

$$I_1^B = \zeta_1 I_1 \tag{35}$$

$$I_1^M = (1 - \zeta_1)I_1 \tag{36}$$

$$I_U^B = \zeta_U I_U \tag{37}$$

$$I_U^M = (1 - \zeta_U)I_U \tag{38}$$

Within the four urban sectors, capital stock is assumed to be completely mobile, thus of the putty-putty type, and is allocated so that a specific structure of the sectorial rate of return is established [see discussions about eq. (13)].

Savings originate from two different sources: private savings and government saving. Private savings are derived from labor and capital incomes in both agricultural and urban sectors. As was discussed earlier, some parts of the expenditure are devoted to cover basic needs of the population. It seems reasonable to assume, therefore, that savings are deducted from the remaining part of the income, the supernumerary income

$$S_j = s^l \left(Y_j^{Dl} - \sum_{i=1}^{5} b_{ij} P_i^D N_j\right) + s^c Y_j^{Dc} \qquad j = A, U \tag{30}$$

where s^l and s^c denote the share of savings from labor and capital incomes. It is assumed that the savings ratio from capital income is higher than from labor income. Notice that demographic changes influence savings. A higher fertility, *ceteris paribus*, leads to a decrease in savings because a larger part of the income has to be devoted to subsistence consumption.

Furthermore, savings are also undertaken by the government and these savings, S^G, are what remains after governmental expenditures, C^G, are deducted from governmental income. This income originates from three sources, taxes on wages and capital incomes, customs duties, and foreign borrowing

$$S^G = \sum_{j=1}^{5} \tau^l W_j L_j + \tau^c \Pi_1 + \sum_{j=2}^{5} \tau^c Q_j K_j + \sum_{i=1}^{3} \phi_i P_i^W IM_i + F - C^G \qquad (31)$$

Government spending (C^G) is an exogenous variable. The total savings in the model determine the amount of resources that are available for investment in a certain year. Thus, total savings equal total investments

$$I = S_A + S_U + S^G \qquad (32)$$

MIGRATION

As has already been pointed out, 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. Migration was stimulated by industrialization and a strong relationship can be seen between the increase in migration and the industrial breakthrough.

Swedish migration began during the second part of the 19th century. Until the 1840s Sweden had been a rather static society with little and well regulated migration. In the 1840s the urban share of the total population was around 10 percent, a figure that had remained constant for decades (Öhngren 1977, p. 265). But at the end of the 1840s the urbanization rate started to increase, slowly but definitively. Even so, as late as the 1870s only slightly more than 13 percent of the population lived in towns and municipal communities, but 40 years later the urban population had increased to 30 percent of the total population.*

However, at this point, it is necessary to notice one specific feature of Swedish industrialization; namely, that the industries, to a great extent, were located in rural areas and not in towns and cities (Population Movements and Industrialization 1941). In particular, the industries that initiated the new epoch, the wood, mining, and metal industries, can be characterized as rural

*The definition of towns in early Swedish statistics is based on administrative rather than functional factors. From 1910 onwards, however, statistics have been available for the more functional definition of towns: "densely populated areas." In that year 34 percent of the population lived in such areas, so the difference between the two concepts is small, at least at the end of the period of study (Historical Statistics of Sweden 1969).

TABLE 4 The share (in percent) of industrial workers occupied in the rural areas of Sweden by branches of industry, 1896 and 1913.

Branches of industry	1896	1913
Mining and basic metal	99.9	98.7
Metal manufacturing	47.5	37.2
Stone, clay, and glass	85.4	86.2
Lumber, etc.	84.1	81.0
Paper and printing	56.1	60.0
Food products	40.5	40.4
Textile and clothing	36.1	35.9
Leather, rubber, etc.	34.2	23.9
Chemical	43.0	33.6
Power, light, and waterworks	50.0	22.0
All branches	63.3	58.2

SOURCE: Thomas (1941) p. 179.

based. Table 4 displays the percentage of industrial workers in rural industries in 1896 and in 1913. In 1896, about 63 percent of all industrial workers were employed in rural areas. The figure decreased to 58 percent in 1913. This decrease not only reflects the fact that urban industries had increased their employment share but also points to a typical feature of the Swedish urbanization process – the creation of new and larger towns. This phenomenon occurred through the growth of population agglomerations around rural industries. After some time, these settlements either received town charters or were incorporated into neighboring cities. Thus, urbanization in Sweden did not reflect the total movement of the population.

This point is important to remember when interpreting the model. In the model all nonagricultural activities are characterized as urban. The simulation result will thus yield a higher degree of urbanization compared with real data, but this rate will reflect more accurately the actual proportion of the population movement than will the official figures on urban growth. Moreover, the model cannot be given a spatial interpretation as has been done in similar studies of Third World countries (see, for example, Kelley and Williamson 1980, p. 13).

As has already been stressed, Swedish emigration was largely directed toward the United States.* The extent, character, and causes have been investigated in several studies (for example, Thomas 1941; Runblom and Norman

*Immigration amounted to slightly more than 200,000 people during the period of study, but 50 percent of them originated in the USA and consisted of emigrants who returned to Sweden after some years in America (Historical Statistics of Sweden 1969, Part 1: Population, pp. 120–125). In the present model immigration is not explicitly treated and the migration concept is thus net migration.

1976). Econometric studies have been made that deal with factors influencing emigration (Wilkinson 1967 and 1970; Williamson 1974; Quigley 1972; Hamberg 1976). The results strongly support the view that economic factors such as employment opportunities and real income gains were most important in the explanation of emigration. These studies also deal with the economic situation in Sweden and the USA at the time, i.e., the push/pull factors, which were crucial to emigration. There seems to be no disagreement that the situation in both the sending and the receiving country strongly influenced the migration even though the relative importance that various studies place on each factor differs. In studies made by historians, push and pull factors explain different waves of emigration. The first wave of emigrants occurred at the end of the 1860s (Figure 3) mainly as a consequence of the famine during those years. The remaining waves during the 19th century were more closely related to industrial recession and agricultural crises. After the turn of the century emigration seemed to be caused mainly by pull factors in the United States (Carlsson 1976).

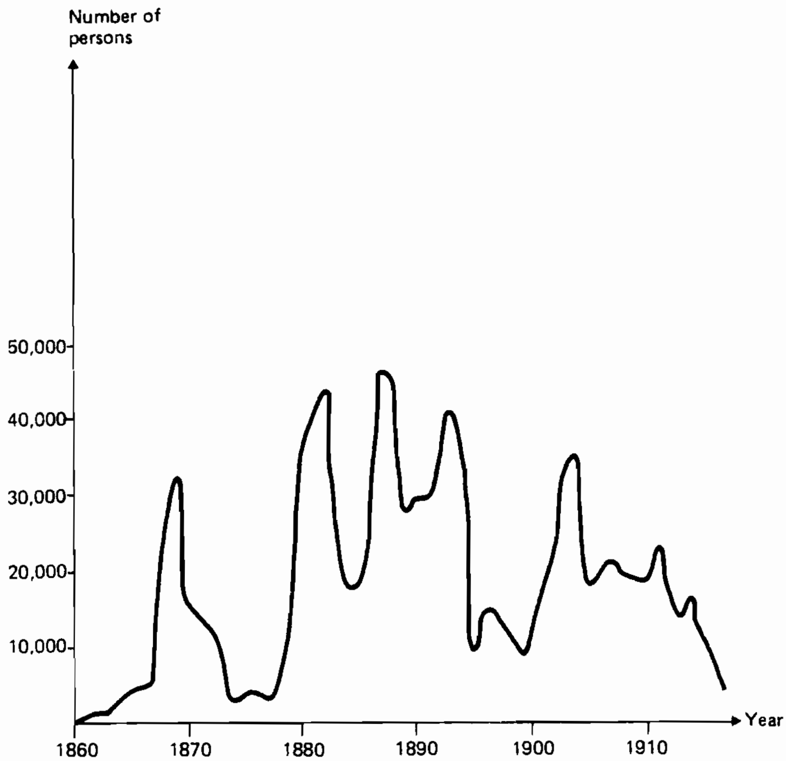

FIGURE 3 Registered emigration from Sweden to non-European countries, 1860–1915. Source: adapted from Runblom and Norman (1976) Table 5.1, p. 117.

In some migration studies, however, it is the relationships between expected income in the different regions that are considered to be the determining factors in migration. By stressing the comparison of the expected income in various regions and not simply what the economic situation is in one region independent of another, the distinction between push and pull factors becomes artificial. This hypothesis is not only supported by empirical findings (Hamberg 1976) but also can be justified from the theoretical point of view (Greenwood 1975; Sjaastad 1962). The theoretical foundation lies in human capital theory. Migration is looked upon as an investment, and it is the present value (*PV*) of an investment in migrating from one region to another that determines whether the move was made or not. The present value of migrating from region A to region U can be defined as

$$PV_{AU} = \sum_{t=1}^{n} \frac{Y_{Ut} - Y_{At}}{(1+r)^t} - \sum_{t=1}^{n} \frac{C_{Ut} - C_{At}}{(1+r)^t}$$

where Y refers to incomes in the different regions, C to the costs associated with residence in the two localities, and r to the rate of discount. Only if $PV > 0$ will an individual residing in A move to U, and in a choice between different moving possibilities, the one that maximizes PV will be chosen. When applying this model, one has to make some very rough approximations.

In this model the present value of future earnings is approximated by current wages in different localities. In some migration studies the income variables have been disaggregated into wages and the probability of working, the latter approximated by the unemployment rate (Todaro 1969). But since the model that will be used in the Swedish case study assumes full employment, and since the wages derived in the model and used in the migration function are sensitive to the supply conditions of labor, there is no need to explicitly capture this aspect in the formulation.

The cost differences between the three possible localities in the model – rural areas, urban areas, and the United States – are captured through a cost-of-living index (*COL*) specific to the different regions. Of course, the costs of transportation across the Atlantic did play a large role, but at present there is no general agreement among historians on whether the price of the ticket explains the fluctuation in emigration or not, even though the price fell in relation to wages over the period studied (Semmingsen 1972, p. 58). On the other hand, the transportation costs do explain the low emigration rate among the poorest social classes, but this effect is captured by parameter values in the migration functions.

Thus, in the present model, the propensity to emigrate (*em*) from Sweden (*S*) to the United States (*USA*) is only a function of the relation between the current real wages (W) in the two countries

$$em = f\left(\frac{W_{USA}/COL_{USA}}{W_S/COL_S}\right)$$

Migration from rural to urban areas within Sweden and from Sweden to the United States is determined in two stages in the model. First, the out-migration rate from agriculture (m) is defined. It is a function of the relation between a weighted real wage in the in-migration regions (the urban areas and the United States) and in agriculture*

$$m \equiv \frac{M}{N_1} = 1 - \exp(-\eta W^*) \tag{45}$$

$$W^* = \left[d\frac{W_U}{COL_U} + (1-d)\frac{W_{USA}}{COL_{USA}}\right] \Bigg/ \frac{W_1}{COL_1} \tag{46}$$

Second, the emigration rate, em, is treated as a function of the relation between real wages in the urban areas and the United States

$$em \equiv \frac{E}{M} = 1 - \exp(-\theta W^{**}) \tag{47}$$

$$W^{**} = \left(\frac{W_{USA}}{COL_{USA}}\right) \Bigg/ \left(\frac{W_U}{COL_U}\right) \tag{48}$$

where M is the total amount of net migrants out of the rural areas, E is the amount of net emigrants moving abroad and η, θ, and d are parameters. The costs of living in the agricultural and urban areas are determined endogenously. But the cost of living, COL_{USA}, and the wage level, W_{USA}, in the United States are exogenous variables

$$COL_j = \sum_{i=1}^{5} P_i^D \frac{P_i^D D_{ij}}{C_j} \qquad j = A, U \tag{49}$$

Recall from the labor market discussion that wages in the urban sectors are in a close relationship to each other. Therefore, W_U, which is used in eq. (14) to capture this relation, can be interpreted as a wage index for the urban sectors.

POPULATION GROWTH

One of the dynamic forces in the model is the growth of the population. The Swedish population experienced great changes during the second part of the 19th and the beginning of the 20th century. With an average growth rate of 0.7 percent per year, the population increased from 4.2 million to slightly

*This formulation of the migration functions is rather *ad hoc*. It would be more consistent with the underlying assumption of rationality in the rest of the model if the functions were derived from utility maximization conditions.

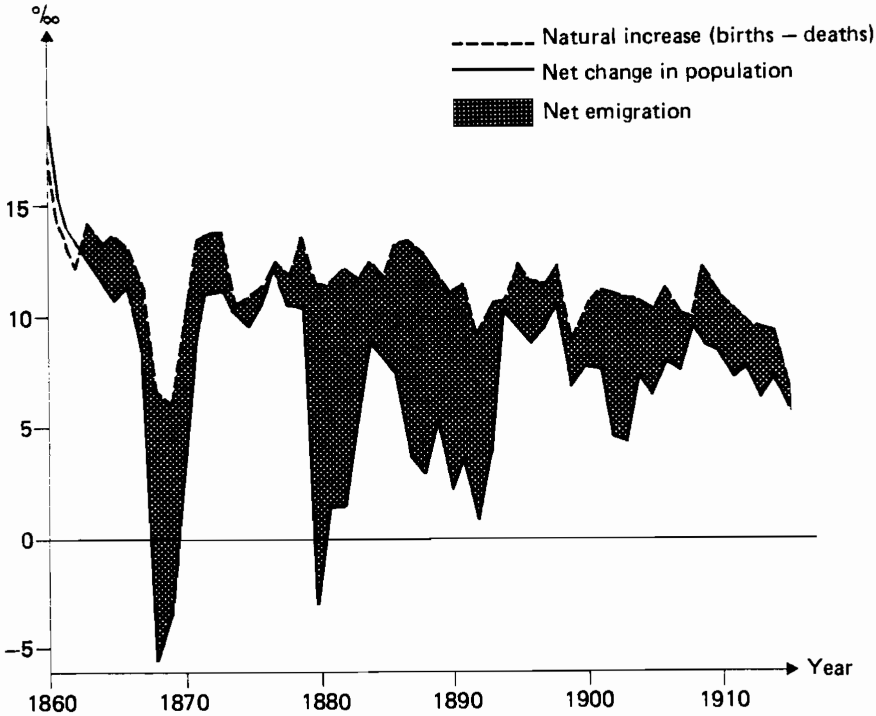

FIGURE 4 Changes in the population of Sweden, 1860–1914. Source: adapted from Historical Statistics of Sweden (1969) Table 28, pp. 95–97.

more than 5.6 million at the outbreak of World War I. As shown in Figure 4, this was not a smooth increase but a fluctuating one which was due to both changes in birth and death rates and to emigration. Fridlizius (1979), in a study about the demographic transition in Sweden, pointed out that the 1890s were the dividing years between a period of accelerating population growth, due mainly to decreasing mortality (1810–1890), and the third phase of demographic transition characterized by a strong decline in fertility.

The magnitudes of the demographic variables are very different between rural and urban areas. In Table 5 the crude birth and death rates, and the resulting increases in population, are displayed for the two types of regions. The urban areas showed higher rates for both births and deaths during the initial years of industrialization. The great difference between the urban and rural death rates is especially notable when one considers that the proportion of the

TABLE 5 Changes in crude birth and death rates in Sweden, 1861–1920.

Period	Crude birth rates			Crude death rates			Natural increase rates		
	Rural	Urban	Ratio of urban to rural (x 100)	Rural	Urban	Ratio of urban to rural (x 100)	Rural	Urban	Ratio of urban to rural (x 100)
1861–1870	31.2	33.0	106	19.3	26.2	136	11.9	6.8	57.1
1871–1880	30.2	32.1	106	17.3	24.1	139	12.9	8.0	62.0
1881–1890	28.7	31.1	108	16.4	19.7	120	12.3	11.4	92.7
1891–1900	27.2	27.1	100	16.1	17.4	108	11.1	9.7	87.4
1901–1910	25.7	25.9	101	14.9	14.9	100	10.8	11.0	101.9
1911–1920	22.7	20.5	90	14.6	13.5	92	8.1	7.0	86.4

SOURCE: Thomas (1941) Table 9, pp. 44, 45.

population in the ages 15–60 was higher in urban areas than in rural areas (Thomas 1941, p. 29). The decline in crude birth and death rates was, on the other hand, higher in the urban areas causing the relation in ratios between the two types of areas to be reversed at the end of the First World War. The patterns of change were similar even though the magnitudes differed. Decline in mortality and fertility began more or less simultaneously in both rural and urban regions. The demographic dualism between rural and urban areas was thus reflected in the initial differences in the demographic variables rather than in the patterns of change.

In the model, population growth is more or less exogenous. Even though there is evidence for causal links between economic factors and some demographic variables, for example, fertility (Wilkinson 1973), it has not been possible at this stage of modeling to endogenize them. Emigration is, on the other hand, endogenous in the model and is responsible for a major part of the change in the Swedish population (see Figure 4). Population growth is described by the following two equations, one for the rural, and one for the urban areas

$$N_1(t) = N_1(t-1)(1+f_1) - M(t-1) \tag{51}$$

$$N_U(t) = N_U(t-1)(1+f_U) + M(t-1) - E(t-1) \tag{52}$$

The changes in population are thus a consequence of the natural rate of population increase (f) and migration. Rates of natural population increase differ between regions and over time, and are, therefore, treated as exogenous variables and not as fixed parameters in the model.

This formulation of population growth makes the model useful for analyzing the phenomena of "long swings" or "Kuznets cycles" in the Swedish prewar development. The Kuznets-cycle hypothesis is concerned with the fluctuations of 15 to 25 years duration in the rate of growth of different variables. A discussion of these cycles can be found, for example, in Kuznets (1958), Abramovitz (1961), and Easterlin (1966). Morris Wilkinson (1967) has found evidence of long swings in the growth of the Swedish population and in some related economic variables. The population growth exhibits long swings, and emigration was primarily responsible for its amplitude until the first decade of the 20th century. He also found that the growth of capital formation and manufacturing output can be described by long waves. Furthermore, swings in manufacturing appear to lead to waves in population growth which are followed by changes in capital formation. He concludes by discussing the sources of the swings in manufacturing:

> It would be very convenient to place the source of the swings in Swedish manufacturing in the growth of the British economy. There is considerable evidence of long swings in significant sectors of the British economy. Furthermore, the turning points of the British long swings are provocatively

> close to the turning points of the Swedish long swings. Swedish exports do indeed give some support for this line of thinking. Prior to 1900, the growth of Swedish exports exhibits swings which consistently lead the swings in manufacturing. (Wilkinson 1967, p. 38)

In the present model, foreign trade is a crucial variable. The formulation makes it possible for long swings in manufacturing output to be initiated through exports, and eventually such swings can, via wage formation, be transmitted to emigration as well as to urbanization, and thus cause waves in population growth.

CONCLUDING REMARKS

This report has discussed a multisector growth model for Sweden during the 1870–1914 period. The model is based on the basic notion of neoclassical theory: prices are flexible enough to balance supply and demand on different markets. But some disequilibrating mechanisms have also been introduced into the model to capture some structural imbalances. The labor market, for instance, is separated between rural and urban areas and linked by migration. Migration, therefore, plays a crucial role in the development process and highlights some of the interrelationships among demographic and economic variables.

Our purpose has been to capture the most important aspects of Swedish demoeconomic development without making the model too large and too complicated. On the one hand, the model is intended to represent the key factors of a huge and complicated system, and on the other hand it should not be so large that the driving mechanisms become hidden in a "black box." This model is a compromise between these two aspects. In future work some parts of the model may be changed and others extended. For the purpose of highlighting demographic aspects and removing some simplifying assumptions, three desirable extensions are briefly discussed.

1. Investments and capital formation are exogenous in the agricultural and urban sectors. This is because of the difficulties in finding a reasonable allocation mechanism to capture the imperfect capital market. If such an allocation could be modeled, it would be possible to analyze how important a growing and more efficient capital market was in the Swedish case.
2. Demographic variables, with the exception of migration, are exogenous in the model. There is evidence indicating a strong influence of economic factors on demographic variables such as fertility (see, for example, Wilkinson 1973). An endogenizing of the natural increase of the population would cast further light on the interrelationships between demographic and economic factors.

3. The role that residential building played in Swedish development has been questioned in studies of the prewar period. Its share of the total investment adds up to one-third of the increase in the investment ratio. Construction of dwellings is one obvious consequence of urbanization and has also been stressed as one of the explanatory variables of the Kuznets cycle (Easterlin 1966). Therefore, it would be worthwhile to treat the housing sector – its demand and investment requirements – more explicitly in the model, and thus analyze its importance in Swedish demoeconomic development.

This report is only the first step in the study of Swedish urbanization and industrialization. The next step will be a simulation of the model and an analysis of numerous crucial questions through counterfactual simulations. It is in the empirical usage that the fruitfulness of this approach will be revealed. It is still open to question whether or not the model can shed further light on the demoeconomic development of industrialization in Sweden; however, the model does lay a foundation for future research in this field.

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Appendix A

THE SWEDISH ECONOMY, 1871–1915: EMPLOYMENT BY SECTOR, PRODUCTION BY SECTOR, AND CHANGES IN PRODUCTIVITY DUE TO REALLOCATION OF LABOR FORCE

TABLE A1 The number (in thousands) and share of people employed in different sectors in Sweden, 1871–1915.

Period	Agriculture		Manufacture		Transport and communication		Public administration		Total[a] employment	Total population
	Number	Share	Number	Share	Number	Share	Number	Share		
1871/1875	1060.7	0.793	200.5	0.150	27.5	0.021	48.9	0.036	1337.6	4274.0
1876/1880	1079.9	0.775	212.2	0.152	39.9	0.027	61.8	0.044	1393.8	4500.0
1881/1885	1081.0	0.755	236.4	0.166	44.5	0.031	69.2	0.048	1431.1	4604.7
1886/1890	1070.9	0.742	254.7	0.177	43.9	0.030	74.1	0.051	1443.6	4741.7
1891/1895	1060.6	0.712	302.1	0.203	48.9	0.032	78.7	0.053	1490.3	4831.8
1896/1900	1054.3	0.667	390.0	0.247	57.7	0.036	79.3	0.050	1581.3	5032.1
1901/1905	1027.5	0.631	443.1	0.272	70.8	0.043	87.3	0.054	1628.7	5214.3
1906/1910	990.7	0.602	483.5	0.244	85.6	0.052	85.8	0.052	1645.5	5405.9
1911/1915	970.1	0.574	531.6	0.314	94.1	0.056	95.4	0.056	1691.2	5620.4

[a]Building activities, commerce, and domestic services are excluded.
SOURCE: Jungenfelt (1966) Table 1, p. 224.

TABLE A2 National product by sector of origin: volume values.[a]

Period	Agriculture	Manufacture	Building and construction	Transport and communication	Personal private services	Public administration	Housing
1871/1875	495	134	121	32	253	186	176
1876/1880	525	151	144	42	297	103	187
1881/1885	560	193	129	55	331	110	196
1886/1890	585	220	130	64	359	113	208
1891/1895	645	317	122	81	408	115	217
1896/1900	681	473	158	114	465	117	230
1901/1905	658	611	184	158	560	118	249
1906/1910	785	823	175	209	682	121	265
1911/1915	848	996	216	256	832	127	282

[a]Millions of Swedish kronor.
SOURCE: Krantz and Nilsson (1975) Table 3.2.1, pp. 172–174.

TABLE A3 Productivity gains due to reallocation of employment among sectors, 1871–1915.[a]

Period	Agriculture and manufacturing			All industries except building and construction, housing and domestic services		
	Change in productivity (%)		Gains (= percentage of actual change due to reallocation)	Change in productivity (%)		Gains (= percentage of actual change due to reallocation)
	Actual	Hypothetical		Actual	Hypothetical	
1871/1875–1876/1880	0.94	0.90	4	1.02	0.57	44
1881/1885–1886/1890	1.23	1.10	11	1.19	1.01	15
1891/1895–1896/1900	2.51	1.91	24	2.38	1.79	25
1901/1905–1911/1915	3.60	3.15	13	3.34	2.80	16
1871/1875–1911/1915	2.28	1.84	19	2.17	1.66	23

[a]The gains in productivity due to reallocation of the labor force are estimated by comparing the actual change in productivity (sectorial value added divided by labor force) with a hypothetical change. The hypothetical change is the development of productivity keeping each sectorial share of the employment constant, i.e., the same as in the beginning of the study period.

Appendix B

MATHEMATICAL STATEMENT OF THE MODEL

PRODUCTION SECTOR SUBSCRIPTS

1	agriculture, forestry, and fishing
2	export-oriented industry
3	home-market-oriented industry
4	services
5	building and construction

HOUSEHOLD SECTOR SUBSCRIPTS

A	households in the agricultural sector (i.e., production sector 1)
U	households in the urban sector (i.e., production sector 2–5)

INCOME SUPERSCRIPTS

l	income from wages
c	income from capital

ENDOGENOUS VARIABLES

P_i	domestic production cost of commodity $i = 1, \ldots, 5$
P_i^D	domestic price of commodity $i = 1, \ldots, 5$
P_j^*	value-added prices in sector $j = 1, \ldots, 5$
X_j	gross output in sector $j = 1, \ldots, 5$
X_{ij}	deliveries of intermediate goods from sector i to sector j
H	composite of labor and capital input in the agricultural sector
L_j	employment in sector $j = 1, \ldots, 5$
L_U	employment in urban sectors
W_U	index of the level of wages in the urban sectors
W_j	wage rate in sector $j = 1, \ldots, 5$
Π_1	rent in the agricultural sector
RC_j	rate of return on capital in sector $j = 2, \ldots, 5$
RC_U	index of rates of return in the urban sectors
S_A	savings in the agricultural sector
S_U	savings in the urban sectors
Y_j^{Dl}	disposable income by workers in sector $j = A, U$
Y_j^{Dc}	disposable income by capitalists in sector $j = A, U$
D_{ij}	consumption of commodity $i = 1, \ldots, 5$ in sector $j = A, U$
C_j	total consumption expenditure in sector $j = A, U$
COL_j	cost of living in sector $j = A, U$
EX_i	export of commodity $i = 1, \ldots, 4$
IM_i	import of commodity $i = 1, \ldots, 3$
S^G	savings by the government
M	total number of net migrants from the rural areas
E	total number of net emigrants
I	total investment
I_j	investment in sector $j = A, U$

I_j^B	investments in buildings and plants in sector $j = A, U$
I_j^M	investments in other capital equipments in sector $j = A, U$
K_j	capital stock in sector $j = 2, \ldots, 5$
Q_j	user cost of capital in sector $j = 2, \ldots, 5$

EXOGENOUS VARIABLES AND PARAMETERS

K_j	capital stock in sector $j = A, U$
P_i^W	price level expressed in Swedish currency, on international markets on commodity $i = 1, \ldots, 3$
h_j	labor augmenting technological change in sector $j = 1, \ldots, 5$
g_j	capital augmenting technological change in sector $j = 1, \ldots, 5$
f_1	net natural rate of population increase in the rural areas
f_U	net natural rate of population increase in the urban areas
COL_{USA}	cost of living in the USA
W_{USA}	wage level in the USA
F	net capital inflow
C^G	consumption expenditures by the government
R	total land acreage
N_1	total population in the rural areas
N_U	total population in the urban areas
RE	remittances from emigrants
p_j^h	sex-specific labor participation rate in sector $j = A, U$ $h = \Gamma$ (female), Ω (male)
z_j^h	share of population in working ages, $j = A, U$ $h = \Gamma, \Omega$
l_j	share of females in total population, $j = A, U$
ϕ_i	*ad valorem* custom duty of imports of commodity $i = 1, \ldots, 3$
a_{ij}	input of commodity $i = 1, \ldots, 5$ per unit of output in sector $j = 1, \ldots, 5$
$\alpha, \delta_j, \gamma_j$	distribution parameters in the production function of sector j
ρ_j	substitution parameter in sector $j = 1, \ldots, 5$
ω_j	index of the relative wage rate in sector $j = 2, \ldots, 5$
β_{ij}	marginal propensity to consume commodity $i = 1, \ldots, 5$ by household in sector $j = A, U$
b_{ij}	per capita subsistence consumption of commodity $i = 1, \ldots, 5$ in sector $j = A, U$
s^l, s^c	rate of savings from labor income (l) and capital and land income (c)
ϵ_i	price elasticity parameter in the export demand for commodity $i = 1, \ldots, 3$
μ_i	price elasticity parameter in the import demand for commodity $i = 1, \ldots, 3$
σ_i	annual rate of change of world market trade with commodity $i = 1, \ldots, 3$
ψ	annual rate of change in import of commodity 2
τ^l, τ^c	tax rate from labor income (l) and capital and land income (c)
κ^B, κ^M	annual rate of depreciation of buildings and plants (B) and other capital equipment (M)

ζ_j	share of buildings and plants in the capital stock of sector $j = 1, \ldots, 5$
ξ	share of total investment in agriculture
r	annual rate of growth in land acreage
λ_j^g, λ_j^h	annual rate of technological change in sector $j = 1, \ldots, 5$
η, θ	parameters in the migration and emigration functions
A_j	constant in the production functions $j = 1, \ldots, 5$
v	export share in sector 4
ν_j^h	growth rate in labor participation $j = A, U$ $h = \Gamma, \Omega$
d	weight in the migration function
q_j	index of the relative rates of return in sector $j = 2, \ldots, 5$

PRICES

$$P_i^D = \frac{im_i}{1 + im_i}(1 + \phi_i)P_i^W + \frac{1}{1 + im_i}P_i \qquad i = 1, 3 \tag{1}$$

$$P_2^D = P_2^W \tag{2}$$

$$P_i^D = P_i \qquad i = 4, 5 \tag{3}$$

PRODUCTION AND TECHNOLOGY

$$P_i^* = P_i - \sum_{j=1}^{5} P_j^D a_{ji} \qquad i = 1, \ldots, 5 \tag{4}$$

$$X_1 = A_1 R^{\alpha} H^{1-\alpha} \tag{5}$$

$$H = \left\{ \delta_1 (g_1 K_1)^{-\rho_1} + \gamma_1 (h_1 L_1)^{-\rho_1} \right\}^{-1/\rho_1} \tag{6}$$

$$X_j = A_j \left\{ \delta_j (g_j K_j)^{-\rho_j} + \gamma_j (h_j L_j)^{-\rho_j} \right\}^{-1/\rho_j} \qquad j = 2, \ldots, 5 \tag{7}$$

$$X_{ij} = a_{ij} X_j \qquad \begin{matrix} i = 1, \ldots, 5 \\ j = 1, \ldots, 5 \end{matrix} \tag{8}$$

$$\frac{W_1 L_1}{P_1^* X_1} = (1 - \alpha)\gamma_1 \left(\frac{H}{h_1 L_1} \right)^{\rho_1} \tag{9}$$

$$\Pi_1 = P_1^* X_1 - W_1 L_1 \tag{10}$$

$$Q_j = P_2^D (RC_j + \kappa^M)(1 - \zeta_j) + P_5^D (RC_j + \kappa^B)\zeta_j \qquad j = 2, \ldots, 5 \tag{10a}$$

$$\frac{W_j L_j}{P_j^* X_j} = \gamma_j \left(\frac{X_j}{h_j L_j A_j} \right)^{\rho_j} \qquad j = 2, \ldots, 5 \tag{11}$$

$$\frac{Q_j K_j}{P_j^* X_j} = \delta_j \left(\frac{X_j}{g_j K_j A_j} \right)^{\rho_j} \qquad j = 2, \ldots, 5 \tag{12}$$

$$RC_j = q_j RC_U \qquad j = 2, \ldots, 5 \tag{13}$$

$$W_j = \omega_j W_U \qquad j = 2, \ldots, 5 \tag{14}$$

FACTOR MARKETS

$$L_A = [p_A^\Gamma z_A^\Gamma l_A + p_A^\Omega z_A^\Omega (1 - l_A)] N_A \tag{15}$$

$$L_U = [p_U^\Gamma z_U^\Gamma l_U + p_U^\Omega z_U^\Omega (1 - l_U)] N_U \tag{16}$$

$$\sum_{j=2}^{5} L_j = L_U \tag{17}$$

$$\sum_{j=2}^{5} K_j = K_U \tag{18}$$

HOUSEHOLD DEMAND AND INCOME

$$\frac{P_i^D D_{ij}}{N_j} = b_{ij} P_i^D + \beta_{ij} \left(\frac{C_j}{N_j} - \sum_{i=1}^{5} b_{ij} P_i^D \right) \qquad \begin{matrix} i = 1, \ldots, 5 \\ j = A, U \end{matrix} \tag{19}$$

$$C_j = (1 - s^l)(Y_j^{Dl} - \sum_{i=1}^{5} b_{ij} P_i^D N_j) + (1 - s^c) Y_j^{Dc} + \sum_{i=1}^{5} b_{ij} P_i^D N_j \qquad j = A, U \tag{20}$$

$$Y_A^{Dl} = (1 - \tau^l) W_1 L_1 + RE \tag{21}$$

$$Y_A^{Dc} = (1 - \tau^c) \Pi_1 \tag{22}$$

$$Y_U^{Dl} = (1 - \tau^l) \sum_{j=2}^{5} W_j L_j \tag{23}$$

$$Y_U^{Dc} = (1 - \tau^c) \sum_{j=2}^{5} Q_j K_j \tag{24}$$

EXPORTS AND IMPORTS

$$EX_i = EX_i^o \left(\frac{P_i}{P_i^W} \right)^{\epsilon_i} \exp(\sigma_i t) \qquad i = 1, 3 \tag{25}$$

$$EX_4 = \upsilon \sum_{i=1}^{3} EX_i \tag{26}$$

$$im_i \equiv \frac{IM_i}{X_i - EX_i} = im_i^o \left[\frac{P_i}{(1+\phi_i)P_i^W}\right]^{\mu_i} \qquad i = 1, 3 \tag{27}$$

$$im_2 \equiv \frac{IM_2}{X_2 - EX_2} = im_2^o \exp(-\psi t) \tag{28}$$

$$P_2 EX_2 = P_1^W IM_1 + P_2^W IM_2 + P_3^W IM_3 - P_1 EX_1 - P_3 EX_3 - P_4 EX_4 - F - RE \tag{29}$$

SAVINGS AND INVESTMENTS

$$S_j = s^l \left(Y_j^{Dl} - \sum_{i=1}^{5} b_{ij} P_i^D N_j\right) + s^c Y_j^{Dc} \qquad j = A, U \tag{30}$$

$$S^G = \sum_{j=1}^{5} \tau^l W_j L_j + \tau^c \Pi_1 + \sum_{j=2}^{5} \tau^c Q_j K_j + \sum_{i=1}^{3} \phi_i P_i^W IM_i + F - C^G \tag{31}$$

$$I = S_A + S_U + S^G \tag{32}$$

$$I_1 = \xi I \tag{33}$$

$$I_U = (1 - \xi) I \tag{34}$$

$$I_1^B = \zeta_1 I_1 \tag{35}$$

$$I_1^M = (1 - \zeta_1) I_1 \tag{36}$$

$$I_U^B = \zeta_U I_U \tag{37}$$

$$I_U^M = (1 - \zeta_U) I_U \tag{38}$$

BALANCING EQUATIONS

$$X_1 = D_{1A} + D_{1U} + \sum_{j=1}^{5} a_{1j} X_j + EX_1 - IM_1 \tag{39}$$

$$X_2 = D_{2A} + D_{2U} + \sum_{j=1}^{5} a_{2j} X_j + I_U^M + I_1^M + EX_2 - IM_2 \tag{40}$$

$$X_3 = D_{3A} + D_{3U} + \sum_{j=1}^{5} a_{3j} X_j + EX_3 - IM_3 \tag{41}$$

$$X_4 = D_{4A} + D_{4U} + \sum_{j=1}^{5} a_{4j} X_j + C^G + EX_4 \tag{42}$$

$$X_5 = D_{5A} + D_{5U} + \sum_{j=1}^{5} a_{5j} X_j + I_U^B + I_1^B \tag{43}$$

$$GDP = X_1 + X_2 + X_3 + X_4 + X_5 - \sum_{i=1}^{5} \sum_{j=1}^{5} X_{ij} \tag{44}$$

MIGRATION

$$m \equiv \frac{M}{N_1} = 1 - \exp(-\eta W^*) \tag{45}$$

$$W^* = \left[d \frac{W_U}{COL_U} + (1-d) \frac{W_{USA}}{COL_{USA}} \right] \Big/ \frac{W_1}{COL_1} \tag{46}$$

$$em \equiv \frac{E}{M} = 1 - \exp(-\theta W^{**}) \tag{47}$$

$$W^{**} = \left(\frac{W_{USA}}{COL_{USA}} \right) \Big/ \left(\frac{W_U}{COL_U} \right) \tag{48}$$

$$COL_j = \sum_{i=1}^{5} P_i^D \frac{P_i^D D_{ij}}{C_j} \qquad j = A, U \tag{49}$$

DYNAMICS

$$K_j(t) = K_j(t-1) + I_j(t-1) - [\kappa^B \zeta_j + \kappa^M (1 - \zeta_j)] K_j(t) \qquad j = A, U \tag{50}$$

$$N_1(t) = N_1(t-1)(1 + f_1) - M(t-1) \tag{51}$$

$$N_U(t) = N_U(t-1)(1 + f_U) + M(t-1) - E(t-1) \tag{52}$$

$$R(t) = R(t-1)\exp(r) \tag{53}$$

$$g_j(t) = g_j(t-1)\exp(\lambda_j^g) \qquad j = 1, \ldots, 5 \tag{54}$$

$$h_j(t) = h_j(t-1)\exp(\lambda_j^h) \qquad j = 1, \ldots, 5 \tag{55}$$

$$p_j^h(t) = p_j^h(t-1)\exp(\nu_j^h) \qquad j = A, U; \; h = \Gamma, \Omega \tag{56}$$

ABSTRACTS OF OTHER IIASA PUBLICATIONS

Reports on the Comparative Migration and Settlement Study

This collection of national reports deals with the comparative analysis of internal migration and spatial population growth in the 17 National Member Organization countries of IIASA. Patterns of population change are explored by applying the new multiregional methodologies and computer programs elaborated in the Human Settlements and Services Area. All reports have the same structure and include multiregional data on fertility, mortality, and migration, multiregional life tables, spatial mortality, fertility, and migration expectancies, and multiregional population projections. Each Migration and Settlement report is authored by a native collaborating scholar familiar with the demographic setting of his/her country. (The first two reports were published in 1979.)

1. United Kingdom
   RR-79-3 P.H. Rees
2. Finland
   RR-79-9 K. Rikkinen
3. Sweden
   RR-80-5 Å.E. Andersson, I. Holmberg
4. German Democratic Republic
   RR-80-6 G. Mohs
5. Netherlands
   RR-80-13 P. Drewe
6. Canada
   RR-80-29 M. Termote
7. Hungary
   RR-80-34 K. Bies, K. Tekse
8. Soviet Union
   RR-80-36 S. Soboleva
9. Federal Republic of Germany
   RR-80-37 R. Koch, H.-P. Gatzweiler

Rogers, A., Migration Patterns and Population Redistribution. IIASA Research Report RR-80-7, March 1980.
Reprinted from *Regional Science and Urban Economics*, Vol. 9, 1979, pp. 275–310.

A complete dynamic model of a system of metropolitan areas interacting through economic and demographic links is proposed. The model introduces interregional and intraregional effects of population. In addition, this model permits the simultaneous determination of migration rates, labor-force-participation rates, and unemployment rates.

Gordon, P., and J. Ledent, Modeling the Dynamics of a System of Metropolitan Areas: A Demoeconomic Approach. IIASA Research Report RR-80-8, March 1980.
Reprinted from *Environment and Planning A*, Vol. 12, 1980, pp. 125–133.

This paper proposes a complete dynamic model of a system of metropolitan areas interacting through economic and demographic links, namely, trade and migration respectively. It not only considers interregional effects (through an interregional input–output submodel) but also intraregional effects (through a set of Garin–Lowry submodels). In addition it allows the simultaneous determination of migration rates, labor-force-participation rates, and unemployment rates. Suggestive of the demoeconomic approach, this model also reveals the methodological difficulties that such an approach implies.

Rogers, A., (ed.), Essays in Multistate Mathematical Demography. IIASA Research Report RR-80-10, May 1980.
Reprinted from *Environment and Planning A*, Vol. 12(5), 1980, pp. 485–622.

The six papers in this special issue were first presented at the session on mathematical demography held at the 1979 Annual Meeting of the Population Association of America in Philadelphia, 26–28 April. They are representative examples of work currently under way in a relatively new branch of mathematical demography becoming known as multistate demography, the study of the transitions that individuals experience over time in the course of passing from one state of existence to another.

Willekens, F., Optimal Migration Policies: An Analytical Approach – Part 1. IIASA Research Report RR-80-16, April 1980.
Reprinted from *Regional Science and Urban Economics*, Vol. 9, 1979, pp. 345–367.

This paper explores the analytical features of population distribution or human settlement policies. It proposes a methodology for quantitative policy analysis and policy design based on optimal control and system theory. The paper consists of two parts. This part shows how policy models may be derived from demographic and demoeconomic or demometric models by adding a new dimension: the goals–means relationship of population distribution policy. It examines a large class of relevant policy models and demonstrates their relationship to the original Tinbergen *Theory of Policy*, which provides a paradigm for static and dynamic policy analysis. Problems of *existence* and of *design* of optimal population distribution policies are studied analytically. In designing optimal policies, use may be made of the minimizing properties of generalized inverses.

Kelley, A.C., and J.G. Williamson, Modeling Urbanization and Economic Growth. IIASA Research Report RR-80-22, May 1980.

This report describes a prototype model of the urbanization and development process. It sets out a general equilibrium perspective that illuminates several fundamental aspects of the process of demoeconomic structural change and synthesizes the growing recent literature on general equilibrium modeling of dualistic development. When subjected to empirical analysis it should be capable of describing the past and of assessing alternative future consequences of rapid urbanization and growth.

Keyfitz, N., Do Cities Grow by Natural Increase or by Migration? IIASA Research Report RR-80-24, June 1980.
Reprinted from *Geographical Analysis,* Vol. 12(2), 1980, pp. 142–156.

In this article, Nathan Keyfitz analyzes the urbanization of a national population that at first is entirely rural. The population is subjected to fixed rates of natural increase and migration and the evolution of its urban and rural subpopulations is studied by means of a pair of differential equations.

Ledent, J., and P. Gordon, A Demoeconomic Model of Interregional Growth Rate Differences. IIASA Research Report RR-80-26, June 1980.
Reprinted from *Geographical Analysis,* Vol. 12(1), 1980, pp. 55–67.

This report argues for a demoeconomic modeling of multiregional systems. It proposes a model that accounts for interregional growth rate differences by means of an endogenous and simultaneous determination of labor-force participation, migration, and unemployment.

Keyfitz, N., Multidimensionality in Population Analysis. IIASA Research Report RR-80-33, August 1980.
Reprinted from *Sociological Methodology 1980,* K. Schuessler (ed.), pp. 191–218.

Material from a number of sources, published originally under such headings as multiregional demography, increment–decrement life tables, marriage tables, and tables of working life, has been synthesized in this essay reproduced from *Sociological Methodology 1980.*

BIOGRAPHIES

Urban Karlström, Sweden

Urban Karlström joined IIASA's Human Settlements and Services Area in July 1979. His first appointment was that of a Research Assistant. Since July 1980, he has been a Research Scholar.

Mr. Karlström came to IIASA from the Stockholm School of Economics where he was involved in a project on the influence of an aging population on economic growth. He is pursuing his doctoral studies, specializing in macro-economics, economic development, economic demography, and economic history. At IIASA, he is involved in the work of the Population, Resources, and Growth Task.

Jacques Ledent, France

Jacques Ledent joined IIASA's Human Settlements and Services Area in February 1977. His research deals with studies of migration and human settlements.

Mr. Ledent received his degree in Engineering from the Ecole Nationale des Ponts et Chaussées in 1969, his master's degree in Economics from the University of Paris (Nanterre) in 1970, and his master's degree in Civil Engineering from Northwestern University, Illinois, USA, in 1972. He is a Ph.D. candidate in Urban Systems Engineering at Northwestern University.

From 1970 to 1971 and again from 1972 to 1973 he was an Engineer with the Bureau Central d'Etudes pour les Equipements d'Outre Mer. From 1974 to 1977 he was a Research Specialist at the Division of Economic and Business Research, College of Business and Public Administration at the University of Arizona, USA.

Mr. Ledent is a member of the American Institute of Planners, the Population Association of America, and the Regional Science Association. His research interests include mathematical demography, land use development, methods of urban regional analysis, and the economics of demographic change.

Zbigniew Pawlowski, Poland

Zbigniew Pawlowski is Professor of Econometrics at the Institute of Econometrics, Academy of Economics, Katowice, Poland. He has been active in the field of econometric modeling for a number of years and has paid special attention to the modeling of centrally planned economies; his many publications include works on the use of dummy variables in econometric modeling, the building of econometric growth equations, and other important problems encountered when modeling national economies.

Professor Pawlowski has participated in the work of several research areas during his frequent visits to IIASA.

Henry Rempel, Canada

Henry Rempel is Associate Professor of the Department of Economics at the University of Manitoba and joined the Human Settlements and Services Area of IIASA in May 1978 to complete a study of rural–urban labor migration and urban unemployment in Kenya.

Professor Rempel graduated from the University of Manitoba in 1961 and received his M.A. in Economics from Ohio State University in 1964. In 1971 he obtained his Ph.D. in Economics from the University of Wisconsin.

He was a lecturer at Bluffton College from 1964 to 1966 and a research associate at the University of Nairobi from 1968 to 1969 and again from 1973 to 1974. He has been with the University of Manitoba since 1970, first as Assistant Professor and then Associate Professor. His speciality is economic development.

He is a member of the Canadian Economic Association, the American Economic Association, and the International Union for the Scientific Study of Population.

Clark W. Reynolds, USA

Clark Reynolds, a Professor at the Food Research Institute, Stanford University, joined IIASA's Human Settlements and Services Area in April 1978 to study the interdependence of economic and migration factors in Mexican economic development.

Professor Reynolds received his B.A. in 1956 from Claremont Men's College, California, and took post-graduate studies in economics at MIT (1956–1957, 1958) and in philosophy and theology at Harvard Divinity School

(1957–1958). He obtained his M.A. and Ph.D. in Economics at the University of California at Berkeley in 1962.

He taught economics at Occidental College from 1961 to 1962, and then at Yale University from 1962 to 1967. Since then he has been Associate Professor and then Full Professor at the Food Research Institute, Stanford University. His specific interests are economic development, international trade and finance, and social history.

He is author of *The Mexican Economy, Employment Problems of Export Economies: The Central American Case of Economic Integration,* and co-author of *Essays on the Chilean Economy.*

Professor Reynolds is a member of the American Economic Association, the Economic History Association, the Latin American Studies Association, and also a member of the editorial board of the *Hispanic American Historical Review.* He is the recipient of a great number of awards, and was Visiting Lecturer at El Colegio de México (1963–1965), and at the Stockholm School of Economics (1968). He was a Visiting Fellow at St. Antony's College, Oxford, and a Visiting Scholar of Queen Elizabeth House, Oxford (1975).

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