THE MIGRATION COMPONENT IN SUBNATIONAL POPULATION PROJECTIONS

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PREFACE

This article was prepared for the Technical Working Group Meeting on Migration and Urbanization organized by the Population Division of the UN Economic and Social Commission for Asia and the Pacific (ESCAP) and convened at Bangkok from 1–5 December 1981. The meeting focused on the UNFPA-funded regional project "Comparative study on migration, urbanization, and development in the ESCAP region" and sought to identify the methods and techniques most suitable for the analysis of data that would be generated from national migration surveys. It provided a particularly opportune moment to set out some of the results produced by IIASA scholars working in the former Human Settlements and Services Area. We are grateful to the Population Division of UN-ESCAP for permission to reproduce this article in order to permit a wider dissemination of IIASA's results.

but the designation of spatial boundaries introduces difficulties in migration measurement that do not arise in fertility analysis.

Migration measurement can usefully apply concepts borrowed from both mortality and fertility analysis, modifying them where necessary to take into account aspects that are peculiar to migration. From mortality analysis, migration can borrow the notion of the life table, extending it to include increments as well as decrements, in order to reflect the mutual interaction of several regional cohorts. From fertility analysis, migration can borrow well-developed techniques for graduating age-specific schedules. Fundamental to both "borrowings" is a workable definition of migration rate.

1. Migration rates

At given moments during the course of a year, or some such fixed interval of time, a number of individuals living in a particular community change their regular place of residence. Their *moves* are *events:* separations from a community. A *mover* is an individual who has made a move at least once during a given interval of time. A *migrant,* on the other hand, is an individual who at the end of a given time interval no longer inhabits the same community of residence as at the start of the interval. (The act of separation from one state is linked to an addition to another.) Thus paradoxically, a multiple mover may be a non-migrant by this definition. If a particular mover returns to the place of initial residence before the end of the unit time interval, no "migration" is said to have taken place.[1]

The simplest and most common measure of migration is the crude migration rate, defined as the ratio of the *number of migrants,* leaving a particular population located in space and time, to the average *number of persons* (more exactly, the number of *person-years)* exposed to the risk of becoming migrants.[2]

Because migration is highly age selective, with a large majority of migrants being young, our understanding of migration patterns and dynamics is aided by computing migration rates for each age. Weighting each of these rates by the proportion of total population exposure contributed by persons of that age and summing over all ages of life gives the *gross migra-production rate* (GMR), the migration analog of the gross reproduction rate and the fundamental index of migration level.

In normal national statistical tabulations, point-to-point movements are aggregated into streams between one civil division and another; consequently, the level of interregional migration depends on the size of the areal units selected. Thus, if the areal unit chosen is a minor civil division such as a commune, a greater proportion of residential relocation will be included as migration than if the areal unit chosen is a major civil division such as a state or province. Moreover, migration occurs over time as well as across space; therefore studies of its patterns must measure its occurrence with respect to a time interval, as well as over a system of geographical areas. In general, the longer the time interval, the larger the number of return movers and, therefore, the more the count of migrants understates the number of inter-area movers. The impact of these spatial and temporal consolidations may be expressed analytically, and their influence on migration measurement and population dynamics may then be assessed.

2. Migration schedules

The most prominent regularity exhibited by empirical schedules of age-specific migration rates is the selectivity of migration with respect to age. Young adults in their early twenties generally show the highest migration rates and young teenagers the lowest. The migration rates of children mirror those of their parents; thus the migration rates of infants exceed those of adolescents. Finally, migration streams directed toward regions with warmer climates and cities with relatively high levels of social services and cultural amenities often exhibit a "retirement peak" at ages in the mid-sixties. In Asia such peaks also may reflect return migration to home towns and villages.

A particularly useful approach for summarizing and analysing the regularities present

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[1] We define migration to be the transition between states experienced by a migrant.

[2] Because data on nonsurviving migrants are generally unavailable, the numerator in this ratio often excludes them.

of destination gives ${}_{i}$NMR, the net migraproduction rate of individuals born in region i, i.e., the average number of migrations an i-born person is expected to make during a lifetime.

The *gross migraproduction rate* measures the intensity of migration between two regions at a particular point in time. The measure, therefore, has a basically cross-sectional character, in contrast to the NMR, which measures the intensity of migration over a lifetime. Consequently, the gross migraproduction rate often may prove to be a more useful measure than the net rate in that it is a "purer" indicator of migration, in the same sense as the gross reproduction rate. Since the gross rate measures the intensity of migration at a given moment and not over a lifetime, it can give a different indication of geographical mobility than the net rate in instances where return migration is an important factor.

3. The ESCAP migration data

The core questionnaire for the ESCAP migration survey, appropriately supplemented by census materials, will contribute significantly toward a better understanding of *patterns* of mobility, their *causes,* and some of their *consequences* on places of origin and destination. *Patterns* of mobility may be studied by analysing the age profiles exhibited by migration schedules and their decomposition by migrant status categories, such as single or married, dependent or head-of-household. *Causes* may be investigated by developing cause-specific schedules, and demographic *consequences* may be assessed by means of population projections that incorporate the exhibited migration patterns.

Prevailing patterns of mobility will become clearer after the data are summarized in ways that concisely identify who moves where and at what pace. Following the practice in mortality, life table analysis should help to clarify this aspect of migration. Multiregional life tables are discussed in section C-1 of this chapter and in appendix I. An example of such a table, calculated for India, appears as appendix III. *The ESCAP migration data will allow one to calculate such tables.* Mortality data may come from census and vital registration systems, suitably adjusted by model schedules. Migration data not found in censuses may be inferred, using the ESCAP sample flows and model schedules that smooth out the observed irregularities.

Factors that cause people to move may be assessed by disaggregating migration schedules by cause (Rogers and Castro, 1981a). Figure V illustrates cause-specific age profiles for Czechoslovakia, by way of example, and shows how they combine to produce the observed aggregate age-specific migration rates.

It is widely recognized that many internal migrations are undertaken by individuals whose moves depend on those of others. For example, children generally migrate with their parents and wives with their husbands. A decomposition along such family status dimensions complements the illumination provided by cause-specific schedules (Castro and Rogers, 1981). *The ESCAP core questionnaire will permit both sets of decompositions to be carried out.*

Age-specific schedules of migration rates in Asia could well exhibit somewhat different profiles than in Western countries. This is because a relatively large fraction of migrants are single. Even married migrants often leave their families behind for long periods.

A problem that will undoubtedly arise with the ESCAP migration data will be the irregularities introduced by age misreporting and sampling variation. Figure VI, which sets out the migration rates found in a one-per cent sample of the 1970 Mexican Census of Population, suggests that such irregularities may be significant. In such an event it would be desirable to once again follow the practice in mortality studies and adopt model schedules, such as the one defined in Equation 1, as graduating mechanisms (Rogers and Castro, 1981b).

Finally, some of the demographic consequences of migration can be studied using multiregional population projection models, which follow the evolution of interacting national subpopulations that are linked to each other by internal migration flows. Such models are described in sections C-2 and D-1, and appendix IV sets out an illustrative projection for India. *Similar projections will be possible using the ESCAP migration data* and regularly collected census and vital registration data. It is likely that rates of fertility, mortality, and migration. The consequences of a change in any single component may be assessed, and alternative "scenarios" of growth may be developed.

None of the four methods described in the United Nations report considers gross (directional) migration flows. Internal migration is viewed as *net* migration, and all of the population models are therefore fundamentally uniregional in character: they analyse a multiregional population system one region at a time.

2. Uniregional versus biregional projection methods

There are at least three principal ways of incorporating internal migration into subregional population projections. The first focuses on net migration, the other two on gross migration. Net migration totals reveal only the "tip of the iceberg" because they describe a difference; they are difficult to model behaviourally because there is no such individual as a net migrant, and they generally introduce a bias into the projection process because both the numerator and the denominator of the net migration rate are changing.

Gross migration may be entered into the projection process either by considering only inflows and outflows (a biregional perspective) or by keeping track of the various origins and destinations (a multiregional perspective). In each case, one obtains a considerable increase in useful information over the net migration projection (a uniregional perspective).

A uniregional perspective of population growth and change can easily introduce biases and inconsistencies into a regional population projection. The problems arise because all migration flows are assessed only with respect to the population in the region of destination. Thus changes in the size of the destination population, arising out of changes in the patterns of natural increase for a given year, for example, will produce a higher net migration total in the following year and introduce a bias into the projection.

Changes in the population at the region of origin are totally ignored in the uniregional perspective, an omission that can produce serious inconsistencies in the projection process. For example, the origin population ultimately may be reduced to zero, but a fixed and positive net migration rate in the destination region will nevertheless continue to generate a flow of net inmigrants from the region of origin.

The growth of multiregional populations may be represented by simple projection models that follow groups of individuals just born into a population, as they age with the passage of time, reproduce, and ultimately leave the population because of death or outmigration. These events and flows enter into an accounting relationship in which the growth of a regional population is determined by the combined effects of natural increase and net migration. The fundamental mechanics of such models may be illustrated with a simple numerical example based on data for India. For ease of exposition, only a biregional projection will be considered and fixed rates of fertility, mortality, and migration will be assumed.

The urban population of India increased by about 3.7 per cent a year during the late 1960s and early 1970s. The urban growth rate, r_u, was the outcome of a birth rate, b_u, of 30 per 1000, a death rate, d_u, of 10 per 1000, an inmigration rate, i_u, of 27 per 1000, and an outmigration rate, o_u, of 10 per 1000 (Rogers, 1978). Expressing these rates on a *per capita* basis leads to the fundamental identity

$$\begin{aligned} r_u &= b_u - d_u + i_u - o_u \\ &= .030 - .010 + .027 - .010 \\ &= .037 \end{aligned}$$

and the corresponding identity for the rural population gives a growth rate, r_r, of 0.017.

The total national population of India in 1970 was about 548 million, of which roughly 109 million (20 per cent) was classified as urban. Multiplying this latter total by the urban growth rate gives 109 (.037) = 4.03 million as the projected *increase* for 1971. An analogous calculation for the rural population gives 7.46 million for the corresponding projected increase in the rural population. These changes imply, for 1971, an urban population of 113 million, a rural reproduce, migrate, and ultimately die. In connecting these events and flows to determine the growth rate of each population, one also obtains the number of people in each region and their age composition.

The ESCAP study of migration, urbanization, and development could consider the possibility of adopting and adapting, for its purposes, the multiregional methodology and computer programmes recently developed at IIASA and elsewhere (Willekens and Rogers, 1978; Rogers, 1975 and 1981). This methodology has been successfully applied in a large-scale comparative study of migration and settlement (Rogers and Willekens, 1983). The methodology is built around three fundamental groups of models: model migration schedules, multiregional life tables, and multiregional projection models. The first was mentioned in Section A; the latter two are described in this section.

1. Multiregional life tables

Vital statistics and censuses of the kind normally collected provide the necessary data for the computation of rates. They may be used to answer questions such as: what is the current rate at which 40-year-old males are dying from heart disease or at which 30-year-old women are bearing their second child? But many of the more interesting questions regarding mortality and fertility patterns are phrased in terms of probabilities, for example: what is the current probability that a man aged 40 will outlive his 38-year-old wife, or that she will bear her third child before she is 45?

Most of the ESCAP member countries have no registration systems for migration similar to the reporting systems for vital statistics. Thus this role will be filled by the sample questionnaire. In instances where censuses report one-year or five-year migrant flows, the sample data will serve as a check. Where such flow data are unavailable, the ESCAP sample data will serve as the basic source of data on interregional movements and the migration rates that will thereby be provided can be used as inputs for all life table calculations.

Demographers normally estimate probabilities from observed rates by developing a life table. Such tables describe the evolution of a hypothetical cohort of babies born at a given moment and exposed to an unchanging age-specific schedule of vital rates. For this cohort of babies, they exhibit a number of probabilities for changes of state, such as dying, and develop the corresponding expectations of years of life spent in different states at various ages.

The simplest life tables recognize only one class of decrement, e.g., death, and their construction is normally initiated by estimating a set of age-specific probabilities of leaving the population, e.g., dying, within each interval of age, q(x) say, from observed data on age-specific exit rates, M(x) say. The conventional calculation that is made for an age interval five-years wide is (Rogers, 1975:12):

$$q(x) = \frac{5M(x)}{1 + \frac{5}{2}M(x)}$$

or alternatively,

$$p(x) = 1 - q(x) = [1 + \frac{5}{2}M(x)]^{-1}$$

$$[1 - \frac{5}{2}M(x)] \quad (3)$$

where p(x) is the age-specific probability of remaining in the population, e.g., of surviving between exact ages x to x+5.

Life tables that recognize several modes of exit from the population are known as *multiple-decrement life tables* (Keyfitz 1968:333). They have been applied, for example, in studies of mortality by cause of death, of first marriage and death, of labour force participation and death, and of school attendance and death.

A further generalization of the life table concept arises with the recognition of entries as well as exits. Such *increment-decrement life tables* (Schoen, 1975) allow for multiple movements between several states, for example, transitions between marital statuses and death (married, divorced, widowed, or dead), or between labour force statuses and death (employed, unemployed, or dead).

migration, and growth rates are all governed by the interaction of the prevailing regime of growth with the current regional age compositions and regional shares of the total population. The dynamics of such growth and change are illustrated, for example, by the biregional population system exhibited in tables 31 and 32, which summarize the projected evolution of the Indian urban and rural populations that appear in appendix IV. These tables show, for example, that India's urban population, which was 20 per cent of the national total and growing at 3.7 per cent per year in 1970, would increase to 28 per cent by the end of this century and grow at 2.7 per cent per annum, if the 1970 regime of growth continued unchanged.

Fixed coefficient projections are but one of several alternative scenarios that could be generated in the ESCAP studies. Projections that reflect changing rates of fertility, mortality, and migration can be readily produced with essentially the same computer programmes. An example of this appears in the next section. Purely demographic models can also be linked with economic models to create demoeconomic forecasts that ascertain the quantitative importance of *indirect* as well as direct effects of changes in the economic or demographic environment. Although the formal modelling of demoeconomic processes of development is an "infant industry", a number of "second- and third-generation" models are available that suggest promising lines of inquiry in the future (Sanderson, 1980). Demoeconomic models fall outside the scope of this review; however they are briefly described in appendix V.

D. POLICY USE

1. Reduced future urban growth

The world has only recently become aware of a second aspect of the "population crisis": the unprecedented growth of urban populations in the developing countries. For the first time in history, most city dwellers are to be found in these countries. On current rates this majority is expected to increase substantially, with the Less Developed Countries (LDC)'s share standing at two-thirds by the end of this century. The United Nations expects some 264 of the world's 414 million-plus cities to be included in this share (United Nations, 1980).

This urban transformation is occurring too fast for the LDC institutions to cope. It is therefore natural to ask whether current rates can be expected to continue for some time to come, or whether there are "limits to urban growth." Biregional projections carried out with the inadequate data that are available suggest that the explosive urban growth rates in today's LDCs are unlikely to continue for long and that reduced urban growth is in prospect after the urban transition phase of development has passed in each developing country.

These multiregional projections indicate that urban growth is partly self-limiting, because urban growth rates ultimately decline as urban proportions increase and as rural populations first stabilize and then decline. To illustrate this pattern of evolution, we have extended a now classic analysis of fertility reduction by Ansley Coale (1969). In this analysis Coale identified some of the ways in which alternative demographic trends might affect the development of less developed countries. He focused on national rather than regional populations, considered only a single future course for mortality, and examined the demoeconomic consequences of two alternative future courses for fertility:

A) maintenance at its current level

B) a rapid decline to half its current level over a period of 25 years.

After generating the two alternative projections or "scenarios," Coale went on to inquire what effects these contrasting trends in fertility would have on important population characteristics.

Multiregional population projections translate assumptions about future trends in mortality, fertility, and migration with respect to a specific initial population into numerical estimates of the future size, age composition, and spatial distribution of that population. Following the Coale analysis, we have studied the evolution of a hypothetical initial population of one million persons with an age composition and fertility-mortality rates typical of a Latin American country (Rogers, 1978). This population is projected 150 years into the future. Coale's two alternative projections (A. fertility unchanged and lower density of people to resources in the long run. The spatial model, however, does bring into sharp focus urban-rural differentials: (1) in dependency burdens and in the relative magnitudes of their decline following fertility reduction, and (2) in initial growth rates of the labour force population and the paths of their gradual convergence in the long run.

The dependency ratio in urban areas is 19 points lower than its rural counterpart at the start of the projection period. With constant fertility, the regional dependency burdens remain essentially unchanged. Declining fertility, however, narrows these differentials to almost a third of their original values, as the urban drop of 33 points is matched by a corresponding decline of 45 points in rural areas.

The annual growth rates of the labour force population in urban and rural areas initially are 0.05 and 0.03, respectively. For both migration regimes, however, they converge to approximately the same values in the long run: 0.04 in the constant fertility scenario and slightly above 0.01 in the reduced fertility projection.

The major demographic impacts of increased rural-urban migration for a given regime of fertility, as set out in figures VII and VIII, are negligible with respect to dependency burdens and are of paramount importance, in the short and medium runs, with regard to the growth rate of the population aged 15 to 64. In the long run migration also has a moderately powerful impact on the density of workers to resources in rural areas.

Increased migration into cities reduces the size of rural populations and hence their density with respect to rural resources such as agricultural land. The projections show that the relative size of the rural population aged 15 to 64 is over two and one half times larger under the fixed migration schedules of projections (a) than under the increased rural-urban migration rates of projections (b) (Rogers, 1978). Thus the (b) scenarios create rapid urban growth and exacerbate human settlement problems, but at the same time reduce the density of rural populations to land and other rural resources. The (a) scenarios, on the other hand, give urban areas more time to cope with growth, but do so at the cost of increasing rural population densities. "Hyperurbanization" and "rural overpopulation", therefore, are the two sides of the fundamental policy question regarding development.

The appeal to the forces of the demographic transition as potentially reducing urban growth rates in the future through "braking" forces, such as the lower fertility rates of city populations, requires a relatively long-run perspective. Economic forces are likely to act earlier to retard urban growth. Rising urban costs of various kinds should reduce rural-urban migration intensities. Growing requirements for "unproductive" urban investments to augment current stocks of public infrastructure and levels of service provision will increasingly take priority over those investments that create capacity for future urban employment. This should slow down urban growth.

2. Managing urban absorption

If the current rapid pace of urban growth in the less developed world is a transitory phase in urban development, then the demographer's contribution to national urban policymaking can come in the form of an improved understanding of the likely levels of the forthcoming demands for resources, jobs, housing, and services during this transition period and beyond. The overwhelming challenge to urban planners and managers of cities in LDCs is how to absorb large numbers of newcomers in an effective and equitable manner in the course of developing an enlarged urban absorptive capacity. Demoeconomic simulation models have an important role to play in these planning efforts, since they can be used to generate the likely consequences of alternative policies on patterns of demand and supply.

Resources and services are demanded by people; hence if all else is fixed (including tastes and prices), the level of demand should be approximately proportional to population size. Demand above this level may be attributed to affluence. However, to obtain a more complete assessment of the impacts of different population trends on resource and service demands it is necessary to go further and to examine the effects of changing population age composition on such demands.

Figure X illustrates the relationships between age composition and demands for a number of

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Table 29. Expectations of life at birth and migration levels by region of residence and region of birth: India, 1970

A. Expectations of life at birth: ${}_i e_j(0)$

	Region of Residence		
	1	2	
Region of Birth	Urban	Rural	Total
1. Urban	42.96	12.71	55.67
2. Rural	9.11	39.34	48.45

B. Migration levels: ${}_i\theta_j = {}_i e_j(0)/{}_i e_{.}(0)$

	Region of Residence		
	1	2	
Region of Birth	Urban	Rural	Total
1. Urban	0.7717	0.2283	1.00
2. Rural	0.1880	0.8120	1.00

Source: Appendix III.

Table 31. Observed and projected annual regional rates of growth $[r_i(t)]$: India, 1970-2000, and at stability

Time t \ Region i	1. Urban		2. Rural
1970	0.036853		0.017186
1980	0.037504		0.018827
1990	0.033184		0.020007
2000	0.027366		0.018559
Stability	———	0.019837	———

Source: appendix IV.

Table 32. Observed and projected regional shares $[SHA_i(t)]$: India, 1970-2000, and at stability

Time t \ Region i	1. Urban	2. Rural
1970	0.1991	0.8009
1980	0.2326	0.7674
1990	0.2583	0.7417
2000	0.2768	0.7232
Stability	0.3384	0.6616

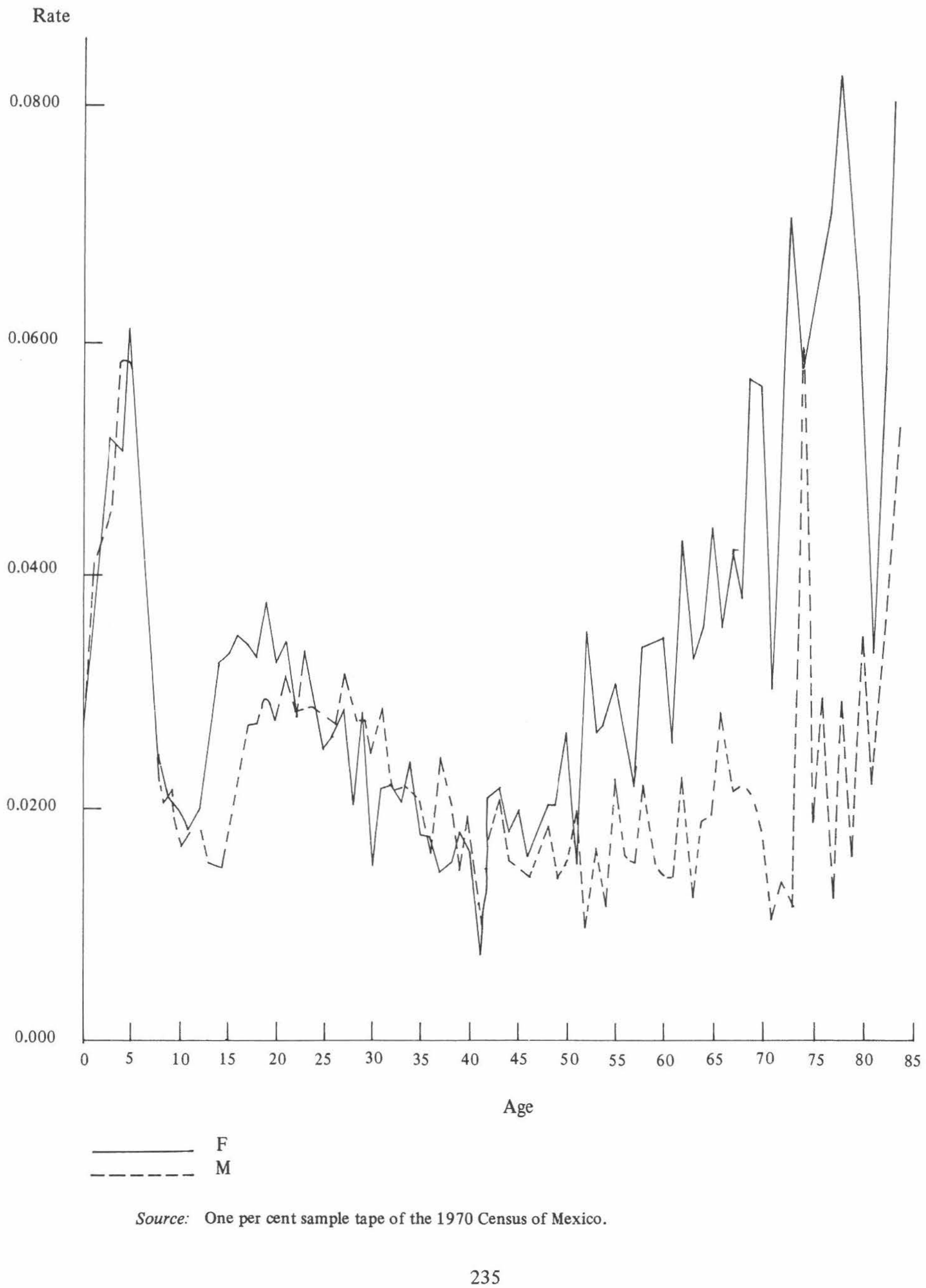
Source: appendix IV.

Table 33. Assumptions in the Coale and in the biregional models

	Coale Model	Biregional Model	
		Urban	Rural
Initial Values			
Population	1,000,000	200,000	800,000
Death Rate	14/1000	11/1000	15/1000
Birth Rate	44/1000	40/1000	45/1000
Outmigration Rate	–	10/1000	7/1000
Future Paths			
Mortality	Decline over 30 years to level with an expectation of life at birth of 70 years; unchanged thereafter	Decline as in Coale's model, but over 25 years; unchanged thereafter	Decline as in Coale's model, but over 35 years; unchanged thereafter
Fertility	A. Unchanged	A. Unchanged	A. Unchanged
	B. Reduction of 50 per cent over 25 years; unchanged thereafter	B. Reduction as in Coale's model, but over 20 years; unchanged thereafter	B. Reduction as in Coale's model, but over 30 years; unchanged thereafter
Migration		a. Unchanged	a. Unchanged
		b. Unchanged	b. Increase of 500 per cent over 50 years followed by a reduction to one half of that peak level over 30 years; unchanged thereafter

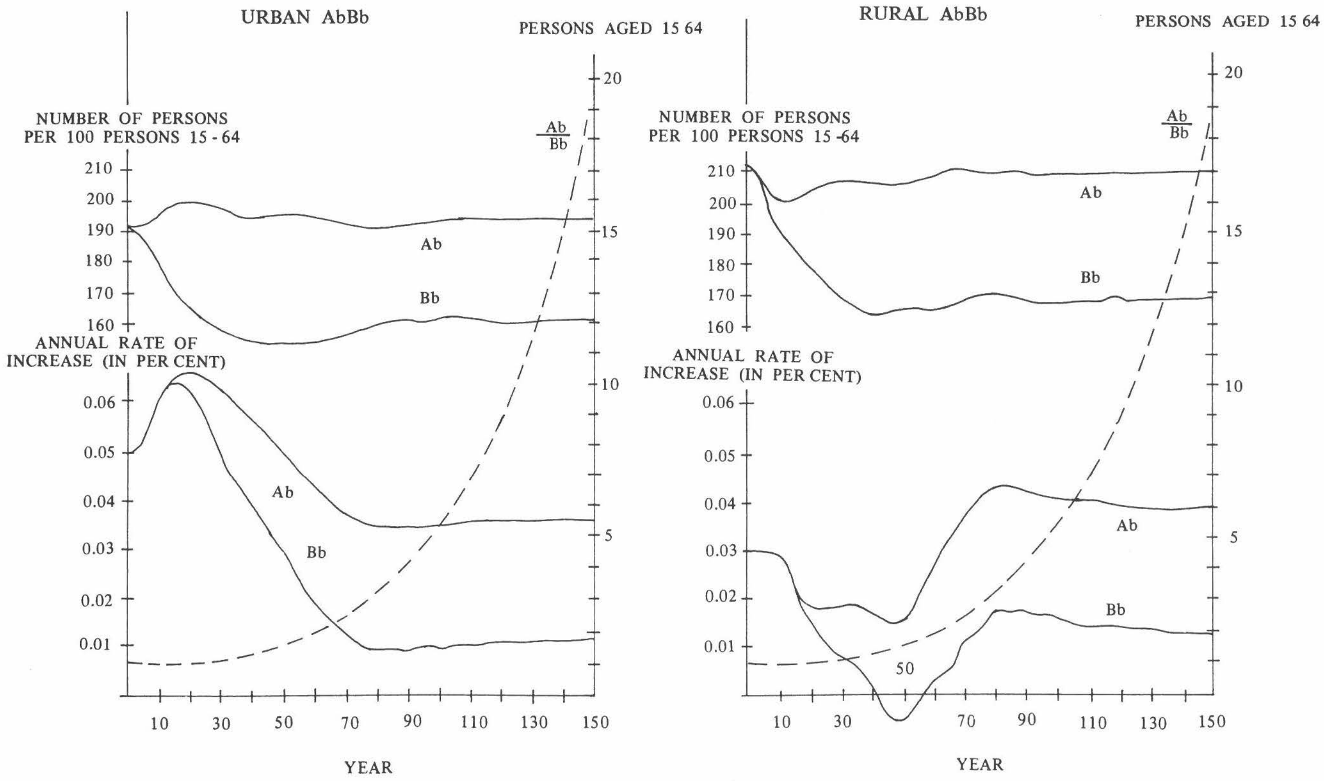
Source: Rogers (1978).

Figure VI. Annual age-specific migration rates of the Mexican national population, 1969-1970



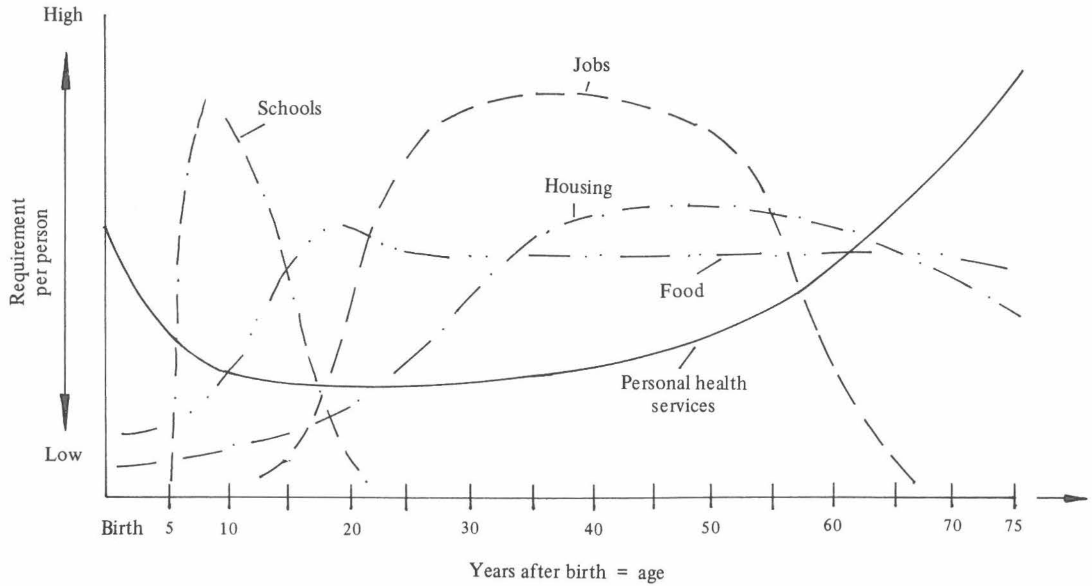
Source: One per cent sample tape of the 1970 Census of Mexico.

Figure VIII. Dependency burden, annual rate of increase, and relative size of population aged 15-64 years: alternative urban-rural projections, migration increased.



Source: Rogers (1978).

Figure X. Time relationships between a birth and future service requirements.



Source: Corsa and Oakley (1971).

Appendix II

INPUT DATA FOR INDIAN EXAMPLE

URBAN

Age	Population		Births		Deaths		Arrivals		Departures		Observed rates (x 1000)				
	Number	%	Number	%	Number	%	Number	%	Number	%	Birth	Death	Inmig.	Outmig.	Net mig.
0	14 140 200.	12.96	0.	0.	540 830.	48.61	360 672.	12.09	131 860.	12.09	0.	38.248	25.507	9.325	16.182
5	14 798 300.	13.57	0.	0.	58 278.	5.24	269 265.	9.03	98 442.	9.03	0.	3.938	18.196	6.652	11.543
10	13 637 500.	12.50	0.	0.	23 598.	2.12	193 276.	6.48	70 661.	6.48	0.	1.730	14.172	5.181	8.991
15	10 944 900.	10.03	361 195.	11.15	20 245.	1.82	415 552.	13.93	151 924.	13.93	33.001	1.850	37.968	13.881	24.087
20	10 454 900.	9.58	923 207.	28.50	29 320.	2.64	693 277.	23.24	253 459.	23.24	88.304	2.804	66.311	24.243	42.068
25	8 955 700.	8.21	805 956.	24.88	24 581.	2.21	300 528.	10.07	109 872.	10.07	89.994	2.745	33.557	12.268	21.289
30	7 612 400.	6.98	580 051.	17.91	23 620.	2.12	174 397.	5.85	63 759.	5.85	76.198	3.103	22.910	8.376	14.534
35	6 881 500.	6.31	367 275.	11.34	25 863.	2.33	119 837.	4.02	43 812.	4.02	53.371	3.759	17.414	6.367	11.048
40	5 714 300.	5.24	148 412.	4.58	27 618.	2.48	88 172.	2.96	32 235.	2.96	25.972	4.833	15.430	5.641	9.789
45	4 476 500.	4.10	53 492.	1.65	30 450.	2.74	65 227.	2.19	23 847.	2.19	11.950	6.802	14.571	5.327	9.244
50	3 810 300.	3.49	0.	0.	39 787.	3.58	43 696.	1.46	15 975.	1.46	0.	10.442	11.468	4.193	7.275
55	2 223 400.	2.04	0.	0.	32 371.	2.91	49 269.	1.65	18 012.	1.65	0.	14.559	22.159	8.101	14.058
60	2 389 900.	2.19	0.	0.	59 037.	5.31	61 358.	2.06	22 432.	2.06	0.	24.703	25.674	9.386	16.288
65	1 129 400.	1.04	0.	0.	37 873.	3.40	56 601.	1.90	20 693.	1.90	0.	33.534	50.116	18.322	31.794
70	1 907 800.	1.75	0.	0.	139 108.	12.50	92 417.	3.10	33 787.	3.10	0.	72.915	48.442	17.710	30.732
Total	109 077 024.	100.00	3 239 588.	100.00	1 112 584.	100.00	2 983 544.	100.00	1 090 770.	100.00					
Gross											1.894	1.130	2.119	0.775	
Crude (x 1000)											29.700	10.200	27.353	10.000	17.353
M. age		24.23		28.01		25.54		24.46		24.45	29.54	51.19	39.11	39.11	
E (0)												57.90			

Single region life table
Urban
mortality level = 57.90

Age	P(x)	Q(x)	1(x)	d(x)	11(x)	m(x)	s(x)	t(x)	e(x)
0	0.825452	0.174548	100 000.	17 455.	4.563629	0.038248	0.895564	57.8991	57.8991
5	0.980501	0.019499	82 545.	1 610.	4.087020	0.003938	0.985890	53.3354	64.6136
10	0.991385	0.008615	80 936.	697.	4.029352	0.001730	0.991091	49.2484	60.8489
15	0.990794	0.009206	80 238.	739.	3.993454	0.001850	0.988446	45.2191	56.3559
20	0.986076	0.013924	79 500.	1 107.	3.947312	0.002804	0.986222	41.2256	51.8563
25	0.986370	0.013630	78 393.	1 069.	3.892925	0.002745	0.985494	37.2783	47.5533
30	0.984605	0.015395	77 324.	1 190.	3.836452	0.003103	0.983005	33.3854	43.1758
35	0.981380	0.018620	76 134.	1 418.	3.771251	0.003759	0.978776	29.5489	38.8118
40	0.976123	0.023877	74 716.	1 784.	3.691210	0.004833	0.971398	25.7777	34.5008
45	0.966558	0.033442	72 932.	2 439.	3.585634	0.006802	0.957986	22.0865	30.2836
50	0.949118	0.050882	70 493.	3 587.	3.434989	0.010442	0.939692	18.5008	26.2449
55	0.929760	0.070240	66 906.	4 699.	3.227832	0.014559	0.907554	15.0658	22.5178
60	0.883671	0.116329	62 207.	7 236.	2.929433	0.024703	0.865670	11.8380	19.0301
65	0.845300	0.154700	54 970.	8 504.	2.535923	0.033534	2.512955	8.9086	16.2061
70	0.	1.000000	46 467.	46 467.	6.372661	0.072915	0.	6.3727	13.7145

Net reproduction rate 1.463012

Net migraproduction rate 0.612946

All of India

Age	Population		Births		Deaths		Arrivals		Departures		Observed rates (x 1000)				
	Number	%	Number	%	Number	%	Number	%	Number	%	Birth	Death	In mig.	Out mig.	Net mig.
0	79 107 000.	14.44	0.	0.	4 290 163.	49.29	492 532.	12.09	492 532.	12.09	0.	54.232	6.226	6.226	0.
5	82 869 800.	15.13	0.	0.	462 774.	5.32	367 707.	9.03	367 707.	9.03	0.	5.584	4.437	4.437	0.
10	68 277 200.	12.46	0.	0.	166 261.	1.91	263 937.	6.48	263 937.	6.48	0.	2.435	3.866	3.866	0.
15	47 446 900.	8.66	2 172 377.	10.72	122 124.	1.40	567 476.	13.93	567 476.	13.93	45.785	2.574	11.960	11.960	0.
20	43 082 400.	7.86	5 255 111.	25.93	167 386.	1.92	946 736.	23.24	946 736.	23.24	121.978	3.885	21.975	21.975	0.
25	40 799 300.	7.45	5 114 688.	25.24	156 463.	1.80	410 400.	10.07	410 400.	10.07	125 362	3.835	10.059	10.059	0.
30	36 164 100.	6.60	3 851 137.	19.01	157 292.	1.81	238 156.	5.85	238 156.	5.85	106.491	4.349	6.585	6.585	0.
35	32 393 400.	6.00	2 454 628.	12.11	173 410.	1.99	163 649.	4.02	163 649.	4.02	74 624	5.272	4.975	4.975	0.
40	28 362 700.	5.18	1 032 836.	5.10	192 786.	2.22	120 407.	2.96	120 407.	2.96	36.415	6.797	4.245	4.245	0.
45	22 792 400.	4.16	382 565.	1.89	218 441.	2.51	89 074.	2.19	89 074.	2.19	16.785	9.584	3.908	3.908	0.
50	20 690 100.	3.78	0.	0.	305 743.	3.51	59 671.	1.46	59 671.	1.46	0.	14.777	2.884	2.884	0.
55	12 655 400.	2.31	0.	0.	261 543.	3.01	67 281.	1.65	67 281.	1.65	0.	20.667	5.316	5.316	0.
60	14 334 200.	2.62	0.	0.	504 248.	5.79.	83 790.	2.06	83 790.	2.06	0.	35.178	5.845	5.845	0.
65	6 821 200.	1.25	0.	0.	325 872.	3.74	77 294.	1.90	77 294.	1.90	0.	47.773	11.331	11.331	0.
70	11 537 400.	2.11	0.	0.	1 198 567.	13.77	126 204.	3.10	126 204.	3.10	0.	103.885	10.939	10.939	0.
Total	547 833 536.	100.00	20 263 344.	100.00	8 703 073.	100.00	4 074 314.	100.00	4 074 314.	100.00					
Gross											2.637	1.604	0.573	0.573	
Crude (x 1000)											36.988	15.886	7.437	7.437	
M. age		24.27		28.44		26.22		24.46		24.46	29.57	51.27	36.88	36.88	
E (0)												48.86			

Appendix III

Multiregional (two regions) life table for subnational population analysis: Indian example

Urban

Age	q(x, 1)	p(x, 1, 1)	p(x, 2, 1)	1(x, 1, 1)	1(x, 2, 1)	11(x, 1, 1)	11(x, 2, 1)	m(x, 2, 1)	md(x, 1)	s(x, 1, 1)	s(x, 2, 1)	e(x, 1, 1)	e(x, 2, 1)
0	0.176147	0.787865	0.035989	100 000.	0.	4.46966	0.08997	0.009325	0.038248	0.858696	0.036686	42.96	12.71
5	0.019656	0.948718	0.031626	78 786.	3 599.	3.84001	0.23792	0.006652	0.003938	0.957236	0.028591	46.72	15.31
10	0.008670	0.966246	0.025084	74 814.	5 918.	3.68010	0.33836	0.005181	0.001730	0.946748	0.044240	42.92	15.33
15	0.009357	0.926091	0.064552	72 390.	7 617.	3.49582	0.48496	0.013881	0.001850	0.904015	0.084133	38.71	15.05
20	0.014304	0.878654	0.107042	67 443.	11 782.	3.19518	0.73586	0.024243	0.002804	0.900593	0.085333	34.68	14.59
25	0.013829	0.928951	0.057220	60 364.	17 653.	2.93042	0.94059	0.012268	0.002745	0.936345	0.048957	31.12	13.87
30	0.015550	0.944797	0.039653	56 853.	19 971.	2.77860	1.02896	0.008376	0.003103	0.947717	0.035121	27.79	12.86
35	0.018764	0.950962	0.030275	54 292.	21 188.	2.65963	1.07412	0.006367	0.003759	0.950085	0.028518	24.61	11.73
40	0.024040	0.949219	0.026742	52 093.	21 777.	2.54858	1.09419	0.005641	0.004833	0.945377	0.025801	21.54	10.53
45	0.033655	0.941354	0.024991	49 350.	21 991.	2.42859	1.09406	0.005327	0.006802	0.935590	0.022110	18.60	9.30
50	0.051132	0.929531	0.019337	47 294.	21 772.	2.28787	1.06379	0.004193	0.010442	0.912065	0.027142	15.83	8.09
55	0.070882	0.893174	0.035944	44 221.	20 780.	2.10384	1.01393	0.008101	0.014559	0.869703	0.036763	13.30	6.96
60	0.117487	0.843403	0.039110	39 933.	19 778.	1.85088	0.93335	0.009386	0.024703	0.810955	0.052643	10.96	5.88
65	0.157475	0.772028	0.070498	34 103.	17 556.	1.52756	0.82320	0.018322	0.033534	1.959624	0.366715	9.08	4.99
70	1.000000	0.	0.	27 000.	15 371.	3.16499	1.75363	0.017710	0.072915	0.	0.	7.47	4.14

KEY

q(x, i) = probability that an individual at age x in region i will die before reaching age x + 5.

p(x, j, i) = probability that an individual at age x in region i will be in region j at age x + 5, i.e. 5 years later.

l(x, j, i) = number surviving at exact age x in region j, of 100,000 born in region i. This is also the probability that a baby born in region i, will survive and be in region j at exact age x, multiplied by 100,000.

ll(x, j, i) = total years lived between ages x to x + 5 in region j, per unit born in region i.

m(x, j, i) = age-specific migration rate from region i to j (equal to observed value).

md(x, i) = age-specific death rates in region i (equal to observed value).

s(x, j, i) = proportion of people in region i and aged x to x + 4 that will survive to be in region j and aged x + 5 to x + 9, five years later.

e(x, j, i) = part of expectation of life of i-born people at age x, that will be lived in region j, i.e. the average number of years lived in region j by i-born people, subsequent to age x.

Rural region

Age	First row	
	Urban	Rural
0	0.	0.
5	0.	0.
10	0.003816	0.102052
15	0.018773	0.368544
20	0.021294	0.552139
25	0.012798	0.525156
30	0.008156	0.411861
35	0.004314	0.253223
40	0.001967	0.120781
45	0.000481	0.038792
50	0.	0.
55	0.	0.
60	0.	0.
65	0.	0.

Age	Survivorship proportions	
	Urban	Rural
0	0.021439	0.821862
5	0.018073	0.960723
10	0.034581	0.952089
15	0.071981	0.910900
20	0.071840	0.907690
25	0.036911	0.941430
30	0.025554	0.949044
35	0.020215	0.948075
40	0.017567	0.939788
45	0.014353	0.923247
50	0.016123	0.894760
55	0.020871	0.844249
60	0.028482	0.777584
65	0.208395	1.449770

Year 2000

Population

Age	Total	Urban	Rural
0	163 181 104.	37 230 860.	125 950 248.
5	127 798 736.	31 166 706.	96 632 032.
10	115 344 880.	28 444 994.	86 899 888.
15	102 423 864.	26 237 282.	76 186 584.
20	87 095 048.	24 619 420.	62 473 628.
25	74 850 512.	22 608 256.	52 242 256.
30	61 812 751.	19 280 872.	42 531 884.
35	74 163 136.	22 883 824.	51 279 308.
40	60 587 404.	19 487 552.	41 099 852.
45	41 022 736.	13 734 509.	27 288 226.
50	35 697 652.	11 615 743.	24 081 908.
55	31 562 834.	9 182 019.	22 380 814.
60	24 962 302.	7 066 061.	17 896 240.
65	19 072 484.	5 565 610.	13 506 875.
70	31 118 370.	11 675 766.	19 442 604.
Total	1 050 691 904.	290 799 488.	759 892 416.

Percentage distribution

Age	Total	Urban	Rural
0	15.5308	12.8029	16.5747
5	12.1633	10.7176	12.7165
10	10.9780	9.7817	11.4358
15	9.7482	9.0225	10.0260
20	8.2891	8.4661	8.2214
25	7.1239	7.7745	6.8750
30	5.8831	6.6303	5.5971
35	7.0585	7.8693	6.7482
40	5.7664	6.7014	5.4086
45	3.9044	4.7230	3.5911
50	3.3975	3.9944	3.1691
55	3.0040	3.1575	2.9453
60	2.3758	2.4299	2.3551
65	1.8152	1.9139	1.7775
70	2.9617	4.0151	2.5586
Total	100.0000	100.0000	100.0000
M. ag.	25.4355	27.7998	24.5307
Sha.	100.0000	27.6770	72.3231
Lam	1.110476	1.146632	1.097235
R	0.020958	0.027366	0.018559

Appendix V

DEMOECONOMIC MODELS OF POPULATION AND DEVELOPMENT

Quantitative models of population growth and economic development, here called *demoeconomic* models, have received considerable attention during the past decade. Such models are characterized by systems of equations that represent fundamental relationships between such central demoeconomic variables as birth rates, migration flows, labour force participation ratios and levels of employment, output, and investment.

The principal function of demoeconomic simulation models of population and development is to assess the quantitative importance of *indirect* effects of changes in the demographic or economic environment. The fundamental importance of this interdependence in demoeconomic modelling leads naturally to the use of *general equilibrium* approaches in both theoretical and empirical analyses. While partial equilibrium models have usefully focused on the operation of various components of the economic growth process, by their very nature they cannot deal with the interdependencies and feedbacks that characterize processes of structural change.

Population's role in models of economic growth has been substantially increased in recent years. Most of the well-known models developed thus far have focused on the impacts of population growth on per capita output or income. Only a few models have also taken into account the influences of economic variables on population growth. Fewer yet have included internal migration as an endogenous variable affecting growth and development.

A prototype model of macrodemoeconomic growth should sketch out the main relationships determining the demographic and economic evolution of a nation experiencing modernization and development. It should contribute to the understanding of population's principal impacts on socioeconomic change and of the consequences of such change on demographic growth and distribution. In order to deal with questions of urbanization, such a model should distinguish between agricultural and nonagricultural production sectors and between rural and urban populations. Differential patterns of fertility, mortality, and internal migration should be incorporated explicitly, and governmental policy variables should constitute an important part of the model.

Most of the research on rural to urban migration has focused on the "micro-behaviour" of migration. The questions to be answered have typically been: who migrates, why, at what age, and what levels of education, and to which destinations. Very few studies have explored analytically the consequences of migration on the aggregate level of the economy and on its further growth.

Migration between rural and urban areas changes population and labour force growth in both regions. It also changes savings-investment behaviour and the growth of capital stock. It alters labour force productivity and both affects and is affected by rural-urban income differentials. A focus on the behaviour of only one of these aspects while the others are held unchanged can lead to erroneous policy conclusions. Efforts to curb rural to urban migration in the less developed nations, for example, might well be shown to be very costly. This would imply that urbanization policies in such countries are likely to be more socially beneficial if their focus is directed at *managing* rapid urban growth and reducing urban poverty instead of at curtailing the flow of migrants to cities.

A useful review of several demoeconomic models of population and development may be found in Sanderson (1980).