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MODEL MIGRATION SCHEDULES: AN APPLICATION USING DATA FOR THE SOVIET UNION

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Résumé — L'absence des données solides et détaillées sur la migration interne, est un problème auquel doivent faire face, à plusiers reprises, les démographes et les géographes démographiques qui s'occupent de la dynamique des populations spatiales. La première partie de cette étude décrit un procédé pour identifier et résumer les régularités persistantes qui apparaissent dans les données empiriques sur la migration interrégionale. Une application basée sur des données pour l'Union Soviétique met en lumière le principal argument. Dans la deuxième partie de l'étude, les courants de migration inférés sont joints aux données sur la fécondité et la mortalité dans la projection de l'accroissement démographique futur de l'Union Soviétique. On a porté une attention toute particulière aux changements dans les compositions d'âges et les parts régionales des populations urbaines et rurales de l'Union Soviétique, — des changements qui pourraient surgir si la fécondité baissait immédiatement jusqu'au niveau de reproduction. En guise de conclusion, on a examiné davantage les régularités dans les silhouettes d'âges migratoires.

Abstract — The absence of reliable and detailed data on internal migration is a problem that repeatedly confronts demographers and population geographers concerned with the dynamics of spatial populations. The first part of this paper describes a procedure for identifying and summarizing the persisting regularities that appear in empirical data on interregional migration. An application based on data for the Soviet Union illustrates the principal argument. In the second part of the paper, the inferred migration flows are combined with fertility and mortality data in a projection of future population growth in the Soviet Union. Particular attention is focused on the changes in age compositions and regional shares of the urban and rural populations of the U.S.S.R. that might arise were fertility immediately to decline to replacement level. The paper concludes with a further examination of regularities in migration age profiles.

Key Words: **Migration, model schedules, population**

I. Introduction

The growth and spatial distribution of a human population is largely determined by its recent history of fertility, mortality, and migration — a history defined by a collection of spatially disaggregated age-specific rates of birth, death, and geographical mobility. These rates exhibit remarkably persistent regularities all over the globe, and it is therefore not surprising that demographers have sought to identify and summarize such regularities by means of various curve-fitting exercises that collectively fall under the designation of "model" schedule construction.

Model fertility and model mortality schedules have received a great deal of attention during the past decade. This has not been the case with model migration schedules. This paper considers the problem of defining model migration schedules and illustrates their use with demographic data for the U.S.S.R.

II. Model Migration Schedules

The age pattern of an age-specific schedule of migration rates is a feature that may be usefully studied independently of its level. This is because there is considerable empirical evidence that although the latter tends to vary significantly from place to place, the former remains much the same in various localities.

Migration rates vary substantially for different age groups. They are relatively high for infants and young workers but decline sharply with age, notably among the middle-aged. The basic age profiles may be summarized in a number of ways, the more useful of which tend to reflect similar efforts in the areas of fertility and mortality.

Like fertility, migration is potentially a repetitive event; thus its level can be expressed in terms of an expected number of events per person. But, like mortality, migration also can be measured in terms of an expected duration time, for example, the fraction of a lifetime that one may expect to live in a particular region. The latter perspective suggests an approach to the construction of model migration schedules that resembles the efforts of Coale and Demeny (1966); the former view leads one to curve-fitting efforts such as those of Keyfitz (1968), Mazur (1976), and Tekse (1967). Having experimented elsewhere with the "mortality" approach (Rogers, 1975, chap. 6 and Rogers and Castro, 1976), we shall consider here the applicability of the "fertility" approach.

2.1 *The migration age profile*

Age-specific migration rates confound a region's migration *age profile* with the region's population *age composition*. This can be easily demonstrated by examining the components in the numerator and denominator of the fraction that defines the age-specific migration rate, $M(x)$. If $O(x)$ denotes the number of out-migrants of age x leaving a region with a population of $K(x)$, then

$$M(x) = \frac{O(x)}{K(x)} = \frac{O \cdot N(x)}{K \cdot C(x)} = cmr \cdot \frac{N(x)}{C(x)} \tag{1}$$

where

O = total number of out-migrants;
$N(x)$ = proportion of migrants of age x;
K = total population;
$C(x)$ = proportion of population of age x; and
cmr = crude migration rate.

We define $N(x)$ to be the migration *age profile* associated with a regional population and $C(x)$ to be that population's *age composition*. Distinguishing among such profiles and compositions on the basis of a summary measure of age pattern such as mean age, we can classify observed migration schedules as falling into one of the following four categories:

1. *Young* migration age profile and *young* population age composition;
2. *Young* migration age profile and *old* population age composition;
3. *Old* migration age profile and *young* population age composition; and
4. *Old* migration age profile and *old* population age composition.

Let $\bar{n}$ denote the mean age of profile $N(x)$, and $\bar{c}$ denote the mean age of composition $C(x)$. Then the above four statements may be summarized by the following two-by-two table:

Population Age Composition, $C(x)$		Migration Age Profile, $N(x)$: Young	Migration Age Profile, $N(x)$: Old
	Young	$\bar{n}$ below average $\bar{c}$ below average	$\bar{n}$ above average $\bar{c}$ below average
	Old	$\bar{n}$ below average $\bar{c}$ above average	$\bar{n}$ above average $\bar{c}$ above average

Figure 1A illustrates the migration age profiles that may be combined with migration levels and age compositions to produce age-specific migration rate curves for Sweden. Similar data for Poland are set out in Figure 1B for purposes of comparison. The respective mean ages for Sweden are $\bar{n}$ = 25.93 and $\bar{c}$ = 26.71 for males and $\bar{n}$ = 25.23 and $\bar{c}$ = 25.48 for females. For Poland they are $\bar{n}$ = 26.27 and $\bar{c}$ = 32.99 for males and $\bar{n}$ = 28.50 and $\bar{c}$ = 34.75 for females.

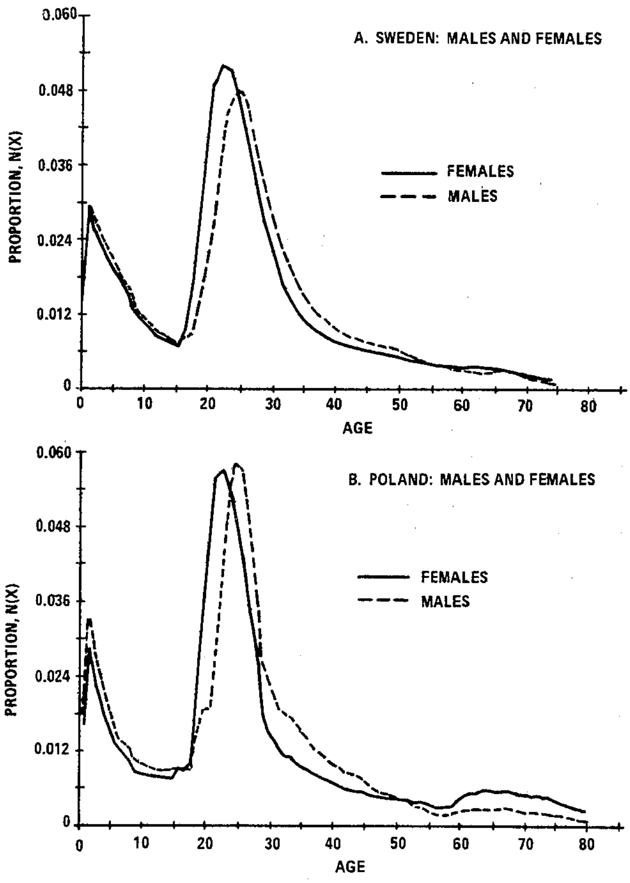

FIGURE 1. OBSERVED MIGRATION AGE PROFILES
Source: Rogers (1976).

2.2 *The Migration Level*

A commonly used summary measure of fertility level is the gross reproduction rate which, for data expressed in five-year age intervals, is defined as

$$GRR = 5\sum_x F(x) \cdot$$

A similarly useful summary measure of *migration level* is the *gross migraproduction* rate (Rogers, 1975:148):

$$GMR = 5\sum_x M(x) \cdot \tag{2}$$

As with age profiles and age compositions, it is sometimes convenient to distinguish various age-specific schedules of migration rates $M(x)$ by their mean age, $\bar{m}$ say; in such instances we shall associate that mean age with the schedule's GMR and write $GMR(\bar{m})$.

Substituting (1) into (2) we observe that

$$GMR = 5 \cdot \frac{O}{K} \cdot \sum_x \frac{N(x)}{C(x)} = 5\, cmr \cdot P = I \cdot P \tag{3}$$

where

$$I = 5 \cdot \frac{O}{K} = \text{the } intensity \text{ of migration, and}$$

$$P = \sum_x \frac{N(x)}{C(x)} = \text{the } age\ pattern \text{ of migration.}$$

Note that the *intensity* of migration deals with the fraction of a population that moves (i.e., the crude migration rate times five), whereas the *age pattern* of migration is a summary index of two age distributions. Migration level is the product of intensity and age pattern. This suggests the following classification of observed migration schedules:

1. Low GMR (or I or *cmr*) and low $\bar{m}$;
2. Low GMR (or I or *cmr*) and high $\bar{m}$;
3. High GMR (or I or *cmr*) and low $\bar{m}$; and
4. High GMR (or I or *cmr*) and high $\bar{m}$.

These are summarized in the following table:

		Pattern, P ($\bar{m}$)	
		Young	Old
Migration Level, GMR ($\bar{m}$) (or I) (or *cmr*)	Low	$\bar{m}$ below average GMR below average	$\bar{m}$ above average GMR below average
	High	$\bar{m}$ below average GMR above average	$\bar{m}$ above average GMR above average

2.3 *Application: Migration in the Soviet Union*

Table 1 presents crude estimates of age-specific migration rates between urban and rural areas for the U.S.S.R. in 1970. They were derived in the following manner. A pair of published age profiles describing in- and out-migrants into and out of urban areas in the

U.S.S.R. was averaged to produce the age profile set out in column 3 of Table 1 and illustrated in Figure 2. (The 0-15 and 60+ age group proportions were disaggregated using the profile exhibited by the Polish data.) Next, the migration age profile was combined with observed urban and rural population age compositions and observed crude migration rates (the latter available only for 1973 and 1974, however) to produce the urban-to-rural and rural-to-urban migration rates that appear in the last two columns of Table 1.

TABLE 1. MODEL MIGRATION SCHEDULES FOR THE USSR, 1970

Age, x	Age Profile[1], N(x)			Age Composition[2], C(x)		Migration Rate[3], M(x)	
	(1.) In- Migration	(2.) Out- Migration	(3.) Average ($\bar{n}$ = 25.82)	(4.) Urban ($\bar{c}$ = 31.27)	(5.) Rural ($\bar{c}$ = 30.70)	(6.) Urban to Rural ($\bar{m}$ = 27.92)	(7.) Rural to Urban ($\bar{m}$ = 27.06)
0-4			0.060	0.0726	0.1007	0.0093	0.0207
5-9	0.011	0.090	0.022	0.0861	0.1210	0.0029	0.0063
10-14			0.018	0.0892	0.1219	0.0023	0.0051
15-19	0.214	0.242	0.229	0.1010	0.0784	0.0255	0.1015
20-24	0.312	0.280	0.296	0.0877	0.0492	0.0379	0.2091
25-29	0.090	0.101	0.095	0.0649	0.0469	0.0164	0.0704
30-34	0.097	0.106	0.103	0.0987	0.0732	0.0117	0.0489
35-39	0.047	0.050	0.049	0.0719	0.0646	0.0077	0.0264
40-44	0.042	0.043	0.042	0.0841	0.0718	0.0056	0.0203
45-49	0.021	0.021	0.021	0.0523	0.0488	0.0045	0.0150
50-54	0.012	0.012	0.012	0.0390	0.0358	0.0035	0.0116
55-59	0.015	0.014	0.015	0.0486	0.0512	0.0035	0.0102
60-64			0.016	0.0400	0.0465	0.0045	0.0120
65-69	0.038	0.038	0.010	0.0266	0.0345	0.0042	0.0101
70+			0.012	0.0372	0.0555	0.0000	0.0000
Unknown	0.002	0.003					
TOTAL	1.000	1.000	1.000	1.0000	1.0000	0.1394	0.5675
						x5	x5
						GMR = 0.6972	2.8375

[1]Source: *Vestnik Statistiki*, 1971, No. 11, p. 81. Average profiles for the 0-15 and 60+ age groups were obtained using the age profile for Poland in Figure 1.B.

[2]Source: Table 2.

[3]M(x) = cmr · (N(x) ÷ C(x)), where cmr(u,r) = 0.01124 and cmr(r,u) = 0.03475, and where cmr = 0 ÷ K.

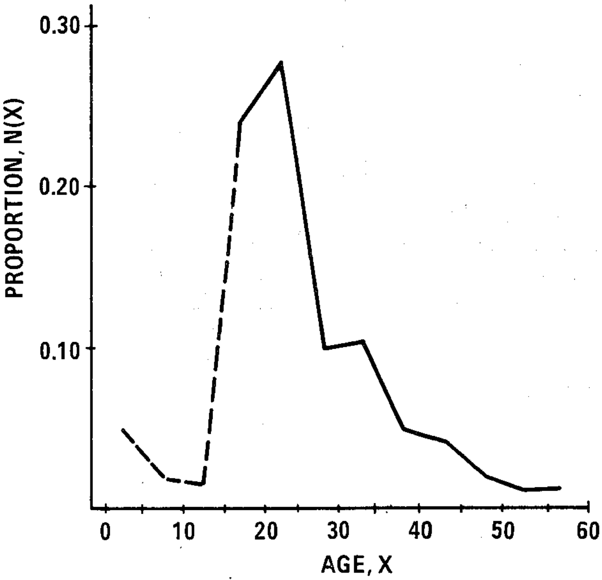

FIGURE 2. AGE PROFILE OF MIGRATION: USSR, 1970
Source: Table 1.

TABLE 2. URBAN AND RURAL POPULATION AND DEATH RATES: USSR, 1970

Age, x	Population[1], K(x), in thousands			Death Rate[2], $M_\delta(x)$		
	(1.) Total	(2.) Urban	(3.) Rural	(4.) Total	(5.) Urban	(6.) Rural
0-4	20,533	9,876	10,657	0.0070	0.0071	0.0069
5-9	24,503	11,712	12,792	0.0007	0.0007	0.0007
10-14	25,017	12,132	12,884	0.0006	0.0006	0.0006
15-19	22,023	13,737	8,286	0.0010	0.0010	0.0010
20-24	17,124	11,922	5,202	0.0016	0.0016	0.0016
25-29	13,785	8,830	4,955	0.0022	0.0023	0.0022
30-34	21,168	13,423	7,745	0.0028	0.0029	0.0028
35-39	16,612	9,783	6,829	0.0038	0.0038	0.0037
40-44	19,024	11,435	7,589	0.0048	0.0048	0.0047
45-49	12,269	7,110	5,159	0.0061	0.0062	0.0060
50-54	9,088	5,301	3,787	0.0088	0.0089	0.0087
55-59	12,027	6,614	5,413	0.0119	0.0120	0.0117
60-64	10,348	5,436	4,912	0.0182	0.0185	0.0180
65-69	7,267	3,618	3,649	0.0278	0.0282	0.0275
70+	10,932	5,062	5,869	0.0766	0.0777	0.0756
TOTAL	241,720	135,992	105,729	0.0083	0.0076	0.0091

[1]Source: All-Union Census of Population, 1970, 1974, Vol. 1, Table 3, p. 15. The "age unknown" population was allocated proportionately to enumerated totals in each age group. Age group 60-69 was disaggregated by polynomial interpolation (5th degree).

[2]Source: Population of the U.S.S.R., 1973, 1975, p. 141. Data for U.S.S.R. in 1969-70 were rescaled to generate the 1970 totals for urban and rural deaths reported in the same publication on p. 99 (i.e., 1,037,135 urban deaths and 959,182 rural deaths). Since the population totals used in the denominator were those set out above, and these include the "age unknown" totals, our total death rates differ slightly from those presented on p. 141 of the cited source publication.

III. A Multiregional Life Table for the U.S.S.R.

Age-specific death rates disaggregated by urban and rural places of residence apparently are not published by the U.S.S.R. Column 4 of Table 2 sets out such rates for the nation as a whole. These were scaled to produce the *total* numbers of deaths in urban and rural areas that were reported in published data. Thus we are forced to assume that the age *curve* of death rates in urban and rural areas is the same (but not the area under the curve). In this manner we obtained the age-specific urban and rural death rates set out in columns 5 and 6. These rates were combined with the age-specific population data in Table 2 and the migration rates in Table 1 to generate a two-region (urban-rural) life table for the U.S.S.R.

A life table describes the evolution of a hypothetical cohort of babies born at a given moment and exposed to an unchanging age-specific schedule of mortality. For this cohort of babies, it exhibits a number of probabilities of dying and surviving, and develops the corresponding expectations of life at various ages.

Conventional life tables deal with mortality, focus on a single region population, and ignore the effects of migration. To incorporate the latter and, at the same time, to extend the life-table concept to a spatial population comprising several regions requires the notion of a multi-regional life table (Rogers, 1973). Such life tables describe the evolution of several regional cohorts of babies, all born at a given moment and exposed to an unchanging multi-regional age-specific schedule of mortality and migration. For each regional birth cohort, they provide various probabilities of dying, surviving, and migrating, while simultaneously generating regional expectations of life at various ages. These expectations of life are disaggregated both by place of birth and by place of residence.

Expectations of life in a multi-regional life table reflect the influences of both mortality and migration. Thus they may be used as indicators of levels of internal migration, in addition to carrying out their traditional function as indicators of levels of mortality. For example, consider the regional expectations of life at birth that are set out

TABLE 3. EXPECTATIONS OF LIFE AT BIRTH AND MIGRATION LEVELS: USSR, 1970

Region of Birth	Region of Residence		Total
	Urban	Rural	
Urban	59.51 (0.8516)	10.37 (0.1484)	69.88 (1.0000)
Rural	41.27 (0.5899)	28.69 (0.4101)	69.96 (1.0000)

Source: Rogers (1976)

TABLE 4. EXPECTATIONS OF LIFE AT BIRTH AND MIGRATION LEVELS: POLAND, 1973

Region of Birth	Region of Residence		Total
	Urban	Rural	
Urban	60.53 (0.8668)	9.30 (0.1332)	69.83 (1.0000)
Rural	30.97 (0.4424)	39.03 (0.5576)	70.00 (1.0000)

Source: Rogers (1976)

in Table 3 for the U.S.S.R. population with both sexes combined. A baby born in a rural area, and exposed to the multi-regional schedule of mortality and migration that prevailed in 1970, could expect to live an average of 69.96 years, out of which total an average of 41.27 years would be lived in urban areas. Taking the latter as a fraction of the former, we have in 0.5899 an indicator of the (lifetime) rural to urban migration level that is implied by the 1970 multi-regional schedule. Note that for urban to rural migration this same indicator is 0.1484.

Table 4 presents comparable data for Poland. Note the differences in the migration levels. For the Polish data, the same indicators of flow levels are 0.4424 and 0.1332, respectively. Thus we may conclude that rural to urban migration is currently proceeding at a much higher rate in the U.S.S.R. than in Poland.

IV. Projection of the Soviet Union's Population to the Year 2000

Population projections illuminate the impacts of current schedules of births, deaths, and migration by drawing out the future consequences of the maintenance of present rates. Methods for developing population projections for single regions are well known, and the mathematics of such exercises have been documented in countless articles, and more recently, in several texts (e.g., Keyfitz, 1968; Pollard, 1973). The mathematics of population projection for multi-regional systems that experience internal migration, however, are less known, and it is only recently that concepts such as the multi-regional life table have given them a methodological consistency with the conventional mechanics of a single-region population projection (Rogers, 1975).

The discrete model of multi-regional demographic growth expresses the population

TABLE 5. THE MULTIREGIONAL NET MATERNITY FUNCTION: URBAN AND RURAL POPULATIONS OF THE SOVIET UNION, 1970

Region	Age x	Fertility Rate[1] $F_u(x)$	Person-Years Lived[2] $_uL_u(x)$	$_rL_u(x)$	Net Maternity Function[3] $_u\phi_u(x)$	$_r\phi_u(x)$
URBAN (u)	15-19	0.01450	4.31681	1.44241	0.06258	0.02091
	20-24	0.07370	4.08939	2.88681	0.30137	0.21275
	25-29	0.05590	3.97299	3.60408	0.22208	0.20146
	30-34	0.03577	3.86942	3.62345	0.13839	0.12960
	35-39	0.01549	3.76770	3.57962	0.05836	0.05545
	40-44	0.00399	3.65839	3.50088	0.01460	0.01397
	45-50	0.00069	3.54007	3.40391	0.00245	0.00236
	Total	0.20003				
	GRR	1.00015		NRR	0.79984	0.63649
Region	**Age x**	**Fertility Rate $F_r(x)$**	**Person-Years Lived $_uL_r(x)$**	**$_rL_r(x)$**	**Net Maternity Function $_u\phi_r(x)$**	**$_r\phi_r(x)$**
RURAL (r)	15-19	0.01637	0.46496	3.34464	0.00761	0.05474
	20-24	0.10364	0.66071	1.86887	0.06848	0.19369
	25-29	0.08452	0.73122	1.10585	0.06180	0.09346
	30-34	0.06238	0.77511	1.02684	0.04835	0.06405
	35-39	0.03875	0.80042	0.99427	0.03101	0.03852
	40-44	0.01494	0.81288	0.97614	0.01214	0.01458
	45-50	0.00340	0.81086	0.95273	0.00276	0.00324
	Total	0.32398				
	GRR	1.61992		NRR	0.23215	0.46229

[1]Source: Population of the USSR, 1973, 1975, p. 136. Data for USSR in 1969-70 were rescaled to generate the 1970 totals for urban and rural births reported in the same publication on p. 99 (i.e., 2,253,537 urban births and 1,972,112 rural births).
[2]Source: Table 4 of Rogers (1976).
[3] $\sum_x {_i\phi_j(x)} = \sum_x {_iL_j(x)}\, F_j(x) = {_iNRR_j}$

projection process by means of a matrix operation in which a multi-regional population, set out as a vector, is multiplied by a projection matrix that survives that population forward through time. The projection calculates the region and age-specific survivors of a multi-regional population and adds to this total the new births that survive to the end of the unit time interval.

Table 5 sets out estimated urban and rural age-specific fertility rates for the Soviet Union in 1970. These imply a gross reproduction rate of 1.00 in the urban areas and of 1.62 in the rural areas (and one of 1.22 for the U.S.S.R. as a whole). When combined with the corresponding mortality-migration data these give a net reproduction rate of 1.05 for the Soviet Union, disaggregated as in the following matrix:

$$\underset{\sim}{NRR} = \begin{bmatrix} 0.80 & 0.64 \\ 0.23 & 0.46 \end{bmatrix}$$
$$\overline{1.03} \qquad \overline{1.10}$$

Urban-born individuals are being replaced, on the average, by 1.03 babies in the next generation, and rural-born individuals by 1.10 babies. Because of migration, roughly 20 per cent of the former babies are born in rural areas (i.e., 0.23/1.03 = 0.22), and about 60 per cent of the latter babies are born in urban areas (i.e., 0.64/1.10 = 0.58).

Table 6 presents the principal results of a projection of the 1970 urban and rural populations of the U.S.S.R. It is assumed that current trends in fertility, mortality, and migration remain unchanged until the year 2000.[1] Such a projection produces an older and much more urbanized population.

TABLE 6. URBAN AND RURAL POPULATIONS OF THE SOVIET UNION: 1970 AND (PROJECTED) 2000.

	Base Year, 1970[1]				Projection, 2000[2]			
	Population (in thousands)		Age Composition		Population (in thousands)		Age Composition	
Age,x	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
0-4	9,876	10,657	0.0726	0.1008	16,350	7,370	0.0711	0.0883
5-9	11,712	12,792	0.0861	0.1210	16,027	7,500	0.0697	0.0898
10-14	12,132	12,884	0.0892	0.1219	16,307	7,897	0.0709	0.0946
15-19	13,737	8,286	0.1010	0.0784	16,701	7,285	0.0726	0.0873
20-24	11,922	5,202	0.0877	0.0492	17,069	5,159	0.0742	0.0618
25-29	8,830	4,955	0.0649	0.0469	16,568	3,862	0.0720	0.0463
30-34	13,423	7,745	0.0987	0.0732	15,619	3,801	0.0679	0.0455
35-39	9,783	6,829	0.0719	0.0646	18,617	4,623	0.0809	0.0554
40-44	11,435	7,589	0.0841	0.0718	18,588	4,712	0.0808	0.0564
45-49	7,110	5,159	0.0523	0.0488	16,006	4,035	0.0696	0.0483
50-54	5,301	3,787	0.0390	0.0358	11,946	3,165	0.0519	0.0379
55-59	6,614	5,413	0.0486	0.0512	8,576	3,090	0.0373	0.0370
60-64	5,436	4,912	0.0400	0.0465	11,886	4,947	0.0517	0.0593
65-69	3,618	3,649	0.0266	0.0345	7,920	4,062	0.0344	0.0487
70+	5,062	5,869	0.0372	0.0555	21,911	11,968	0.0952	0.1434
Total U.S.S.R.	135,992 241,720	105,729	0.5626 1.0000	0.4374	230,090 313,567	83,477	0.7338 1.0000	0.2662
Mean Age			31.27 31.02	30.70			35.81 35.86	36.02
Annual Growth Rate	0.0265 0.0125	-0.0071			0.0128 0.0094	0.0005		

[1]Source: Table 2

[2]Source: Cohort-survival projection using the fertility data in Table 5 and the mortality-migration data in Tables 1 and 2.

V. Spatial Zero Population Growth in the U.S.S.R.

Demographers agree that because of the large number of young people in most countries of the world today, *immediate* zero population growth is not a practical national or global objective. Consequently, most projected paths toward a stationary population assume an average of just over two births per woman from now on, and hold mortality fixed. On the assumption of zero or negligibly small net immigration, such projections normally evolve into stationary populations in about a century and imply an ultimate population increase of anywhere from zero to 300 per cent. Much has been made of the social and economic consequences of such zero growth populations, and particularly important have been the analyses of their stationary age compositions — age compositions that have a high mean age and virtually constant numbers from age zero to 50.

If mortality is fixed, and 1,000 babies born at each moment replace themselves, on the average, with a thousand babies as they move past their child-bearing years, we will ultimately obtain a stationary zero-growth population. But, the babies who survive to the child-bearing ages must have enough children to replace not only themselves but also those who have not survived to become parents. Thus we specify that the *net* (and not the *gross*) reproduction rate of the population be unity, i.e., $NRR = 1$. Reducing observed age-specific fertility rates proportionally to obtain a net reproduction rate of unity, then, is one way of achieving a stationary population.

The multi-regional analog of the above calculation is straightforward. We simply reduce the observed age-specific regional fertility rates proportionally until the aggregate national net reproduction rate is equal to unity. (Note that such a reduction can be

TABLE 7. URBAN AND RURAL ZERO GROWTH POPULATIONS IN THE SOVIET UNION: TWO ALTERNATIVE PROJECTIONS ASSUMING IMMEDIATE DECLINE OF FERTILITY TO REPLACEMENT LEVEL

	Alternative A[1]				Alternative B[2]			
	Population (in thousands)		Age Composition		Population (in thousands)		Composition	
Age, x	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
0-4	17,316	4,683	0.0694	0.0740	16,125	6,421	0.0647	0.0900
5-9	16,775	4,798	0.0672	0.0758	15,756	6,354	0.0632	0.0891
10-14	16,643	4,859	0.0667	0.0768	15,684	6,354	0.0629	0.0891
15-19	16,681	4,733	0.0668	0.0748	16,077	5,871	0.0645	0.0823
20-24	17,202	4,071	0.0689	0.0643	17,203	4,600	0.0690	0.0645
25-29	17,449	3,619	0.0699	0.0572	17,750	3,841	0.0712	0.0538
30-34	17,098	3,702	0.0685	0.0585	17,435	3,883	0.0699	0.0544
35-39	16,696	3,762	0.0669	0.0594	17,045	3,924	0.0683	0.0550
40-44	16,235	3,790	0.0650	0.0599	16,583	3,942	0.0665	0.0552
45-49	15,725	3,761	0.0630	0.0594	16,067	3,905	0.0644	0.0547
50-54	15,086	3,685	0.0604	0.0582	15,416	3,820	0.0618	0.0535
55-59	14,264	3,557	0.0571	0.0562	14,579	3,684	0.0585	0.0516
60-64	13,148	3,381	0.0527	0.0534	13,443	3,499	0.0539	0.0490
65-69	11,629	3,107	0.0466	0.0491	11,894	3,213	0.0477	0.0450
70+	27,695	7,776	0.1109	0.1229	28,327	8,037	0.1136	0.1126
Total	249,643	63,285	0.7978	0.2022	249,382	71,350	0.7775	0.2225
U.S.S.R.	312,927		1.000		320,732		1.0000	
Mean Age			37.58	37.39			38.21	35.21
			37.54				37.54	
Annual Growth Rate	0.0000	0.0000			0.0000	0.0000		
	0.0000				0.0000			

[1]Each individual is replaced by one child in the next generation.

[2]Each urban-born individual is replaced by 0.98 of a child and each rural-born individual is replaced by 1.05 children in the next generation.

achieved a number of alternative ways.) The mechanics of the population projection process itself, however, remain unchanged.

Table 7 sets out some of the more interesting consequences of an immediate movement to replacement levels of fertility by the 1970 U.S.S.R. population. In particular, it shows the growth and distributional consequences of two alternative paths to spatial zero growth. Alternative A reduces fertility in urban and rural areas in such a way as to ensure that each individual, no matter where he (or she) was born, is replaced in the next generation by a single baby. Alternative B, however, reduces births to urban-born individuals more than births to rural-born individuals. That is, each urban-born person is on the average replaced in the next generation by 0.98 of a baby and each rural-born person is similarly replaced by 1.05 babies.[2] Both alternatives, however, give a unit net reproduction rate for the U.S.S.R. as a whole. But the growth and distributional consequences are different.

Alternative A gives the urban areas proportionally more births than Alternative B. Hence, the mean age of that population is younger in the former than in the latter case, and its share of the total population is correspondingly higher. Because Alternative B gives rural areas proportionally more births than it does to urban areas under either alternative, the mean age of the rural population is much lower, and its share of the total is higher.

Note that owing to the low level of fertility observed in 1970, the zero growth results in general do not differ substantially from a projection of current trends. Urban areas receive over 70 per cent of the population in all projections, and the mean ages all lie in the range of 35 to 38 years.

VI. Conclusion: Model Migration Age Profiles

In our previous research on model migration schedules (Rogers, 1975; Rogers and Castro, 1976) we adopted the "mortality" approach and developed model schedules by regressing age-specific probabilities of migration on the migration level. In this paper we instead have adopted the "fertility" approach and have focused on model age profiles and their associated gross migra production rates and mean ages. We believe this second approach to be a more useful one than the first for the following reasons:

1. The fertility approach more easily preserves the regularities in observed migration schedules by separating out the influences of migration level, regional age composition, and migration age profile.[3] Such a separation has the additional benefit of allowing the three different components of migration rates to be estimated on the basis of different sample sizes, thereby suggesting that more extensive sampling be carried out to determine the value of the component that fluctuates most in the short run, that is, the migration level.
2. The identification of a migration age profile unconfounded by the influences of age composition suggests further carry-overs from the fertility literature on model schedules; for example, the framework indicates that it may be useful to decompose a typical migration age profile into three broad sets of age groups:
   a. the pre-labour force migrants (0-14 years);
   b. the labour force migrants (15-64 years); and
   c. the post-labour force migrants (65+ years).

The migration age profile of the first group may be related to levels of fertility, in addition to the usual association with the migration profiles of parental age groups. Migration by labour-force age groups may be related to indices such as labour-force participation rates and ages of entry and exit from the labour force. Finally, retirement migration may be expressed as a function of variables such as climate and the general quality and quantity of social services in a particular region.

Decomposing a migration age profile into pre-labour, labour, and post-labour sets of age groups suggests the development of families of model profiles that may be characterized by more than a single parameter. For example, borrowing the double exponential curve of Coale and McNeil (1972), we may describe a migration age profile as the sum of four components:

1. a single negative exponential curve of the *pre-labour force* ages, with its rate of descent, α_1;
2. a left-skewed unimodal curve of the *labour force* ages with its rates of ascent and descent, λ_2 and α_2, respectively;
3. an almost bell-shaped curve of the *post-labour force* ages with its rates of ascent and descent, λ_3 and α_3, respectively; and
4. a constant curve c, the inclusion of which improves the quality of fit provided by the mathematical expression of the schedule.

The decompostion described above suggests the following simple sum of four curves (Rogers, Raquillet, and Castro, 1978):

$$\begin{aligned} N(x) \quad &= a_1 e^{-\alpha_1 x} \\ &+ a_2 e^{-\alpha_2 (x-\mu_2) - e^{-\lambda_2 (x-\mu_2)}} \\ &+ a_3 e^{-\alpha_3 (x-\mu_3) - e^{-\lambda_3 (x-\mu_3)}} \\ &+ c \qquad , x = 0, 1, 2, \ldots \end{aligned} \tag{4}$$

The "full" model profile in (4) has 11 parameters: a_1, α_1, a_2, α_2, μ_2, λ_2, a_3, α_3, μ_3, λ_3, and c. Migration profiles *without* a retirement peak may be represented by a "reduced" model with seven parameters, because in such instances the third component of (4) is omitted.

Figure 3 illustrates a typical age-sex-specific migration profile with a retirement peak. Several important points along the age profile may be identified: the *low point,* x_1, the *high peak,* x_p, and the *retirement peak,* x_r. Associated with the first two points is the labour-force shift, which is defined as the difference in years between the ages of the low point and the high peak, that is, $X = x_p - x_1$. Associated with this shift is the jump, B, the increase in the migration profile of individuals aged x_p over those aged x_1.

The close correspondence between the proportion migrating among children and their parents suggests another important shift in observed migration profiles. If, for each point x on the pre-labour-force part of the migration curve, we obtain by interpolation the point $x + A_x$, say, with the identical proportion migrating on the labour force-curve, then the average of the values of A_x, calculated for the first dozen or so years of age may be defined to be the observed *parental shift, A.*

Table 8 sets out parameter estimates obtained by fitting the model profile in (4) to the curves presented in Figures 1 and 2. The patterns exhibited by the observed Swedish and Polish data are quite similar. The incomplete migration data for the Soviet Union, however, suggests a rather different pattern. How much of this difference may be

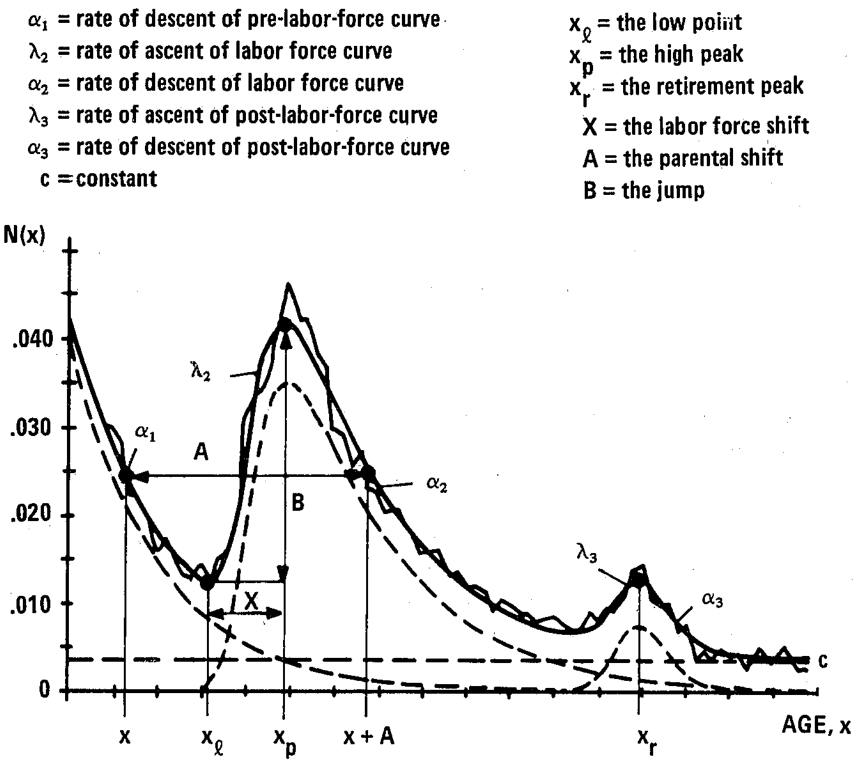

FIGURE 3. THE MODEL MIGRATION AGE PROFILE
Source: Rogers (1976).

TABLE 8. MODEL MIGRATION AGE PROFILES: SWEDEN, POLAND, USSR[1]

Region / Parameter	Sweden, 1968-73		Poland, 1973		USSR, 1970
	Males	Females	Males	Females	Total
a_1	0.0275	0.0261	0.0260	0.0229	0.0851
α_1	0.0975	0.1109	0.1009	0.1562	0.2623
a_2	0.0751	0.0940	0.0951	0.1352	0.4867
α_2	0.1190	0.1535	0.1514	0.2560	0.1265
μ_2	21.35	19.87	21.71	20.85	17.45
λ_2	0.4419	0.4610	0.4012	0.4188	12.4092
c	0.0021	0.0030	0.0027	0.0052	0.0119
$\bar{n}$	25.8	25.0	25.6	26.8	26.0
x_1	17.11	15.65	16.86	15.70	17.30
x_p	24.21	22.18	24.06	22.00	17.85
A	29.3	26.7	29.0	25.6	39.9
B	0.186	0.231	0.203	0.272	0.456

1 Minimum chi-square estimates. Data sources are: Swedish Central Bureau of Statistics (1974), Polish Central Bureau of Statistics (1974), and Table 1.

attributed to the crude method used for inferring the age-specific schedule is impossible to ascertain.

Migration profiles of the form specified in (4) may be classified into *families* according to the values taken on by their principal parameters. For example, we may distinguish those schedules with a retirement peak from those without; or we may refer to schedules with relatively low or high values for the rate of ascent λ_2. In many applications, it is also meaningful and convenient to characterize migration schedules in terms of several of the fundamental measures illustrated in Figure 3, such as the low point x_1, the high peak x_p, the labour-force shift X, the parental shift A, and the jump B.

Finally, migration profiles are sensitive to economic changes. The decomposition in (4) permits one to trace through some of the impacts of economic factors, such as labour-force participation, on migration-age patterns. For example, we could reinterpret in Coale andMcNeil's (1972) model:

1. entry into the marriage market as entry into the job market;
2. marital search as job search;
3. first marriage frequency as first job frequency, and
4. proportion ever married as proportion ever active.

This suggests a way for drawing out the consequences of changes in patterns of labour- force activity on migration profiles and rates.

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Footnotes

1. This means the fertility rates in Table 5 and the survivorship and migration proportions of the life table in Table 4 of Rogers (1976) are assumed to be constant over the 30 projection period.
2. The mathematics of the two alternative fertility reductions appear in Rogers and Willekens (1976).

3. For example, we offer the conjecture that the *level* of migration varies inversely with the size of areal unit used but that the migration age profile does not. The implications of this for econometric modeling of migration flows are significant and could greatly simplify the specification of such models.

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