TWO METHODOLOGICAL NOTES ON SPATIAL POPULATION DYNAMICS IN THE SOVIET UNION

Andrei Rogers

June 1976

Prepared for the XXIII International Geographical Congress, July, 1976, Minsk and Moscow.

Preface

Interest in human settlement systems and policies has been a critical part of urban-related work at IIASA since its inception. Recently this interest has given rise to a concentrated research effort focusing on migration dynamics and settlement patterns. Four sub-tasks form the core of this research effort:

I. the study of spatial population <u>dynamics</u>;

II. the definition and elaboration of a new research area called <u>demometrics</u> and its application to migration analysis and spatial population forecasting;

III. the analysis and design of migration and settlement <u>policy</u>;

IV. a <u>comparative study</u> of national migration and settlement patterns and policies.

This paper, the fifth in the comparative study series, examines two aspects of spatial population dynamics in the Soviet Union: the migration age profile in the U.S.S.R. and some of the distributional consequences of zero population growth. The former topic deals with the problem of summarizing observed regularities in migration data, the latter considers how stabilization of the Soviet national population might affect its urban and rural population distributions.

Related papers in the comparative study series, and other publications of the migration and settlement study, are listed on the back page of this report.

A. Rogers

June 1976

Table of Contents

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 of the two short notes assembled in 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.

The second note considers some of the geographical consequences of zero population growth in the Soviet Union. Specifically, attention is focused on the changes in age compositions and in 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.

Acknowledgements

The author is deeply indebted to Frans Willekens for programming and carrying out all of the numerical calculations that form the basis of this paper. He also is grateful to Galina Kiseleva of the U.S.S.R. for providing him with the published demographic data for the Soviet Union, to Arne Arvidsson and Folke Snickars for the data on Sweden, and to Kazimierz Dziewonski and Piotr Korcelli for the data on Poland.

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

Andrei Rogers

1. Introduction

The spatial evolution 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 schedules have two important applications:

1) they may be used to infer, disaggregate, or adjust the empirical schedules of populations for which the requisite data are lacking or inaccurate, and
2) they can be applied in mathematical studies of spatial population dynamics.

Model fertility and model mortality schedules have received a significant amount 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.

2. Model Migration Schedules

The shape, or <u>profile</u>, of an age-specific schedule of migration rates is a feature that may be usefully studied independently of its intensity, or <u>level</u>. 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. Illustrations of this property appear in Figure 1, which sets out migration rates for the U.S.A. and Sweden.

Migration rates vary substantially for different age groups. They are relatively high for the young but decline sharply with age among the middle-aged. The basic age profiles may be

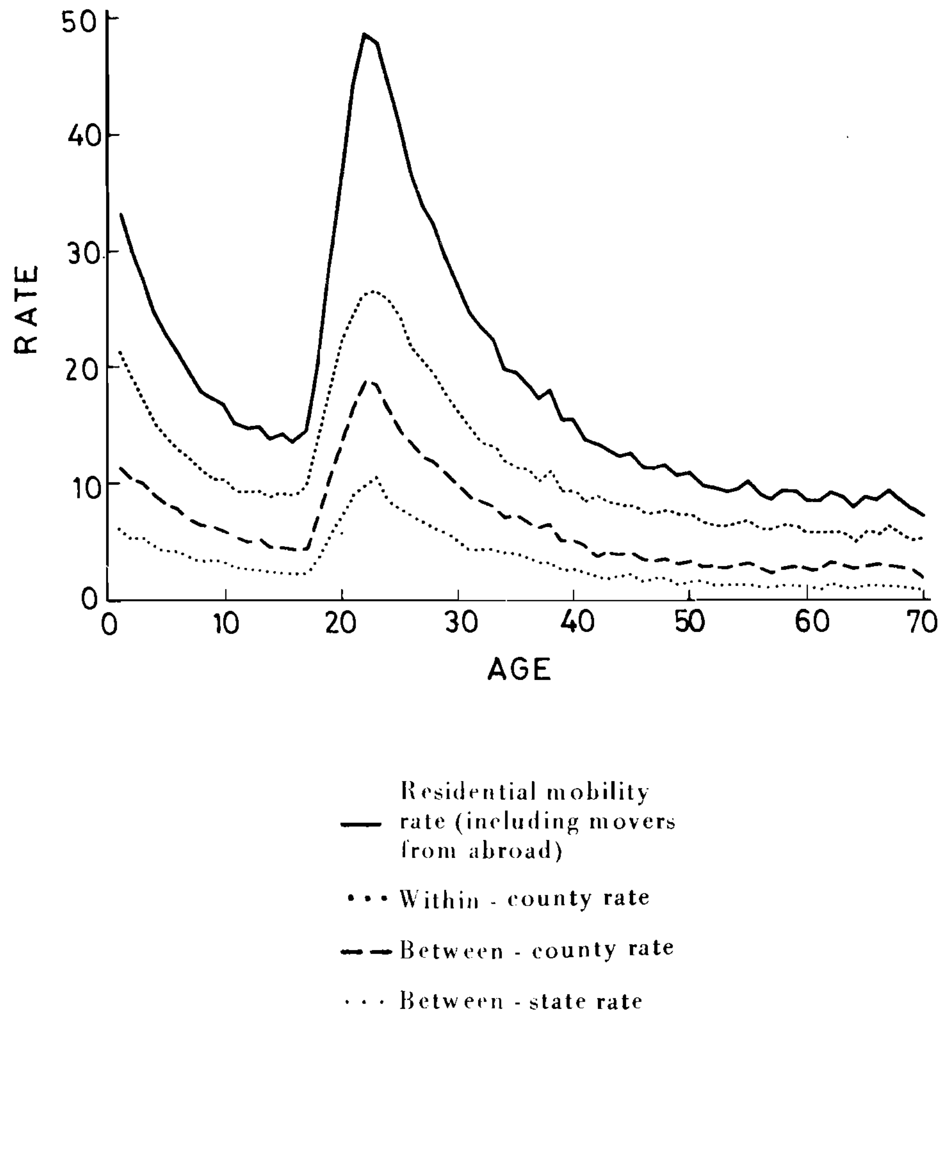


FIGURE 1.A: Age-Specific Annual Migration Rates of the Total United States Population by Category of Move: Average of 1966-1971.

Source: Long (1973), p. 38

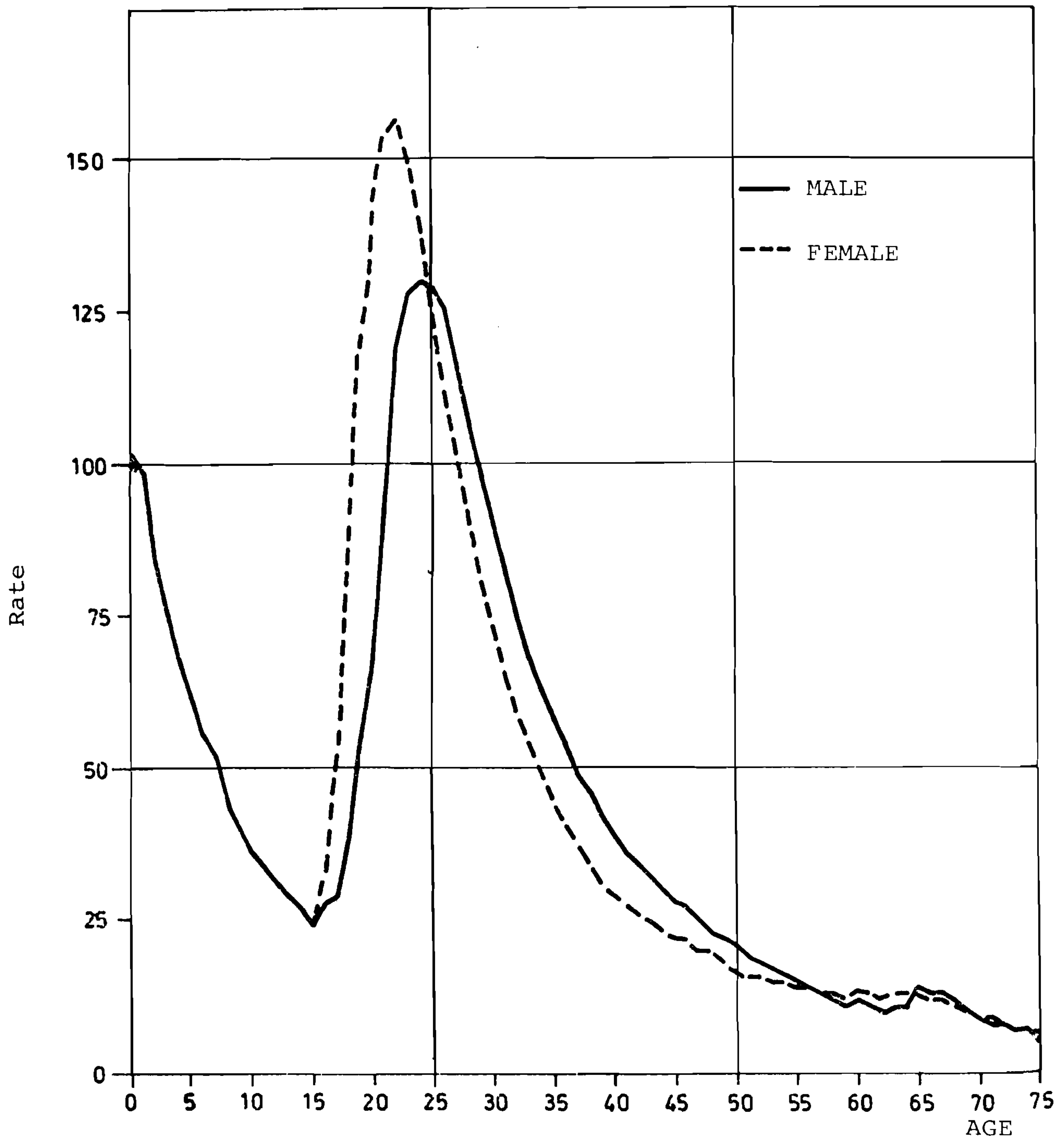


FIGURE 1.B: Age-Specific Annual Migration Rates of the Swedish Population by Sex: Average of 1968-1973.

Source: <u>Internal Migration in Sweden 1968-1973</u>, 1974, p. 10.

summarized in a number of ways, the more useful of which tend to reflect similar efforts in the areas of fertility and mortality.

Because migration, like fertility, is potentially a repetitive event, its level can be expressed in terms of an expected number of events per person. But, like mortality, migration can be measured in terms of an expected duration time, e.g., 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, Ch. 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, such as those illustrated in Figure 1 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 outmigrants of age x leaving a region with a population of K(x), then

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

where

O = total number of outmigrants;

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 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:

		Migration Age Profile, N(x)	
		Young	Old
Population Age Composition, C(x)	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 2.A illustrates the age profiles and age compositions that combine to produce the migration rate curves of Figure 1.B. Similar data for Poland are set out in Figure 2.B for purposes of comparison (See also Appendix). 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.

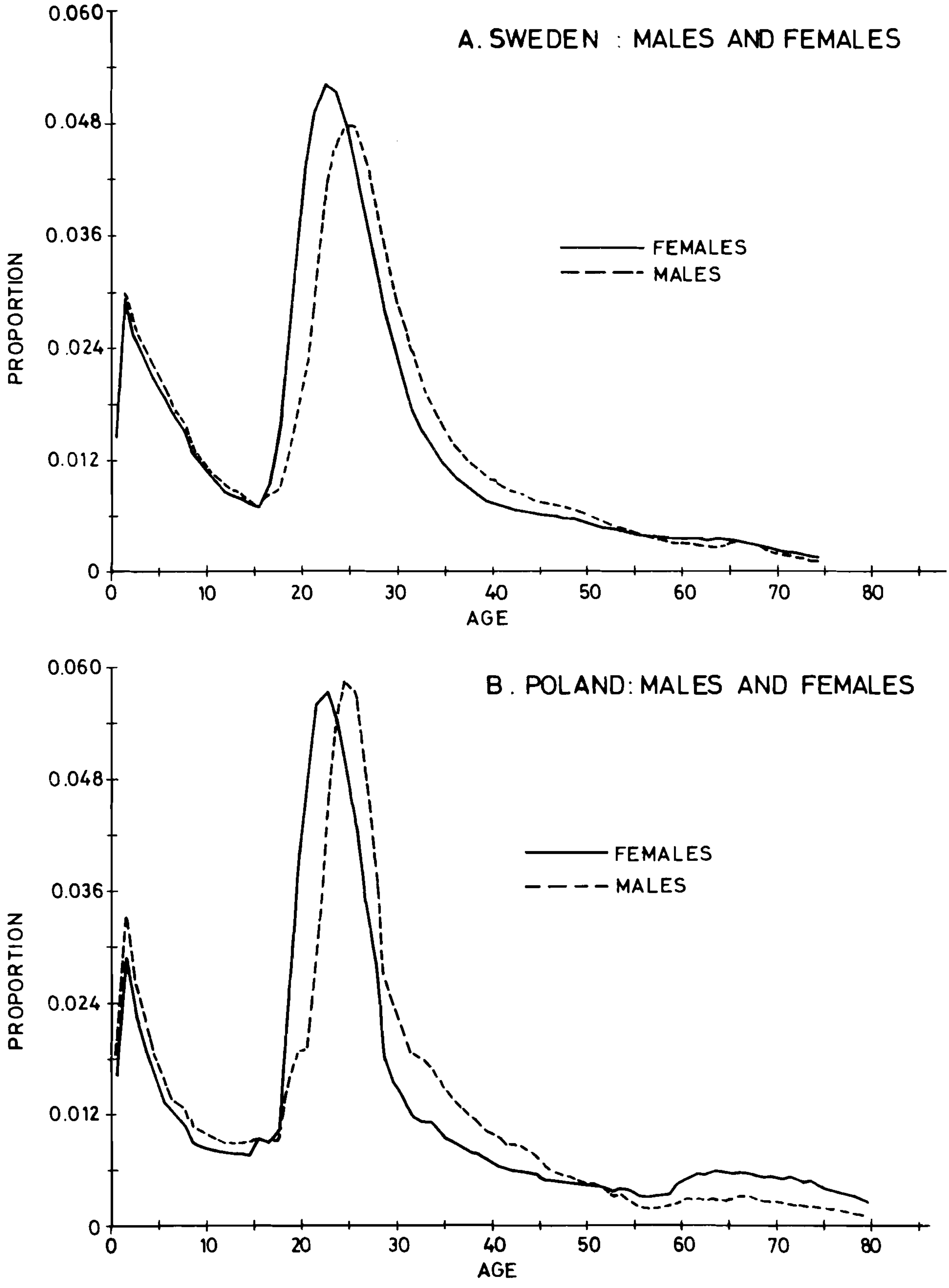
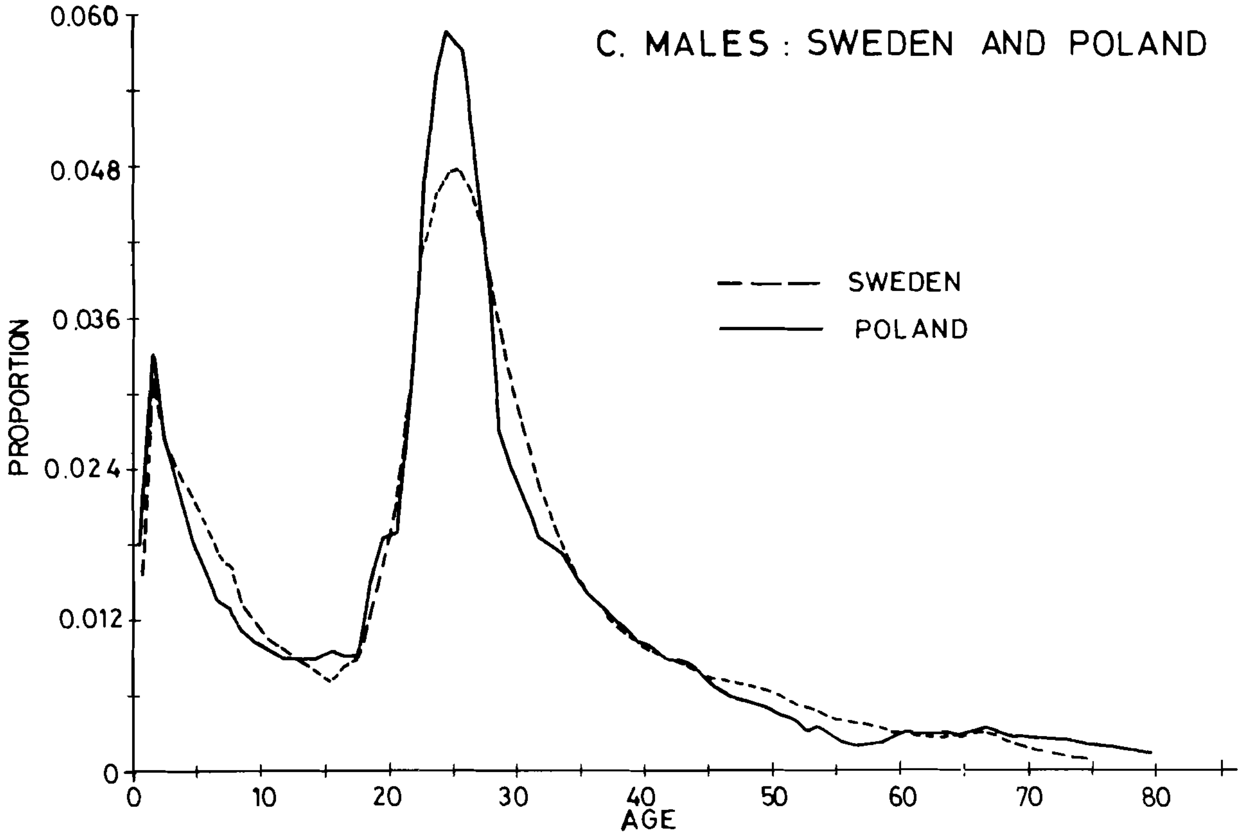


Figure 2 : Observed Migration Age Profiles
Source : Appendix



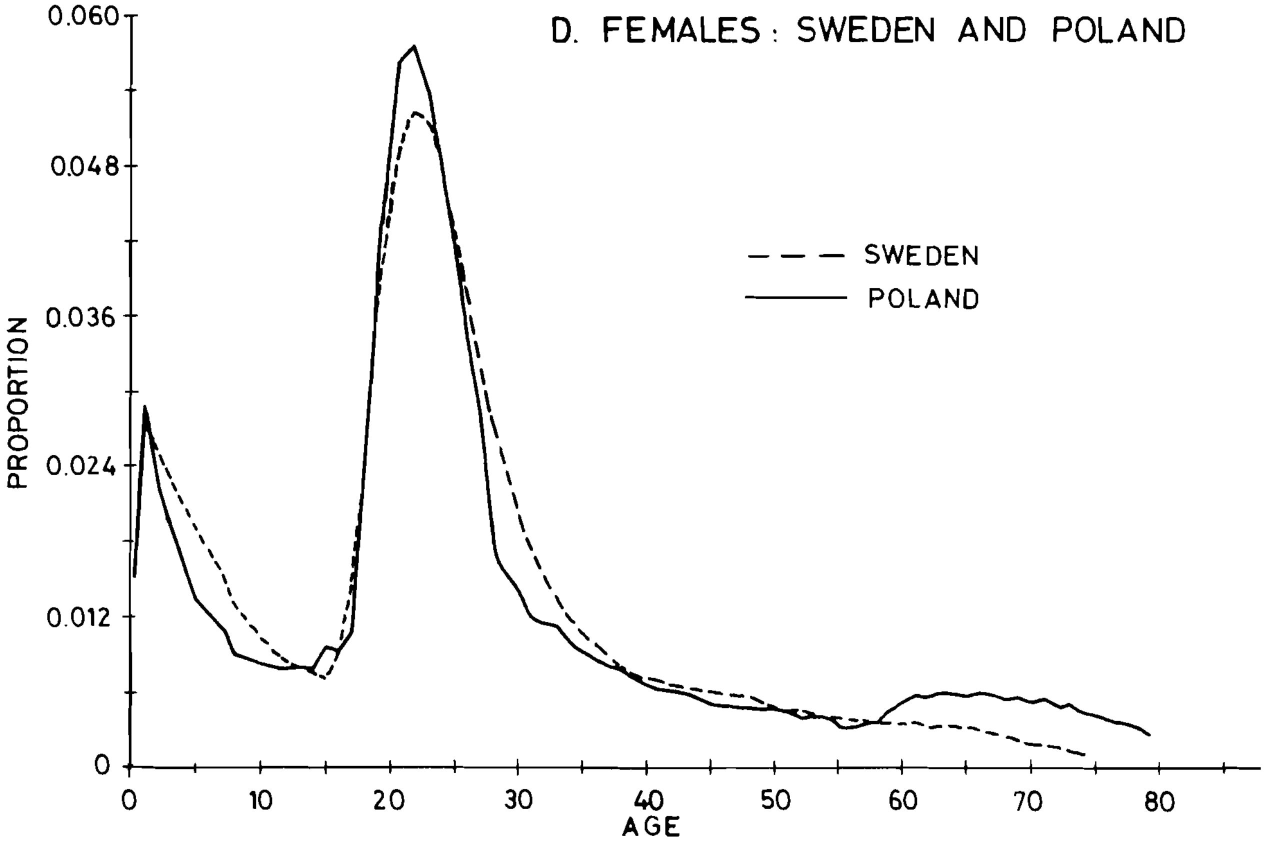


Figure 2 : Observed Migration Age Profiles (continued)

Source : Appendix

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

$$GRR = 5\sum_{x} F(x) \quad .$$

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

$$GMR = 5\sum_{x} M(x) \quad . \tag{2}$$

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

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

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

Note that the intensity of migration deals with the fraction of a population that moves (i.e., the crude migration rate times 5), 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 Illustrations

The decomposition of an age-specific migration schedule, M(x), into a level component, cmr, say, and a pattern component, $P(\bar{m})$, suggests a more direct focus on the ways in which different regional migration age profiles combine with different regional age compositions to produce observed distributions of migration rates by age.

Table 1 presents two regional migration age profiles (Figure 3) and two regional age compositions (Figure 4). Given a cmr of 0.10 say, these four distributions may be combined to form the four sets of migration rates that appear in Columns 5 through 8 and which are illustrated in Figure 5.

A young (old) migration age profile and a young (old) age composition generates an old (young) migration schedule. But what are the results of mixed combinations? Consider, for example, the combination of a young migration age profile and an old age composition--a combination that presumably exists in economically declining areas which have been consistently losing their younger population. Such

TABLE 1: Hypothetical Model Migration Schedules.

Age, x	Age Profile[1], N(x)		Age Composition[2], C(x)		Migration Rate[3], M(x)			
	(1.) Young ($\bar{n}$ = 21.84)	(2.) Old ($\bar{n}$ = 25.83)	(3.) Young ($\bar{c}$ = 22.16)	(4.) Old ($\bar{c}$ = 30.65)	(5.) Y-Y ($\bar{m}$=32.73)	(6.) Y-O ($\bar{m}$=22.73)	(7.) O-Y ($\bar{m}$=40.75)	(8.) O-O ($\bar{m}$=26.89)
0-4	0.1360	0.1099	0.181	0.082	0.0751	0.1659	0.0607	0.1340
5-9	0.1002	0.0918	0.148	0.073	0.0677	0.1373	0.0620	0.1258
10-14	0.0982	0.1023	0.123	0.064	0.0798	0.1534	0.0832	0.1598
15-19	0.1809	0.1875	0.101	0.070	0.1791	0.2584	0.1856	0.2679
20-24	0.1707	0.1126	0.083	0.071	0.2057	0.2404	0.1357	0.1586
25-29	0.0885	0.0759	0.070	0.060	0.1264	0.1475	0.1084	0.1265
30-34	0.0610	0.0601	0.060	0.057	0.1017	0.1070	0.1002	0.1054
35-39	0.0469	0.0476	0.050	0.059	0.0938	0.0795	0.0952	0.0807
40-44	0.0339	0.0385	0.043	0.063	0.0788	0.0538	0.0895	0.0611
45-49	0.0225	0.0306	0.035	0.064	0.0643	0.0352	0.0874	0.0478
50-54	0.0157	0.0277	0.029	0.063	0.0541	0.0249	0.0955	0.0440
55-59	0.0126	0.0363	0.023	0.064	0.0548	0.0197	0.1578	0.0567
60-64	0.0103	0.0377	0.019	0.059	0.0542	0.0175	0.1984	0.0639
65-69	0.0083	0.0211	0.014	0.051	0.0593	0.0163	0.1507	0.0414
70+	0.0143	0.0204	0.020	0.100	0.0715	0.0143	0.1020	0.0204
TOTAL	1.0000	1.0000	1.000	1.000	1.3664	1.4710	1.7125	1.4940
					x5	x5	x5	x5
				GMR =	6.8319	7.3551	8.5623	7.4698

[1]The young profile is that of South to North Central in Figure 3; the old profile is that of the reverse flow.

[2]The young composition is that of Mexico in Figure 4; the old composition is that of England and Wales in the same figure.

[3]$M(x) = cmr \cdot (N(x) \div C(x))$ with cmr = 0.10. Illustrated in Figure 5.

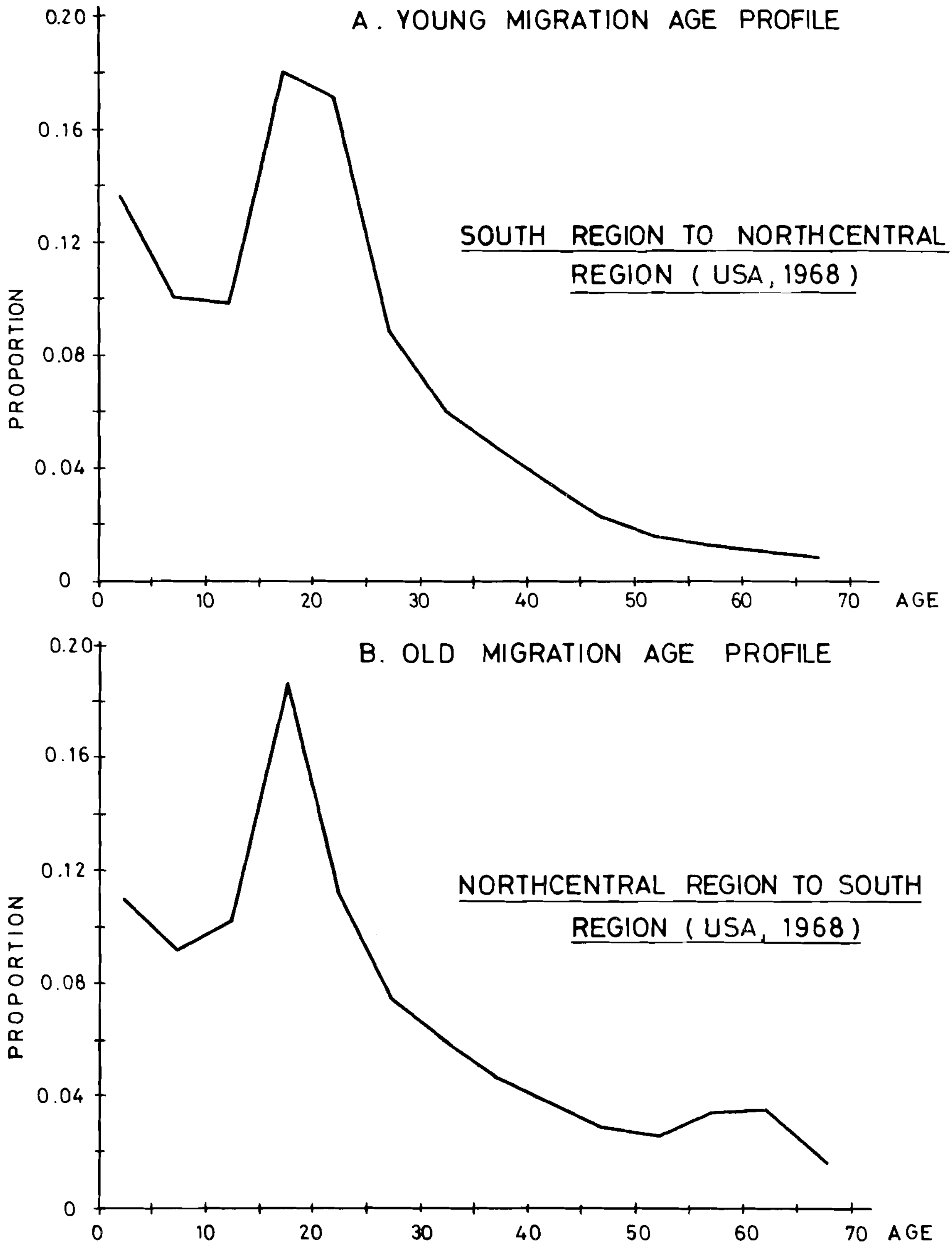


Figure 3 . Alternative Observed Migration Age Profiles

Source : Rogers and Castro , 1976

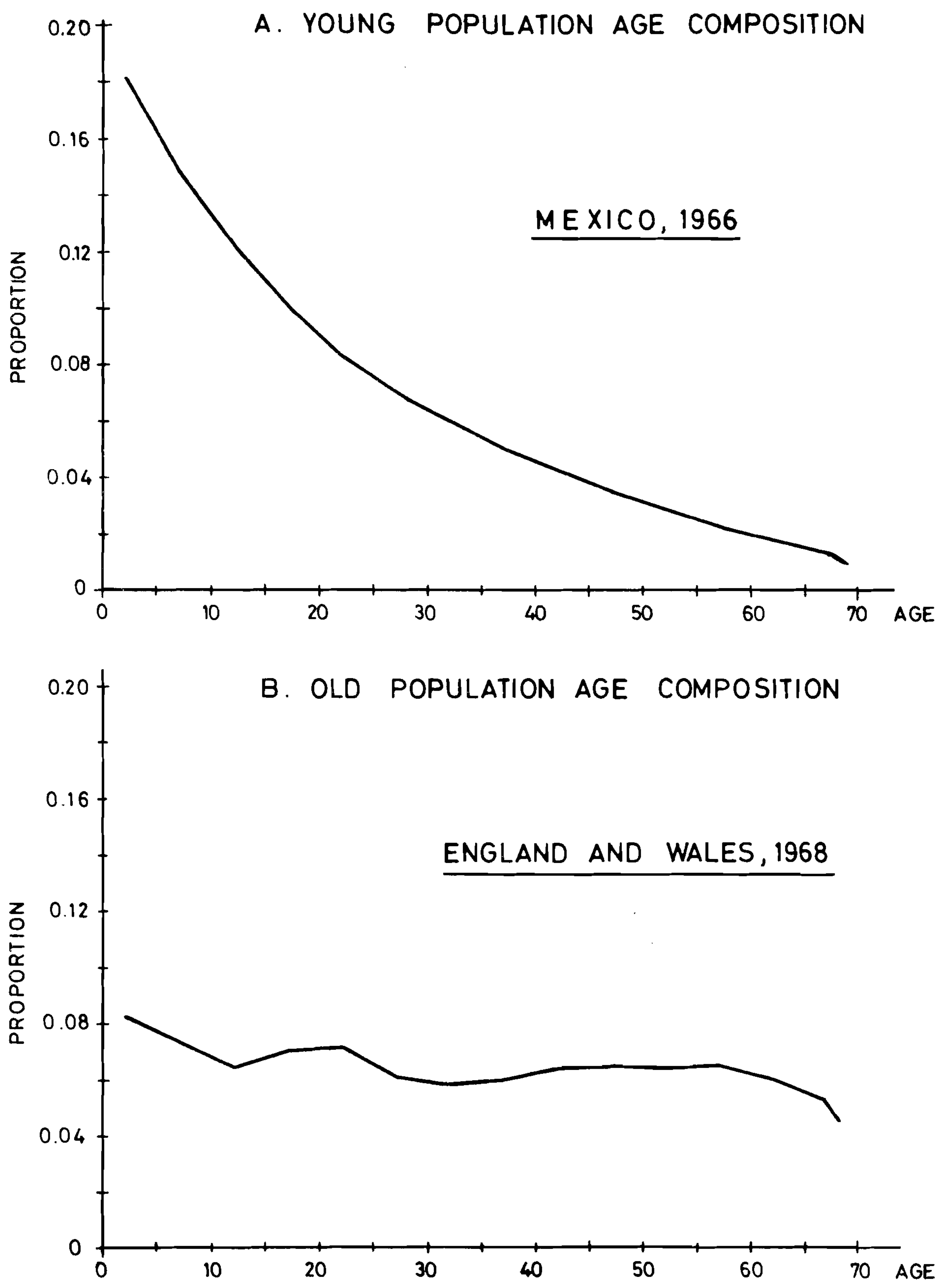


Figure 4 . Alternative Observed Population Age Compositions

Source : Keyfitz and Flieger , 1971

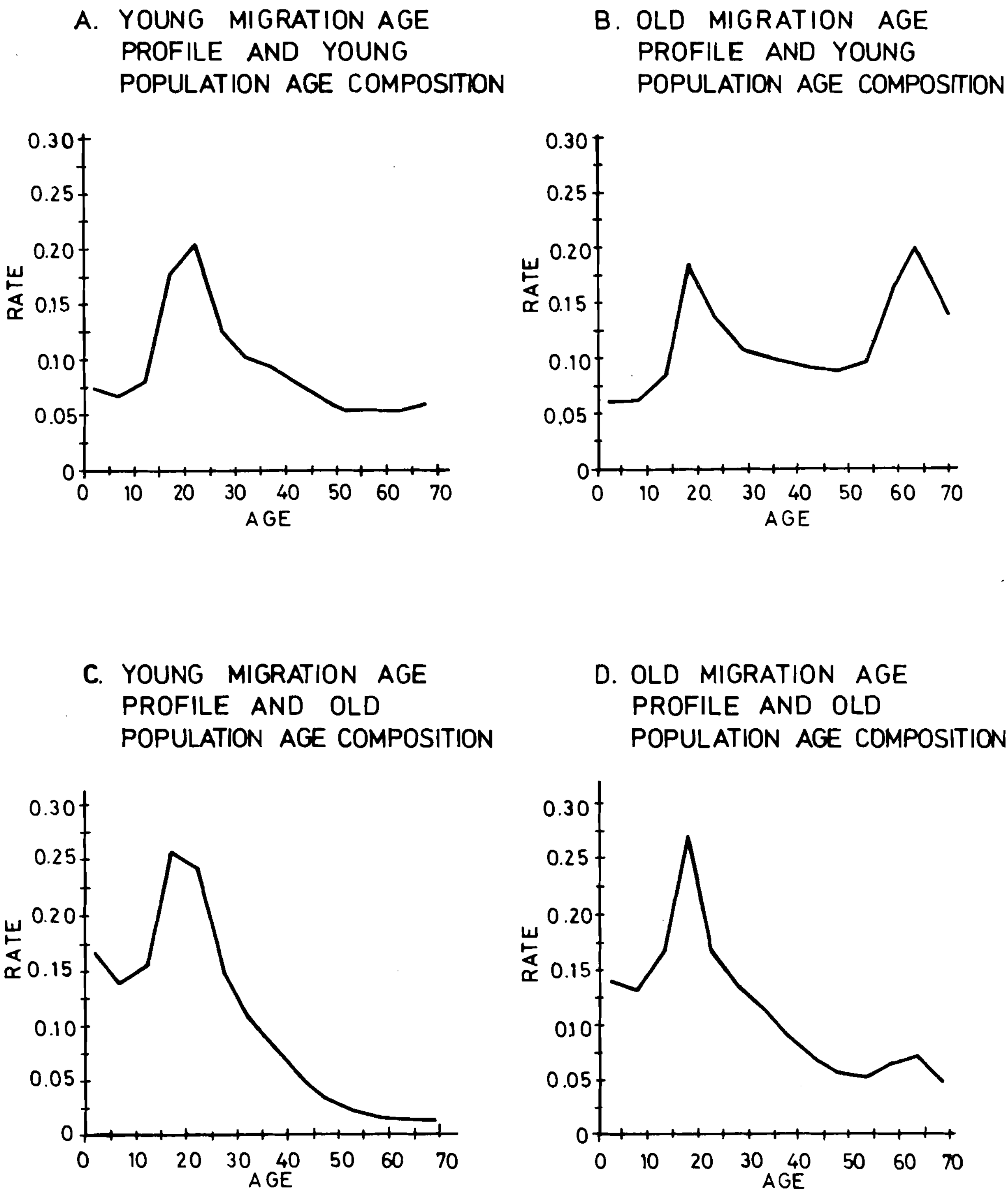


Figure 5 : Alternative Hypothetical Migration Schedules

Source : Table 1

migration schedules differ substantially in mean age from those of economically growing regions with their combinations of young profiles and young compositions.

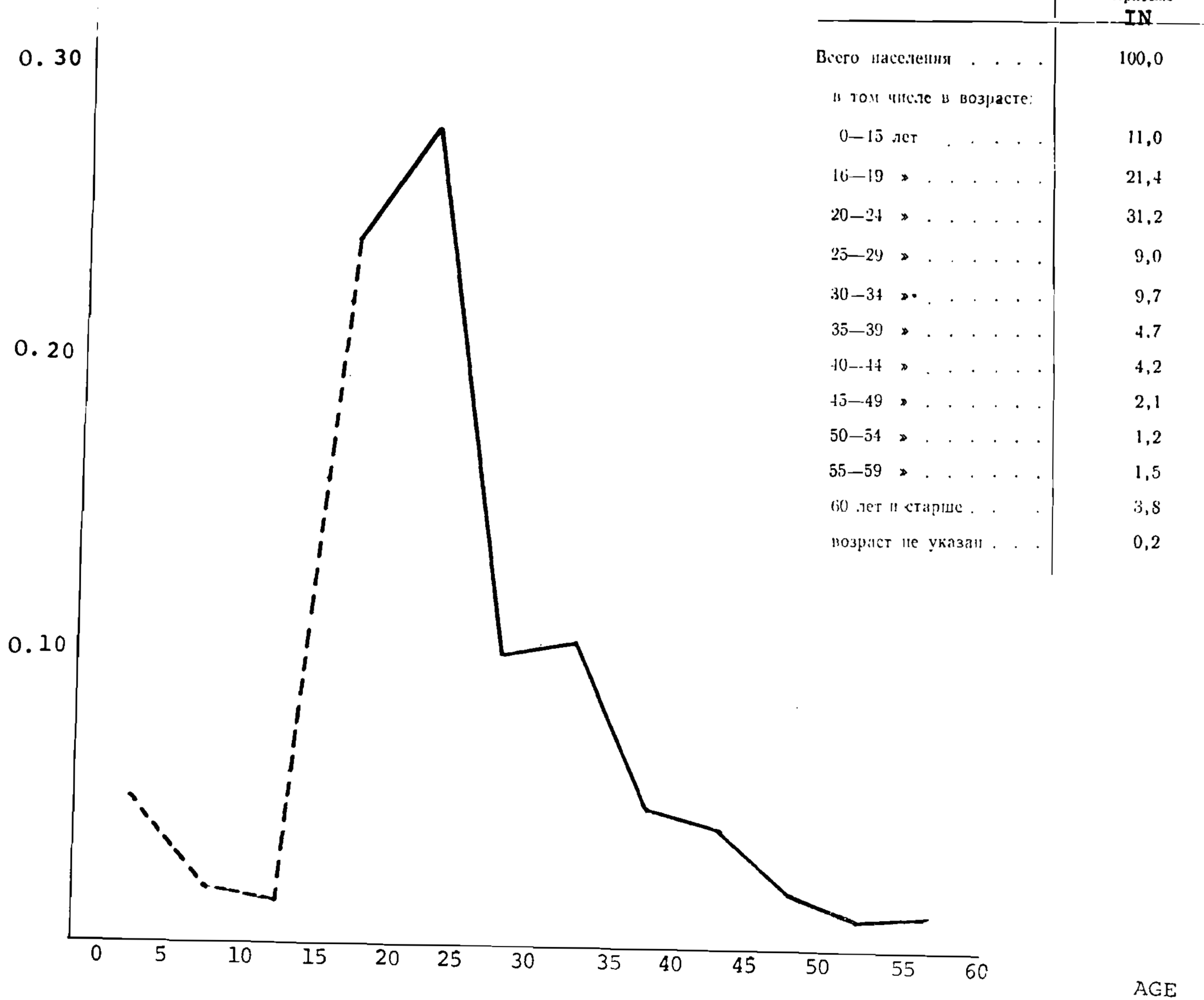
The reverse combination of an old migration age profile and a young age composition may perhaps be characteristic of a rapidly growing region in a cold climate. In such a case one might expect to find a relatively large outmigration of the elderly to milder and sunnier climates.

2.4 Application: Migration in the Soviet Union

Table 2 presents crude estimates of age-specific migration rates between urban and rural areas for the Soviet Union 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 and illustrated in Figure 6. (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 2.

3. A Multiregional Life Table for the USSR

Age-specific death rates disaggregated by urban and rural places of residence apparently are not published by the USSR. Column 4 of Table 3 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 3 and the migration rates in Table 2 to generate the two-region life table for the USSR that appears in Table 4.



6. Состав прибывших в городские поселения и выбывших из них по возрастным группам

(в процентах к итогу)

	Прибыло IN	Выбыло OUT	Механический прирост
Всего населения	100,0	100,0	100,0
в том числе в возрасте:			
0—15 лет	11,0	9,0	19,2
16—19 »	21,4	24,2	10,3
20—24 »	31,2	28,0	44,5
25—29 »	9,0	10,1	4,2
30—34 »	9,7	10,6	6,0
35—39 »	4.7	5,0	3,1
40—44 »	4,2	4,3	3,7
45—49 »	2,1	2,1	2,2
50—54 »	1,2	1,2	1,1
55—59 »	1,5	1,4	1,6
60 лет и старше . . .	3,8	3,8	4,2
возраст не указан . . .	0,2	0,3	0,1

FIGURE 6: Age Profile of Migration: U.S.S.R., 1970

Source: Table 2

TABLE 2. 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 ($\bar{\bar{n}}$ = 25.82)	(4.) Urban ($\bar{c}$ = 31.27)	(5.) Rural ($\bar{c}$ = 30.70)	(6.) Urban to Rural ($\bar{\bar{m}}$ = 27.92)	(7.) Rural to Urban ($\bar{\bar{m}}$ = 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 2.B.

[2] Source: Table 3.

[3] $M(x) = cmr \cdot (N(x) \div C(x))$, where cmr(u,r) = 0.01124 and cmr(r,u) = 0.03475, and where cmr = O ÷ K .

TABLE 3: Urban and Rural Populations and Death Rates: U.S.S.R., 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
45-59	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.

Life tables describe 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, they exhibit a number of probabilities of dying and surviving and develop the corresponding expectations of life at various ages.

Conventional life tables deal with mortality, focus on a single regional 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 comprised of several regions requires the notion of a multiregional 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 multiregional 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 and will be denoted by ${}_ie_j(x)$, where i is the region of birth and j is the region of residence.

Expectations of life in a multiregional life table reflect the influences of mortality and migration. Thus they may be used as indicators of levels of internal migration, in addition to carrying out their traditional role as indicators of levels of mortality. For example, consider the regional expectations of life at birth that are set out in Table 4 below for the U.S.S.R. population with both sexes combined. A baby born in a rural area, and exposed to the multiregional 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 41.17 years would be lived in urban areas. Taking the latter as a fraction of the former, we have in ${}_r\theta_u = 0.5899$ an indicator of the (lifetime) rural to urban migration level that is implied by the 1970 multiregional schedule. Note, that for urban to rural migration this same indicator decreases to 0.1484.

TABLE 4 - MULTIREGIONAL (TWO-REGION) LIFE TABLE OPTION 3 U.S.S.R., 1970

MORTALITY LEVELS $_{u}e(0)$ = 69.87 $_{r}e(0)$ = 69.96 MIGRATION LEVELS $_{u}\theta_{r}$ = 0.1484 $_{r}\theta_{u}$ = 0.5899

AGE	Q(X,1)	P(X,1,1)	P(X,2,1)	L(X,1,1)	L(X,2,1)	LL(X,1,1)	LL(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	0.034767	0.923444	0.041769	100000.	0.	4.80861	0.10442	0.009285	0.007085	0.951008	0.029520	59.51	10.37
5	0.003587	0.982430	0.013983	92344.	4177.	4.57987	0.23755	0.002871	0.000719	0.984093	0.012576	56.67	10.63
10	0.003075	0.985827	0.011098	90851.	5325.	4.51368	0.28771	0.002267	0.000616	0.943558	0.052349	52.11	10.42
15	0.005114	0.898628	0.096258	89697.	6184.	4.31681	0.46496	0.025477	0.001027	0.895970	0.097394	47.56	10.15
20	0.008167	0.875306	0.116526	82976.	12415.	4.08939	0.66071	0.037944	0.001643	0.879440	0.110878	43.28	9.72
25	0.011221	0.921919	0.066861	80600.	14014.	3.97299	0.73122	0.016442	0.002259	0.926801	0.060468	39.32	9.10
30	0.014262	0.935483	0.050254	78320.	15235.	3.86942	0.77511	0.011727	0.002875	0.939492	0.043992	35.51	8.42
35	0.018807	0.946544	0.034649	76457.	15769.	3.76770	0.80042	0.007655	0.003799	0.948171	0.030534	31.83	7.70
40	0.023833	0.950407	0.025760	74251.	16248.	3.65839	0.81288	0.005613	0.004826	0.949444	0.023517	28.27	6.97
45	0.032327	0.946775	0.020898	72085.	16267.	3.54047	0.81086	0.004514	0.006161	0.944588	0.018514	24.82	6.21
50	0.043679	0.940350	0.015971	69518.	16167.	3.39397	0.79719	0.003460	0.008933	0.933305	0.015869	21.46	5.46
55	0.058302	0.925875	0.015823	66240.	15721.	3.20753	0.77165	0.003466	0.012013	0.909571	0.017579	18.30	4.74
60	0.068304	0.891900	0.019796	62061.	15145.	2.95526	0.73546	0.004499	0.018482	0.872236	0.018703	15.27	4.03
65	0.131840	0.850296	0.017864	56150.	14273.	2.61253	0.67767	0.004224	0.028236	2.364306	0.027945	12.54	3.37
70	1.000000	0.000000	0.000000	48351.	12834.	6.22070	1.69796	0.000000	0.077727	0.000000	0.000000	10.17	2.78

AGE	Q(X,2)	P(X,2,2)	P(X,1,2)	L(X,2,2)	L(X,1,2)	LL(X,2,2)	LL(X,1,2)	M(X,1,2)	MD(X,2)	S(X,2,2)	S(X,1,2)	E(X,2,2)	E(X,1,2)
0	0.033908	0.873048	0.093044	100000.	0.	4.68262	0.23261	0.020683	0.006889	0.915479	0.065580	28.69	41.27
5	0.003490	0.965736	0.030774	87305.	9304.	4.29371	0.52830	0.006318	0.000699	0.968735	0.028024	24.85	42.48
10	0.002992	0.971888	0.025120	84443.	11828.	4.16611	0.64022	0.005132	0.000599	0.794778	0.201224	20.48	42.08
15	0.005007	0.611410	0.383583	82201.	13781.	3.34464	1.44241	0.101526	0.000999	0.516764	0.476718	16.20	41.54
20	0.008029	0.349962	0.642010	51585.	43915.	1.86887	2.88681	0.209057	0.001598	0.420451	0.570027	12.78	40.24
25	0.010967	0.702621	0.286412	23170.	71557.	1.10585	3.60408	0.070433	0.002197	0.731474	0.256081	10.91	37.52
30	0.013923	0.776702	0.209375	21064.	72606.	1.02684	3.62345	0.048859	0.002796	0.813048	0.170832	9.85	34.09
35	0.018333	0.862362	0.119305	20009.	72332.	0.99427	3.57962	0.026358	0.003694	0.871835	0.107408	8.88	30.66
40	0.023222	0.883481	0.093297	19761.	70653.	0.97614	3.52068	0.020331	0.004693	0.891676	0.081972	7.96	27.30
45	0.029541	0.901230	0.069229	19284.	69183.	0.95273	3.40391	0.014954	0.005991	0.902316	0.061731	7.05	24.00
50	0.042543	0.903716	0.053741	18825.	66974.	0.92268	3.27410	0.011642	0.008687	0.900400	0.050083	6.15	20.78
55	0.056790	0.896732	0.046479	18082.	63990.	0.88274	3.10195	0.010181	0.011682	0.880028	0.048967	5.31	17.73
60	0.086061	0.861285	0.052654	17227.	60088.	0.83137	2.86467	0.011966	0.017972	0.846266	0.047371	4.49	14.81
65	0.128547	0.828880	0.042573	16027.	54499.	0.75714	2.53805	0.010067	0.027458	2.397856	0.064762	3.75	12.18
70	1.000000	0.000000	0.000000	14258.	47023.	1.86643	6.04975	0.000000	0.075583	0.000000	0.000000	3.08	9.87

Table 5 presents a comparable urban-rural life table for Poland. Note the differences in the migration levels. For Polish data, ${}_{r}\theta_{u} = 0.4424$ and ${}_{u}\theta_{r} = 0.1332$. Thus we may conclude that rural to urban migration is currently proceeding at a much higher rate in the Soviet Union than in Poland.

4. Conclusion

In our previous research on model migration schedules (Rogers, 1975, and Rogers and Castro, 1976) we adopted the "mortality" approach and developed model schedules by regressing age-specific probabilities of migration, $p_{ij}(x)$, on the migration level ${}_{i}\theta_{j}$. In this paper we instead have adopted the "fertility" approach and have focussed on model age profiles and their associated gross migraproduction 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, amd migration age profile[1]. 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, i.e., 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, e.g., the framework

---

[1]For example, recalling the age-specific USA migration rates illustrated in Figure 1.A, we can 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.

TABLE 5 - MULTIREGIONAL (TWO-REGION) LIFE TABLE OPTION 1 POLAND, 1973

MORTALITY LEVELS $_{u}e(0)$= 69,83 $_{r}e(0)$= 70,00 MIGRATION LEVELS $_{u}\theta_{r}$ = 9,30/69,83 $_{r}\theta_{u}$ = 30,97/70,00

AGE	Q(X,1)	P(X,1,1)	P(X,2,1)	L(X,1,1)	L(X,2,1)	LL(X,1,1)	LL(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	0,043263	0,919316	0,037421	100000.	0.	4,79829	0,09355	0,007799	0,009016	0,947521	0,029259	60,53	9,30
5	0,002238	0,979351	0,018411	91932.	3742.	4,55452	0,22382	0,003721	0,000452	0,983331	0,014618	58,25	9,62
10	0,001863	0,987627	0,010510	90249.	5211.	4,48896	0,27958	0,002115	0,000375	0,981103	0,016210	53,61	9,41
15	0,003513	0,974320	0,022167	89309.	5973.	4,41802	0,33773	0,004491	0,000712	0,949826	0,045696	49,00	9,13
20	0,005451	0,922693	0,071856	87411.	7536.	4,24564	0,48890	0,014949	0,001134	0,930767	0,063304	44,52	8,81
25	0,006416	0,939444	0,054140	82414.	12020.	4,06721	0,63951	0,011166	0,001323	0,949277	0,043464	40,26	8,34
30	0,008102	0,963709	0,028188	80274.	13561.	3,98147	0,69141	0,005742	0,001650	0,966913	0,023487	36,19	7,71
35	0,011108	0,971104	0,017788	78984.	14096.	3,91499	0,71326	0,003610	0,002254	0,971523	0,015357	32,20	7,03
40	0,015153	0,972202	0,012645	77615.	14435.	3,84085	0,72684	0,002565	0,003073	0,969293	0,011723	28,31	6,34
45	0,022875	0,966365	0,010759	76019.	14639.	3,74764	0,73348	0,002189	0,004653	0,961280	0,010976	24,51	5,63
50	0,032729	0,956012	0,011259	73887.	14700.	3,62400	0,73299	0,002302	0,006693	0,943960	0,012708	20,85	4,93
55	0,054298	0,931316	0,014386	71073.	14619.	3,44448	0,72401	0,002980	0,011246	0,914023	0,016254	17,32	4,25
60	0,086039	0,895403	0,018558	66706.	14341.	3,17550	0,70290	0,003916	0,018157	0,866430	0,020001	14,07	3,60
65	0,143700	0,833986	0,022314	60314.	13775.	2,78162	0,65726	0,004867	0,031341	0,798875	0,023845	11,10	2,99
70	0,216510	0,756685	0,026805	50951.	12516.	2,25364	0,57701	0,006103	0,049300	0,704858	0,027510	8,58	2,45
75	0,332922	0,636267	0,030831	39195.	10564.	1,61720	0,45760	0,007537	0,081381	0,582976	0,029888	6,41	1,96
80	0,468468	0,499121	0,032411	25493.	7740.	0,96540	0,30792	0,008648	0,124998	0,615663	0,026987	4,73	1,56
85	1,000000	0,000000	0,000000	13122.	4577.	0,60755	0,21190	0,000000	0,215990	0,000000	0,000000	3,43	1,20

AGE	Q(X,2)	P(X,2,2)	P(X,1,2)	L(X,2,2)	L(X,1,2)	LL(X,2,2)	LL(X,1,2)	M(X,1,2)	MD(X,2)	S(X,2,2)	S(X,1,2)	E(X,2,2)	E(X,1,2)
0	0,041736	0,851672	0,106592	100000.	0.	4,62918	0,26648	0,023026	0,009016	0,891735	0,085925	39,03	30,97
5	0,002192	0,940133	0,057675	85167.	10659.	4,13580	0,65026	0,011891	0,000452	0,951691	0,046293	35,89	32,04
10	0,001841	0,964236	0,033923	80265.	15351.	3,94551	0,83088	0,006906	0,000375	0,947699	0,049663	31,65	31,43
15	0,003435	0,930340	0,066225	77555.	17884.	3,75262	1,01112	0,013723	0,000712	0,849851	0,145925	27,57	30,62
20	0,004995	0,761474	0,233531	72549.	22561.	3,23537	1,50801	0,053031	0,001134	0,758319	0,236266	23,72	29,66
25	0,005812	0,756986	0,237202	56866.	37759.	2,54891	2,16802	0,054002	0,001323	0,804725	0,188525	20,42	28,22
30	0,007724	0,872576	0,119699	45091.	48961.	2,14540	2,53858	0,025569	0,001650	0,896353	0,094373	17,84	26,09
35	0,010844	0,924384	0,064773	40725.	52582.	1,98266	2,65706	0,013464	0,002254	0,934751	0,052362	15,68	23,58
40	0,014953	0,946157	0,038890	38581.	53700.	1,89410	2,68521	0,007993	0,003073	0,947190	0,034031	13,71	20,96
45	0,022663	0,948322	0,029015	37183.	53708.	1,82555	2,66721	0,005957	0,004653	0,943251	0,029260	11,83	18,32
50	0,032426	0,937895	0,029679	35839.	52980.	1,75122	2,61735	0,006126	0,006693	0,924927	0,032169	10,05	15,75
55	0,053728	0,911048	0,035223	34210.	51714.	1,65331	2,52701	0,007373	0,011246	0,893512	0,037517	8,36	13,23
60	0,085073	0,874173	0,040753	31911.	49367.	1,51806	2,37176	0,008698	0,018157	0,844711	0,043061	6,80	10,88
65	0,141886	0,810901	0,047213	28812.	45504.	1,32976	2,12033	0,010429	0,031340	0,776979	0,047897	5,39	8,71
70	0,213828	0,734975	0,051197	24379.	39310.	1,08376	1,75757	0,011803	0,049298	0,685611	0,049747	4,21	6,83
75	0,329232	0,618216	0,052552	18971.	30993.	0,79139	1,29275	0,012990	0,081382	0,567262	0,049400	3,19	5,19
80	0,463942	0,484628	0,051430	12684.	20717.	0,48756	0,79274	0,013857	0,124999	0,603552	0,042826	2,40	3,90
85	1,000000	0,000000	0,000000	6818.	10993.	0,31566	0,50894	0,000000	0,216005	0,000000	0,000000	1,77	2,86

indicates that it may be useful to decompose a typical migration age profile into three broad sets of age groups:

a) the pre-labor force migrants (0-14 years)

b) the labor force migrants (15-64 years)

c) the post-labor 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 labor force age groups may be related to indices such as labor force participation rates and ages of entry and exit from the labor 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.

The fertility approach to model migration schedules also has a practical application. Much of the published data on internal migration streams appears in the form of broadly aggregated age groups, e.g., 0-14, 15-64, and 65+. A typical example may be found in Fielding (1971), where a 20 by 20 inter-city migration flow table is given for each of the above three age groups. How can such data be efficiently disaggregated into the five-year age groups typically used in multiregional population projections and analyses?

Assume that a family of standard migration age profiles N(x) has been developed (for each sex) and that each such profile has been categorized according to its mean age $\bar{n}$. Further, imagine that using these profiles we have calculated a regression equation (for each sex) of the form

$$\bar{n} = b_0 + b_1 \cdot N(0-14) + b_2 \cdot N(15-64) + b_3 \cdot N(65+) \quad .$$

Entering a particular triple of observed values into this equation gives us an estimate of $\bar{n}$ and, through it, a complete model migration age profile. Combining this profile with the observed age composition and the observed crude migration rate gives us the desired age-specific schedule of migration.

APPENDIX

Observed Population and Migration Profiles

A. Sweden (1968-1973): Intercommunal movements

Source: Internal Migration in Sweden 1968-1973, Nr. 1974:9,
National Central Bureau of Statistics,
Stockholm, Sweden, 1974, p. 73.

B. Poland (1973): Intervoivodship movements

Source: Rocznik Demograficzny, 1974, N. 33,
Glowny Urzad Statystyczny,
Warszawa, 1974, pp. 282-289.

SWEDEN POPULATION AND MIGRANTS

	MALES			FEMALES		
AGE	PERC POP,	PERC. MIG	MIG.RATES	PERC POP,	PERC. MIG	MIG.RATES
0	0.007018	0.015090	0.101400	0.006622	0.014111	0.099300
1	0.014334	0.029910	0.098400	0.013544	0.028719	0.098800
2	0.014641	0.026049	0.083900	0.013843	0.025015	0.084200
3	0.014869	0.023932	0.075900	0.014051	0.022737	0.075400
4	0.015182	0.021860	0.067900	0.014340	0.020589	0.066900
5	0.015314	0.020004	0.061600	0.014463	0.018934	0.061000
6	0.015191	0.017718	0.055000	0.014339	0.016864	0.054800
7	0.014804	0.016261	0.051800	0.014024	0.015409	0.051200
8	0.014376	0.013353	0.043800	0.013618	0.012684	0.043400
9	0.014300	0.011846	0.039900	0.013246	0.011399	0.040100
10	0.013667	0.010521	0.036300	0.012889	0.010234	0.037000
11	0.013490	0.009784	0.034200	0.012773	0.009183	0.033500
12	0.013512	0.008796	0.030700	0.012738	0.008311	0.030400
13	0.013586	0.008326	0.028900	0.012786	0.007903	0.028800
14	0.013628	0.007716	0.026700	0.012854	0.007283	0.026400
15	0.013697	0.006884	0.023700	0.012946	0.006946	0.025000
16	0.013826	0.008297	0.028300	0.013046	0.009015	0.032200
17	0.013903	0.008668	0.029400	0.013176	0.014139	0.050000
18	0.014095	0.011717	0.039200	0.013420	0.023962	0.083200
19	0.014446	0.016757	0.054700	0.013819	0.035321	0.119100
20	0.014923	0.021520	0.068000	0.014405	0.044022	0.142400
21	0.015438	0.030545	0.093300	0.014934	0.049485	0.154400
22	0.016119	0.040574	0.118700	0.015473	0.052101	0.156900
23	0.016753	0.045543	0.128200	0.015971	0.051243	0.149500
24	0.017232	0.047613	0.130300	0.016308	0.048473	0.138500
25	0.017360	0.047599	0.129300	0.016322	0.043646	0.124600
26	0.017115	0.045258	0.124700	0.015965	0.038373	0.112000
27	0.016525	0.040750	0.116300	0.015324	0.033117	0.100700
28	0.015732	0.035330	0.105900	0.014544	0.027936	0.089500
29	0.014958	0.030958	0.097600	0.013814	0.024132	0.081400
30	0.014095	0.026900	0.090000	0.013056	0.020399	0.072800
31	0.013335	0.023103	0.081700	0.012368	0.017226	0.064900
32	0.012709	0.020185	0.074900	0.011869	0.015105	0.059300
33	0.012319	0.017842	0.068300	0.011545	0.013430	0.054200
34	0.011980	0.015903	0.062600	0.011316	0.011803	0.048600
35	0.011608	0.014277	0.058000	0.011037	0.010564	0.044600
36	0.011397	0.012955	0.053600	0.010922	0.009681	0.041300
37	0.011292	0.011805	0.049300	0.010890	0.008834	0.037800
38	0.011267	0.010966	0.045900	0.010947	0.008058	0.034300
39	0.011308	0.010023	0.041800	0.011038	0.007391	0.031200
40	0.011431	0.009526	0.039300	0.011257	0.007078	0.029300
41	0.011596	0.008803	0.035800	0.011436	0.006823	0.027800
42	0.011693	0.008505	0.034300	0.011561	0.006426	0.025900
43	0.011920	0.008139	0.032200	0.011778	0.006269	0.024800
44	0.012075	0.007631	0.029800	0.011958	0.006031	0.023500
45	0.012361	0.007365	0.028100	0.012219	0.005900	0.022500
46	0.012564	0.007087	0.026600	0.012478	0.005838	0.021600
47	0.013012	0.006843	0.024800	0.012891	0.005561	0.020100
48	0.013481	0.006718	0.023500	0.011812	0.005704	0.022500
49	0.013494	0.006353	0.022200	0.013328	0.005234	0.018300
50	0.013392	0.005907	0.020800	0.013268	0.004955	0.017400

SWEDEN

51	0.013302	0.005388	0.019100	0.013269	0.004613	0.016200
52	0.013165	0.004969	0.017800	0.013131	0.004537	0.016100
53	0.012671	0.004667	0.017100	0.012840	0.004216	0.015300
54	0.012461	0.004149	0.015700	0.012490	0.004021	0.015000
55	0.012525	0.003957	0.014900	0.012532	0.003819	0.014200
56	0.012619	0.003720	0.013900	0.012607	0.003768	0.014000
57	0.012540	0.003510	0.013200	0.012625	0.003522	0.013000
58	0.012520	0.003186	0.012000	0.012609	0.003464	0.012800
59	0.012588	0.002990	0.011200	0.012724	0.003359	0.012300
60	0.012369	0.003043	0.011600	0.012621	0.003467	0.012800
61	0.012121	0.002725	0.010600	0.012483	0.003402	0.012700
62	0.011860	0.002565	0.010200	0.012212	0.003119	0.011900
63	0.011422	0.002640	0.010900	0.011988	0.003319	0.012900
64	0.011007	0.002497	0.010700	0.011792	0.003214	0.012700
65	0.010504	0.003185	0.014300	0.011379	0.003175	0.013000
66	0.009994	0.002861	0.013500	0.011081	0.002830	0.011900
67	0.009570	0.002719	0.013400	0.010703	0.002756	0.012000
68	0.009125	0.002245	0.011600	0.010413	0.002391	0.010700
69	0.008637	0.001813	0.009900	0.010009	0.002105	0.009800
70	0.008158	0.001609	0.009300	0.009555	0.001825	0.008900
71	0.007775	0.001368	0.008300	0.009191	0.001696	0.008600
72	0.007278	0.001204	0.007800	0.008745	0.001539	0.008200
73	0.006774	0.000963	0.006700	0.008230	0.001307	0.007400
74	0.006193	0.000906	0.006900	0.007741	0.001146	0.006900
75+	0.044564	0.005103	0.005400	0.062462	0.007775	0.005800
	1.000000	1.000000	0.047157	1.000000	1.000000	0.046596

POLAND POPULATION AND MIGRANTS
****** *************************

AGE	MALES PERC POP,	MALES PERC. MIG	MALES MIG.RATES	FEMALES PERC POP,	FEMALES PERC. MIG	FEMALES MIG.RATES
0	0.017709	0.017872	0.027355	0.015951	0.015861	0.028082
1	0.017746	0.033144	0.050626	0.015887	0.028998	0.051546
2	0.017071	0.026617	0.042582	0.015347	0.023027	0.042372
3	0.016819	0.022455	0.036136	0.015178	0.019143	0.035616
4	0.015684	0.018819	0.032524	0.014232	0.016233	0.032211
5	0.015880	0.015863	0.027078	0.014360	0.013301	0.026159
6	0.015665	0.013510	0.023378	0.014209	0.012156	0.024160
7	0.015819	0.012707	0.021843	0.014325	0.011046	0.021775
8	0.016255	0.010905	0.018191	0.014679	0.009006	0.017326
9	0.016697	0.010149	0.016312	0.015068	0.008531	0.015988
10	0.017132	0.009640	0.015186	0.015504	0.008153	0.014850
11	0.017427	0.008932	0.013892	0.015672	0.007912	0.014257
12	0.018090	0.008557	0.013271	0.016357	0.007766	0.013408
13	0.019471	0.008625	0.012206	0.017733	0.007922	0.012563
14	0.020601	0.008901	0.011764	0.018627	0.007698	0.011671
15	0.021718	0.009550	0.011919	0.019655	0.009553	0.013725
16	0.022286	0.009045	0.011101	0.020102	0.009082	0.012759
17	0.022000	0.009149	0.011272	0.019975	0.010460	0.014788
18	0.022528	0.015456	0.018597	0.020387	0.023298	0.032273
19	0.021693	0.018588	0.023226	0.019835	0.039322	0.055984
20	0.021570	0.018891	0.023739	0.019719	0.049038	0.070227
21	0.021435	0.027918	0.035304	0.019545	0.056288	0.081328
22	0.020981	0.045452	0.058721	0.019260	0.057517	0.084332
23	0.020349	0.055056	0.073339	0.018674	0.054542	0.082481
24	0.018919	0.058625	0.083997	0.017484	0.048976	0.079110
25	0.018759	0.057212	0.082670	0.017275	0.043202	0.070625
26	0.017482	0.049212	0.076303	0.016125	0.035080	0.061437
27	0.015917	0.041123	0.070031	0.014813	0.028667	0.055033
28	0.011731	0.027148	0.062732	0.010969	0.018142	0.046707
29	0.011602	0.023896	0.055831	0.010934	0.015510	0.040058
30	0.011264	0.021441	0.051597	0.010585	0.013902	0.037087
31	0.011203	0.018644	0.045112	0.010339	0.011765	0.031526
32	0.011976	0.017976	0.040687	0.011271	0.011249	0.028187
33	0.012805	0.017134	0.036314	0.012095	0.011227	0.026212
34	0.012835	0.015444	0.032616	0.012256	0.009979	0.022989
35	0.012940	0.014095	0.029526	0.012380	0.009109	0.020779
36	0.013234	0.013164	0.026962	0.012554	0.008622	0.019394
37	0.013560	0.012072	0.024133	0.012995	0.008054	0.017502
38	0.013633	0.011287	0.022440	0.012960	0.007766	0.016922
39	0.013333	0.010148	0.020631	0.012757	0.007104	0.015726
40	0.013234	0.009778	0.020028	0.012583	0.006553	0.014707
41	0.013910	0.008907	0.017357	0.013343	0.006183	0.013085
42	0.014137	0.008814	0.016900	0.013483	0.006060	0.012692
43	0.014876	0.008422	0.015419	0.014296	0.005889	0.011633
44	0.013769	0.007609	0.014980	0.013378	0.005568	0.011753
45	0.013498	0.006529	0.013111	0.013419	0.004933	0.010381
46	0.012277	0.005831	0.012875	0.012658	0.004875	0.010876
47	0.011859	0.005512	0.012598	0.012925	0.004828	0.010548
48	0.012332	0.005276	0.011598	0.013703	0.004735	0.009758
49	0.011270	0.004948	0.011901	0.012745	0.004617	0.010214
50	0.011221	0.004368	0.010553	0.012577	0.004657	0.010457

POLAND

51	0.010724	0.004106	0.010378	0.012142	0.004368	0.010206
52	0.009324	0.003179	0.009243	0.010289	0.003802	0.010435
53	0.009527	0.003540	0.010071	0.010371	0.004100	0.011165
54	0.008029	0.002792	0.009427	0.009151	0.003898	0.012030
55	0.005727	0.002040	0.009657	0.006689	0.003183	0.013438
56	0.005703	0.001907	0.009064	0.006445	0.003078	0.013466
57	0.005862	0.002072	0.009581	0.006898	0.003378	0.013830
58	0.006347	0.002188	0.009342	0.007653	0.003489	0.012876
59	0.008023	0.002622	0.008860	0.009761	0.004610	0.013337
60	0.008183	0.003071	0.010173	0.009552	0.005204	0.015386
61	0.008551	0.002955	0.009368	0.010289	0.005741	0.015756
62	0.008047	0.002876	0.009687	0.009453	0.005562	0.016677
63	0.008385	0.003023	0.009773	0.009935	0.005964	0.016967
64	0.007955	0.002804	0.009552	0.009343	0.005790	0.017502
65	0.007483	0.003046	0.011034	0.009047	0.005642	0.017612
66	0.007421	0.003367	0.012299	0.008919	0.005811	0.018398
67	0.006740	0.003143	0.012641	0.008466	0.005683	0.016957
68	0.006114	0.002654	0.011767	0.007909	0.005313	0.018972
69	0.005813	0.002672	0.012460	0.007607	0.005451	0.020237
70	0.005291	0.002543	0.013028	0.007067	0.005101	0.020386
71	0.004984	0.002502	0.013608	0.007003	0.005404	0.021791
72	0.004266	0.002287	0.014532	0.006132	0.004744	0.021647
73	0.004401	0.002226	0.013710	0.006904	0.005021	0.020538
74	0.003198	0.001943	0.016468	0.004959	0.004295	0.024461
75	0.002916	0.001834	0.017053	0.004883	0.004028	0.023294
76	0.002578	0.001771	0.018619	0.004343	0.003664	0.023824
77	0.002210	0.001443	0.017694	0.003948	0.003438	0.024588
78	0.001927	0.001354	0.019045	0.003594	0.003189	0.029057
79	0.001559	0.001171	0.020354	0.002956	0.002712	0.029914
80+	0.006777	0.005729	0.022917	0.014911	0.015012	0.028431
	1.000000	1.000000	0.027106	1.000000	1.000000	0.028240

POLAND ******

POPULATION AND MIGRANTS ************************

AGE GP	MALES PERC POP,	MALES PERC. MIG	MALES MIG.RATES	FEMALES PERC POP,	FEMALES PERC. MIG	FEMALES MIG.RATES
0	0.085030	0.119106	0.037969	0.076594	0.103263	0.038072
5	0.080315	0.063139	0.021309	0.072640	0.054040	0.021009
10	0.092721	0.045153	0.013200	0.083893	0.039431	0.013273
15	0.110025	0.061787	0.015222	0.099954	0.091715	0.025912
20	0.103255	0.225943	0.054064	0.094682	0.266362	0.079445
25	0.075490	0.198590	0.071308	0.070114	0.140800	0.056710
30	0.060083	0.090660	0.040901	0.056748	0.058122	0.028924
35	0.066700	0.060765	0.024694	0.063646	0.040655	0.018039
40	0.069855	0.043530	0.016891	0.067083	0.030252	0.012735
45	0.061237	0.028097	0.012437	0.065452	0.023981	0.010347
50	0.048825	0.017985	0.009985	0.054529	0.020845	0.010795
55	0.031662	0.010829	0.009271	0.037447	0.017739	0.013377
60	0.041121	0.014729	0.009709	0.048572	0.028287	0.016446
65	0.033571	0.014883	0.012017	0.041947	0.027900	0.018783
70	0.022141	0.011502	0.014081	0.032064	0.024565	0.021635
75	0.011190	0.007573	0.018345	0.019725	0.017031	0.024383
80+	0.006777	0.005729	0.022917	0.014911	0.015012	0.028431
	1.000000	1.000000	0.027106	1.000000	1.000000	0.028240

SWEDEN POPULATION AND MIGRANTS
****** ***********************

AGE GP	MALES PERC POP,	MALES PERC. MIG	MALES MIG.RATES	FEMALES PERC POP,	FEMALES PERC. MIG	FEMALES MIG.RATES
0	0.066044	0.116841	0.083427	0.062400	0.111171	0.083014
1	0.073685	0.079182	0.050675	0.069690	0.075291	0.050341
2	0.067883	0.045143	0.031360	0.064040	0.042914	0.031224
3	0.069967	0.052322	0.035265	0.066406	0.089382	0.062718
4	0.080465	0.185795	0.108886	0.077091	0.245325	0.148281
5	0.081688	0.199895	0.115396	0.075969	0.167205	0.102556
6	0.064437	0.103933	0.076062	0.060154	0.077962	0.060390
7	0.056872	0.060027	0.049773	0.054834	0.044528	0.037638
8	0.058715	0.042605	0.034218	0.057990	0.032627	0.026216
9	0.064913	0.034367	0.024966	0.062727	0.028236	0.020975
10	0.065191	0.025080	0.018142	0.064998	0.022342	0.016016
11	0.062792	0.017363	0.013040	0.063096	0.017951	0.013257
12	0.058778	0.013470	0.010807	0.061096	0.016521	0.012600
13	0.047829	0.012823	0.012643	0.053585	0.013257	0.011528
14	0.036178	0.006050	0.007886	0.043462	0.007514	0.008055
15	0.044564	0.005103	0.005400	0.062462	0.007775	0.005800
	1.000000	1.000000	0.047157	1.000000	1.000000	0.046596

SOME SPATIAL CONSEQUENCES OF ZERO POPULATION GROWTH IN THE SOVIET UNION

Andrei Rogers

1. Introduction

During the past decade, several nations have attempted to define the outlines of a desirable national population growth policy, taking as their starting point the widespread conviction that such growth is not taking place the way it should. Their common contention that national population problems stem from a propensity to overbreed overlooks the evident fact that an important component of many demographic imbalances in the developed and developing countries today is not only a consequence of absolute numbers but also of their maldistribution. The notion of a population distribution policy therefore has wide appeal but, unfortunately, insufficient substance. An important contributing factor to this lack of substance is our poor understanding of the dynamics of multiregional demographic growth and distribution. A useful tool for developing such an understanding is population projection.

In this paper we shall illustrate how alternative projections of the urban and rural populations of the Soviet Union help to illuminate important aspects of spatial population dynamics in that country. We begin with a projection that assumes a continuation of present trends and then contrast the results with those produced by two alternative evolutions to a national zero growth population.

2. 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 multiregional systems that experience internal migration, however, are less known, and it is only recently that concepts such as the multiregional life table have given them a methodological consistency with the conventional mechanics of single-region population projection (Rogers, 1975).

The mechanics of population projections typically revolve around three basic steps. The first ascertains the starting age distribution and the age-specific schedules of fertility, mortality, and migration to which this population has been subject during a past period. The second adopts a set of assumptions regarding the future behavior of such schedules (e.g., that they will remain constant). And the third derives the consequences of applying these schedules to the initial population.

The discrete model of multiregional demographic growth expresses the population projection process by means of a matrix operation in which a multiregional 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 multiregional population and adds to this total the new births that survive to the end of the unit time interval.

Table 1 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 (see Table 1) these give a net reproduction rate of 1.05 for the Soviet Union, disaggregated according to the following matrix:

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

$$\begin{matrix} \overline{1.03} & \overline{1.10} \end{matrix}$$

Table 1: 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 GRR	0.20003 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 GRR	0.32398 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 "Model Migration Schedules: An Illustration Using Data for the Soviet Union".

[3] $\sum_x {}_i\phi_j(x) = \sum_x {}_iL_j(x)\ F_j(x) = {}_iNRR_j$

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 twenty percent of the former babies are born in rural areas (i.e., 0.23/1.03 = 0.22) and about sixty percent of the latter babies are born in urban areas (i.e., 0.64/1.10 = 0.58).

Table 2 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.

3. 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 percent. 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 fifty.

But what of the spatial distribution of such stationary national populations? What are the alternative paths in a geographic context? Will most countries, for example, have as Alonso (1973, p. 191) puts it "a nationally stable population... composed of many localities declining in population, many localities growing, and only some remaining stable"?

---

[1] This means the fertility rates in Table 1 and the survivorship and migration proportions of the life table in Table 4 of "Model Migration Schedules..." are assumed to be constant over the thirty-year projection period.

TABLE 2: 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	135,992	105,729	0.5626	0.4374	230,090	83,477	0.7338	0.2662
U.S.S.R.	241,720		1.0000		313,567		1.0000	
Mean Age			31.27	30.70			35.81	36.02
			31.02				35.86	
Annual Growth Rate	0.0265	-0.0071			0.0128	0.0005		
	0.0125				0.0094			

[1]Source: Table 3 of "Model Migration Schedules: An Illustration Using Data for the Soviet Union".

[2]Source: Cohort-survival projection using the fertility data in Table 1 and the survivorship proportions set out in Table 4 of "Model Migration Schedules: An Illustration Using Data for the Soviet Union".

A nationally stationary population may arise out of a growth process which exhibits a zero growth rate in each short interval of time or it may develop out of a long-run average zero growth rate which occurs as a consequence of a combination of sequences of positive growth, of zero growth, and of decline. Since no obvious advantages arise from the latter case, demographers quite naturally have viewed the attainment of a stationary population as arising from a continuation of zero growth in the short-run. Thus the normal assumption involves a fixed mortality schedule and fertility set at replacement level.

An analogous situation arises in the case of a multiregional population. By augmenting the assumptions of fixed migration we may obtain a stationary multiregional population. In such a case, each region in the system will grow at a zero rate of growth. (Alternatively, we may assume that zero growth for the multiregional system is a consequence of an aggregation of zero and nonzero growth rates in its constituent regions. The dynamics of this situation are more complex and will not be considered in this paper.)

If mortality is fixed and one thousand babies born at each moment replace themselves, on the average, with a thousand babies as they move past their childbearing years, we will ultimately obtain a stationary zero growth population. But the babies who survive to the childbearing 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 <u>net</u> (and not the <u>gross</u>) 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 multiregional 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 achieved a number of alternative ways.) The mechanics of the population projection process itself, however, remain unchanged.

Table 3 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 Soviet Union 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 later 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 due 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 percent of the population in all projections and the mean ages all lie in the range of 35 to 38 years.

4. Conclusion

This note has developed two principal conclusions. The first is that current trends in fertility and migration in the Soviet Union suggest an evolution of its present population into one that is highly urban and relatively old, at least when compared to today's situation. The second conclusion is that a sudden reduction to replacement level fertility is not likely to change matters very much.

---

[2]The mathematics of the two alternative fertility reductions appear in Rogers and Willekens (1976).

TABLE 3: 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)		Age 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		1.0000		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.

References

Alonso, W. (1973), "Urban Zero Population Growth," Daedalus, CII, 191-206.

Coale, A.J. and P. Demeny (1966), Regional Model Life Tables and Stable Populations (Princeton, N.H.: Princeton University Press).

Fielding, A.J. (1971), Internal Migration in England and Wales: A Presentation and Interpretation of 'City-Region' Data, CES UWP 14, Centre for Environmental Studies, London.

Keyfitz, N. (1968), Introduction to the Mathematics of Population (Reading, Mass.: Addison-Wesley).

_______ and W. Flieger (1971), Population: Facts and Methods of Demography (San Francisco, Calif.: Freeman).

Long, L.H. (1973), "New Estimates of Migration Expectancy in the United States," Journal of the American Statistical Association, LXVIII, 37-43.

Mazur, D.P. (1976), "Constructing Fertility Tables for Soviet Populations," Demography, XIII, 19-35.

Polish Central Bureau of Statistics (Glowny Urzad Statystyczny) (1974), Rocznik Demograficzny, 1974, No. 33, Warsaw.

Pollard, J.H. (1973), Mathematical Models for the Growth of Human Populations (London: Cambridge University Press).

Rogers, A. (1973), "The Multiregional Life Table," The Journal of Mathematical Sociology, III, 127-137.

_______ (1975), Introduction to Multiregional Mathematical Demography (New York: John Wiley).

_______ and L.J. Castro (1976), Model Multiregional Life Tables and Stable Populations, RR-76-09, International Institute for Applied Systems Analysis, Laxenburg, Austria, forthcoming.

_______ and F. Willekens (1976), Spatial Zero Population Growth, RM-76-25, International Institute for Applied Systems Analysis, Laxenburg, Austria.

Swedish Central Bureau of Statistics (Statistiska Centralbyrån), (1974) Internal Migration in Sweden 1968-1973, No. 9, Stockholm.

Tekse, K. (1967), "On Demographic Models of Age-Specific Fertility Rates," Statistisk Tidskrift, 3, 189-207.

U.S.S.R. Central Bureau of Statistics, Council of Ministers (Tsentral' noye Statisticheskoye Upravleniye pri Sovete Ministrov SSSR) (1975), Population of the USSR, 1973, Statistical Handbook (Moscow: Statistika).

____________ (1974), All-Union Census of Population, 1970, (Moscow: Statistika).

____________ (1971), Vestnik Statistiki, No.11 (Moscow: Statistika).

PAPERS OF THE MIGRATION AND SETTLEMENT STUDY

June 1976

I. Papers in the Dynamics Series

1. Andrei Rogers and Frans Willekens, "Spatial Population Dynamics," RR-75-24, July, 1975, forthcoming in Papers, Regional Science Association, Vol. 36, 1976.

2. Andrei Rogers and Jacques Ledent, "Multiregional Population Projection," internal working paper, August, 1975, forthcoming in Proceedings, 7th I.F.I.P. Conference, Nice, 1976.

3. Andrei Rogers and Jacques Ledent, "Increment-Decrement Life Tables: A Comment," internal working paper, October, 1975, forthcoming in Demography, 1976.

4. Andrei Rogers, "Spatial Migration Expectancies," RM-75-57, November, 1975.

5. Andrei Rogers, "Aggregation and Decomposition in Population Projection," RM-76-11, February 1976.

6. Andrei Rogers and Luis J. Castro, "Model Multiregional Life Tables and Stable Populations," RR-76-09, forthcoming.

7. Andrei Rogers and Frans Willekens, "Spatial Zero Population Growth," RM-76-25, April, 1976.

II. Papers in the Demometrics Series

1. John Miron, "Job-Search Migration and Metropolitan Growth," RM-76-00, forthcoming.

2. Andrei Rogers, "The Demometrics of Migration and Settlement," RM-76-00, forthcoming.

III. Papers in the Policy Analysis Series

1. Yuri Evtushenko and Ross D. MacKinnon, "Non-Linear Programming Approaches to National Settlement System Planning," RR-75-26, July, 1975.

2. R.K. Mehra, "An Optimal Control Approach to National Settlement System Planning," RM-75-58, November, 1975.

3. Frans Willekens, "Optimal Migration Policies," RM-76-50, forthcoming.

IV. <u>Papers in the Comparative Study Series</u>

1. Ross D. MacKinnon and Anna Maria Skarke, "Exploratory Analyses of the 1966-1971 Austrian Migration Table," RR-75-31, September, 1975.

2. Galina Kiseleva, "The Influence of Urbanization on the Birthrate and Mortality Rate for Major Cities in the U.S.S.R.," RM-75-68, December, 1975.

3. George Demko, "Soviet Population Policy," RM-75-74, December, 1975.

4. Andrei Rogers, "The Comparative Migration and Settlement Study: A Summary of Workshop Proceedings and Conclusions," RM-76-01, January, 1976.

5. Andrei Rogers, "Two Methodological Notes on Spatial Population Dynamics in the Soviet Union," RM-76-48, June 1976.

6. Frans Willekens and Andrei Rogers, "Computer Programs for Spatial Demographic Analysis," RM-76-00, forthcoming.