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Migration and Settlement: A Multiregional Comparative Study

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IIASA Working Paper

WP-82-085

September 1982

MIGRATION AND SETTLEMENT: A MULTIREGIONAL COMPARATIVE STUDY

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Paper presented at the Annual Meeting
of the Population Association of America,
San Diego, California, April 29-May 1, 1982.

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FOREWORD

The evolution of human populations over time and space has been a central concern of many scholars in the Human Settlements and Services Area at IIASA during the past several years. From 1975 through 1978 some of this interest was manifested in the work of the Migration and Settlement Task, which was formally concluded in November 1978. Since then, attention has turned to disseminating the Task's results, to concluding its comparative study, and to exploring possible future activities that might apply the mathematical methodology to other reseearch topics.

This paper is part of the Task's dissemination effort. It reports on results that are to appear in a volume entitled *Migration and Settlement: A Comparative Study*. Other selected publications summarizing the work of the Migration and Settlement Task are listed at the back.

Andrei Rogers
Chairman
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ABSTRACT

In 1976, the International Institute for Applied Systems Analysis initiated a study of migration and population distribution patterns in its 17 member nations. In each country, the analysis was carried out by a national scholar using techniques of multiregional demography. This paper describes the organization of the study, discusses the data bases used, evaluates the main results obtained, and reviews some of the methodological research that has been generated by the study. Among the conclusions of the paper are recommendations for researchers wishing to carry out a multiregional demographic analysis.

CONTENTS

MIGRATION AND SETTLEMENT: A MULTIREGIONAL COMPARATIVE STUDY

1. INTRODUCTION

The "population problem" in most parts of the world has two distinct dimensions: growth (positive or negative) and spatial distribution. Concern about population growth has focused attention on fertility patterns and has fostered family planning and family allowance programs in scores of countries. The issue of population distribution, on the other hand, has only recently received serious analytical attention, as programs to encourage the development of economically declining regions, to stem the growth of large urban centers in the less developed countries, and to revitalize the central cores of metropolitan areas have become parts of national agendas all over the globe.

The unanticipated postwar baby boom had a salutary influence on demographic research. Extrapolations of past trends appropriately adjusted for expected changes in the age, sex, and marital composition of the population were very much wide of the mark.

So long as trends were stable, demographic projections prospered; but when a "turning point" occurred, the projections floundered. The net result was increased pressure to consider the complex interrelationships between fertility behavior and socioeconomic development.

But the poor predictive performance also had another important effect--it stimulated research in improved methods for *measuring* fertility and for understanding the *dynamics* by which it, together with mortality, determines the age composition of a population. Inasmuch as attention was principally directed at national population growth, measurement of internal migration and the *spatial* dynamics through which it affects a national settlement pattern were neglected. This neglect led Dudley Kirk (1960) to conclude, in his 1960 Presidential address to the Population Association of America, that the study of migration was the stepchild of demography. Sixteen years later, Sidney Goldstein echoed the same theme in *his* Presidential address to the same body:

> ...the improvement in the quantity and quality of our information on population movement has not kept pace with the increasing significance of movement itself as a component of demographic change.... Redistribution has suffered far too long from neglect within the profession.... It behooves us to rectify this situation in this last quarter of the twentieth century, when redistribution in all its facets will undoubtedly constitute a major and increasingly important component of demographic change...
>
> (Goldstein 1976, pp. 19-21)

Despite a general recognition that migration processes and settlement patterns are intimately related and merit serious study, one nevertheless finds that the dynamics of their interrelationships are not at all well understood. An important reason for this lack of understanding is that demographers have in the past neglected the spatial dimension of population growth. Thus, whereas problems of fertility and mortality long ago stimulated a rich and scholarly literature, studies of migration have only recently begun to flourish.

The pressing need for developing improved methods for measuring migration and understanding its important role in human spatial population dynamics led the International Institute for Applied Systems Analysis (IIASA) in 1976 to organize a multinational study of internal migration and population distribution patterns in its member countries. Recently developed techniques of multiregional demographic analysis (Rogers 1975) provided the unifying methodological framework for this study, in which scholars from the 17 member nations participated.*

Multiregional demography deals with the evolution of spatially interdependent regional populations. It focuses on their sizes, age compositions, and geographical distributions, as well as on the changes of these characteristics over time. Such a perspective allows researchers to examine the demographic interactions between the urban and rural agglomerations that shape national human settlement patterns. The ability of such a method to identify the demographic impacts of interregional migration flows and of regionally differentiated regimes of mortality and fertility,

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*A list of the scholars and their national reports appears at the end of this paper.

make it an especially useful tool for projecting subnational and multiregional populations. The Comparative Migration and Settlement (CMS) Study at IIASA was organized primarily to disseminate this tool to scholars and professionals dealing with population problems in the IIASA countries.

This paper focuses on some of the results of the CMS study. It begins with a short review of the study's organization and design, which had as a major objective the promotion of collaboration between scientists in IIASA's member countries. The following section describes the data base used for the study and especially the severe data problems that resulted from the limited comparability and availability of regional statistics on mortality, fertility, and migration. Section 4 describes national and subnational patterns of mortality, fertility, and migration in the 17 member countries of IIASA. Section 5 considers the age compositions and regional distributions of the populations.

The delineation of appropriate regions for comparative analysis and the use of harmonized migration statistics were not available options for this study. Consequently, the results reported in this paper should be interpreted with great care and some skepticism. The IIASA study is the first study of its kind, and a great deal has been learned about population redistribution patterns and about analytical-conceptual problems in comparative migration analysis. A rich agenda for future research is an important outcome of the CMS study. Thus, in the last section of the paper, an example is given of some of the research questions that have been generated by the study. The section considers problems of migration measurement (movement versus transition perspectives) and reports on experiments conducted to evaluate the reliability of the simple Markovian model, which underlies the multiregional analysis, and the accuracy of the procedures that were used to fit that model to the available data.

2. DESIGN AND ORGANIZATION OF THE CMS STUDY

The design and organization of the CMS study was affected by the environment in which it was carried out.* IIASA is an international nongovernmental organization, with scientific institutions in over two dozen countries participating in its work. The most important of these are the National Member Organizations (NMOs), which are the representative bodies of the scientific communities in the 17 member nations. The NMO countries differ (Table 1) in size, level of development, and economic system as well as in the demographic characteristics of their populations. Large variations are also to be found in the characteristics and quality of available demographic data.

By engaging in research that is both interdisciplinary and international, IIASA tries to contribute to a better understanding, and ultimately to a resolution, of the problems that are of significance to its member countries. The CMS study was initiated in this context, having as its aim a quantitative assessment of patterns of migration and population redistribution in the NMO

*For an early description of the study's purpose and design, see Rogers (1976a, b).

Table 1. Basic demographic and economic indicators for IIASA member nations: 1978.

Country	Area (1000s of sq. km.)	Population ($x\ 10^6$)	Avg. annual growth of population in 1970-78 (per 1000)	Crude birth rate (per 1000)	Crude death rate (per 1000)	Life expectancy at birth (years)	Total fertility rate (per woman)	GNP per capita ($)
1 Austria	84	7.5	2	11	12	72	1.7	7,030
2 Bulgaria	111	8.8	5	16	11	72	2.3	3,230
3 Canada	9,976	23.5	12	16	8	74	1.9	9,180
4 Czechoslovakia	128	15.1	7	18	11	70	2.4	4,720
5 Federal Republic of Germany	249	61.3	1	9	12	72	1.4	9,580
6 Finland	337	4.8	4	14	9	72	1.7	6,820
7 France	547	53.3	6	14	10	73	1.9	8,260
8 German Democratic Republic	108	16.7	-2	13	13	72	1.8	5,710
9 Hungary	93	10.7	4	16	12	70	2.2	3,450
10 Italy	301	56.7	7	13	9	73	1.9	3,850
11 Japan	372	114.9	12	15	6	76	1.8	7,280
12 Netherlands	41	13.9	8	13	8	74	1.6	8,410
13 Poland	313	35.0	9	19	9	71	2.3	3,670
14 Soviet Union	22,402	261.0	9	18	10	70	2.4	3,700
15 Sweden	450	8.3	4	12	11	75	1.7	10,210
16 United Kingdom	244	55.8	1	12	12	73	1.7	5,030
17 United States	9,363	221.9	8	15	9	73	1.8	9,590

SOURCE: World Bank (1980) as presented in Table 1 of Rees and Willekens (1981, p. 4).

countries to be carried out by national scholars who would use the same methodology. A network of collaborating scholars was established, and multiregional demography was adopted as the common methodology, which, it was felt, would enhance the comparability of the results.

The CMS study involved a number of steps:

- *Data collection.* The national collaborator assembled the population, birth, death, and migration data for the set of regions to be studied, using official published or unpublished sources. Regions were defined by the national scholar so as to make the results as useful to his or her country as possible.
- *Data processing.* Data processing generally was done at IIASA. A package of standard computer programs was developed for this purpose (Willekens and Rogers 1978). In many cases, data processing also included data adjustment and the estimation of missing data. The standard output of the data processing consisted of single and multiregional life tables, measures of fertility and mobility, multiregional population projections, and statistics of the associated stable multiregional populations.
- *Analysis and preparation of report.* The analysis of the computer output was done by the national scholar in close cooperation with IIASA. The analysis was complemented by a more traditional and descriptive exposition of recent migration patterns and spatial population structures, and each study included an overview of current migration and population distribution policies. The contributing scholars prepared a report on the basis of this research, following a common outline. The reports were published by IIASA, in the order listed at the end of this paper.

Four major outputs have resulted from the CMS study. The first is a collection of 17 reports, each presenting a national demographic analysis as well as appendixes containing the observed data used for the particular country, age-specific rates, selected life table results, and population projections. The second is the establishment of an active network of collaborating scholars in many countries, which is now linked by the newsletter POPNET. The third result that the study has generated is a IIASA data bank containing information on regional population structures and on the components of regional demographic change. Although this data bank has a number of weaknesses, it nevertheless is a unique resource for comparative regional demographic analysis; the results reported in this paper are based on this information. Finally, the CMS study has generated a rich agenda for further research. For example, during the course of the study many of the currently available techniques for migration analysis and for subnational population projection were challenged. As a result, researchers in several IIASA countries are now working on specific topics of the continuing research agenda. A few of their findings will be mentioned in this paper.

3. DATA BASE FOR THE CMS STUDY

The purpose of this section is to describe briefly the data base used in the CMS study and to list some of the problems encountered in preparing a complete data set for multiregional analysis.

Multiregional demographic techniques require more data than conventional methods. The necessary data consist of population, births, deaths, and migrants by age and region (and, if possible, by sex), and the migration data should be disaggregated by area of origin and area of destination.

Data on external migration are not necessary if the multi-regional system may be assumed to be relatively unaffected by emigration and immigration, which was the assumption adopted by the CMS study.

For a number of reasons, the available published data were never complete or in the right form for use by the CMS study. In some instances, the data need was satisfied by special tabulations carried out by national statistical offices, but in most cases we had to rely on techniques of indirect estimation. The data base for the CMS study is discussed in some detail by Rees and Willekens (1981). In that paper, the authors present the time and space frameworks for which the data were collected and review the estimation techniques that were used to generate missing data, which generally were those referring to migration. Details on mortality data may be found in Termote (1982), on fertility data in Kim (1982), and on migration data in Rogers and Castro (1982). An overview of the data base is given below.

3.1 Base Period

The first step in the initiation of the CMS study was the selection of a base period for which to obtain data. To reduce the amount of data processing involved, a decision was made to limit the base period to a single year whenever possible, the period selected being mainly determined by data availability. And whenever possible, the year selected was the most recent one for which a relatively complete set of necessary data were available. For countries with a registration system, that is, most European countries, a year in the mid-1970s was used, whereas for countries in which population censuses are the main source of migration data, the year of the last census was selected.

3.2 Sex and Age Disaggregation

For the CMS study the population generally was not disaggregated by sex. Data availability was only a minor consideration in this decision. Although several countries did not have all of the requisite data disaggregated by sex, such data could have been estimated. A major consideration was methodological convenience, inasmuch as two-sex models are not yet fully developed in multiregional demography.*

The age classification of the population in all but two instances was in terms of five-year age groups, with 85 being the highest open-ended age group in 15 of the 17 countries (the two exceptions were Finland and the German Democratic Republic). In some cases, this required an interpolation, extrapolation, or respecification of the age grouping.

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*One of the more recent results of demographic research carried out at IIASA is an improved specification of a two-sex marriage model (Sanderson 1981).

3.3 The Multiregional System

The selection of an appropriate set of regions was one of the most difficult tasks in the CMS study. Theoretical, methodological, and data considerations, as well as the interests of potential users, were all taken into account, and the outcome had to be a compromise. The concept of a region has always been much debated in social sciences, particularly in geography, where two conflicting views are often presented. The first sees countries as being divided up into functional regions, that is, areas centered on nodes around which human activities take place. The second views regions as homogeneous units of the nation; in this view spatial units are classified on the basis of their characteristics and not on the basis of their pattern of interaction with other units.

The identification of either functional or homogeneous regions is generally made difficult, if not impossible, by data limitations. Furthermore, in most countries these regions have only a limited relevance for planning, because traditional administrative regions constitute regional planning units. Consequently, the main criterion for the selection of a multiregional system in the CMS study was neither nodality nor homogeneity but the relevance of the system for existing planning activities. The final selection of the set of regions was left to the national scholars participating in the project, because they were more informed about which multiregional systems were most relevant for their countries.

Table 2 lists the multiregional systems used in the CMS study. The regions are illustrated in Figure 1 and their names are set out in Table 3.

Each regional system used in the CMS study has the advantage of being planning oriented, and therefore the problems of data availability are minimized. There are, however, important disadvantages, because the regions are not necessarily homogeneous with respect to their demographic characteristics, and they differ greatly in size. Both features complicate the comparative assessments of the study's analytic results.

3.4 The Measurement of Migration

A major problem in comparative migration analysis arises as a consequence of differences among countries in the procedures that are used to measure migration: a change of community of residence. There are, nevertheless, two principal types of data collection procedures—registration systems and censuses—both of which are implemented in many countries. The registration system, generally used in Europe, requires each change of address to be registered with the local authorities. Thus every move (a passage from one place of residence to another) is counted and the aggregate statistical data that describe the number of moves are said to be *movement data*. Other countries, such as France, the United Kingdom, and the United States, derive migration statistics from a retrospective question in the national census. In such censuses, migration is measured by comparing places of residence at two consecutive points in time, the second of which is the time of enumeration. For most IIASA countries this date

Table 2. The regions used in the CMS study.

Country	Scale of regions: Coarse	Medium	Fine
1 Austria	4 Länder aggregations[a]	9 Länder[bd] (states)	95 Gemeinden
2 Bulgaria	---	7 Regions[bd]	28 Districts
3 Canada	---	10 Provinces[bd]	
4 Czechoslovakia	2 Republics	10 Regions[bd]	12 Administrative Regional Units
5 FRG	---	10 Länder[bd] and W. Berlin	58 Functional Urban Regions
6 Finland	---	12 Läani (provinces)[bd]	16 Economic Regions
7 France	8 ZEATs[bd] (planning zones)	22 Regions[c]	95 Departments
8 GDR	5 Regions[bd]	15 Regions (districts)[cd]	219 Kreise (counties)
9 Hungary	---	6 Economic Planning Regions[bd]	25 Counties & County Towns[c]
10 Italy	5 Regions[bd]	---	20 Administrative Units[acd]
11 Japan	---	8 Regions[bd]	47 Prefectures
12 Netherlands	5 Geographic Regions[bd]	12 Provinces[cd]	40 COROP Regions 129 Economic Geographic Areas
13 Poland	---	13 Regions[bd]	22 Voivodships (to 1975), 49 voivodships (since (1975)[c]
14 Soviet Union	Urban and Rural Areas[ad]	8 Units: 7 Urban Regions & 1 Rural Remainder[bd]	15 Republics
15 Sweden	---	8 Regions[bd]	24 Counties[c] 70 A-Regions
16 United Kingdom	2 Standard Regions & Remainder of Country[a]	10 Standard Regions[bd]	18 Conurbations & Region Remainder 61 Counties & Regions
17 United States	4 Regions[bd]	9 Census Divisions[a]	50 States

[a]Secondary multiregional analysis carried out at this scale.
[b]Principal multiregional analysis carried out at this scale.
[c]Additional single-region analysis carried out at this scale.
[d]Data provided in Research Report at this scale for multiregional analysis.

Notes for this Table are on the following page.

Notes for Table 2

Austria:	The four regions are groupings of the nine Austrian Länder.
Bulgaria:	The seven Bulgarian regions are groupings of 28 administrative districts.
Canada:	The Canadian study omits the Yukon and North West Territories from the multiregional analysis. The provinces are administrative units.
Czechoslovakia:	Seven of the regional units fall in the Czech Republic and three in the Slovak Republic.
FRG:	The Länder are administrative regions.
Finland:	The provinces are administrative units.
France:	The ZEATs are the *zones d'etude et d'aménagement du territoire*, originally defined for the regionalization of the Sixth National Plan. They are groupings of the 22 programming regions.
GDR:	The multiregional analysis of the German Democratic Republic was carried out principally using five macroregions, though some analysis was done with 15 regions, which were the 15 administrative districts of the German Democratic Republic (Bezirke). The macroregions were aggregations of the administrative districts.
Hungary:	The 6 regions are groupings of the 25 administrative districts.
Italy:	The 5 regions are amalgamations of the 20 administrative units.
Japan:	The eight regions are aggregations of the 47 administrative prefectures.
Netherlands:	The five regions are groups of the 11 administrative provinces and the Ysselmeerpolders.
Poland:	The 13 Polish regions are groupings of the 49 (post-1975) administrative voivodships. Before 1975 there were 22 voivodships.
Soviet Union:	The urban regions are not contiguous.
Sweden:	The regional units are amalgamations of counties (administrative units).
United Kingdom:	The United Kingdom regional analysis covers 11 regions: the eight standard regions of England, plus Wales, Scotland, and Northern Ireland. In the multiregional analysis Northern Ireland was omitted. The three regions (coarse regionalization) are used in the United Kingdom chapter analysis and the Ledent and Rees (1980) study. The standard regions are aggregations for statistical purposes of the administrative counties.
United States:	The four regions are aggregations of the nine census divisions, which are amalgamations of the 50 administrative states.

SOURCE: Rees and Willekens (1981, pp. 44-45), with corrections by authors.

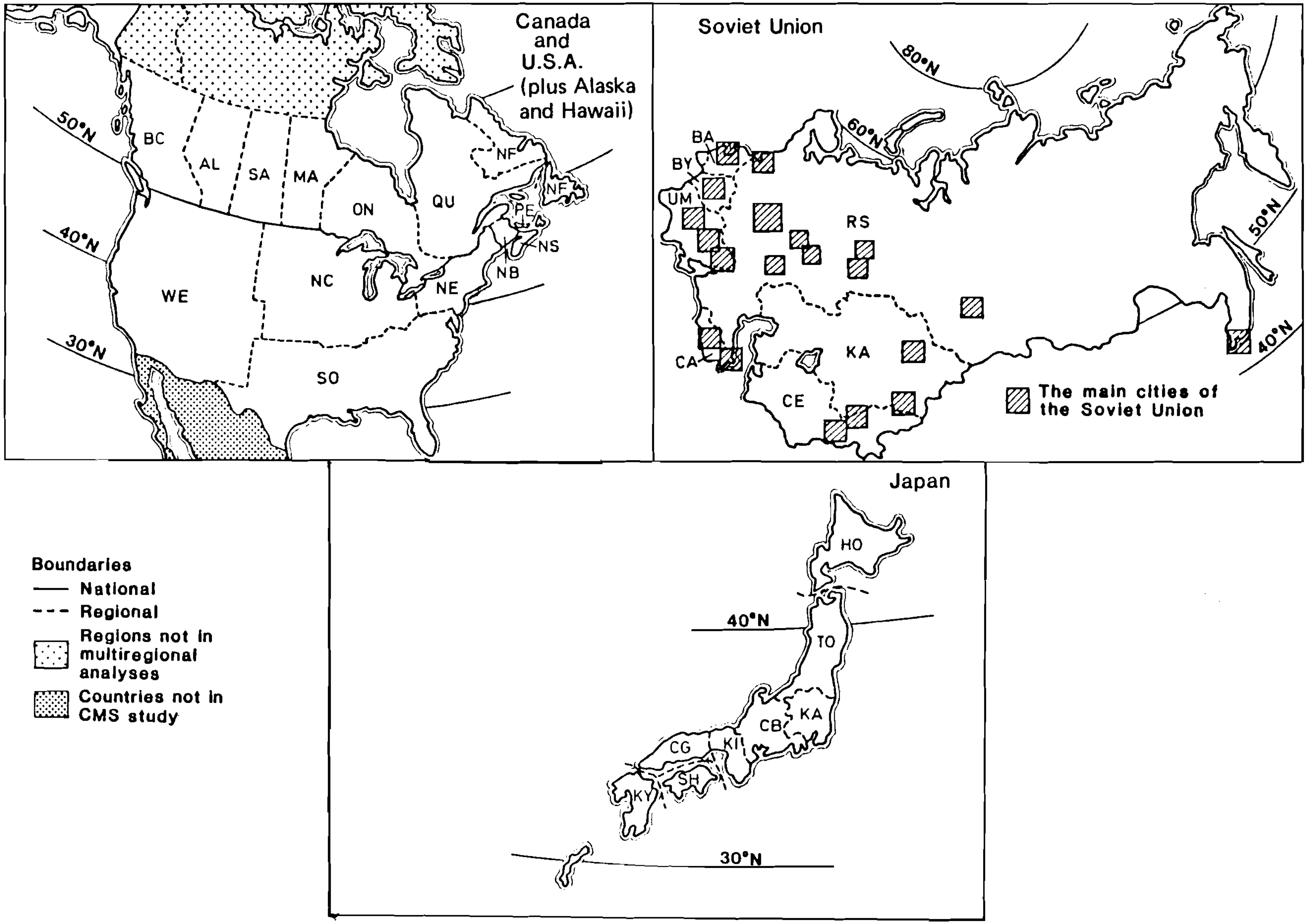

Figure 1 The regions used in the CMS study: (A) North America, Soviet Union, and Japan.

Source: Rees and Willekens (1981, p. 46).

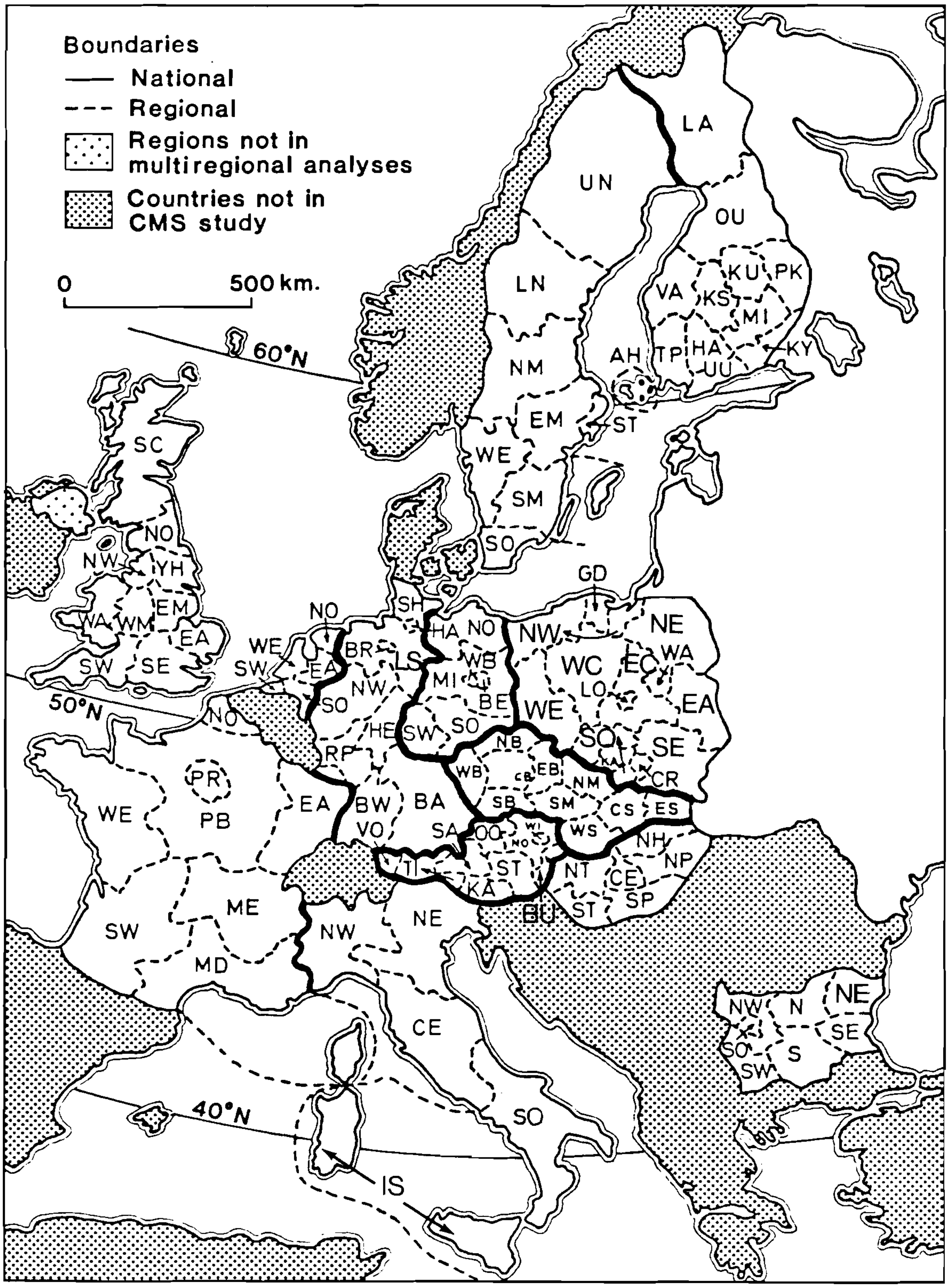

Figure 1 (contd.) The regions used in the CMS study: (B) Europe.

Source: Rees and Willekens (1981, p. 47).

Table 3. Names of the regions and reference year used in the multiregional population analyses.

1. Austria (1971)

BU	Burgenland
KA	Carinthia
NO	Lower Austria
OO	Upper Austria
SA	Salzburg
ST	Styria
TI	Tyrol
VO	Vorarlberg
WI	Vienna

2. Bulgaria (1975)

NW	North West
NO	North
NE	North East
SW	South West
SH	South
SE	South East
SP	Sofia

3. Canada (1971)

NF	Newfoundland
PE	Prince Edward Island
NS	Nova Scotia
NB	New Brunswick
QU	Quebec
ON	Ontario
MA	Manitoba
SA	Saskatchewan
AL	Alberta
BC	British Columbia

4. Czechoslovakia (1975)

CB	Central Bohemia
SB	Southern Bohemia
WB	Western Bohemia
NB	Northern Bohemia
EB	Eastern Bohemia
SM	Southern Moravia
NM	Northern Moravia
WS	Western Slovakia
CS	Central Slovakia
ES	Eastern Slovakia

5. Federal Republic of Germany (1974)

SH	Schleswig-Holstein
HA	Hamburg
LS	Lower Saxony
BR	Bremen
NW	N. Rhine-Westphalia
HE	Hessen
RP	Rheinland-Palatinate
BW	Baden-Wuerttemburg
BA	Bavaria
SA	Saarland
WB	West Berlin

6. Finland (1974)

UU	Uusimaa
TP	Turku and Pori
AH	Ahvenanmaa
HA	Häme
KY	Kymi
MI	Mikkeli
PK	Pohjois-Karjala
KU	Kuopio
KS	Keski-Suomi
VA	Vaasa
OU	Oulu
LA	Lappi

7. France (1975)

PR	Paris Region
PB	Paris Basin
NO	North
EA	East
WE	West
SW	South West
ME	Middle East
MD	Mediterranean

8. German Democratic Republic (1975)

NO	North
BE	Berlin
SW	Southwest
SO	South
MI	Middle

Table 3. Continued.

9. Hungary (1974)

CE	Central
NH	North Hungary
NP	North Plain
SP	South Plain
NT	North Trans-Danubia
ST	South Trans-Danubia

10. Italy (1978)

NW	North West
NE	North East
CE	Center
SO	South
IS	Islands

11. Japan (1970)

HO	Hokkaido
TO	Tohoku
KA	Kanto
CB	Chubu
KI	Kinki
CG	Chugoku
SH	Shikoku
KY	Kyushu

12. Netherlands (1974)

NO	North
EA	East
WE	West
SW	South-West
SO	South

13. Poland (1977)

WA	Warsaw
LO	Łódz
GD	Gdańsk
KA	Katowice
CR	Cracow
EC	East-Central
NE	Northeast
NW	Northwest
SO	South
SE	Southeast
EA	East
WC	West-Central
WE	West

14. Soviet Union (1974)

RS	Urban areas of the RSFSR
UM	Urban areas of the Ukrainian and Moldavian SSRs
BY	Urban areas of the Byelorussian SSR
CE	Urban areas of the Central Asian Republics (Uzbek, Kirghiz, Tadzhik and Turkmen SSRs)
KA	Urban areas of the Kazakh SSR
CA	Urban areas of the Caucasian Republics (the Georgian, Azerbaijan and Armenian SSRs)
BA	Urban areas of the Baltic Republics (the Estonian, Latvian and Lithuanian SSRs)
RU	Rural areas of the USSR

15. Sweden (1974)

ST	Stockholm
EM	East Middle
SM	South Middle
SO	South
WE	West
NM	North Middle
LN	Lower North
UN	Upper North

16. United Kingdom (1970)

NO	North
YH	Yorkshire and Humberside
NW	North West
EM	East Midlands
WM	West Midlands
EA	East Anglia
SE	South East
SW	South West
WA	Wales
SC	Scotland

17. United States (1970)

NE	Northeast
NC	North Central
SO	South
WE	West

SOURCE: Rees and Willekens (1981, pp. 48-49), amended.

was five years prior to the census; however, in France, the interval was seven years and in Japan it was only one year. In this form of migration measurement, individual moves are not recorded; what are recorded are transitions made between the start and the end of a given time interval. These data on migration are therefore referred to as *transition data*. Return migration and other multiple moves during the interval are not represented in transition data.

In the CMS study both registration-based movement data and census-based transition data were employed; movement data were used in 11 out of 17 country studies and transition data were used in the remaining 6 studies (Table 4).

Table 4. The CMS studies classified by type of migration data.

Movement data (registration)	Transition data[a] (census)	
Bulgaria	Austria	(5)
Czechoslovakia	Canada	(5)
Federal Republic of Germany	France[b]	(7)
Finland	Japan	(1)
German Democratic Republic	United Kingdom	(1 and 5)[c]
Hungary	United States	(5)
Italy		
Netherlands		
Poland		
Soviet Union		
Sweden		

[a]The length of the reference period, in years, is given in parentheses.

[b]For the analysis, the seven-year transition rates were factored down to five-year rates (Ledent with Courgeau 1982).

[c]The UK 1970-census contained questions on the place of residence one and five years ago. A comparison of the results obtained for the two intervals was made by Ledent and Rees (1980).

3.5 Assessment

It is clear from the above discussion that a comparative analysis of regional patterns of mortality, fertility, and migration in IIASA's NMO countries is troublesome if not impossible. Because of the problems of comparability, we will place the major emphasis of our analysis on interregional differences within a country, paying only limited attention to differentials between countries.

The regions used in the CMS study are not uniformly defined and show considerable variation in size and degree of homogeneity. This complicates comparative analysis because the regional disaggregation scheme affects regional differentials in the components of demographic change. For a few countries (Austria, the German Democratic Republic, Italy, the Netherlands, the Soviet Union, and the United Kingdom) the multiregional analysis was carried out at more than one level of disaggregation. The experiments illustrate the impact of regional disaggregation schemes on the results, some of which will be touched on in this paper.

Another major problem encountered in the CMS study is associated with national differences in migration measurement. The results of the demographic analysis are sensitive not only to the data collection procedure adopted (registration vs. census), but also to the length of the reference period employed for the measurement of migration in the census. In Section 6 of this paper, a few implications of such differences are discussed.

4. COMPARATIVE ANALYSIS OF MORTALITY, FERTILITY, AND MIGRATION PATTERNS

A comparative analysis requires answers to at least two questions: *what* is being compared, and *how* is the comparison carried out. The answer to the first question generally involves the selection of summary measures of mortality, fertility, and migration. The growth regimes are defined by sets of curves of age-specific rates (or probabilities). Levels are relatively easy to summarize, and the demographic literature contains several indicators of levels of mortality (e.g., life expectancy or gross death rate), fertility (e.g., gross reproduction rate) and migration (e.g., gross migraproduction rate, the migration analog of the gross reproduction rate).* Age profiles may be summarized and parametrized by fitting mathematical functions to the age-specific schedules of rates.

The answer to the question of how comparisons are carried out involves the selection of measures of disparity. These measures describe the distributions of indicators around a central value (a mean or median). An example of a simple measure is the difference in absolute (or in relative) terms between the maximum and the minimum values of an indicator, e.g., the expectation of life at birth. More complex measures may call for global indices of regional differentials, such as used by Termote (1982), for example.

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*All are measures of the area under the curve defined by the schedule of age-specific rates.

4.1 Mortality

Termote (1982) examines regional mortality disparities in the IIASA member countries, using the data base assembled by the CMS study. This section of the paper draws on his analysis and on the several indices of regional mortality differentials set out in Table 5. The table presents regional data for the expectation of life at birth, the first set of which is derived from conventional (single-region) life tables, the second from a multiregional life table. Several conclusions may be drawn from these data.

a. On the whole, regional disparities in life expectancies at birth seem relatively small. The deviation between the highest and lowest values is largest in the Soviet Union (5.3 years), followed by France (4.5), and the United Kingdom (3.2). The smallest discrepancy is observed in Japan (1.3 years), Hungary (1.4), and Sweden (1.5).

b. The regional disaggregation influences the regional mortality disparities. The difference in the Soviet Union may in part be related to the peculiar regional disaggregation adopted. Seven of the eight regions are urbanized areas; region 8 is a combination of all the rural areas in the country and has the lowest life expectancy (68.2 years).

   For a few countries, the analysis was carried out at more than one level of disaggregation (see Termote 1982, p. 24). A general conclusion of these experiments is that the greater the

Table 5. Regional differentials in the expectation of life at birth (both sexes combined).

Country	Reference year	Number of regions	Single-region measure			Multiregional measure	
			National	Lowest	Highest	Lowest	Highest
1 Austria	1971	9	70.5	69.6	71.7	69.9	71.6
2 Bulgaria	1975	7	70.9	69.9	71.8	70.5	71.4
3 Canada	1971	10	72.5	71.5	73.8	--	--
4 Czechoslovakia	1975	10	70.3	68.7	71.5	--	--
5 Federal Republic of Germany	1974	11	71.9	70.4	72.8	71.4	72.3
6 Finland	1974	12	71.7	69.9	72.8	71.2	72.7
7 France	1975	8	73.5	70.2	74.7	73.3	74.2
8 German Democratic Republic	1975	5	71.7	70.8	72.2	71.1	72.0
9 Hungary	1974	6	69.0	68.4	69.8	68.4	69.7
10 Italy	1978	5	74.1	73.5	75.3	--	--
11 Japan	1970	8	72.1	71.2	72.5	72.0	72.5
12 Netherlands	1974	5	74.7	74.0	75.7	74.3	74.8
13 Poland	1977	13	70.6	69.4	71.8	70.1	71.5
14 Soviet Union	1974	8	69.3	68.2	73.5	67.8	71.4
15 Sweden	1974	8	75.2	74.4	75.9	74.8	75.6
16 United Kingdom	1970	10	71.9	70.3	73.5	71.1	72.6
17 United States	1970	4	70.8	69.9	71.8	70.5	71.1

level of geographical detail, the larger the mortality difference. This conclusion indicates a lack of homogeneity among the larger regions.

c. The single-region life-expectancy measures indicate larger regional mortality disparities than the multiregional measures. With the exception of the Soviet Union, the range of single-region life-expectancies is larger than the range of multiregional life expectancies. Rees (1979a), who first observed the relationship between the life-expectancy measures in the United Kingdom, suggested that the multiregional measures represent a regression of the single-region values to the mean. This phenomenon can be attributed to a combination of two factors: the interchange of people between regions through migration and the assumption that migrants do not carry their demographic history with them but adopt the demographic regime of growth of their new region of residence (the Markovian assumption).

The regression to the mean differs considerably between the 17 countries (Rees and Willekens 1981, p. 87) and is highest in Japan and the Netherlands. An increase of one year in the single-region life expectancy leads, on the average, to an increase in the multiregional life expectancy of 0.29 and 0.30 years, respectively. The lowest regression to the mean is exhibited by the data for Czechoslovakia and the Soviet Union.

The regional disparities exhibited in Table 5 are for the total population. A disaggregation by sex suggests that regional disparities tend to be slightly higher for males than for females. In the Federal Republic of Germany, for instance, the female life expectancies lie between 73.4 and 75.7 years; those for males vary between 66.5 and 69.4.

As we have seen, a comparative analysis of life expectancies indicates a relatively low level of regional disparity in most of the 17 IIASA countries. But what about the age structure of mortality? For the comparative study of these age patterns, we considered the age-specific rates directly rather than parametrize the mortality schedules, because the data were available only for five-year age groups. Our results show large disparities in infant mortality (here defined as the mortality rate of the 0-4 age group) and in the mortality rates of young adults (those 15-29 years). In 7 out of the 17 IIASA countries, the highest regional infant mortality rate is more than 50% above the lowest regional rate, and in all of the 17 countries considered, this percentage is above 20% (Termote 1982, p. 27). The disparities are even greater when young adult mortality is considered: in seven countries the highest mortality rate for young adults is more than 50% above the lowest rate, and in all but one (United Kingdom), this percentage exceeds 30% (Termote 1982, p. 31). Infant and young adult mortality, therefore, account for most of the regional mortality disparities found in the 17 countries.

4.2 Fertility

Considerable regional variations are also exhibited in the levels of fertility within IIASA countries. Table 6 gives, for each country, the national value and the lowest and highest regional gross reproduction rates (GRR). The largest regional disparities, measured as the difference between the highest and lowest GRR, are observed in the Soviet Union, Canada, and Poland. A woman in the urban areas of the Central Asian Republics of the Soviet Union

Table 6. Regional differentials in gross reproduction rates (both sexes combined).

Country	Reference year	Number of regions	National	Lowest	Highest
1 Austria	1971	9	1.09	0.82	1.31
2 Bulgaria	1975	7	1.10	0.96	1.22
3 Canada	1971	10	1.23	1.10	1.90
4 Czechoslovakia	1975	10	1.21	1.13	1.39
5 Federal Republic of Germany	1974	11	0.73	0.58	0.81
6 Finland	1974	12	0.79	0.73	0.96
7 France	1975	8	0.94	0.83	1.12
8 German Democratic Republic	1975	5	0.76	0.74	0.80
9 Hungary	1974	6	1.14	0.99	1.36
10 Italy	1978	5	0.91	0.76	1.17
11 Japan	1970	8	1.05	1.01	1.15
12 Netherlands	1974	5	0.87	0.91	0.98
13 Poland	1977	13	1.10	0.81	1.41
14 Soviet Union	1974	8	1.33	0.97	1.92
15 Sweden	1974	8	0.92	0.86	0.97
16 United Kingdom	1970	10	1.18	1.11	1.26
17 United States	1970	4	1.26	1.22	1.30

(highest GRR) may expect to have more than twice the number of children, on the average, than a woman in the urban areas of the Baltic Republic (lowest GRR). In Newfoundland, Canada, the GRR is 73% higher than in Quebec. The United States and the German Democratic Republic exhibit the smallest differences in regional fertility levels, but it must be remembered that in the former case this is a consequence of the high level of regional aggregation.

4.3 Migration

The comparative analysis of migration is complicated by differences in reference periods and in sizes of regions. Although regional disparities in mobility levels, to a large extent, reflect such differences, migration age profiles are not as sensitive to these time and space dimensions. This section, therefore, mainly considers the age structure of migration. The discussion of mobility levels is meant to be illustrative only and indicates the difficulties that complicate comparative migration analyses if appropriate data are not available.

A simple indicator of mobility (immobility) is the retention level, the proportion of a lifetime that a person may expect to spend in the region of birth. Table 7 shows that the largest regional disparities in retention levels are observed in the Federal Republic of Germany (0.423), Canada (0.417), and Japan (0.382). The impact of regional disaggregation on the retention level is illustrated by the FRG study. In this country the lowest retention level is for the city region of Bremen, which with a population of 724 thousand in 1974 is the smallest region. The high level of outmigration is probably a result of the suburbanization process, which overlaps regional boundaries. The highest retention level is exhibited by the largest region, North Rhine-Westphalia, with a population of 17.2 million. Differences in retention levels therefore reflect not only mobility differentials but also size differences in the regions between which migration takes place.

Table 7. Regional differentials in retention levels (both sexes combined).

Country	Number of regions	Median	Lowest	Highest
1 Austria	9	0.819	0.732	0.882
2 Bulgaria	7	0.823	0.742	0.867
3 Canada	10	0.574	0.373	0.790
4 Czechoslovakia	10	--	--	--
5 Federal Republic of Germany	11	0.475	0.271	0.694
6 Finland	12	0.439	0.310	0.592
7 France	8	0.682	0.572	0.705
8 German Democratic Republic	5	0.745	0.725	0.800
9 Hungary	6	0.471	0.372	0.506
10 Italy	5	--	--	--
11 Japan	8	0.431	0.352	0.734
12 Netherlands	5	0.600	0.461	0.689
13 Poland	13	0.711	0.584	0.839
14 Soviet Union	8	0.472	0.330	0.666
15 Sweden	8	0.499	0.464	0.641
16 United Kingdom	10	0.539	0.411	0.653
17 United States	4	0.560	0.530	0.586

The problems associated with comparisons of mobility levels are eased if we look at the age patterns of migration. Rogers and Castro (1981) in a study of over 500 migration schedules of IIASA countries found remarkably persistent regularities. To carry out a comparative analysis, they parametrized the curves of age-specific migration rates using a model migration schedule that combined additively four simple curves: a negative exponential curve, two double exponential curves, and a constant curve. The full model schedule had 11 parameters of which seven determined the profile of the migration schedule, with the remaining four determining its level. Figure 2 shows such a model migration schedule. The four components, and their associated parameters, are:

- a single negative exponential curve of the pre-labor force ages, with its rate of descent α_1 and level coefficient a_1
- a skewed unimodal curve of the labor force ages, positioned at mean age μ_2 on the age axis and exhibiting rates of ascent λ_2 and descent α_2, with a level coefficient a_2
- an almost bell-shaped curve of the post-labor force ages, positioned at μ_3 on the age axis and exhibiting rates of ascent λ_3 and descent α_3, with a level coefficient a_3
- a constant curve, c

α_1 = rate of descent of pre-labor force component
λ_2 = rate of ascent of labor force component
α_2 = rate of descent of labor force component
λ_3 = rate of ascent of post labor force component
α_3 = rate of descent of post-labor force component
c = constant

x_l = low point
x_h = high peak
x_r = retirement peak
X = labor force shift
A = parental shift
B = jump

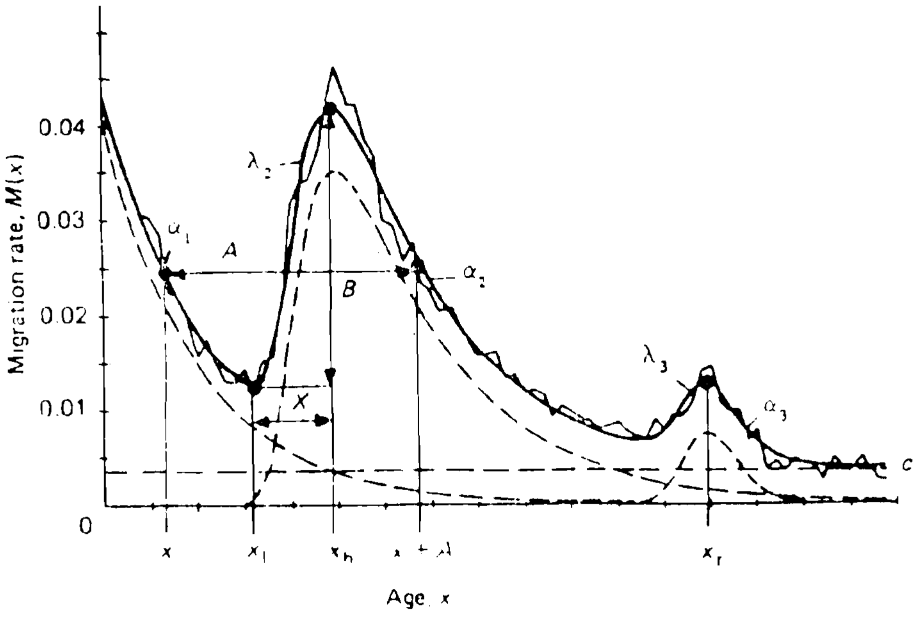

Figure 2. The model migration schedule.

Source: Rogers and Castro (1981, p. 6).

Table 8 presents, by way of illustration, regional differentials of the parameters for males in the United Kingdom. The statistics are based on the 59 schedules without a retirement peak and show large regional disparities. The mean age of the migration schedule ranges from 25 years to 36 years. The age at which the curve peaks (its high point x_h) ranges from 17 years (the flow from East Anglia to South East) to 28 years (the flow from Scotland to North West). The disparity between the mean ages of the labor force component (μ_2) follows the same pattern. In fact, the parameters of the model schedule are not independent. Rogers and Castro (1981, p. 21) conclude that a large fraction in the variation shown by the more than 500 schedules they studied arises from changes in the values of four parameters and derived variables:

- μ_2 the mean age of the labor force component
- δ_{12} the index of child dependency, the ratio of a_1 (level of pre-labor force component) to a_2 (level of labor force component)
- σ_2 the index of labor asymmetry, the ratio of λ_2 (rate of ascent of labor force component) to α_2 (rate of descent of labor force component)
- β_{12} the index of parental shift, the ratio of α_1 (rate of descent of pre-labor force component) to α_2 (rate of descent of labor force component)

Regional disparities in migration age patterns may be studied by considering each of the parameters or combinations of them. The model schedules also may be classified into families on the basis of the values of these parameters. Rogers and Castro

Table 8. Regional differentials of parameters of model migration schedules (males of the United Kingdom without a retirement peak: 59 schedules).

Parameters and variables	Summary statistics						
	lowest value	highest value	mean value	median	mode	std. dev.	std. dev. / mean
gmr (obs)	0.02521	1.05541	0.15658	0.09630	0.07672	0.18257	1.16594
gmr (mms)	1.00000	1.00000	1.00000	1.00000	1.00000	0.00000	0.00000
mae%m	5.59109	25.51109	11.66710	10.93198	10.57109	4.25471	0.36468
a1	0.00852	0.04154	0.02073	0.01979	0.01678	0.00665	0.32070
alpha1	0.02167	0.26591	0.09937	0.09878	0.10715	0.04812	0.48427
a2	0.01559	0.11192	0.05946	0.06078	0.06857	0.01676	0.28177
mu2	14.68744	43.96579	22.00013	20.11916	19.07919	5.36015	0.24364
alpha2	0.06427	0.27413	0.12654	0.11611	0.09575	0.04760	0.37617
lambda2	0.06051	0.90653	0.25947	0.24042	0.27202	0.15062	0.58048
a3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
mu3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
alpha3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
lambda3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
c	0.00000	0.00587	0.00286	0.00280	0.00205	0.00155	0.54198
mean age	25.15435	36.36529	30.65815	30.45968	30.19927	2.60321	0.08491
%(0-14)	15.19911	29.69068	20.88979	20.46828	18.82200	3.45535	0.16541
%(15-64)	60.27293	78.68406	69.70760	69.30323	66.71683	3.85501	0.05530
%(65+)	1.35734	16.64217	9.40261	9.56441	6.70703	3.74348	0.39813
delta1c	0.00000	108.15191	10.09796	6.40383	5.40760	16.02651	1.58710
delta12	0.13305	1.53679	0.39065	0.34557	0.20324	0.22076	0.56511
delta32	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
beta12	0.08403	2.64845	0.89863	0.69816	0.46869	0.56755	0.63157
sigma2	0.30349	11.98600	2.50122	2.07064	0.88762	2.01686	0.80635
sigma3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
x low	6.91004	17.19028	12.70424	12.61017	12.56417	1.82025	0.14328
x high	17.11028	28.14053	23.16957	22.82041	22.07389	1.81849	0.07849
x ret.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
x shift	4.50010	16.93039	10.46532	10.35024	10.09373	2.21174	0.21134
a	22.33532	34.75360	30.56486	30.77489	31.64904	2.64842	0.08665
b	0.01107	0.04390	0.02347	0.02331	0.02256	0.00595	0.25341

Notes for Table 8

[a]Definitions for the parameters and variables.

gmr (obs)	Observed gross migraproduction rate
gmr (mms)	Unit gross migraproduction rate
mae%m	Goodness-of-fit index E (mean absolute error as a percentage of the observed mean)
a1	a_1, level of pre-labor force component
alpha1	α_1, rate of descent of pre-labor force component
a2	a_2, level of labor force component
mu2	μ_2, mean age of labor force component
alpha2	α_2, rate of descent of labor force component
lambda2	λ_2, rate of ascent of labor force component
a3	a_3, level of post-labor force component
mu3	μ_3, mean age of post-labor force component
alpha3	α_3, rate of descent of post-labor force component
lambda3	λ_3, rate of ascent of post-labor force component
c	c, constant component
mean age	$\bar{n}$, mean age of migration schedule
%(0–14)	Percentage of *GMR* in 0–14 age interval
%(15–64)	Percentage of *GMR* in 15–64 age interval
%(65+)	Percentage of *GMR* in 65 and over age interval
delta1c	$\delta_{1c} = a_1/c$
delta12	$\delta_{12} = a_1/a_2$
delta32	$\delta_{32} = a_3/a_2$
beta12	$\beta_{12} = \alpha_1/\alpha_2$
sigma2	$\sigma_2 = \lambda_2/\alpha_2$
sigma3	$\sigma_3 = \lambda_3/\alpha_3$
x low	x_l, low point
x high	x_h, high point
x ret.	x_r, retirement peak
x shift	X, labor force shift
a	A, parental shift
b	B, jump

Source: Rogers and Castro (1981, p. 58).

set out several families of migration schedules using the four measures listed above. Each measure defines two families, depending on whether its value is above or below the "average." (The average values are: $\mu_2 = 20$, $\delta_{12} = 1/3$, $\sigma_2 = 4$, and $\beta_{12} = 1$.) Approximately 30% of the schedules for males in the United Kingdom are early peaking ($\mu_2 < 19$ years); about half of the schedules are "normal" (i.e., near the average profile). If we examine the index of child dependency, then 27% of the schedules are child-dependent ($\delta_{12} > 0.4$) and 10% are labor dependent ($\delta_{12} < 0.2$). Close to 7% of the schedules are labor asymmetric ($\sigma_2 > 5$) and 73% are irregular ($\beta_{12} < 0.8$ or $\beta_{12} > 1.2$).

5. COMPARATIVE ANALYSIS OF POPULATION STRUCTURE

Although the IIASA countries show considerable variation in national rates of fertility, they nevertheless are all tending toward levels of reproduction that are below replacement. By the end of the 1970s, not enough children were being born to replace their parents in 13 of the 17 countries; in the remaining 4 countries (Bulgaria, Czechoslovakia, Poland, and the Soviet Union) the number of children born was only slightly above replacement level. Consequently, in most IIASA national populations the elderly (that is, those above 65 years of age) increased their share of the total during that decade. Population aging and spatial redistribution are two principal dimensions illuminated by the CMS study.

5.1 Population Aging

Table 9 describes the age compositions of the IIASA countries during years in the 1970s. The "oldest" populations were France, Sweden, and the German-speaking countries of Europe (Austria, the Federal Republic of Germany, and the German Democratic Republic). They showed the highest fractions of population above 65 years of age and the oldest mean ages. Close behind these five countries were Hungary and the United Kingdom. The "youngest" countries on these indices were Canada and Japan; however, by 1980, sharp declines in fertility produced a substantial "graying" of these populations as well.

Table 10 indicates some of the regional differences in age compositions within IIASA countries. Shown there are the lowest and highest percentages under 15 and over 64. The region with the highest proportion of the aged (i.e., of those 65 and over) was Vienna, Austria, with one out of every five residents being in that age group. The region with the lowest proportion was the Kanto region in Japan, with approximately only 5.8 percent of its population being aged 65 and over. A comparison of Tables 9 and 10 indicates that differences in age compositions *within* countries are greater than those *between* countries.

Although the process of aging is becoming an important issue in all of the IIASA member countries, it will affect some countries more than others. Under current regimes of fertility and mortality, the proportion of the aged will decline, for example, in Austria (from 14.2% of the national population in 1971 to 11.9% by the year 2000), but it will increase rapidly in Japan (from 7.1% in

Table 9. Population structure in IIASA countries in the reference year.

Country (Reference Year)	Population (millions)	Mean Age	%(0-14)	%(15-64)	%(65+)	Elderly Dependency Ratio*	%(75+)
1 Austria (1971)	7.5	36.1	24.4	61.3	14.2	0.23	4.7
2 Bulgaria (1975)	8.7	35.2	22.2	66.8	10.9	0.16	3.3
3 Canada (1971)	20.7	30.3	31.2	60.9	7.9	0.13	3.0
4 Czechoslovakia (1975)	14.8	34.6	23.4	64.5	12.1	0.19	3.7
5 Federal Republic of Germany (1974)	62.0	36.8	21.7	64.0	14.3	0.22	4.7
6 Finland (1974)	4.7	34.0	22.4	67.3	10.3	0.15	3.1
7 France (1975)	52.4	35.9	22.7	63.1	14.2	0.23	5.6
8 German Democratic Republic (1975)	16.8	37.0	21.3	62.4	16.3	0.26	5.7
9 Hungary (1974)	10.4	36.1	19.9	67.8	12.3	0.18	3.9
10 Italy (1978)	56.6	35.6	23.3	63.9	12.8	0.20	4.5
11 Japan (1970)	104.7	31.5	24.0	68.9	7.1	0.10	2.1
12 Netherlands (1974)	13.5	33.1	26.1	63.3	10.6	0.17	3.9
13 Poland (1977)	34.7	32.8	23.9	66.2	9.9	0.15	3.1
14 Soviet Union (1974)	250.9	32.9	27.0	63.0	10.0	0.16	3.0
15 Sweden (1974)	8.2	37.6	20.7	64.4	14.8	0.23	5.5
16 United Kingdom (1970)	54.2	36.0	23.9	63.2	12.9	0.20	4.6
17 United States (1970)	203.2	32.4	28.5	61.6	9.9	0.16	3.8

*Elderly Dependency Ratio $= \frac{\%(65+)}{\%(15-64)}$

Table 10. Regional differentials in age composition in the reference year.

Country (Reference Year and Number of Regions)	Percent of the population aged 0-14				Percent of the population aged 65+			
	National (N)	Lowest (L)	Highest (H)	(H-L)/N	National (N)	Lowest (L)	Highest (H)	(H-L)/N
1 Austria (1971:9)	24.4	16.3	29.8	0.55	14.2	9.5	20.0	0.74
2 Bulgaria (1975:7)	22.2	19.2	24.4	0.23	10.9	7.7	16.0	0.76
3 Canada (1971:10)	31.2	29.9	38.8	0.31	7.9	6.0	10.9	0.62
4 Czechoslovakia (1975:10)	23.4	18.9	28.6	0.41	12.1	9.1	15.7	0.55
5 Federal Republic of Germany (1974:11)	21.7	15.9	23.1	0.33	14.3	12.9	22.2	0.65
6 Finland (1974:12)	22.4	21.2	26.7	0.25	10.3	7.3	13.4	0.59
7 France (1975:8)	22.7	20.1	25.7	0.25	14.2	12.1	17.7	0.39
8 German Democratic Republic (1975:5)	21.3	20.0	24.0	0.19	16.3	13.5	17.9	0.27
9 Hungary (1974:6)	19.9	16.1	23.9	0.39	12.3	11.2	13.7	0.21
10 Italy (1978:5)	23.3	21.1	27.5	0.27	12.8	10.8	14.0	0.25
11 Japan (1970:8)	24.0	22.9	26.0	0.13	7.1	5.8	9.9	0.58
12 Netherlands (1974:5)	26.1	24.4	27.9	0.13	10.6	8.2	13.7	0.52
13 Poland (1977:13)	23.9	17.4	26.8	0.39	9.9	6.3	11.5	0.53
14 Soviet Union (1974:8)	27.0	21.3	34.7	0.50	10.0	6.3	12.0	0.57
15 Sweden (1974:8)	20.7	19.6	21.9	0.11	14.8	12.8	16.8	0.28
16 United Kingdom (1970:10)	23.9	22.5	26.2	0.15	12.9	11.0	14.9	0.30
17 United States (1970:4)	28.5	27.2	29.2	0.07	9.9	8.9	10.6	0.17

1970 to 12.5% by 2000) and the Federal Republic of Germany (from 14.3% in 1974 to 15.3% in 2000).

Given current migration patterns, some regions will experience a considerable aging of their populations, which will require adaptation on the part of the local economies, particularly the service sectors. In the Kanto region of Japan, for example, the number of aged persons will increase by 280% between 1970 and 2000. Because of the high overall growth rate of the region, however, the share of the elderly will continue to be lower in Kanto than in the rest of Japan. Other regions experiencing a high increase in the number of aged persons by the year 2000 are British Columbia (220%) in Canada, the Caucasian Republics (210%) in the Soviet Union, and Sofia (200%) in Bulgaria. A few regions, mainly those centered on large cities, may expect a substantial decline in the number of their aged. The largest decline will probably occur in the Paris region between 1975 and 2000; the number of people 65 and over is expected to decrease by 64% from 1.198 million to 0.427 million, and the proportion of the aged will drop from 12% to 5%. In West Berlin, the population in this age group will decrease by 55% and in Vienna by 35%. In 1971, one out of every five persons in Vienna was older than 65; by the year 2000, it will be one out of every seven (under the 1971 regimes of fertility, mortality, and migration).

Extrapolation of current trends identifies important differences in the graying of IIASA's national populations; it also reveals important regional differences within countries. In a number of countries, one can already identify spatial concentrations of the aged: British Columbia in Canada, the Mediterranean

Region in France, and the Hokkaido Region in Japan. The analysis also shows that some regions with relatively old populations today are likely to exhibit younger age structures in the future, for example, Paris, Vienna, and West Berlin.

5.2 Population Redistribution

A number of IIASA member countries and regions within such countries may expect substantial changes in the age structures of their populations. Another demographic process that in some countries takes on an important dimension is the territorial redistribution of the national population. One of the most significant redistributions will probably occur in Japan. Whereas in 1970 the size of the largest region (Kanto) was 7.6 times the size of the smallest one (Shikoku); the ratio is expected to be 17.5 by the year 2000, and a further projection to stability shows it growing to 32.4. Table 11 sets out the long-run implications of current regimes of fertility, mortality, and migration for selected regions in IIASA countries.

Regions with declining population shares are Quebec, Vienna, Northern France, and the Kyushu Region in Japan. Areas with large gains in their shares of the total population are British Columbia, Berlin (GDR), the Kanto Region of Japan, and the Central Asian Republics of the Soviet Union. It is a striking observation that, were the current regimes of the components of demographic growth to continue, almost half of the Japanese population eventually would live in the Kanto Region. The substantial changes expected in the population structure in Japan, both in age composition and in regional distribution, have led the

Table 11. Changes in shares of total population for selected regions in the IIASA member countries (percent).

Country/Region	Regional share of national total		
	Reference year	Year 2000	At stability
Austria/Vienna	21.7	17.8	7.4
Canada/Quebec	28.5	25.3	12.1
Canada/British Columbia	9.8	13.0	21.1
France/Mediterranean	10.4	15.4	16.8
France/North	7.5	4.4	3.6
GDR/Berlin	6.5	8.4	14.9
Italy/South	23.8	25.3	36.4
Japan/Kanto	28.2	38.5	47.0
Japan/Kyushu	12.4	6.4	3.8
Soviet Union/Rural Areas	40.4	25.1	20.2
Soviet Union/Central Asia	3.5	5.2	7.2
United States/West	17.1	20.7	23.0

government of Japan to initiate a study on population aging and on regional differences in aging populations. The analytical tools of multiregional demography, developed at IIASA, were used in this analysis (Kawashima et al. 1981).

6. METHODOLOGICAL RESEARCH STIMULATED BY THE CMS STUDY

The methodological work of the CMS study did not stop with the formalization of the analytical framework for spatial analysis adopted in the beginning of the study (Rogers, 1976a, b). As that framework was applied to the various IIASA member countries, additional theoretical and empirical research was carried out to assess the validity and comparability of the various national results. Much of this reseach naturally was limited to the common element of each case study: the multiregional life table. Investigations were conducted to evaluate

a. the *accuracy* of the procedure used to implement the simple Markov chain model, which underlies the multiregional life table

b. the *reliability* of this model

6.1 Estimation of Survival Probabilities in the CMS Study

The key element in the construction of a multiregional life table is the estimation of the age-specific probability matrices $\underset{\sim}{p}_x$ from which all multiregional life table functions originate. As noted in section 3.4, migration data may be collected by counting either movements (migrations) or transitions (migrants). Population registers record all changes of address and therefore represent the number of migrations observed during a given period, between each origin and destination. Population censuses, on the other hand, count the number of migrants who resided in a given region at an earlier fixed date and in another region at the time of the census. Since data on different geographical mobility flows are collected in these two ways, it is reasonable to expect that two distinct approaches to survival probability estimation would arise (Ledent 1980). However, the earliest estimation methods (Rogers 1973, 1975) developed approximate estimators that were consistent with both the movement and the transition perspectives by adopting the simplifying assumption that no multiple movements could take place within a unit age/time interval. These approximate estimators were called "Option 1" estimators (Rogers 1975).

From an applied viewpoint, the problem was seen as one of appropriately measuring observed mobility rates. First, in the case of mobility data coming from a population register (movement perspective), each age-specific mobility rate M_x^{ij} could be readily estimated as the ratio of the observed number of movements (migrations) D_x^{ij} made from region i to region j over a given period (t, t + T) by persons aged x to x + n (at the time of the movement) to the number of person-years $\hat{K}_x^i$ lived in region i during that period by people aged x to x + n. Hence, taking the latter number as T times the arithmetic average of the beginning- and end-of-period populations aged x to x + n, M_x^{ij} could be derived from

$$\bar{M}_x^{ij} = \frac{1}{T} \frac{D_x^{ij}}{\frac{K_x^i(t)+K_x^i(t+T)}{2}} \qquad (j \neq i) \tag{1}$$

Alternatively, in the case of mobility data coming from a population census (transition perspective), Rogers (1975, pp. 87-88) suggested that the number of transitions (migrants) O_x^{ij} from region i to region j observed over the period (t, t + T) be simply substituted for the corresponding number of movements D_x^{ij}, which led to the following observed rate

$$M_x^{ij} = \frac{1}{T} \frac{O_x^{ij}}{\frac{K_x^i(t)+K_x^i(t+T)}{2}} \qquad (j \neq i) \tag{2}$$

Because of the assumption that only a single movement could occur per unit age/time interval, the application of "Option 1" estimators to mobility data for either movement or transition counts was perceived to be inadequate.

Fortunately, in the case of the movement perspective, this restrictive assumption could be relaxed (Schoen 1975), and improved estimators, called "Option 3" estimators (Willekens and Rogers 1978), could be obtained. The survival probability p_x^{ij} becomes the j,i-th element of the matrix $\underset{\sim}{p}_x$ (Rogers and Ledent 1976):

$$\underset{\sim}{p}_x = (\underset{\sim}{I} + \frac{n}{2} \underset{\sim}{\overline{M}}_x)^{-1} (\underset{\sim}{I} - \frac{n}{2} \underset{\sim}{\overline{M}}_x) \tag{3}$$

where $\underset{\sim}{I}$ is an identity matrix, and $\underset{\sim}{\overline{M}}_x$ is an age-specific matrix of annual mortality and mobility rates.

By contrast, in the case of the transition perspective, no useful alternative to the "Option 1" estimators were available. An attempt made by Rogers (1975, p. 85-88) led to estimators, known as "Option 2" estimators, which generally produced unstable results. Thus Willekens and Rogers (1978) suggested the substitution of "Option 3" for the "Option 1" estimators. The former seemed to yield more acceptable death probabilities than the latter, while producing very similar migration probabilities (Ledent and Rees 1980, pp. 53-57).

In other words, our initial investigations led us to conclude that, regardless of whether the mobility information available was in the count of movements or of transitions, the calculation of a multiregional life table could be performed by application of equation (3). It would be necessary, however, to measure the mobility rates appropriately, either by using equation (1), in the case of data counting movements, or by using equation (2), in the case of data counting transitions.

As shown in Table 4, registration-based movement data for the CMS study were available in 11 out of the 17 countries (that is, all of the European member nations of IIASA except Austria, France, and the United Kingdom) and census-based transition data were obtained in the other 6 (that is, the 3 countries just cited plus Canada, the United States, and Japan). The "Option 3" estimators were applied to all national case studies, except France. The French case study (Ledent with Courgeau 1982) and additional analyses of the UK case study by Ledent and Rees (1980) incorporated some of the developments reported in this section.

We now shift the focus of our discussion to the transition perspective, for which only approximate estimators, "Option 1" and "Option 3", were found to be applicable. Fitting the latter estimators to the six IIASA countries with census-based mobility data revealed a certain ambiguity in the measurement of the observed mobility rates to be incorporated in equation (3). The definition of such rates in equation (2) does not indicate whether the age subscript attached to the numerator refers to the beginning of the period, the end of the period, or even the mid-period. Consequently, the observed rates were not measured uniformly; thus the numerator of equation (2) was measured with the age subscript referring to the end of the period in the Canadian case and to the beginning of the period in the US case.

Unfortunately, neither choice was correct because the transition perspective, unlike the movement perspective, does not allow an equivalence of the age/time space in which the data are gathered with that used in the model (Ledent and Rees 1980, pp. 45-47). Thus a possible procedure, following Rees (1979a), is to estimate the number of migrants O_x^{ij} from data on adjacent groups, as follows

$$O_x^{ij} = \left(1 - \frac{T}{2n}\right) K_{x-n,\cdot}^{ij} + \frac{T}{2n} K_{x,\cdot}^{ij} \qquad (j \neq i) \tag{4}$$

where $K_{x,\cdot}^{ij}$ is the number of migrants from region i to region j relating to people aged x to x + n at the beginning of the observation period.*

*This revision of the measurement of the mobility rates was actually implemented in the UK case study (Rees 1979a, b).

Beyond the measurement of the mobility rates, a more important element of the transition perspective requiring improvement lay in the fundamental estimation equation which, as used in the CMS study, continued to be based on the assumption of no multiple movements. In attempting to relax this restrictive assumption, we explored two alternative approaches, hereafter denoted as approaches A and B.

First we investigated whether the occurrence of multiple movements could be built into the "Option 1" framework (Ledent 1981b). The removal of the no-multiple-movement assumption allows deaths, occurring before age x + n to the closed group of people present at age x in region i, to take place not only in region i but also in the other regions. New estimates, which did not differ significantly from those of the "Option 1" and "Option 3" methods, were then derived by disaggregating the total number of corresponding deaths according to the region of occurrence and introducing additional accounting equations. These equations reflect the hypothesis that when an individual moves into another region he or she becomes immediately subject to the risk of dying in that region.

This *first* approach (A) to relaxing Rogers's no-multiple-movement assumption was largely influenced by the classical estimation of survival probabilities in an ordinary life table; that is, it was based on the assumption of equal life table and observed mobility *rates*. By contrast, the *second* approach (B) that was investigated drew on a technique sometimes used by demographers to calculate an ordinary life table, from census information, for countries in which the appropriate mortality data are lacking. This approach makes use of the concept of *survivorship proportions* and estimates the transition probability matrices $\underset{\sim}{p}_x$ on the assumption of equal life table and observed survivorship proportion matrices.

The initial development of this second approach was due to Rogers who devised the "Option 2" method, which was applicable to transition data over a fixed period of time. Specifically, this method derived the transition probability matrices $\underset{\sim}{p}_x$ from the known values of the survivorship proportions $\underset{\sim}{S}_x$ on the basis of an equation that follows from a linear estimation of the various numbers of person-years lived in the stationary population (Rogers 1975, p. 85).

"Option 2", however, led to unsatisfactory results in that the transition probability estimates that were obtained did not always lie between 0 and 1. The problem was traced to the inappropriateness of the underlying Markov chain model, whose impacts were amplified by the adoption of the linear integration hypothesis (Ledent and Rees 1980, p. 106).

The logic behind the "Option 2" method, however, is sound and it appears that more reasonable results may be obtained by the substitution of a somewhat different equation to link transition probabilities with survivorship proportions. For example, Rees and Wilson (1977) proposed the derivation of $\underset{\sim}{p}_x$ by interpolating linearly between the survivorship proportions associated with the two age groups located immediately before and after age x. Recently, various extensions of this method, based on a cubic spline interpolation rather than a linear interpolation, were suggested by Ledent (1980, 1981b) and Ledent and Rees (1980).

6.2 Heterogeneity and the Markov Chain Model

The above discussion has been devoted to an essentially empirical issue: the development of adequate methods for implementing the mathematical model underlying the multiregional life table concept. Taking this model as given, we have attempted to devise appropriate probability estimation methods. Now we turn to an examination of the mathematical model itself.

The simple Markov chain model on which the multiregional life table is based relies on two stringent assumptions: the population homogeneity assumption and the Markovian assumption. Evidence scattered throughout the literature, however, suggests that these two assumptions are far from being realistic. This casts doubts on the reliability of the statistics provided by a multiregional life table, even the most appropriately estimated one.

According to the assumption of population homogeneity, all individuals constituting the radix, or initial cohort, of a multiregional life table have identical demographic characteristics so that the same patterns of mortality and mobility apply to all. In the real world, however, mortality and especially mobility patterns generally vary from one homogeneous subgroup to another. Under these conditions it may be advisable to construct separate multiregional life tables for the mutually exclusive subgroups.

Ledent (1981a), for example, showed that the calculation of multiregional life tables based on interregional mobility data cross-classified by place of birth produces significantly different results than those obtained without such a cross-classification.

He calculated four multiregional life tables for data on the four US census regions observed during the period 1965-1970, one for each regional share of the initial cohort. Since the available mobility data were in the form of counts of migrants, he used the transition-based approach B.

The numerical results obtained by Ledent confirmed the general observation that the probability of moving from region i to region j is smaller for those born in region i and much higher for those born in region j than for those born neither in region i nor in region j.

Total years of expected life--disaggregated into periods specific to the regions in which they are to be spent--were found to be substantially different from the corresponding figures obtained in simple multiregional life table calculations using the same data but aggregated over all regions of birth. According to Ledent's calculations of the US, switching from place-of-birth-independent to place-of-birth-dependent mobility data cuts the proportion of lifetime to be spent outside the region of birth by about half, except in the case of western-born women for whom the cut amounts to slightly more than 70%.

The second important assumption implicit in a Markov chain model is the so-called Markovian property, which holds that the probability of an individual changing states is independent of his or her past mobility history. Obviously this assumption does not adequately reflect reality, especially in the case of geographical mobility. Individuals who have just moved are prone to move again, either to a third region or back to their region of origin. They tend, in consequence, to constitute a pool of "chronic" movers (Morrison 1971).

The Markovian assumption has important consequences for the statistics of a multiregional life table, consequences that are likely to occur between, as well as within, the various age intervals considered. Regarding the impacts *between* the age intervals, we note that the Markovian assumption is used to proceed from one age interval to the next. Therefore, everything else being equal, the degree of error increases with the number of age intervals. To put it in approximate but more revealing terms, the model based on single-year groups (generally 85 such age groups plus one open-ended group 85 and over) uses the Markov assumption 86 times, whereas the model based on five-year age groups (generally 17 such age groups plus one open-ended group of 85 and over) uses it only 18 times. Thus the wider the age interval, the smaller the number of intervals and the smaller the impact of the Markovian assumption.

This conclusion, however, is valid only to the extent that everything else is indeed equal--that is, the age-specific transition probabilities in the models with both one-year and five-year age groups are known exactly. Since this is not the case, we are brought naturally to the second impact of the Markovian assumption, the one *within* age groups.

In this case, we must distinguish between the movement and transition perspectives, which appear to be affected differently. In the movement perspective the estimation equations reflect a mobility process that is close to being Markovian, throughout each age interval, thus giving rise to little return or chain migration. We believe that the estimators of the movement perspective, therefore, fail to account adequately for return migration. In other words, the Markovian assumption tends to inflate migration probabilities and to deflate retention probabilities, a phenomenon that actually is well substantiated in the literature on social mobility (see for example Singer and Spilerman 1978). Moreover, since the importance of return migration and the bias introduced therefrom tend to increase with the length of the observation period, the smaller the age interval, the more accurate the transition probability estimates.

In contrast to the movement perspective, the transition perspective (if correctly implemented) adequately accounts for return and chain migration; this is especially the case in approach B. Moreover, such a statement applies regardless of the choice of the age interval width n, provided that it is equal to the length of the observation period T.

The consequences of violating the equality between age interval and observation period length have been well illustrated by Rees, who analyzes a three-region system of the United Kingdom and a population disaggregated into five-year and one-year age groups. The migration (retention) probabilities obtained using one-year mobility data (Rees 1979a) are substantially higher than those obtained using five-year mobility data (Rees 1979b). In other words, taking $n > T$ rather than $n = T$ leads to transition probabilities that suffer from the same defect as those derived in the movement perspective; they fail to accurately account for multiple movements.

Summarizing, we note that the Markovian assumption affects the movement perspective both within and between age groups, that is, it tends to exaggerate at any single age the probability of transferring to another region. As a result

a. the smaller the age interval width, the more reliable the transition probability estimates, *but*

b. the age interval width has no impact on the reliability of the multiregional statistics relating to an extended period of time (possibly a lifetime)

The transition perspective is affected by the Markovian assumption only at the passage from one age group to the next so that, compared with the movement perspective, it attenuates the stringent consequences of this assumption. Therefore

a. the width of each age interval n has no bearing on the reliability of the transition probability estimators so long as n = T

b. the larger the T (regardless of n), the better the estimates of the multiregional statistics relating to an extended period of time because of the less frequent use of the Markovian assumption when advancing through the age groups

Finally, going one step further, we argue that the availability of mobility data in the count of transitions over a longer period (for example T = 5) necessarily leads to substantially better statistics than the availability of similar data over a shorter period and hence of data in the count of movements (regardless of the length of the observation period). Consequently, it is impossible to carry out a direct comparison of the results obtained in the various national case studies of the CMS project, in which these alternative types of data were used.

7. CONCLUDING REMARKS

A comparative analysis of patterns of migration and population distribution requires comparable data bases and the application of uniform analytical techniques to derive demographic measures that are truly comparable. The CMS study satisfied the second requirement by consistently applying the methods of multiregional demography, which provides the analytical framework needed to integrate migration flows with regional fertility and mortality patterns. This is necessary because population redistribution is not only a consequence of migration; regional differences in fertility and mortality regimes also determine spatial population change. The application of this framework in each of the 17 country studies was made possible by the availability of a standard package of computer programs.

The major obstacle in the CMS study was the inadequacy of the data bases. Data, particularly those describing migration, were incomplete in several countries and were never directly comparable. The problem of incomplete data was resolved by the application of estimation techniques developed for this purpose (Willekens, Pór, and Raquillet 1981), but the limitations in comparability could not be dealt with satisfactorily. Methodological research, which was lacking at the time, has only recently been initiated. As a consequence, cross-national comparisons of the results of the CMS study have been de-emphasized in this paper. Interregional comparisons are drawn instead.

The comparative research revealed the following:

- *Mortality*. Although regional disparities in aggregate levels of mortality, expressed as life expectancies, are small, there are considerable differences in mortality regimes. Large disparities in infant mortality and young adult mortality are evident.
- *Fertility*. Fertility disparities are significant, both in terms of level and age structure. Countries with large regional variations in the levels of fertility also tend to have large regional variations in the age pattern of fertility.
- *Migration*. The comparison of migration levels is impossible unless measures can be developed that remove the effects of variations in reference periods and in sizes of regions. Regional disparities in retention levels confound the effects of regional size and mobility level. The age profile of migration is less affected by differences in spatial and temporal dimensions. Parametrization of migration schedules indicates large regional variations--variations that are not random but that exhibit systematic patterns, which allows the development of synthetic *model* schedules. Families of migration schedules may be distinguished on the basis of the values exhibited by the parameters of such model migration schedules.

A comparative analysis like the CMS study can give the impression (at least to the researchers involved) that it creates more problems than it solves. The application of the improved methodology of multiregional analysis to the conventional data bases that are currently available poses many problems. Because of the methods considered, weaknesses in the data were revealed that otherwise might have remained hidden, thus generating new empirical and methodological research efforts.

A few illustrations of the research generated by the CMS study were presented in the latter half of this paper. Such research has produced several interesting conclusions, which help us to judge the validity and comparability of the various national results and to advise researchers on the appropriate design of future studies of this sort.

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