MIGRATION AND SETTLEMENT:
14. UNITED STATES

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FOREWORD

Interest in human settlement systems and policies has been a central part of urban-related work at the International Institute for Applied Systems Analysis (IIASA) from the outset. From 1975 through 1978 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 dissemination of the Task's results and to the conclusion of its comparative study, which, under the leadership of Dr. Frans Willekens, is focusing on a comparative quantitative assessment of recent migration patterns and spatial population dynamics in all of IIASA's 17 National Member Organization countries.

The comparative analysis of national patterns of interregional migration and spatial population growth is being carried out by an international network of scholars who are using methodology and computer programs developed at IIASA.

Like many countries, the US is experiencing a change in patterns of migration and natural increase. Adopting the traditional US Census Bureau's four-region aggregation, Long and Frey examine the multiregional demographic implications of this emerging spatial reallocation process. Special emphasis is placed on intraregional city–suburb redistribution, and a model is presented, which links such local intraregional shifts with the national interregional redistribution within the US.

Reports summarizing previous work on migration and settlement at IIASA are listed at the end of this report.

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ACKNOWLEDGMENTS

We are especially pleased to have this opportunity to participate in the IIASA Comparative Migration and Settlement Study. This study, which examines the internal redistribution implications of current migration, fertility, and mortality patterns in a consistent and rigorous fashion for each of 17 industrial nations, constitutes a significant milestone in comparative migration research. The international community of demographers owes a great deal to Andrei Rogers and his colleagues for developing and coordinating this important study, as do the authors of each of the 17 national reports.

Our preparation of the United States report was aided immeasurably by several members of the Human Settlement and Services Area staff at IIASA. We are, first of all, indebted to Andrei Rogers and Frans Willekens for developing the user-oriented multiregional computer programs, which form the basis of our section 3 analysis and for their continued assistance throughout the report's preparation. Various aspects of the analysis have benefited from the reactions and suggestions of Jacques Ledent, Dimiter Philipov, Luis Castro, and Kao-Lee Liaw. Finally, we are extremely grateful for the kind cooperation given us by Peer Just in his computer programming efforts, Maria Rogers, our copy editor, and Susanne Stock for her expert typing of the manuscript.

In addition, Dr. Frey wishes to acknowledge support from the Center for Population Research, NICHD, US Department of Health and Human Services (Grant No. HD-10666) for his section 4 and Appendix E analyses of intrametropolitan city–suburb redistribution. Much of this work was performed at the Center for Demography and Ecology, University of Wisconsin–Madison and at the Population Studies Center, of The University of Michigan. Thanks are due to Cheryl Knobeloch of the former institution for programming assistance rendered and to Judy Mullin of the latter for assistance with manuscript preparation.

The foregoing makes clear that this report on United States migration and settlement is a product of the combined efforts of many individuals, whose assistance we gratefully acknowledge. The ultimate responsibility for the report, of course, rests with us.

CONTENTS

1 INTRODUCTION

Settlement patterns and spatial population trends in the United States (US) have probably received more attention in newspapers, on television, and in public discussion over the past decade than in any other period since World War II. Two reasons for the increased popular interest are that (a) migration has become a more important and more highly visible component of population growth or decline in many localities as fertility has fallen to near replacement levels, and (b) some dramatic and largely unanticipated changes in migration patterns occurred causing policy planners, researchers, and others to reassess reasons for moving and locational preferences of individuals.

Some of the recent changes in migration and settlement patterns are the following:

- An accelerated shift of population out of the highly industrialized states in the nation's Northeast region toward the generally less densely settled states of the nation's South and West regions. Much of this movement is to the "Sunbelt", the southernmost tier of states within the South and West regions, but an accelerated search for energy has produced population growth in other areas of these regions as well, especially parts of Alaska (for oil) and coal mining areas in West Virginia and the Rocky Mountains.
- A movement away from large metropolitan areas toward smaller cities, towns, and even distinctly rural areas. This development of net out-migration from large metropolitan areas seems *not* to be simply a "spill-over" of population into settlements just beyond the fringes of metropolitan areas.
- An increased attractiveness of some large cities due to the combination of sustained out-migration from central cities and other developments,

such as a prolonged rise in energy costs. If this is true, then a countercurrent of back-to-the-city movers may be developing.

The substantial migration to the South and West and the net flow of population away from large metropolitan areas have been highly publicized, but in all of the common residential categories – big cities, suburbs, small towns, and rural areas – there has been a trend toward a sharper focus on the dynamics of migration and the concomitants of population growth or decline. Many areas planning for growth (especially the large metropolitan areas) have had to reorient their attention to devising ways of coping with decline. Other areas (especially some small towns) unaccustomed to growth, now find a need to expand public services, like fire protection, and must build schools at a time when other areas are looking for new ways to use school buildings that have been emptied because of falling fertility and out-migration.

Because most long-distance migration streams consist of persons at the prime reproductive ages, in-migration often has a positive effect on an area's fertility in subsequent periods. But the exact relationship varies because some migration streams consist disproportionately of either males or females, have an overrepresentation of retirees, result in extensive return movements, or for some other reason mediate the generally positive association between in-migration and fertility. For the same reason, sustained out-migration often lowers fertility by removing persons at the reproductive ages, thus leaving a relatively old population. In analyzing the intensity of these effects, researchers and policy planners need age-specific data on fertility (births by age of woman), mortality, and migration, along with other socio-demographic data. The methods employed in the national reports of the IIASA Comparative Migration and Settlement Study permit multiregional demographic analyses, which interrelate births, deaths, and internal spatial movements.

The purpose of this report is to illustrate how multiregional demographic methods can shed light on both the short- and long-term redistribution implications of newly emerging patterns of migration and natural increase in the United States. Section 2 provides a general overview of current US redistribution in order to develop a context for the more formal demographic analyses that follow. Section 3 presents analyses consistent in format with the other national reports in the IIASA series. It employs the multiregional techniques and programs, developed by Andrei Rogers and his colleagues, to examine population redistribution across the four US census regions. Section 4 introduces an extension of the multiregional methodology to the intraregional context of city–suburb redistribution in individual metropolitan areas. Presented here are illustrative analyses for one declining US metropolitan area (Pittsburgh) and one fast-growing area (Houston).

2 CURRENT PATTERNS OF SPATIAL POPULATION DEVELOPMENT

Current and newly emerging patterns of spatial population change in the US represent departures from the general redistribution themes that evolved historically as the nation continued to fill in its vast frontier and undergo the transition from an agriculturally based to an industrially based economy.*

The first of these themes is the east to west regional redistribution of the population – a process that has been recorded continuously since the first US census was taken in 1790. Because most Americans are descendants of immigrants who initially settled on the country's East Coast, a dominant current in the nation's development has been the westward expansion and redistribution of its population. Following the Census Bureau's traditional practice of grouping the US into four regions – Northeast, North Central, South, and West (Figure 1) – one finds that in 1850, less than 1 percent of the nation's population resided in the West region (Table 1). This share expanded to 6 percent in 1900, to 13 percent in 1950, to 17 percent in 1970, and to 19 percent in 1980. Hence, although each of the four regions have experienced an absolute growth in population during this period, the more recently developed West region has received the largest

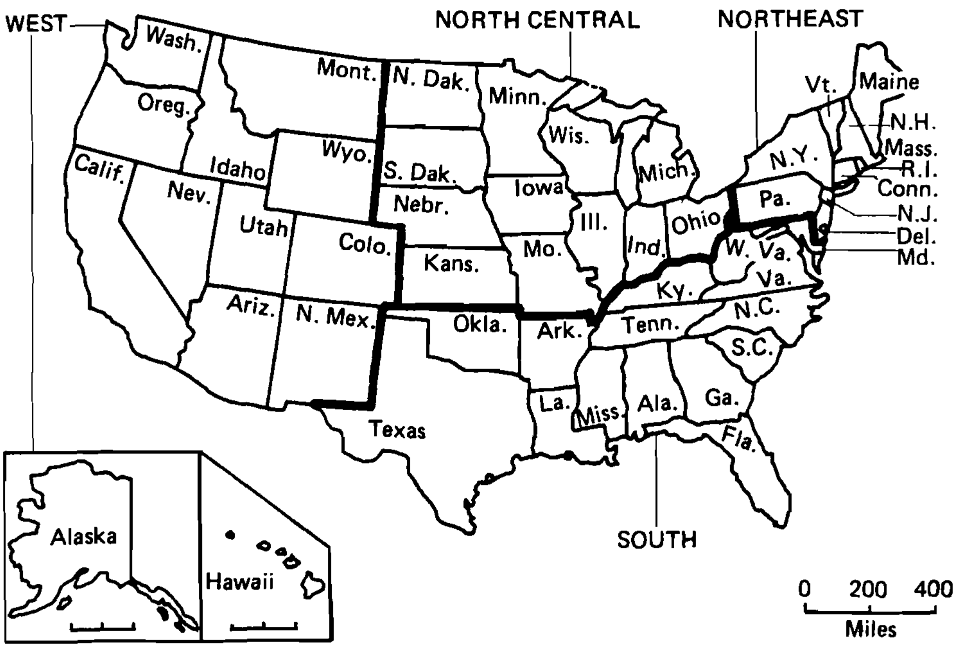

FIGURE 1 Regions and states of the United States.

*For an authoritative discussion on US population redistribution throughout the twentieth century, the reader is referred to Taeuber and Taeuber 1971, Taeuber 1972, and Shryock 1964. The historical statistics cited in this section are drawn from census sources.

TABLE 1 Total US population size and shares among the four regions: selected years between 1790 and 1980.

Total US population and regional shares	Years 1790	1850	1900	1910	1920	1930	1940	1950	1960	1970	1980
Size (in thousands)											
Total US	3929	23193	76213	92229	106022	123203	132165	151326	179323	203212	226505
Population shares											
Northeast	50.1	37.2	27.6	28.0	28.0	28.0	27.2	26.1	24.9	24.2	21.7
North Central	–	23.3	34.6	32.4	32.1	31.3	30.4	29.4	28.8	27.8	26.0
South	49.9	38.7	32.2	31.9	31.2	30.7	31.5	31.2	30.7	30.9	33.3
West	–	00.8	5.6	7.7	8.7	10.0	10.9	13.3	15.6	17.1	19.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

SOURCES: United States Bureau of the Census 1975a, 1979.

share of the nation's growth. This westward redistribution process is obviously a product of both internal and international migrant stream contributions.

A second major theme in the history of American spatial population development has been the increasing metropolitanization of its residents: a continual concentration of population into areas that lie both inside and surrounding the nation's cities. The largest cities, particularly those on the East Coast, have always served as major destinations for immigrants and as a consequence, have grown continuously since the early years of nationhood. However, a more widespread metropolitanization began to take place after the turn of the twentieth century when the transition from a rural–agricultural economy to an urban–industrial economy attracted large streams of rural-to-urban migrants into metropolitan concentrations within each of the four census regions. Officially designated metropolitan areas (referred to as Standard Metropolitan Statistical Areas or SMSAs) include cities with populations greater than 50000 as well as those surrounding counties that are economically and socially linked to that city.* The nation's metropolitan population, then, consists of the sum of all residents in each individual metropolitan area. If constant 1960 metropolitan boundaries are assumed, one finds that only 42 percent of the US population could be classed as metropolitan in 1900, as compared with 59 percent in 1950 and 64 percent in 1970. Although metropolitanization has always been more advanced in the Northeast region, a majority of the residents in all four regions could be classed as metropolitan (using the above definition) by 1970: 78 percent in the Northeast, 61 percent in the North Central, 51 percent in the South, and 74 percent in the West) (Taeuber and Taeuber 1971).

The third significant theme in US spatial population development has been the deconcentration or suburbanization of the metropolitan population from the confines of the legal boundary of the central city to a constantly expanding metropolitan periphery. Improvements in short-distance public transportation, eventual widespread use of the automobile, and a decreasing necessity for industries to locate in the city center have all been cited as explanations for the pervasive suburbanization phenomenon. This changing balance of city–suburban populations is brought about as much by streams of local intrametropolitan "residential" movers, as by streams of long-distance internal migrants or immigrants. Although the exact nature and timing of the suburbanization process varies largely with individual metropolitan areas, aggregate national figures show that central city growth has lagged behind that of suburbs since 1920. Again, holding 1960 metropolitan area boundaries constant, one finds that 62 percent of the total metropolitan population resided in central cities in 1900, as contrasted with 66 percent in 1920, 59 percent in 1950, and only 47 percent in 1970 (Taeuber and Taeuber 1971).

*This definition applies to SMSAs in all states except the New England states of Connecticut, New Hampshire, Maine, Massachusetts, Rhode Island, and Vermont where SMSAs are defined in terms of towns: minor civil divisions that are administratively more important than counties.

Even though population changes in individual regions, metropolitan areas, and central cities were greatly affected by large streams of international migrants, internal migrants, and (in the case of central cities) residential movers, it would be a mistake to discount the role of natural increase components in the nation's spatial population development. For most of the country's history, fertility levels were well above mortality levels, thereby insuring positive rates of natural growth for most of the nation's areas. To be sure, the nation underwent a demographic transition over the course of the nineteenth century when, as a result of lowered fetility and mortality levels, the annual rate of natural increase dropped from 32 per thousand population in the 1810–1820 decade to 13 per thousand population one hundred years later. During the 1930s, lowered fertility reduced the rate of natural increase to 8 per thousand population and there was fear that the nation's population would be headed toward negative natural growth. This fear was averted by the post-World War II "baby boom" when the crude birth rate rose to a peak of 25 per thousand population in 1957, resulting in a rate of natural increase of over 15.

Hence in the 1950s, as in earlier decades, high positive levels of natural increase tended to cancel out population losses that would have otherwise occurred in areas of net out-migration and to augment population gains in areas experiencing net in-migration. During this decade, as over much of the nation's history, virtually all broad areas of the country experienced absolute population growth. The major exceptions were the large, older cities in the Northeast and North Central regions and a number of countries that were highly dependent on agriculture. The population redistribution that resulted from the various migration streams merely served to define the level of absolute growth that would be sustained.

The characterization of US spatial population development as a continual westward expansion, metropolitanization, and suburbanization of a population that is sustaining moderately high levels of natural growth seems appropriate until the mid-1960s. Since that time, there is evidence of a significant reversal in the long-standing pattern of regional and metropolitan redistribution. Moreover, not all central cities are sustaining net out-migration levels since the city–suburb redistribution process differs substantially across regions and individual metropolitan areas. The most significant post-1960s departure from previous demographic trends, however, is the marked decline in national fertility levels. As is shown in Table 2, annual crude birth rates have been declining steadily since the 1960–1964 period, and the 1975–1978 crude birth rate of 15 per thousand population translates into rates of natural growth and overall national growth (which includes the small increase due to immigration) that are less than half the magnitudes observed in the 1950s.

The redistribution implication of these new, lower fertility levels should be plain. Areas of net out-migration, now experiencing lower natural growth, are more likely to sustain absolute population loss, and areas of net in-migration will no longer benefit as greatly from the additional population gains of migrant fertility. In this context of lower fertility, then, the newly observed migration

TABLE 2 Average annual components of change for the total US population: 5-year intervals between 1945 and 1978.

Period	Population at beginning of period (in thousands)	Average annual component rates per thousand mid-period population				
			Natural increase			
		Net growth rate	Rate of natural increase	Crude birth rate	Crude death rate	Net civilian immigration rate
1945–1949	139 767	15.7	14.0	24.1	10.1	1.6
1950–1954	151 135	17.1	15.2	24.8	9.5	1.8
1955–1959	164 588	17.2	15.4	24.8	9.4	1.8
1960–1964	179 386	14.9	13.2	22.6	9.4	1.9
1965–1969	193 223	10.7	8.7	18.3	9.5	2.1
1970–1974	203 849	8.6	6.8	16.2	9.3	1.7
1975–1978	212 748	7.9	6.2	15.0	8.8	1.7

SOURCE: United States Bureau of the Census 1979.

patterns leading to redistribution across regions, metropolitan areas, central cities, and suburbs take on even greater significance than in the past. The following subsections examine each of these recent patterns in turn.

2.1 Regional Population Redistribution

A milestone was reached in 1980 when, for the first time, the US census showed that a majority of the population lived in the South and West regions (see Table 1). This change marks the culmination of a long-term population shift away from the older northern areas where heavy manufacturing is concentrated, to areas of more recent settlement, which contain much of the nation's energy resources. The shift of population toward the South and West has accelerated in recent years as a result of changes in migration patterns, as illustrated in Figure 2, which shows net migration for each of the four major regions from 1880 to 1975. This historical series begins with 1880 because that is about the earliest date for which there are reliable figures on net migration for individual states.*

One of these changes pertain to the Northeast region, which sustained net in-migration from at least 1880 to around 1970. After 1970 the pattern was reversed, as more persons moved *from* than *to* the Northeast between 1970 and 1975. Much of the Northeast's population gain from migration between 1880

*Net migration data up to 1940 were prepared using the census survival rate method of estimation (Shryock et al. 1971); after that date, the estimates of net migration are from application of the residual method (simply subtracting natural increase from total population change and attributing the difference to net migration). The entire series is presented in order to illustrate that recent changes reflect an alteration in long-standing trends.

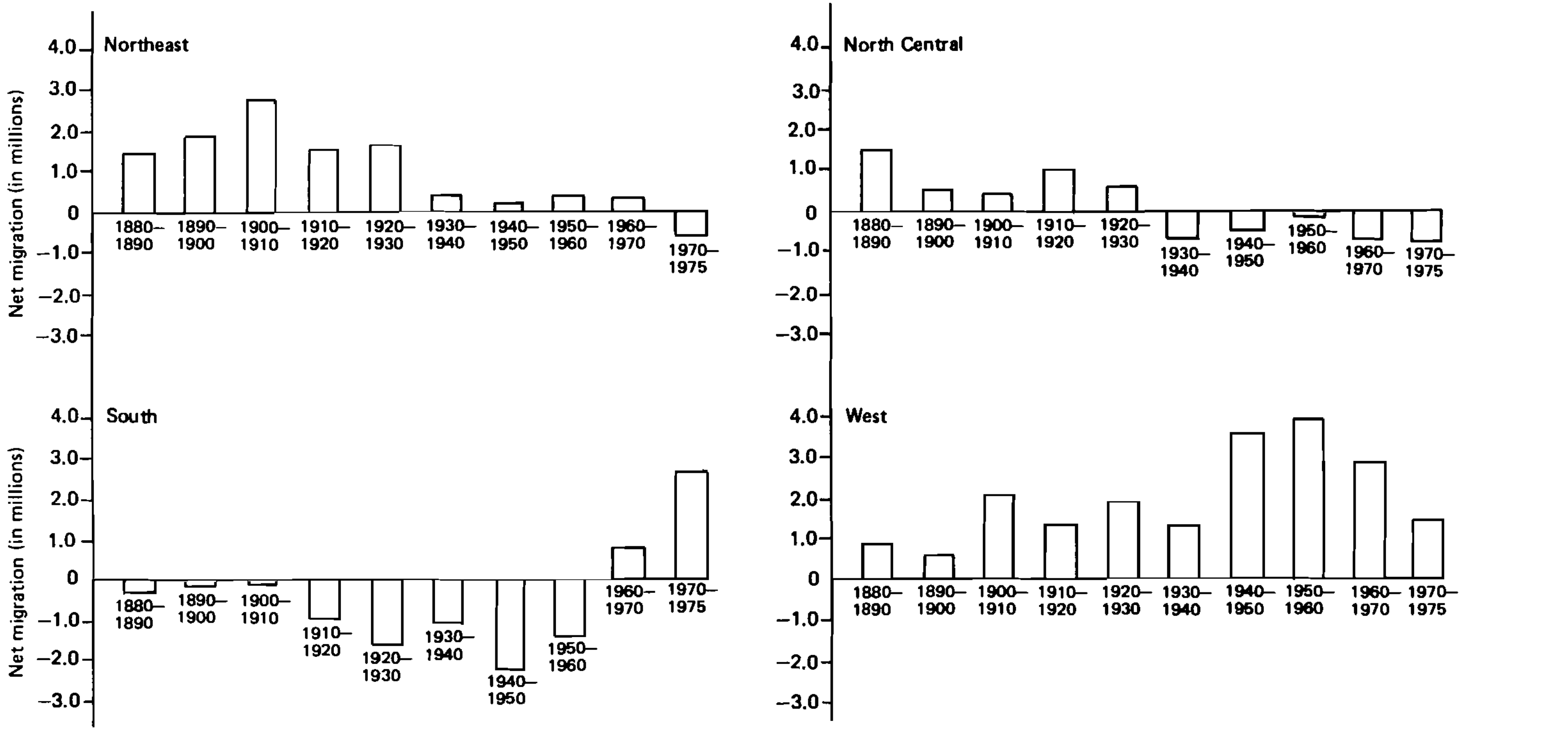

FIGURE 2 Net migration for the four major regions of the United States: 1880–1975. Sources: Data for 1880–1950 are from Eldridge and Thomas 1964; data for 1950–1960 are from Bowles and Tarver 1965; data for 1960–1970 are from Bowles et al. 1977; and data for 1970–1975 are from the United States Bureau of the Census 1976.

and 1930 was immigration from Europe, which was reduced through legislation passed in the 1920s in the United States. After 1930 the Northeast's net in-migration was comprised increasingly of migrants from other regions of the US, especially black migrants from the rural South. In fact, in spite of harsh economic and social discrimination and limited employment opportunities, relatively few blacks left the South until around the time of World War I and especially after the cessation of European migration. As long as the need for labor in northern factories was met by immigrants, few blacks left the South, and in this way immigration appears to have restricted the internal redistribution of the labor force during the late nineteenth and early twentieth centuries. The recent reversal to net out-migration from the Northeast, in part, reflects a shift of the US economy away from heavy manufacturing and the concomitant demand for labor – a shift that also explains the increased net out-migration from the North Central region.

The other major region to experience a marked change in migration patterns in recent years is the South. Historically a low-income region of small farms and small towns, the South experienced net out-migration from at least 1880 (and probably earlier) until the 1960s. The net in-migration that first characterized the South in the 1960s accelerated in the 1970s. In the first half of the latter decade the South gained over three and one-half times as many new residents through migration as during the entire decade of the 1960s. Because of this unexpectedly large volume of in-migration, the South gained more new residents than the West – historically the nation's high-growth region.

Hence the major changes in regional migration patterns have involved the Northeast's transition to net out-migration and the South's change to substantial net in-migration in the 1970s. The West continues to gain population through migration, as it has since at least 1880, but its net gain was down in the 1970s, and the clear suggestion is that more of the out-migration from the Northeast and North Central regions is now going to the South rather than to the West.

The data in Table 3 provide some indication of how the current lower levels of natural increase are interacting with changing migration patterns to affect net population change across regions. Only in the South can one observe an

TABLE 3 Average annual components of change for populations of the four US regions: 1960–1970 and 1970–1977.

	Average annual component rates per thousand mid-period population					
	Net growth		Natural increase		Net migration	
Region	1960–1970	1970–1977	1960–1970	1970–1977	1960–1970	1970–1977
Northeast	9.3	0.7	8.5	4.1	0.8	–3.4
North Central	9.1	3.4	10.5	6.6	–1.4	–3.2
South	13.2	15.0	12.2	7.7	1.0	7.3
West	21.3	17.3	12.3	8.7	9.0	8.6

SOURCE: United States Bureau of the Census 1979.

increase in the annual rate of growth between 1960–1970 and 1970–1977. However, this 1.8 increase in the growth rate masks a +6.3 change in the net migration rate coupled with a −4.5 change in the rate of natural increase. The Northeast experienced a decrease in the rate of growth from 9.3 to 0.7. Yet while the direction of net migration to this region reversed from positive to negative, better than half this decrease is attributable to a lower natural increase. A continuation of these trends suggests the likelihood of lower rates of growth for the nation's West and South coupled with little, or perhaps even negative, growth for the Northeast region. In section 3, we return to a more rigorous examination of the implication that currently observed demographic change components hold for future population redistribution across the US regions.

2.2 *Metropolitan–Nonmetropolitan Population Redistribution*

Perhaps the most surprising recent change in US redistribution patterns has been the post-1970 reversal in the long-standing metropolitanization in the US population. Beginning in 1973 and continuing to the present, Census Bureau population estimates have shown that the nation's aggregate metropolitan area (the sum of all the individual SMSAs), when defined by a constant set of boundaries, has been growing slower than its nonmetropolitan area since the 1970 census (Beale 1975, Morrison and Wheeler 1976). Also since that time, the metropolitan US has been sustaining net out-migration to the nonmetropolitan US.

This break with previous patterns was first thought to be a consequence of an outdated and too narrow definition of the nation's metropolitan area. Because US counties continue to become added to the nation's metropolitan area as new SMSAs come into existence and old SMSAs expand, it was felt that most of the new growth recorded as "nonmetropolitan" was actually occurring in counties that would soon be added to the metropolitan area. This explanation has been generally proved false by data showing that population growth and in-migration are occurring not only in nonmetropolitan counties that lie adjacent to existing metropolitan areas (these counties being the most likely candidates for inclusion in a new, extended redefinition of the metropolitan area), but also in nonmetropolitan counties that are *not* adjacent to existing metropolitan areas. These data, shown in Table 4, discredit the spillover hypothesis, which claims that nonmetropolitan growth was occurring entirely in territories contiguous to metropolitan areas.

Moreover, the faster rate of population growth in nonmetropolitan countries is observed even when metropolitan area boundaries are updated to 1980 (Long and De Are 1980). The net shift of population growth to nonmetropolitan areas accelerated during the 1970s, being somewhat greater in 1974–1978 than in 1970–1974 (Long and De Are 1980).

The only consensus regarding explanations for the change in US redistribution patterns is that no single factor is fully responsible. Instead, a number of factors are customarily cited. One is simply the decentralization of employment.

TABLE 4 Population and net migration for counties classified according to metropolitan and nonmetropolitan status: 1960–1970 and 1970–1976.

	Population					Net migration			
	Number (in thousands)			Percent change		1960–1970		1970–1976	
Area	1960	1970	1976	1960–1970	1970–1976	Number (in thousands)	Rate[a]	Number (in thousands)	Rate[a]
Total United States	179 323	203 301	214 658	13.4	5.6	3 001	1.7	2 800	1.4
Metropolitan counties[b]	127 191	148 877	155 901	17.0	4.7	5 959	4.7	545	0.4
Nonmetropolitan counties	52 132	54 424	58 757	4.4	8.0	–2 958	–5.7	2 255	4.1
Adjacent counties[c]	26 116	28 033	30 433	7.3	8.6	–705	–2.7	1 328	4.7
Nonadjacent counties	26 016	26 391	28 324	1.4	7.3	–2 253	–8.7	928	3.5

[a] Net migration expressed as a percent of the population at the beginning of the period.
[b] Metropolitan status as of 1974.
[c] Nonmetropolitan counties adjacent to Standard Metropolitan Statistical Areas.
SOURCE: Taken from Census Bureau estimates by Calvin Beale in a statement before the House Select Committee on Population, February 8, 1978.

Employers can encounter cost savings by relocating in nonmetropolitan areas where both taxes and labor costs are relatively low. More and more small towns can offer the facilities needed to support small plants and their workers, partly through subsidies from the federal government to construct municipal water systems, sewage disposal facilities, highways, and other aspects of "infrastructure". In particular, the completion in the 1970s of the Interstate Highway System, financed almost entirely by the federal government, has probably hastened the decentralization of employment. Better highways also allow workers to commute longer distances, even allowing more nonmetropolitan residents to work in metropolitan areas.

Another employment-related explanation of population growth in nonmetropolitan areas is the renewed search for energy. Increased demand for coal has helped the South's West Virginia shift from massive out-migration in the 1960s and earlier decades to net in-migration in the 1970s. Exploitation of coal deposits has also produced explosive growth in a number of small towns in the West.

A third factor accounting for population growth in the nonmetropolitan sector is the increase in retirement and recreational pursuits. More people have been retiring at younger ages, and with life expectancy rising slightly, more active years can be spent away from employment centers and in scenic locations. Furthermore, the development of recreational facilities in rural areas – especially around dams and lakes, many of which were built with federal money – has provided employment opportunities for persons living in such areas or wanting to live there. Second homes also allow for leisure activities to be located in isolated areas and have been increasing in number.

The final major explanation for the surge of population growth in nonmetropolitan locations is the possibility of a change in individuals' preferences or an increased willingness to act on the basis of desires for low-density residential environments. With rising per capita income, smaller household size, and an extension of many types of social benefits (like pensions) to larger segments of the population, there may be less incentive to choose jobs that maximize income. Instead, more people may be able and willing to trade income for a chance to live where they want.

These four sets of explanations suggest a variety of motives and a fairly wide demographic base characterizing the new migrants to nonmetropolitan areas and "new nonmigrants" (persons who would have moved to metropolitan areas if past patterns had continued). These considerations suggest that the current population shift toward nonmetropolitan areas can continue even in the face of countervailing forces, such as rising energy prices and sluggish economic growth.

Although it is clear that nonmetropolitan counties in all regions are now experiencing a surge of growth (Beale and Fuguitt 1978), recent shifts in population change are by no means uniform across categories of metropolitan areas. It is apparent from Table 5, which shows 1960–1970 and 1970–1977 components of change for region and metropolitan size (using the 1970 metropolitan definition), that the post-1970 reversal to metropolitan net out-migration is evident only in metropolitan area categories in the Northeast and North Central regions.

TABLE 5 Population shares and average annual components of change by region and metropolitan size for the four regions and total US: 1960–1970 and 1970–1977.

Region and metropolitan size	Population shares			Average annual component rates per thousand mid-period population: Net growth		Natural increase		Net migration	
	1960	1970	1977	1960–1970	1970–1977	1960–1970	1970–1977	1960–1970	1970–1977
Northeast									
Large metropolitan	58.9	59.0	57.5	9.5	–3.1	8.6	4.0	0.9	–7.1
Other metropolitan	27.5	27.6	28.0	9.7	2.8	8.7	4.2	1.0	–1.4
Nonmetropolitan	13.6	13.4	14.5	8.1	12.0	7.8	4.3	0.3	7.7
Total	100.0	100.0	100.0						
(Pop. in thousands)	(44 678)	(49 061)	(49 299)						
North Central									
Large metropolitan	38.9	39.9	38.9	12.0	–0.2	11.7	7.6	0.3	–7.8
Other metropolitan	29.1	30.2	30.5	12.7	5.0	11.9	7.8	0.8	–2.8
Nonmetropolitan	32.0	29.9	30.6	2.3	6.5	7.6	4.6	–5.3	1.9
Total	100.0	100.0	100.0						
(Pop. in thousands)	(51 619)	(56 593)	(57 941)						
South									
Large metropolitan	18.6	21.8	22.1	28.9	16.8	12.6	8.1	16.3	8.7
Other metropolitan	41.0	41.9	42.2	15.6	16.2	12.9	8.5	2.7	7.7
Nonmetropolitan	40.4	36.3	35.7	2.6	12.9	10.4	6.5	–7.8	6.4
Total	100.0	100.0	100.0						
(Pop. in thousands)	(54 961)	(62 812)	(69 849)						
West									
Large metropolitan	45.2	46.6	43.7	24.6	7.7	11.6	7.3	13.0	0.4
Other metropolitan	32.9	34.1	36.0	25.3	24.8	13.2	9.9	12.1	14.9
Nonmetropolitan	21.9	19.3	20.3	8.6	24.7	12.2	9.5	–3.4	15.2
Total	100.0	100.0	100.0						
(Pop. in thousands)	(28 053)	(34 839)	(39 263)						
Total US									
Large metropolitan	38.6	40.1	38.6	16.2	3.4	10.7	6.2	5.5	–2.8
Other metropolitan	33.0	33.8	34.7	15.2	12.5	11.8	7.8	3.4	4.7
Nonmetropolitan	28.4	26.1	26.7	3.9	12.3	9.4	6.0	–5.5	6.3
Total	100.0	100.0	100.0						
(Pop. in thousands)	(179 311)	(203 305)	(216 351)						

SOURCE: United States Bureau of the Census 1979.

Moreover, it is the largest SMSAs (those with 1970 populations of 1.5 million or more) that contribute most significantly to this pattern. The metropolitan areas in the South and West regions sustained net in-migration during 1970–1977, and in both regions annual rates for this period actually exceeded those for 1960–1970 for metropolitan areas with under 1.5 million population.

It should be emphasized that region- and size-specific rates reflect regional aggregations of 243 individual metropolitan areas (see Figure 3) and, therefore, do not characterize variations in these patterns for individual SMSAs within regions. It would also be unwarranted to conclude that the large SMSAs are the sole contributors to the post-1970 metropolitan–nonmetropolitan growth reversal because the net rates shown here merely summarize the outcome of the migration streams that flow between pairs of region-size classes for each period. What these net rates do indicate is that the nationwide upsurge in nonmetropolitan growth rates is not brought about by an equally pervasive pattern of metropolitan decline. The interlinkages are more complex and require examination of the experiences of individual SMSAs and gross migration streams. Frey's (1979b) study of selected 1955–1960 and 1965–1970 migration streams, suggests that metropolitan to nonmetropolitan reversal is not new for many individual SMSAs. The largest Northeast and North Central SMSAs have experienced net outmigration since the mid-1950s.

Finally, it is worth emphasizing that these new metropolitan–nonmetropolitan migration patterns, such as the regional patterns discussed earlier, are operating in the context of lower natural increase. In spite of this, nonmetropolitan areas in all four regions displayed higher annual rates of net growth in the 1970–1977 period than during the 1960–1970 period because the increases in net in-migration rates outweighed the decreases in rates of natural increase (see Table 5). Just the opposite is true for all metropolitan categories except southern metropolitan areas under 1.5 million population, and as a result the largest metropolitan areas in the nation's Northeast and North Central regions sustained absolute population losses in the 1970–1977 period.

2.3 City–Suburb Population Redistribution

Despite a half century of city–suburb population deconcentration and, in the case of some older cities, more than two decades of absolute population loss, it is now being speculated that central cities will become more attractive to a broader segment of the metropolitan population. The reasoning goes somewhat like this (Long 1980): first, some large US cities continued to appeal to young people throughout the 1950s and 1960s, having a net in-migration of persons between 18 and 25 years of age. Since this age group has been increasing in recent years – as the baby boom cohort of the late 1940s and early 1950s matures into adulthood – the 20- to 30-year-old population of cities is actually increasing. Since the presence or impending presence of children was in the past a strong inducement to move from cities to suburbs, the low fertility of this cohort may reduce

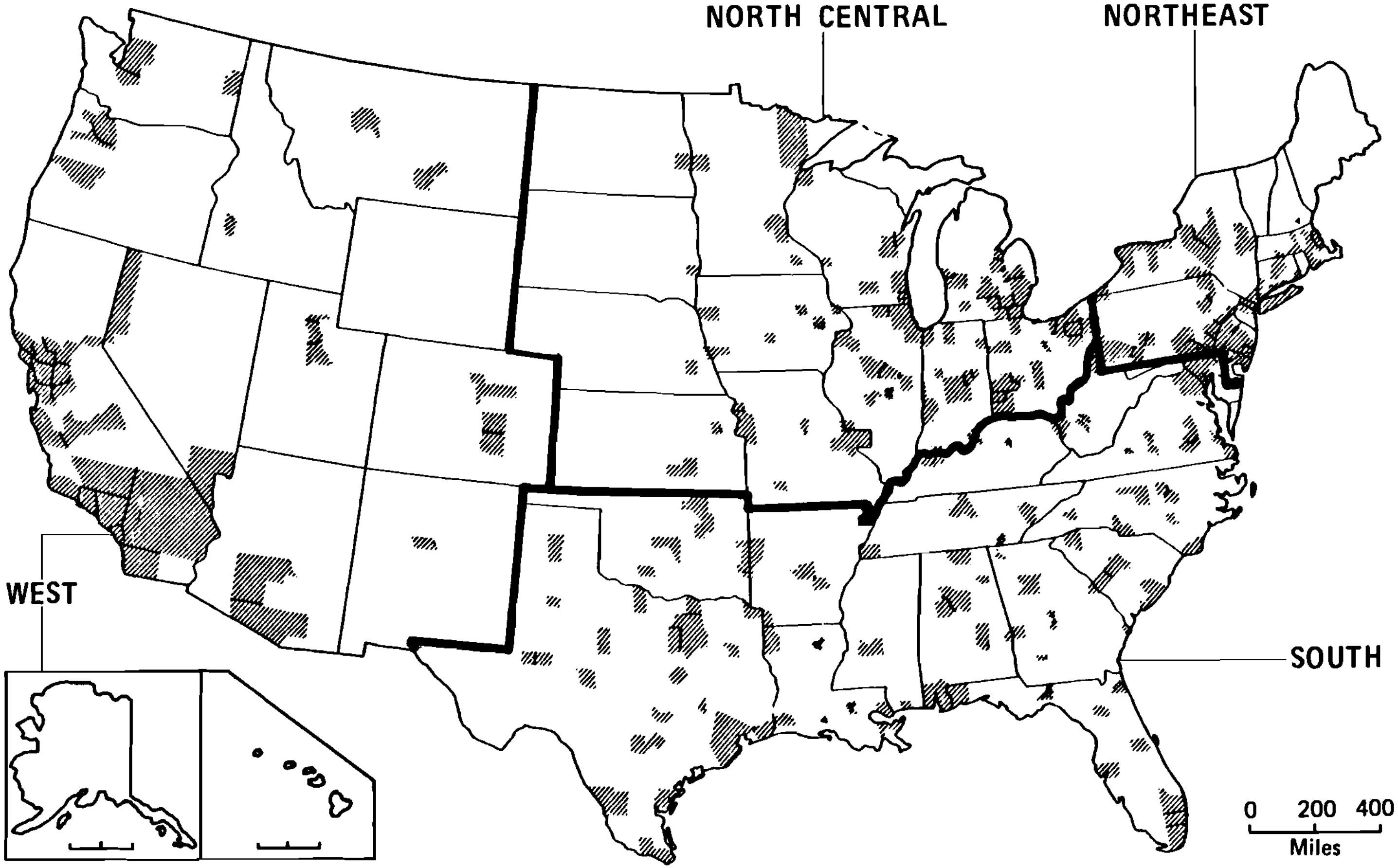

FIGURE 3 Standard Metropolitan Statistical Areas of the United States: 1970.

some of the pressure to move to the suburbs. Another factor that may keep more people in cities is the growing incidence of two-earner couples, and when both husband and wife are commuting to work, there can be a saving of time and money in a central residential location.

More households may also be induced to live in cities as a result of the enactment of growth-limiting policies in the suburbs, a reaction to very rapid growth in the past. Growth-limiting policies can include refusal to extend water and sewer lines to new housing developments, refusal to grant building permits to large apartment buildings, and rules requiring any new homes to be built on large lots. Such policies can make suburban housing expensive, and the cheaper, smaller townhouses in cities may become more appealing simply as a result of declining household size. Finally, the energy shortage may also be cited as a possible inducement to suburbanites to "return to the city".

Speculation along these lines is plausible and appears to be quite widespread, but there is little evidence to support the notion of a pervasive back-to-the-city trend that is large enough to affect city populations. In fact, 1980 census results indicate that America's older, larger central cities generally lost population more rapidly in the 1970s than in the 1960s, as indicated in Table 6.

One cannot help being struck by high rates of population decrease. For example, St. Louis, Cleveland, and Detroit each lost at least 20 percent of their population between 1920 and 1980. The city of St. Louis has lost nearly one-half of the peak population it reached in 1950, and it now has shrunk to its 1890 population. The city of Cleveland has lost 37 percent of its population since 1950 and has shrunk to what its population was around the time of World War I. Detroit, home of the US automobile industry, has lost 35 percent of its peak population, which was reached in 1950, and now has about as many residents as it did in the 1920s.

Up to the present each of the above three cities has tended to have growing suburbs with population increases great enough to offset declines in the central city, and in this way their metropolitan areas continued to register population growth. In the 1970–1980 decade, however, a change occurred. For the metropolitan areas of St. Louis, Cleveland, Detroit, and a number of other cities, population growth in the suburbs was no longer great enough to offset decline in the central city. The result was that entire metropolitan areas shifted to population decline. As can be seen in Table 6, the population of the St. Louis metropolitan area declined by 2.3 percent between 1970 and 1980, after growing by 12.4 percent in the 1960–1970 decade. The Cleveland metropolitan area population declined by 8 percent in the 1970s, after growing by 8 percent in the 1960s. The metropolitan areas of Detroit, Philadelphia, Boston, Milwaukee, and New York City each declined in population in the 1970s after having grown in the 1960s. Clearly, population decline has come to encompass a number of metropolitan areas in the US.

Moreover, the area of population loss seems to be spreading outward from many central cities and encompasses a ring of "inner suburbs" that lie along city boundaries. Ten of the 11 cities included in Table 6 have a ring of inner suburbs that collectively declined in population between 1970 and 1980. In the 1960s only two of these cities had inner suburban rings that declined in population. In some cases the transition of these inner suburbs from growth to decline was even more sudden than the cities' change from growth to decline.

These and other 1980 census data (see Spain 1981) show that a back-to-the-city trend was not of sufficient magnitude to slow rates of loss in any large city in the Northeast or North Central regions where the trend was thought to be especially pronounced. The data suggest a spreading of population loss outward from America's older industrial cities, and the metropolitan areas associated with these cities may be thought of as a doughnut whose hole – the area of population loss – is getting bigger. Results of the 1980 census have indicated that population loss is spreading to some cities in the South and West, and one reason for the spread and acceleration of population loss in large central cities is that blacks are now leaving cities in larger numbers than ever before (Long and De Are 1981).

It should be noted, however, that several large and medium-sized metropolitan areas in the South and West regions continue to grow and exhibit distinctly different internal redistribution patterns. Between 1970 and 1980, the central city population of the Houston SMSA increased 29 percent, while its entire SMSA population increased 45 percent. Comparable figures for the Anaheim–Santa Ana–Garden Grove SMSA are 24 and 36 percent, and for the Phoenix SMSA they are 31 and 55 percent. These are examples of metropolitan areas that have developed more recently, have lower population densities, and are able to annex additional territory to their central city areas. The central cities in these SMSAs share in the metropolitan growth and expansion and as a result are less differentiated from surrounding suburbs in terms of population and housing characteristics.

From an analytic standpoint, it is important to realize that the net migration experienced by a central city and its suburbs is the product of both long-distance in- and out-migration streams and intrametropolitan residential mobility streams. Because older northern central cities are located in metropolitan areas that are increasingly sustaining net out-migration and population losses, any return-to-the-city movement must necessarily involve the attraction of residential movers from the suburbs. Growing southern and western cities, on the other hand, can afford to lose residential movers to their suburbs since the high levels of in-migration to the entire SMSA will compensate for this loss. In section 4 we examine the implications that long-distance migration and residential mobility stream contributions hold for future city–suburb redistribution in one declining (Pittsburgh) and one growing (Houston) SMSA.

TABLE 6 Population change in the central city and the inner and outer suburban jurisdictions of 11 metropolitan areas (SMSA boundaries as of January 1, 1980 are used): 1960–1970 and 1970–1980.

Metropolitan area	Population			Percent distribution of population			Percent change in population	
	1960	1970	1980	1960	1970	1980	1960–1970	1970–1980
St. Louis	2 144 205	2 410 884	2 355 276	100.0	100.0	100.0	12.4	−2.3
St. Louis city	750 026	622 236	453 085	35.0	25.8	19.2	−17.0	−27.2
Inner suburbs[a]	269 011	256 840	217 733	12.5	10.7	9.2	−4.5	−15.2
Remainder of metro. area	1 125 168	1 531 808	1 684 458	52.5	63.5	71.5	36.1	10.0
Cleveland	1 909 483	2 063 729	1 898 720	100.0	100.0	100.0	8.1	−8.0
Cleveland city	876 050	750 879	573 822	45.9	36.4	30.2	−14.3	−23.6
Inner suburbs	520 757	599 404	531 878	27.3	29.0	28.0	15.1	−11.3
Remainder of metro. area	512 676	713 446	793 020	26.8	34.6	41.8	39.2	11.2
Detroit	3 949 720	4 435 051	4 352 762	100.0	100.0	100.0	12.3	−1.9
Detroit city	1 670 144	1 514 063	1 203 339	42.3	34.1	27.6	−9.3	−20.5
Inner suburbs	794 796	904 896	792 528	20.1	20.4	18.2	13.9	−12.4
Remainder of metro. area	1 484 780	2 016 092	2 356 895	37.6	45.5	54.1	35.8	16.9
Pittsburgh	2 405 435	2 401 362	2 263 894	100.0	100.0	100.0	−0.2	−5.7
Pittsburgh city	604 332	520 089	423 938	25.1	21.7	18.7	−13.9	−18.5
Inner suburbs	410 913	434 994	395 834	17.1	18.1	17.5	5.9	−9.0
Remainder of metro. area	1 390 190	1 446 279	1 444 122	57.8	60.2	63.8	4.0	−0.1
Washington, D.C.	2 096 662	2 910 111	3 060 240	100.0	100.0	100.0	38.8	5.2
Washington city	763 956	756 668	637 651	36.4	26.0	20.8	−1.0	−15.7
Inner suburbs	438 859	514 427	448 373	20.9	17.7	14.7	17.2	−12.8
Remainder of metro. area	893 847	1 639 016	1 974 216	42.6	56.3	64.5	83.4	20.5

Philadelphia	4 342 897	4 824 110	4 716 818	100.0	100.0	100.0	11.1	−2.2
Philadelphia city	2 002 512	1 949 996	1 688 210	46.1	40.4	35.8	−2.6	−13.4
Inner suburbs	642 430	698 061	665 263	14.8	14.5	14.1	8.7	−4.7
Remainder of metro. area	1 697 955	2 176 053	2 363 345	39.1	45.1	50.1	28.2	8.6
Boston	2 688 083	2 899 101	2 763 357	100.0	100.0	100.0	7.9	−4.7
Boston city	697 197	641 071	562 994	25.9	22.1	20.4	−8.1	−12.2
Inner suburbs	663 262	657 097	606 006	24.7	22.7	21.9	−0.9	−7.8
Remainder of metro. area	1 327 624	1 600 933	1 594 357	49.4	55.2	57.7	20.6	−0.4
Kansas City	1 108 620	1 273 926	1 327 020	100.0	100.0	100.0	14.9	4.2
Kansas City	475 539	507 330	448 159	42.9	39.8	33.8	6.7	−11.7
Inner suburbs	164 105	268 362	286 504	14.8	21.1	21.6	63.5	6.8
Remainder of metro. area	468 976	498 234	592 357	42.3	39.1	44.6	6.2	18.9
Milwaukee	1 278 850	1 403 884	1 397 143	100.0	100.0	100.0	9.8	−0.5
Milwaukee city	741 324	717 372	636 212	58.0	51.1	45.5	−3.2	−11.3
Inner suburbs	252 328	294 902	285 706	19.7	21.0	20.4	16.9	−3.1
Remainder of metro. area	285 198	391 610	475 225	22.3	27.9	34.0	37.3	21.4
Chicago	6 220 913	6 974 755	7 102 328	100.0	100.0	100.0	12.1	1.8
Chicago city	3 550 404	3 369 357	3 005 072	57.1	48.3	42.3	−5.1	−10.8
Inner suburbs	736 425	882 621	824 156	11.8	12.7	11.6	19.9	−6.6
Remainder of metro. area	1 934 084	2 722 777	3 273 100	31.1	39.0	46.1	40.8	20.2
New York City	9 539 655	9 973 716	9 119 737	100.0	100.0	100.0	4.6	−8.6
New York City	7 781 984	7 895 563	7 071 030	81.6	79.2	77.5	1.5	−10.4
Inner suburbs (NY State only)	431 771	447 376	416 131	4.5	4.5	4.6	3.6	−7.0
Remainder of metro. area	1 325 900	1 630 777	1 632 576	13.9	16.4	17.9	23.0	0.1

[a]Those suburbs that lie adjacent to the central city.

SOURCES: 1960, 1970 US Census of Population and unpublished 1980 census data.

3 MULTIREGIONAL POPULATION ANALYSIS

In this section, several elements of multiregional demographic analysis, as developed by Rogers (1975), are brought to bear on one aspect of US population change: redistribution across the four census regions, based on demographic components observed during a single year, 1970. While these techniques, in principle, can be applied to any regionalization scheme that exhausts the nation's population and area, the census four-region scheme constitutes a relatively parsimonious one that distinguishes geographic areas settled at different stages of the nation's historical development – areas that continue to reflect distinctly different patterns of population growth and decline. The focus on demographic components for the year 1970 is also significant. As discussed in section 2, components of interregional population change in the decade of the 1970s depart significantly from those evident up through the mid-1960s. The following multiregional analyses, therefore, will serve to point out demographic consequences for life histories of cohorts and redistribution across regions implied by these "new" components of regional population change.

The results presented below are derived from three distinct elements of multiregional demography: the multiregional life table, multiregional population projection and stability, and spatial fertility and mobility analysis. Each of these constitutes extensions of corresponding single-region demographic analysis techniques, and statistics for each can be derived from given age schedules of *region*-specific fertility, mortality, and out-migration to other regions (Rogers 1975). Subsequent to his theoretical formulation Rogers, along with a team of scholars at IIASA, has developed a package of user-oriented computer programs, which produces statistics for each element of multiregional demographic analysis, based on any given set of region- and age-specific demographic rates (Willekens and Rogers 1978). The analyses that follow, like those of the other national reports in this series, are based on computations from the IIASA computer programs.*

3.1 The Data

The most desirable demographic information for calculation of the observed rates required for a multiregional analysis would be region- and age-specific data for births (by age of mother), deaths, and internal moves of a single sex (or each sex) for the year of observation, as well as an estimate for the corresponding total resident populations at the middle of the year (Willekens and Rogers 1978). For US regions in 1970, appropriate data for births and deaths are available from the National Center for Health Statistics, and the occurrence of the decennial US census on April 1, 1970 provides a reasonably close estimate of the total mid-year populations by age and sex.

*The authors are grateful to Andrei Rogers and Frans Willekens for their assistance in producing the results for this section.

A complete record of interregional moves on a yearly basis is, unfortunately, impossible in the United States because there does not exist a population register. It was decided, therefore, to estimate the number of 1970 interregional moves using unpublished data from the US Census Bureau's Current Population Surveys taken in March, 1968, 1969, 1970, and 1971. These annual surveys query respondents on their place of residence exactly 1 year prior to the survey and provide crude estimates of the number of yearly moves out of each region (not counted are return moves and multiple moves during the same year as well as moves made by individuals who died during the year). Although the number of respondents in a 1-year survey constitutes too small a sample for an aggregate estimation, the combining of males with females across 4 survey years provides a sufficient basis to estimate the average number of age-specific moves out of each region in a given year (around 1970). The pooling of males with females, however, forces us to perform multiregional analyses for the total population rather than for a single sex.

As a source of reference for the interested reader, observed raw data are given in Appendix A and corresponding age-specific rates for regional fertility, mortality, and out-migration are presented in Appendix B. It is instructive to examine some summary measures for these 1970 regional demographic components, in light of trends discussed in the previous section. The crude birth rates for each region (shown in column (1) of Table 7) lie between the "high" levels of 20–25 births per thousand population observed in the 1950s and the "low" level of about 15 evident in the late 1970s (see Table 2). The observed 1970 crude birth rates range from 16.9 in the Northeast region to 19.2 in the South. However, observed age-specific rates – the rates upon which the multiregional analysis will be based – vary somewhat less across regions. This is implied by the relatively narrow interregional variation in gross reproduction rates (a measure that is not affected by regional age composition differences), which show levels to be highest in the North Central region and lowest in the West.

TABLE 7 Regional fertility and mortality differentials of the four US regions: 1970.

Region	Crude birth rate (per thousand)[a] (1)	Gross reproduction rate[b] (2)	Crude death rate (per thousand)[c] (3)	Gross death rate[d] (4)	Life expectancy[e] (5)
Northeast	16.9	1.24	10.2	2.44	71.0
North Central	18.4	1.30	9.6	2.38	71.3
South	19.2	1.27	9.5	2.34	69.9
West	18.8	1.22	8.3	2.22	71.8

[a]Total births for year per thousand midyear population.
[b]Sum of age-specific fertility rates multiplied by age interval (5).
[c]Total deaths for year per thousand midyear population.
[d]Sum of age-specific death rates multiplied by age interval (5).
[e]Life expectancy e_0 computed from respective single-region life tables (Appendix B.2).

Observed regional levels of mortality generally conform to levels registered in the post-World War II period. As with the crude birth rates, regional variation in crude death rates (shown in column (3) of Table 7) are reduced when regional differences in age composition are eliminated. The gross death rate varies between 2.22 and 2.44 and the life expectancy (based on calculations of a single-region life table for each region) varies between 69.9 and 71.8.

Of particular importance for a multiregional demographic analysis are the observed regional out-migration rates. (The reader is reminded that this analysis is confined to internal migration and excludes international migration.) Observed 1970 out-migration rates for the total population (Table 8) appear to be consistent with the post-1970 pattern of negative net migration for the Northeast region discussed in section 2. The 1970 rates show the Northeast as the least

TABLE 8 One-year out-migration rates (per thousand) between the four US regions: 1968–1971 (averaged).

	Region of destination				
Region of origin	Northeast	North Central	South	West	Total
Northeast	–	3.5	7.7	3.8	15.0
North Central	2.5	–	9.3	6.4	18.2
South	4.8	7.7	–	7.5	20.0
West	3.3	7.3	10.3	–	20.9

SOURCE: Compiled from the United States Census Bureau's Population Surveys (March) 1968, 1969, 1970, 1971 (unpublished).

attractive destination for out-migrants from the remaining three regions. On the other hand, the South constitutes the most attractive destination among migrants not born in the South, attracting greater than half the out-migrants from each of the other three regions. It should be noted that when the observed rates are applied to the *actual* 1970 populations of each region, the resulting net migration rates (per thousand population) are −3.6, −2.1, +0.1, and +8.2 for the Northeast, North Central, South, and West regions, respectively. The strong net in-migration to the South, which is evident over most of the 1970s (see Table 3), is not yet evident in these rates. Of course, the multiregional analyses that follow (with the exception of the projection analysis) are dependent on only the observed *rates* and not on the observed 1970 *populations*.

To sum up, the observed 1970 rate schedules for fertility, mortality, and migration represent a transition between the regional demographic components operating before 1965 and those that characterize the late 1970s. They indicate relatively low levels of fertility and mortality coupled with a general redistribution out of the nation's North and North Central regions and into the Sunbelt (the South and West regions). However, the extremely low fertility levels of the late 1970s and the increased attractiveness of the South *vis-à-vis* the West are not yet implied by these rates.

3.2 The Multiregional Life Table

The multiregional life table generates a particularly useful set of statistics that show the implications of observed regional mortality rates for the life histories of cohorts: age-specific probabilities of survival *and regional location* and the expected number of years that will be lived *in each region.* The methodology parallels that of a single-region life table, which translates an observed schedule of age-specific death rates into statistics on age-specific survival and life expectancy.

In the single-region case, an initial hypothetical cohort of 100000 births is subjected to a set of age-specific mortality rates that can be computed from an observed schedule of death rates. The derived survival probabilities and life expectancy estimates are therefore based on the assumption that cohort members surviving to a given age will be subject to mortality rates consistent with those in the observed schedule at that age. In the multiregional life table *each region* is given an initial, hypothetical cohort of 100000 babies, which is then subjected to rates of mortality and out-migration compiled from the observed schedules of death rates and migration rates. Consequently, the derived survival and life expectancy statistics assume that a region's initial cohort, surviving to a given age *and located in a given region* will be subject to rates of mortality *and out-migration* consistent with those in the observed schedule of that age *and region.*

The multiregional life table, like the single-region table, is comprised of a series of "functions" that can be used to derive a wide array of useful measures and indices. We focus here on selected derived life-table statistics that provide insights into the implications of the 1970 regional schedules on cohort mortality and migration rates.

To what extent will individuals born in the Northeast region redistribute themselves across other regions, and at what stages of their lives will it be likely that this redistribution will take place? Answers to such questions for each region can be gleaned from the statistics shown in Appendix C.1 (expected number of survivors at exact age x). Assuming that 100000 babies are born in each region, this table shows how many of them still are alive and their regional location at subsequent ages (in 5-year intervals). One can then compute a cohort member's probability of surviving and residing in a given region at a given age by dividing the corresponding number of survivors by 100000.

Presented in Table 9 are selected probabilities illustrating how likely it is that members of each region's initial cohort will be located in that same region

TABLE 9 Probabilities (proportions) of surviving at exact age 20, 35, and 65 in the region of birth for the four US regions.

	Region of birth			
Probability of surviving to age:	Northeast	North Central	South	West
20	0.719	0.677	0.658	0.654
35	0.480	0.458	0.437	0.416
65	0.302	0.290	0.305	0.270

at ages 20, 35, and 65. The broad pattern shows that about two-thirds of each region's original cohort resides in the same region at age 20. This proportion changes to below half at age 35, and by age 65 less than one-third of the original cohort's members reside in their region of birth.

The regional differences within these broad patterns are most noteworthy here. We see that of the four regions, it is the Northeast that tends to retain the greatest proportion of its initial cohort at age 20 and 35 – and to an appreciably greater degree than the South or West. The West, in fact, retains the least proportion of its initial cohort members at all three ages. One would not intuitively expect such results on the basis of known net migration levels for each region in the year of observation. How is it that individuals born in the "declining" Northeast show a greater probability of living in their region of birth at practically all ages (according to Appendix C.1) than individuals born in the "growing" West? Further insights into this apparent inconsistency can be derived from another set of life-table statistics – those on expectations of life by region of birth.

The complete age-disaggregated tables for life expectancy by region of birth are given in Appendix C.2. This table shows for a given region of birth and for a given age (in 5-year intervals) the number of remaining years a person can expect to live in each of the four regions. For example, a Northeast-born individual of age 20 can expect to live 53.2 more years: 25.9 of which will be in the Northeast, 7.6 in the North Central, 12.2 in the South, and 7.5 in the West. Perhaps the most useful measure that can be derived from this table is the expected number of years lived in each region for each region of birth. These data are reproduced in the first part of Table 10. In the second part, proportional allocations of life expectancy are compiled, which indicate what proportion of their lifetimes individuals born in a given region can expect to live in each of the four regions.

TABLE 10 Expectations of life and allocations of life expectancies by region of birth for the four US regions.

	Region of birth			
Expected residence in region	Northeast	North Central	South	West
Expectations of life (in years)				
Northeast	41.7	5.8	7.7	6.6
North Central	8.2	39.9	11.9	11.6
South	13.2	14.7	39.5	15.2
West	8.0	10.7	11.3	37.7
Total	71.1	71.1	70.5	71.1
Proportional allocations of life expectancy (in percent)				
Northeast	59	8	11	9
North Central	12	56	17	16
South	18	21	56	22
West	11	15	16	53
Total	100	100	100	100

Three main generalizations can be gleaned from these tables: (1) an individual born in each of the regions can expect to live more than half of his lifetime in that region, (2) individuals not born in the South can expect to spend more years of their lives in the South (between 13 and 15 years) than in any other region outside of their region of birth, and (3) individuals born outside the Northeast can expect to spend fewer years in the Northeast region (less than 5) than in any other region outside the region of birth. Again, we note the greater lifetime "retention" of individuals born in the Northeast than those born in the South or West. This seeming inconsistency with observed migration rates, however, can in part be resolved by observing the generalizations (2) and (3) above.

Although the Northeast retains more of its birth cohort's lifetime than any other region, it constitutes the region of fewest years' residence for individuals born in other regions. In a like manner, both South and West regions are the expected location of residence for disproportionate shares of other regions' birth cohort's lifetimes, whereas they are less successful than the Northeast or North Central regions in retaining their own cohorts. These observations point out the utility of computing multiregional life tables since such generalizations pertaining to cohort life histories are not intuitively apparent when examining age-specific mobility schedules themselves.

It should further be noted that the multiregional life table provides a more refined estimation of *total* life expectancy than a single-region estimate, because it attributes region-specific mortality levels for years lived in each given region. Such an application is not very significant for the analysis of the four US regions because, as discussed earlier, there is little regional variation in age-specific mortality levels. It is, nevertheless, instructive to contrast region-of-birth-specific total life expectation values as calculated from the multiregional life table (in Table 10) with those values calculated from the single-region table (in Table 7). This comparison shows that the multiregional calculations have virtually eliminated regional disparities that existed in the single-region tables. Only South-born individuals (with a 70.5 life expectancy) diverge from the 71.1 life expectancy calculated for individuals born in the other three regions. The largest discrepancy between the two sets of expectancies is shown for individuals born in the West – the region with the highest single-region life expectancy (71.8). The comparable statistic from the multiregional calculation is 0.7 years lower than from the single-region tables, which implies that out-migration for West-born individuals will tend to lower slightly the life expectancy.

Finally, we make reference to still another useful cohort-based statistic that can be derived from the multiregional life table: the expected number of remaining years lived by region of residence. The complete age-disaggregated tables for these statistics are given in Appendix C.3. They are similar in format to the life expectancy by region of birth tables (Appendix C.2) and show for a given region of *residence* at a given age (in 5-year intervals) the number of remaining years an individual can expect to live in each of the four regions. To illustrate the utility of these statistics we reproduce in Table 11 the expected number of remaining years lived by individuals that reside in each region at age 20.

TABLE 11 Expectations of remaining life (in years) by region of residence at exact age 20 for the four US regions.

	Region of residence at exact age 20			
Expected remaining residence in region	Northeast	North Central	South	West
Northeast	33.2	3.9	5.5	4.6
North Central	5.2	31.7	8.3	7.9
South	9.5	10.2	31.4	10.8
West	5.4	7.6	7.8	30.2
Total	53.2	53.4	53.0	53.5

It is clear from this table that the region of residence at age 20 has a strong influence on an individual's residence experienced over the remainder of his lifetime. Twenty-year-old residents in each region can expect to live in that same region for greater than 60 percent of the remainder of their lives. It is also interesting to note that Northeast *residents* at age 20 are expected to live 33.2 of their remaining 53.2 years in that region whereas (as cited earlier) Northeast-*born* individuals at age 20 are expected to live only 25.9 of their remaining years in that region. Similar results for the other ages and regions suggest that for purposes of predicting future residence in the region beyond a given age, the knowledge of where a person is living at that age is better than knowing where he was born.

We can also make generalizations from the Table 11 data on current region of residence (at age 20) that are similar to those from the data on region of birth. The South and Northeast constitute "most likely" and "least likely" alternatives, respectively, for residence outside the current region (for non-South residents). Nevertheless, 20-year-old residents of the Northeast are expected to live more remaining years in their current region than 20-year-old residents in any of the other regions. This reflects a "retaining power" particular to the Northeast region, which is exerted both on individuals born there and individuals who eventually locate there during their lifetime.

3.3 Multiregional Population Projection and Stability

We turn now from a focus on what the observed rates imply for cohorts to what they imply for regions. Perhaps the most practical application of the multiregional demographic techniques presented here will result from the population projection analyses. Once again one can draw an analogy between the methodology for single-region cohort component projections based on rate schedules for a given period and those for the multiregional case.

Single-region cohort component projections typically begin with the region's population disaggregated by 5-year age categories at the "starting" year. To this population are applied age-specific 5-year survival rates, usually estimated from the region's life table, to estimate the survived population 5 years later. The number of individuals in the first (0–4) age group is projected by applying the region's observed age-specific fertility rates to the estimated number of females in the childbearing ages during the projection period and surviving the births to the end of the period. If the population is not disaggregated by sex, the number of women in each age group 10–14 to 45–49 are estimated by applying age-specific sex ratios to the corresponding total populations in these age groups. The process is repeated over as many 5-year periods as desired.

The multiregional cohort component projections begin with age-disaggregated populations *for each region* at the starting year. Applied to these are age- *and region*-specific rates of 5-year survival and out-migration to each other region where these rates are derived from the multiregional life table. Projecting the number of individuals for the first (0–4-year-old) age group is also analogous to the single-region case. Here age- *and region*-specific fertility rates are employed along with *region*-specific survival rates. The multiregional projections given in this report start with actual 1970 regional age distribution. Rates of survival and out-migration are based on the multiregional life table discussed earlier, and age-specific fertility rates are those shown in Appendix B.1.

The complete set of US regional population projections for 5-year intervals between 1970 and 2020 can be found in Appendix D. Presented there for each region are projected population totals by age, in addition to several summary statistics, including the median age in each region and period rate of growth. Our text discussion will focus on two aspects of these projections: changes in total regional size and changes in regional population shares over the period 1970–2020. We emphasize that these projections are intended to show what observed 1970 rates of migration, mortality, and fertility imply for future regional population change and hence do *not* represent a *forecast* of future changes.

According to these projections, the total US population will increase 59 percent between 1970 and 2020: from 203 million to 322 million. Yet the level of increase differs among the four regions in the study. The West, which constituted the smallest region (in population) in 1970, exhibited the fastest projected rate of growth (98 percent) adding 35.4 million to its 34.8 million 1970 population. The South, the largest 1970 region, was projected to increase its 1970 population of 62.8 million by 37.8 million or 60 percent over the 50-year period. The North Central region registers a slightly lower level of increase – 53 percent – thus increasing its 1970 population of 56.6 million to 86.7 million in 2020. It is only the Northeast that exhibits a level of increase (32 percent) that stands significantly lower than the rest of the country. Its 1970 population of 49 million is projected to grow to 65 million.

Figure 4 shows graphically the period-by-period population growth in each of the four regions. The slower rate of growth observed for the Northeast region is particularly evident in this figure, which indicates that after the year 2000, the Northeast will surpass the West as the region with the smallest total population. These projected trends should not be too surprising in light of the observed

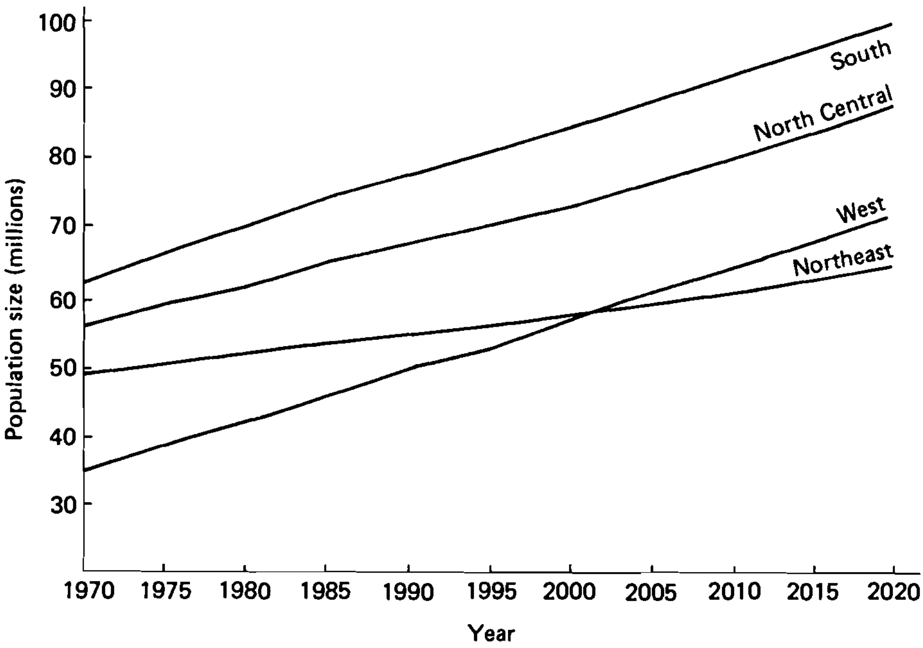

FIGURE 4 Projections of population sizes for the four US regions: 1970–2020.

1970 migration rates that imply greatest growth for the West and least growth for the Northeast (see Table 8). The small observed regional differences in fertility and mortality levels are much less significant in accounting for projected regional sizes of populations.

Multiregional projections also permit us to examine how the regional shares of the US population might be expected to change over the 1970–2020 period, assuming observed 1970 rates. The data in Table 12 indicate significant shifts in the share of only two regions: the Northeast and West. The 1970 share of the

TABLE 12 Projected US population size and shares among the four regions: 10-year intervals between 1970 and 2020.

Total US population and regional shares	Years 1970	1980	1990	2000	2010	2020
Size (in thousands)						
Total US	203 212	225 016	248 617	270 681	295 996	321 970
Population shares						
Northeast	24.1	22.9	21.9	21.1	20.6	20.2
North Central	27.9	27.4	27.2	27.0	27.0	26.9
South	30.9	31.1	31.1	31.2	31.1	31.1
West	17.1	18.6	19.8	20.7	21.3	21.8
Total	100.0	100.0	100.0	100.0	100.0	100.0

former region, 24.1 percent, becomes gradually reduced to 20.2, whereas that of the latter region is increased from 17.1 to 21.8 percent. Less significant is the decline in the North Central region from 27.9 to 26.9 percent.

Perhaps the most remarkable finding here is the relatively constant share projected for the South region – varying only 0.3 percent over the entire 50-year period. This may appear to contradict observed 1970 out-migration rates (Table 8), which showed the South to constitute the most popular destination for out-migrants from the other three regions. It should be recognized, however, that the initial population of the South was the largest of the four regions. What the projections tell us is that the observed levels of migration between all regions (as reflected in the projected survival and out-migration rates) do not result in a net gain in that initially large South region's share. Of course, we might speculate that projections based on observed rates from the late 1970s (when they become available) would indicate increasingly greater shares for the South region's population. Nevertheless, even the present projections establish the continued supremacy of the South in terms of population size. The next largest region – the North Central – has been declining in its relative share, and the only region increasing its share over time – the West – holds an appreciably smaller share of the total population than the South.

One further methodological link can be established between single-region cohort component projections based on constant rate schedules of fertility and survival on the one hand and multiregional projections based on constant schedules of fertility, mortality, and out-migration on the other. It has long been established that the repeated projection of a single-region age distribution will yield, at some point, a *stable population* that will retain a constant age distribution and a constant period rate of growth when projected further. In a like manner Rogers (1975) has shown that the repeated projections of the multiregional population will yield an analogous *multiregional stable population* that will retain, upon further projection, a constant age *and region distribution* and a constant rate of growth *for each region*. In the stable population, these distributions and growth rates will not depend on the "starting" population of the projection but only on the fertility, survival, and out-migration rates used in the projection process.

It is useful to examine the regional shares in the stable population implied by the observed 1970 rates: Northeast 18.8, North Central 27.1, South 31.1, and West 23.0. These rates can be obtained from the stable equivalent population shown in Appendix D. This is the total population that, if distributed as the stable population, would increase at the same rate as would, in the long run, the observed population under projection.

The stable equivalent regional shares, like the ones projected for 2020, differ significantly from the 1970 shares for only the Northeast and West regions. The shares of these regions are almost reversed, with the Northeast region share changing from 24.1 to a stable equivalent of 18.8 and the West region share from 17.1 to 23.0. The stable share for the South suggests remarkable consistency – differing from its 1970 counterpart by only 0.2. Despite this compatibility of stable and 1970–2020 projected shares, the stable regional growth rate of 7.3 over a period is not within the ranges shown for any region over the initial 50 years. The Northeast region's 5-year rate ranges from 4.2 to 6.8, whereas all of the other region–period rates lie between 7.8 and 19.0.

3.4 Multiregional Fertility and Migration Measures

The traditional, single-region net reproduction rate (NRR) encapsulates an extraordinary amount of information about a population's age-specific mortality and fertility levels into a single index, which indicates how well a hypothetical cohort, experiencing these levels, is able to reproduce itself (i.e., a value of 1.0 or greater indicates replacement). This well-known measure, compiled solely from given schedules of age-specific fertility and mortality rates, can be generalized to the multiregional context to produce comparably calculated indexes of fertility and migration. The fertility index – the *spatial* net reproduction rate – is calculated separately for each region. It indicates the number of babies that will be born to a member of a *region-born* cohort, subjected to given age- *and region-specific* schedules of fertility, mortality, *and out-migration* rates. This index can be further decomposed to show what portion of the (region-born) cohort's lifetime reproduction takes place in each of the other regions. As with the nonspatial NRR, a value of 1.0 or greater signals replacement.

The spatial net reproduction rates for the four US regions are shown in the first part of Table 13, along with corresponding nonspatial net reproduction

TABLE 13 Spatial net reproduction rates and net reproduction allocations for the four US regions.

	Region of birth of parent			
Region of residence of parent	Northeast	North Central	South	West
Net reproduction rates				
Northeast	0.74	0.09	0.13	0.10
North Central	0.13	0.74	0.21	0.20
South	0.20	0.23	0.70	0.24
West	0.12	0.16	0.18	0.65
Total	1.19	1.22	1.22	1.19
(Nonspatial NRR)	(1.19)	(1.24)	(1.21)	(1.17)
Net reproduction allocations				
Northeast	63	8	11	9
North Central	11	60	17	17
South	16	19	57	20
West	10	13	15	54
Total	100	100	100	100

rates.* Because the spatial NRR for a region-born cohort reflects exposure to different region-specific fertility and mortality rates (resulting from interregional migration) whereas the nonspatial NRR assumes the fertility and mortality rates for that region only, comparison between the two rates indicates the influence of migration on a region-born cohort's replacement capacity. It is not surprising to find that migration tends to moderate extreme regional reproduction levels as measured by the nonspatial NRR. While the nonspatial NRR from the "high fertility" North Central is computed as 1.24, its corresponding spatial value falls to 1.22. The "low fertility" West's nonspatial NRR of 1.17 climbs to 1.19 when migration is taken into account. Hence, although the range of nonspatial NRRs across regions is not very wide (0.07), it virtually disappears when the spatial NRRs are considered.

The allocation of reproduction across the four regions (second part of Table 13) closely parallels the allocation of its life expectancy (second part of Table 10) for cohorts born in each region. Only in the two northern regions do we find a slightly greater tendency to reproduce in the region of birth, than to live in that region, suggesting that those years lived in other regions tend to be concentrated in the post-reproductive portion of the life cycle.

Just as the spatial net reproduction rate constitutes a refined measure of the number of lifetime births occurring to a member of a region-born cohort, a comparable index – the spatial net migraproduction rate (NMR) – constitutes an equally refined measure of the number of moves a region-born cohort member can expect to make. A region's spatial NMR value indicates the total number of interregional moves a member of a region-born cohort can expect to undertake over the course of a lifetime if subjected to given age- and region-specific schedules of fertility, mortality, and out-migration rates. As with the spatial NRR, the total index value can be decomposed to reflect the portion of these moves that originated from each region.

Net migraproduction rate values, both spatial and nonspatial, for cohorts born in the four US regions are shown in the first part of Table 14. According to the spatial NMRs, West-born individuals undertake the greatest number of lifetime interregional moves (1.27) while Northeast-born residents move the least often (1.09 times). The NMRs for individuals born in the South and North Central regions are 1.24 and 1.20, respectively. The gap between the highest (West) and lowest (Northeast) regions is only slightly more accentuated when nonspatial NMRs are compared (1.33 versus 1.02), indicating that rates of out-migration from the region of birth strongly influence the total number of expected lifetime moves.

It is important to emphasize that the analysis of lifetime number of moves, as measured by the spatial NMR, provides information on the occurrence of migration as an *event*. This stands in contrast to the earlier analysis of expected

*As strictly defined the net reproduction rate should be computed from schedules that apply only to the female population (Shryock et al. 1971). Since the data employed here combine both sexes, however, the spatial and nonspatial net reproduction rates presented in this report are computed from the age-specific schedules of mortality, fertility, and migration in Appendix B.

TABLE 14 Spatial net migraproduction rates and net migraproduction allocations for the four US regions.

	Region of birth			
Region of out-migration	Northeast	North Central	South	West
Net migraproduction rates				
Northeast	0.66	0.07	0.10	0.08
North Central	0.12	0.74	0.18	0.17
South	0.19	0.22	0.78	0.23
West	0.12	0.17	0.18	0.79
Total	1.09	1.20	1.24	1.27
(Nonspatial NRR)	(1.02)	(1.20)	(1.26)	(1.33)
Net migraproduction allocations				
Northeast	61	6	8	6
North Central	11	62	15	14
South	17	18	62	18
West	11	14	15	62
Total	100	100	100	100

number of years lived in each region: a measure of duration of stay. An examination of the spatial net migraproduction allocation (second part of Table 14) makes clear that these two types of measures do not necessarily exhibit the same tendencies. We find that despite a significant variation in total expected lifetime moves across region-born cohorts, the *share of total moves that originate from the region of birth* remains almost constant (61–62 percent) for individuals born in each region. In the earlier analysis of life expectancy allocations (lower portion of Table 10), it was found that the *share of total years lived in the region of birth* was smaller for individuals born in the West (53 percent) than for those born in South (56 percent), North Central (56 percent), or Northeast regions (59 percent). Because West-born individuals migrate out of their birth region at earlier ages than individuals born in other regions (Table 9), they accumulate fewer initial, and hence total, years lived in their region of birth.

3.5 Place-of-Birth-Dependent Multiregional Analyses

The previous sections have highlighted various elements of multiregional population analysis that can be undertaken with age schedules of region-specific fertility, mortality, and out-migration rates observed for a single period. This analysis of the four US regions has illustrated how the multiregional techniques can provide insights into cohort life histories and regional population change that are not possible from a mere inspection of the observed rates schedules. It has also shown how the multiregional framework allows the computation of more refined counterparts to standard demographic measures (such as the life expectancy at birth, or the net reproduction rate) based only on fertility and mortality schedules for a single region.

Yet it is necessary to point out that the multiregional analysis framework, as set out above, is also limited by the nature of its assumptions and data base. Perhaps its most limiting assumption for the analysis of migration is its Markovian assumption: that an individual's rate of interregional migration is dependent only on his current region of residence and his age and is independent of his mobility history or residence at a previous point in time (including region of birth). This assumption, which also applies to rates of fertility and mortality, is necessitated by the nature of the data upon which the model is based – period demographic rates classed by age and region of residence at the beginning of the period. However, it is a particularly tenuous assumption to impose upon migration rates. Given the vast literature on the topics of return migration, repeat migration, and duration of residence effects (see Lee 1974, Goldstein 1958, 1964, Taeuber et al. 1968, Morrison 1971, Toney 1976), it is safe to assert that the rate of out-migration from a region is not indifferent to an individual's previous residence history.

A more refined schedule of rates that can sometimes be computed from available population census or survey information is a schedule of period interregional migration rates disaggregated by age, region of residence at the beginning of the period, *and* region of birth. Such a disaggregation, based on US census data, was compiled for Long and Hansen's (1975) study of migration streams between the South region and the non-South (the sum of Northeast, North Central, and West regions) over two periods: 1955–1960 and 1965–1970. For this analysis, out-migrants from the non-South were disaggregated into two groups: (1) those born in the South or "return migrants" and (2) those born in the non-South. Out-migrants from the South were similarly disaggregated. The two rates of out-migration from the non-South are shown in Figure 5 and from the South in Figure 6.

These data are useful in showing that the South's change from net out-migration in 1955–1960 to net in-migration in 1965–1970 was the product of simultaneous declines in *both* rates of out-migration from the South (persons born in the South and those born elsewhere but living in the South) and increases in *both* rates of out-migration from the non-South (i.e., South return migrants and persons born outside the South).

Further, the data illustrated in Figures 5 and 6 show distinct age curves associated with different types of migration. For example, the rate of out-migration from the non-South of persons not born in the South reaches a peak at ages 20 to 24 (age after migrating) and then falls until it starts to rise again after ages 45 to 54. The continued rise at ages 55 to 64 and 65 and over reflects a tendency of non-South-born individuals to move to the South at the time of retirement or, apparently, in anticipation of retirement.

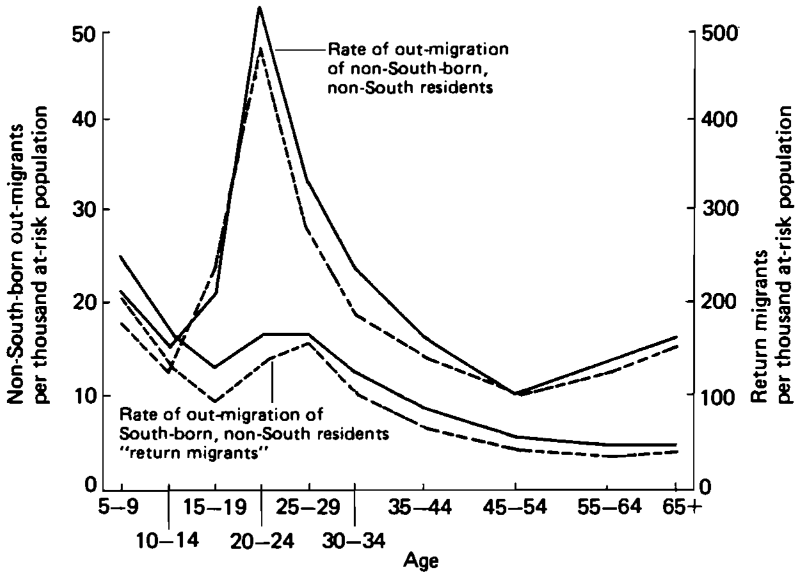

FIGURE 5 Changes between 1955–1960 (– – –) and 1965–1970 (——) in rates of out-migration from the non-South among persons born in the South (right-hand scale) and persons born in the non-South (left-hand scale) by age. Source: Adapted from Long and Hansen 1975, p. 610.

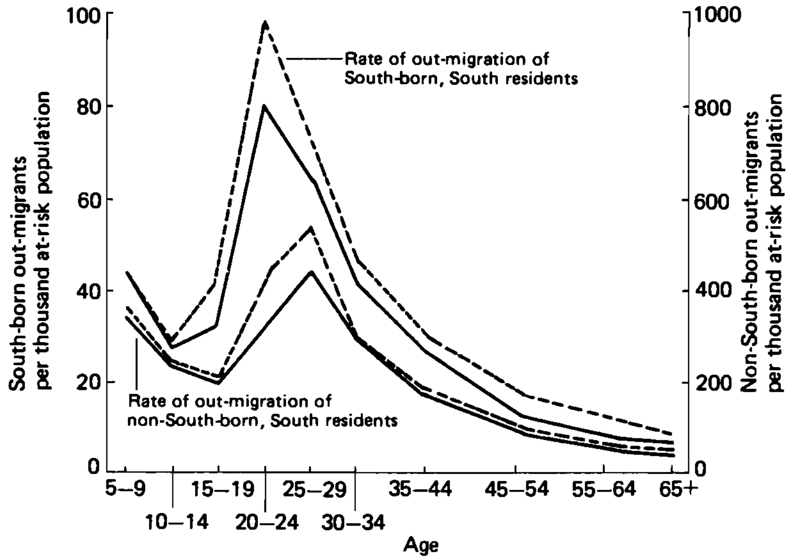

FIGURE 6 Changes between 1955–1960 (– – –) and 1965–1970 (——) in rates of out-migration from the South among persons born in the South (left-hand scale) and persons born in the non-South (right-hand scale) by age. Source: Adapted from Long and Hansen 1975, p. 610.

The age curve associated with rates of return migration to the South is different. The probability of going back to the South reaches a peak at ages 5 to 9 and again at ages 20 to 24 and 25 to 29. In other words, the people who are most likely to move back to the South during both periods of time are parents with young children. Among potential returnees, there is little increase in the probability of returning to the South upon reaching retirement; the failure of the rate of return migration to rise at age 65 is contrary to expectations. It should be pointed out, however, that the number of retirement-age returnees to the South is probably rising at the present time, a reflection (perhaps it should be called an echo) of the massive out-migration from the South in the 1940s (refer to Figure 2). The many people who left the South in the 1940s were probably in their twenties when they left and are now in their sixties. Many may be pulled back to their region of birth because of its relatively low living costs, warm climate, and the presence of friends and relatives.

These findings from the Long and Hansen (1975) analysis demonstrate the utility of separating return migrants from non-return migrants in an examination of interregional migration flow rates, based on data that are generally collected in population censuses and surveys. While this illustration deals only with two regions (the South and non-South), it is possible to generalize the analysis to several regions and disaggregate each interregional migration stream by all regions of birth.

Recent work by IIASA scholars has shown how these more-refined migration data can be incorporated into the various elements of multiregional population analysis illustrated earlier in this section. Ledent (1980a) has constructed a life table from data similar to those used by Long and Hansen (1975), which allows interregional migration rates to be dependent on region of birth as well as region of residence. Aside from permitting more refined calculations of the life table statistics that were discussed earlier, this place-of-birth-dependent life table provides additional information not available with the place-of-birth-independent life table.

Presented in Table 15 is an example of one statistic unique to the place-of-birth-dependent life table: expectations of remaining years lived at a given age

TABLE 15 Expectations of remaining life (in years) for the South region's female residents at exact age 20, according to place of birth.

	Region of residence at exact age 20: South			
Expected remaining residence in region	Born in Northeast	Born in North Central	Born in South	Born in West
Northeast	25.3	2.1	1.5	1.6
North Central	3.4	25.8	3.2	3.4
South	22.1	20.1	49.3	16.4
West	5.5	8.8	2.6	36.1
Total	56.3	56.8	56.6	57.5

SOURCE: Ledent 1980a, Table 4.

by region of residence *and by region of birth*. These data, drawn from Ledent's (1980a) treatment, show the expected remaining years lived for South-born females at exact age 20, disaggregated by the region of their birth. According to this table, South-born, South-resident 20-year-old females are expected to live significantly more years in the South than are comparably aged South region residents born in other regions. In fact, those born in each of the other regions are expected to live more remaining years in their regions of birth than in the South – their current region of residence.

While the standard place-of-birth-independent multiregional life table permits calculation of separate tables of life expectancy by region of birth (e.g., Table 10) and life expectancies by region of residence (e.g., Table 11), it does not allow the cross-classification just discussed. The significance of this refinement is pointed out by referring to our earlier observation (based on Tables 10 and 11) that knowing a person is resident in a region at a given age is better than knowing he was born in that region when predicting future residence in that region. It is clear from the data shown in Table 15, however, that it is far better still to know both pieces of information than either one in isolation. (The reader should bear in mind that Ledent's (1980a) analysis is based on females only and estimated from migration tabulations in the 1970 US census. While this differs from the data base employed in the analyses in section 3.2, the disparity in data sets should not affect the conclusion drawn here.)

The place-of-birth-dependent approach as set out by Ledent (1980a) can be incorporated in other elements of the multiregional population framework as well (see Philipov and Rogers 1980 for an extension to multiregional population projections). Such extensions provide a practical means of modifying the somewhat limiting Markovian assumption in the standard multiregional model in an analysis of generally available migration data.

4 INTRAREGIONAL POPULATION ANALYSIS: CITY–SUBURB REDISTRIBUTION

This section examines population redistribution between central cities and suburbs within individual US metropolitan areas (SMSAs) based on an analytic framework advanced by Frey (1978, 1979a, forthcoming). Formulated in this manner, city–suburb redistribution constitutes a special case of *intraregional* population redistribution, which can be linked to the Rogers (1975) multiregional analysis framework if metropolitan areas (rather than census regions) are considered as regional units in a nationwide system of regions. This analysis will focus on city–suburb redistribution in two metropolitan areas – the Pittsburgh SMSA and the Houston SMSA – whose 1965–1970 experiences exemplify the different metropolitan redistribution patterns reviewed in sections 2.2 and 2.3. The former represents a declining industrial metropolitan area that sustains net out-migration for the SMSA as a whole, in addition to considerable redistribution out of its central city. The latter is a large, fast-growing Sunbelt metropolitan area enjoying a large amount of net in-migration at the metropolitan level as well as a growing suburbanization within the boundaries of the SMSA. What follows is a discussion of the utility of examining city–suburb redistribution as a consequence of both interregional migration and intraregional residential mobility streams (section 4.1) and a presentation of cohort component projections for the cities and suburbs of Pittsburgh and Houston consistent with Frey's (forthcoming) projection methodology (sections 4.2 and 4.3).

4.1 Interregional Migration and Intraregional Mobility Streams

Any classification of movement streams as either interregional or intraregional draws directly from definitions of the regions themselves. In the analysis in section 3, where each of the four census regions consisted of groupings of states, a move from the state of Alaska to the state of New Mexico would not be classed as an interregional move despite the vast distance traversed. This and many more moves, however, would be counted if each of the 50 states were considered as separate regions. The choice of regional units is an important one in any given application of multiregional demographic analysis and should be based, in part, on spatial units that are meaningful for the migration process itself.

This consideration underlies Frey's (1978) framework, which attributes central city population change to two distinct types of movement streams: (a) inter-labor market migration streams, involving long-distance moves that are usually made in conjunction with job changes, college attendance, military service, and like considerations and (b) local residential mobility streams that occur between the city and its immediate hinterland as local residents repeatedly adjust dwelling units, neighborhoods, and communities according to life-cycle changes in residential preferences and constraints. Because the entire labor market area (as approximated by the SMSA) constitutes an appropriate spatial origin or destination "region" for streams of the former type and the commuting field surrounding the central city (also approximated by the SMSA) establishes an outer boundary for streams of the latter type, it is useful to think of the entire SMSA as the fundamental regional unit for examining population change in the city and its hinterland.

According to this view, central city population change results from the following *inter*regional streams:

1. Migration from the SMSA's central city to destinations outside the SMSA
2. Migration from origins outside the SMSA to the SMSA's central city

and the following *intra*regional streams:

3. Intrametropolitan residential mobility from the central city to its suburbs

4. Intrametropolitan residential mobility from the suburbs to the central city

Similarly, the term "suburb" can be substituted for "central city" in order to designate the corresponding four streams that contribute to population change in the suburbs (considered, for purposes here, as that portion of the SMSA that lies outside the central city).

The analytic utility of distinguishing inter-labor market region *migration streams* (1 and 2) from intraregional *residential mobility streams* (3 and 4) is grounded in the considerable body of migration literature that indicates a difference in each type of movement with respect to frequency of occurrence, subgroup variation, and areal determinants (see Greenwood 1975, Shaw 1975, Speare et al. 1975).

A comparison of these two types of streams for the Pittsburgh and Houston SMSAs, 1965–1970, provides a good illustration. Columns (2), (3), and (4) of Table 16 indicate that each of these SMSAs show distinctly different patterns of city–suburb redistribution over the 1965–1970 period. Pittsburgh's central city sustains a large net out-migration of −16.0 percent whereas its suburbs are barely gaining with a net migration of 0.3 percent. Within the Houston SMSA, it is the central city that is barely gaining due to net migration (0.6 percent) and the suburbs that are sustaining a relatively high rate of gain (20.8 percent).

Added insights, however, are provided when one examines separately the contributions to city–suburb change of residential mobility streams (columns (5), (6), and (7) of Table 16) and inter-labor market migration streams (columns (8), (9), and (10)). The former data make clear that residential movers in both SMSAs are bringing about a quite similar pattern of internal redistribution – net out-migration for the city and net in-migration for the suburbs. Although the relative magnitudes of these components vary for Pittsburgh and Houston, the city-to-suburb flow is dominant in both cases, signaling the familiar city "flight" common to most large United States SMSAs.

The city–suburb redistribution resulting from contributing migration streams (columns (8), (9), and (10)), however, is very different for the two SMSAs. In Pittsburgh, both central cities and suburbs sustain net out-migration levels of −5.0 and −2.8 percent, respectively, whereas in Houston these metropolitan areas show net migration gains of 7.0 and 10.3 percent. Despite this disparity between SMSAs, the migration stream contributions within each SMSA are roughly similar for its central cities and suburbs. This latter observation underscores the importance of viewing the entire metropolitan area as the relevant regional unit for the analysis of migration stream levels and determinants. This view is also important for distinguishing the contributions of these streams from the contributions of intraregional residential mobility streams in an examination of city–suburb population redistribution. In the present comparison of Pittsburgh and Houston, we find that the disparate overall patterns of city–suburb redistribution (column (2), Table 16) are a product of relatively similar

TABLE 16 Migration and residential mobility stream contributions to city and suburb population sizes (ages 5 and over) for the Pittsburgh and Houston SMSAs: at the end of the period 1965–1970.

SMSA	End of period population size, ages 5 and over (1)	Change from all mobility and migration streams[a]			Change from within SMSA city–suburb mobility streams[a]			Change from migration streams with outside SMSA[a]		
		Net (2)	In (3)	Out (4)	Net (5)	In (6)	Out (7)	Net (8)	In (9)	Out (10)
Pittsburgh										
City	485 429	–16.0	12.8	–28.8	–11.0	5.5	–16.5	–5.0	7.3	–12.3
Suburb	1 738 066	0.3	12.2	–11.9	3.1	4.6	–1.5	–2.8	7.6	–10.4
Houston										
City	1 414 892	0.6	23.6	–23.0	–6.4	3.5	–9.9	7.0	20.1	–13.1
Suburb	680 970	20.8	37.6	–16.8	10.5	16.3	–5.8	10.3	21.3	–11.0

[a]Expressed as percent change of end-of-period population ages 5 and over (shown in column (1)).
SOURCE: Special tabulations from the 1970 US census with adjustments discussed in Appendix E.

redistribution tendencies of residential mobility streams, coupled with the distinctly different influences associated with each SMSA's migration streams.

Aside from distinguishing between different types of movement flows, it is also useful, from an analytic standpoint, to think of the sequence of stream contributions as occurring in two stages as depicted in Figure 7. The first stage might be termed "the interregional exchange" stage, which involves the exchange of migration streams both *from* and *to* the entire labor market (or SMSA) to all other labor markets in the national system. These streams are depicted by the darker arrows in Figure 7. The second stage might be termed "the intraregional allocation" stage, which involves both the intraregional residential mobility of city and suburb residents who are not attracted out of the labor market *and* the allocation of all SMSA in-migrants (from the first stage) to city and suburb destinations. These processes are depicted by the lighter arrows in Figure 7.

The reader will note that this two-stage view of city–suburb redistribution differs slightly from the four distinct streams presented above in that in-migration streams to the city and suburbs (the second interregional stream listed above) are now seen as the product of both stages just reviewed. Hence

Migration to the central city = Migration to the SMSA (stage one)
× City destination propensity rate of SMSA in-migrants (stage two)

and

Migration to the suburbs = Migration to the SMSA (stage one)
× Suburb destination propensity rate of SMSA in-migrants (stage two)

where the respective *destination propensity rates* indicate the proportion of SMSA in-migrants that located in city or suburb destinations. This decomposition of a single stream into two (stage) components is consistent with the view that the entire labor market (or SMSA) constitutes the most appropriate analytic region of destination for explanation of the size and structure of migration streams; but that once arrived, the allocation of these SMSA in-migrants to city and suburb destinations is influenced by the same intrametropolitan factors (e.g., housing, neighborhoods, schools) that determine the residential mobility destinations of existing SMSA residents.

This two-stage conception of the intrametropolitan redistribution process is explicated by Frey (1978, 1979a) in terms of appropriate populations at risk and rates.* Moreover, it is a straightforward matter to link this model of intraregional redistribution to a multiregional population analysis if the SMSA

*The specification in these sources introduces an additional set of rates not discussed here. The city-to-suburb mobility stream rate is seen as the product of two component rates: the mobility incidence rate of city residents and the suburban destination propensity rate of city-origin movers. The first component rate is an analytic analog of "the resident's decision to move" while the latter rate is analogous to "the (city-origin) mover's choice of (suburban) destination". Corresponding rates are defined for the suburb-to-city mobility stream and all are defined more precisely in Appendix E of this report.

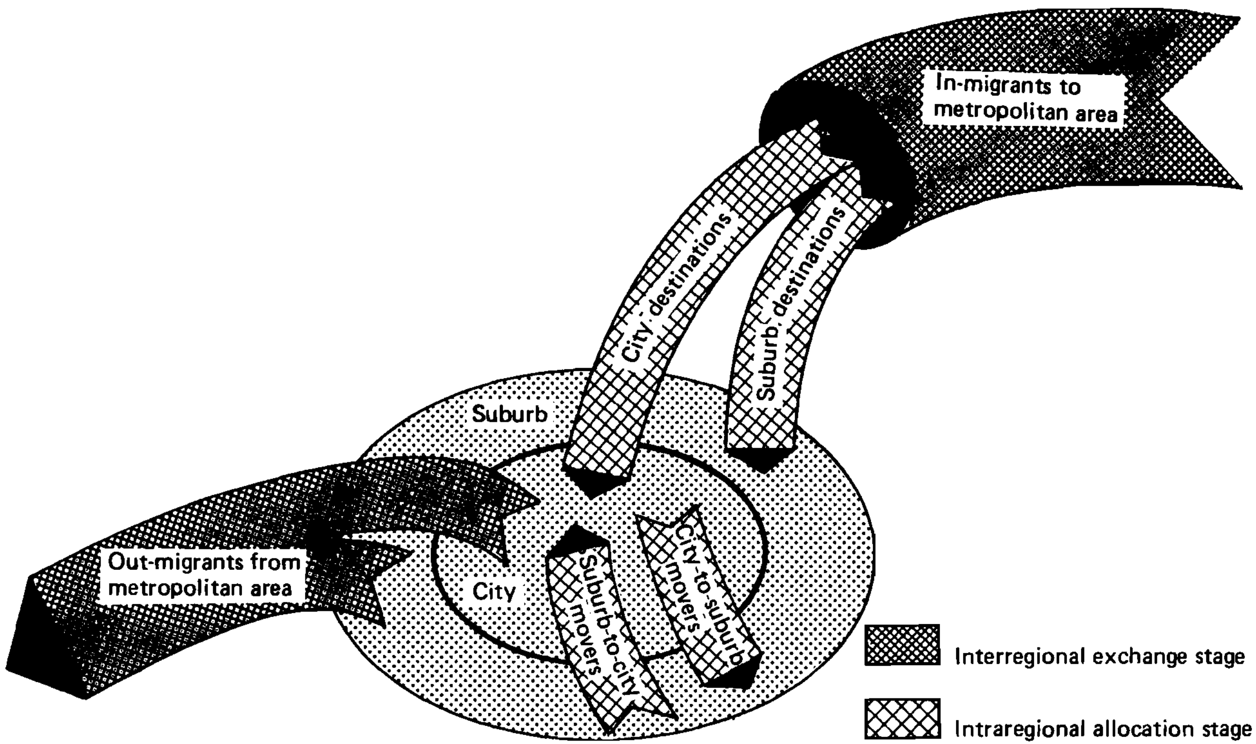

FIGURE 7 The *interregional exchange* and *intraregional allocation* stages of the city–suburb redistribution process.

(region) of interest is included in a nationwide multiregional system of labor market areas. It is on the basis of the foregoing framework that illustrative population projections are prepared for the cities and suburbs of the Pittsburgh and Houston SMSAs.

4.2 Projection Methods and Data

The preceding view of the city–suburb redistribution process lends itself to intraregional projections that are consistent with the multiregional projection methodology discussed in section 3.3. If one assumes that the entire metropolitan area is one region in a nation-wide system of regions, then "the interregional exchange" stage involves the projection of migration streams among regions, as in the multiregional case. This is followed by "the intraregional allocation" stage, which projects (within the same projection period) residential mobility streams between the SMSA's city and suburbs and allocates the SMSA in-migrants (from the interregional exchange stage) to city and suburb destinations.

From the standpoint of the SMSA of interest, there exists an initial city and suburb population, disaggregated by 5-year age groups. The interregional exchange stage begins with the multiregional projection wherein the SMSA's observed age-specific rates of survival, out-migration, and in-migration are applied to both city and suburb populations.

Within the same projection period, the intraregional allocation stage redistributes the non-out-migrating city residents by applying to them observed age-specific rates of survival and city-to-suburb mobility and the non-out-migrating suburb residents by applying to them observed age-specific rates of survival and suburb-to-city mobility. Finally in this stage, the pool of survived SMSA in-migrants disaggregated by age (that has accumulated from the first stage) is allocated to city and suburb destinations by age-specific city and suburb destination propensity rates.

Projecting the size of the first (0–4) age group for the city and suburb populations follows from the multiregional procedure. The region's observed age-specific fertility rates are applied to the estimated number of females living in the city and suburbs during the projection period. These births are then survived to the end of the period.

The methodology just outlined should yield projected city and suburb population sizes consistent with the projected SMSA population size that would result from the multiregional population projection alone. We note this consistency in order to emphasize the complementarity between the multiregional projection methodology discussed in section 3.3 and the intraregional redistribution framework presented here. (See Appendix E for a detailed discussion of this projection methodology.)

The illustrative projections to be undertaken for Pittsburgh and Houston are based on a less refined variant of this methodology. This is because there does not now exist in the US a generally recognized system of labor market regions for which appropriate interregional migration data are routinely processed.* Hence it is not possible to undertake a full-scale multiregional analysis to project the number of age-specific in-migrants to the SMSA during each period. These values in the projections that follow are obtained by applying observed "in-migrant to beginning-of-period resident" ratios to the SMSA's age-disaggregated population at the beginning of each period. It should also be noted that the fertility rates used to project the 0–4 age group and the life table used to estimate survival rates (probabilities of not dying) at all age groups pertain to the total US population (from Appendix B.1). Finally, as with the multiregional analyses in section 3, these projections pertain to the total population not disaggregated by sex.

The migration data employed in the projections were prepared from special tabulations from the 1970 US census, which recorded the reported 1965 residence location of census respondents ages 5 and over. They were further adjusted to allocate individuals who did not report their previous residence and to compensate for census underenumeration. The use of this 5-year fixed interval census question permits calculation of rates of out-migration transitions, conditional on surviving, without resorting to a multiregional life-table estimation (Ledent 1980b). Hence required rates of survival and out-migration can be computed as the product of appropriate life-table-calculated survival rates and these census-calculated rates of out-migration transitions. Age-specific schedules of these census-calculated rates for the Pittsburgh and Houston SMSAs are presented in Appendix E, Table E1.

It is instructive to examine the census-calculated rates for the total populations that correspond to the age-disaggregated rates used in the projections for Pittsburgh and Houston. The measures in Table 17 correspond to those employed in the "interregional exchange" portion of the projection analysis: rates of

TABLE 17 Rates of out-migration from the metropolitan area and ratios of in-migration to the metropolitan area for the Pittsburgh and Houston SMSAs: 1965–1970.

Rate or ratio	Pittsburgh SMSA	Houston SMSA
Rate of out-migration from the SMSA[a]	0.1044	0.1333
Ratio of in-migration to the SMSA[b]	0.0728	0.2234

[a]Rate of out-migration from SMSA for beginning-of-period SMSA residents who survived to the end of the period.
[b]Ratio of the number of in-migrants to the SMSA over the period (who survived to the end of the period) to the beginning-of-period SMSA residents (who survived to the end of the period).
SOURCE: Special tabulations from the 1970 US census with adjustments discussed in Appendix E.

*Two officially designated candidates for such regions that exhaust the national territory would be the 510 State Economic Areas designated by the US Census Bureau (groups of counties that are homogeneous with respect to economic and social characteristics) or the 183 Bureau of Economic Analysis (BEA) areas (groups of counties based on the nodal functional concept). Unfortunately, appropriate migration data are not compiled for either of these areal systems.

out-migration from the SMSA and the ratio of in-migrants to the SMSA. We see that during the period of observation (1965–1970) the interregional exchange is much kinder to the Houston SMSA than to the Pittsburgh SMSA. Although the out-migration rates from both of these metropolitan areas occur at relatively similar levels, Houston receives a far greater volume of in-migrants from other regions than does Pittsburgh. When assessed as a ratio to their respective beginning-of-period SMSA populations, in-migration to Houston is more than three times heavier than it is to Pittsburgh. Hence, as a result of the interregional exchange, the Houston metropolitan area possesses an extra reservoir of population that can be allocated to city or suburb destinations.

The rates in Table 18 correspond to those employed in the intraregional allocation portion of the projection analysis: city-to-suburb mobility rates for city residents, suburb-to-city rates for suburb residents, and city–suburb destination propensity rates for in-migrants to the SMSA. A direct comparison of

TABLE 18 Rates that allocate metropolitan residents and in-migrants to city and suburb destinations for the Pittsburgh and Houston SMSAs: 1965–1970.

	Pittsburgh SMSA		Houston SMSA	
Type of rate and population of origin	City destination	Suburb destination	City destination	Suburb destination
Intrametropolitan mobility rate				
City residents[a]	–	0.1589	–	0.1137
Suburb residents[b]	0.0172	–	0.0847	–
Destination propensity rate				
In-migrants to metropolitan area[c]	0.2147	0.7853	0.6098	0.3902

[a] City-to-suburb mobility rate for beginning-of-period city residents who survive and do not migrate from the metropolitan area over the period.
[b] Suburb-to-city mobility rate for beginning-of-period suburb residents who survive and do not migrate from the metropolitan area over the period.
[c] City–suburb destination propensity rates for in-migrants to the metropolitan area who survive to the end of the period (expressed as a proportion).
SOURCE: Special tabulations from the 1970 US census with adjustments discussed in Appendix E.

the redistribution implied by Pittsburgh's and Houston's rates is confounded by the different city shares of total population in each SMSA. As in most older industrial SMSAs, the suburbs of Pittsburgh have expanded to the extent that the central city holds only 21.8 percent of the total 1970 SMSA population. By contrast, 62.3 percent of Houston's 1970 metropolitan residents live in its central city. Hence the ratio of city-to-suburb population is about 1:4 in the Pittsburgh SMSA and about 1:0.6 in the Houston SMSA. Keeping these ratios in mind, it is clear that the observed 1965–1970 intrametropolitan mobility rates should bring about a city-to-suburb redistribution of the resident population in both SMSAs. The ratio of the city-to-suburb mobility rate to its counterstream's rate in the Pittsburgh SMSA is 9.4:1 (0.1337/0.0142); and in the Houston SMSA the rate of city-to-suburb mobility is *greater* than that in the reverse direction with a ratio of 1.4:1 (0.0895/0.0651).

The other rates involved in the intrametropolitan allocation stage are the city and suburb destination rates for SMSA in-migrants. The observed 1965–1970 values for these rates are surprisingly close to the actual city–suburb population distributions in both SMSAs. Hence the allocation to city and suburb destinations of SMSA in-migrants – unlike that of city and suburb residents – should not serve to increase suburban growth at the expense of the city.

The age-disaggregated counterparts of the observed 1965–1970 rates just reviewed will form the basis of the illustrative projections for Pittsburgh and Houston SMSAs. The major difference between observed rates for each occurs with levels of SMSA in-migration from other regions, reflecting the strong attractiveness of the Houston SMSA as a labor market area as compared with a relatively weak in-migrant "pull" to the Pittsburgh SMSA. There are strong similarities, however, between the two SMSAs with respect to the allocation of metropolitan residents and in-migrants to city and suburb destinations. The projections that follow indicate what these observed rates and observed US 1970 fertility and mortality levels will imply for city–suburb redistribution in Pittsburgh and Houston for future periods.

4.3 City–Suburb Population Projections

We present here the results of illustrative projections for the city and suburb populations of Pittsburgh and Houston over the interval 1970–2020. In so doing we focus on three aspects: projected changes in total central city and suburb size, the changing city shares of the total metropolitan populations, and the contributions to projected population change attributable to inter-labor market migration and intrametropolitan residential mobility. It should again be emphasized that these projections are not intended as predictions of future population changes within the Pittsburgh and Houston SMSAs. They are intended to show the future implications of observed 1965–1970 migration and mobility rates when projected according to the assumptions discussed in the previous section. The projections also assume that the future boundaries of the central cities and SMSAs of Pittsburgh and Houston, hold constant throughout the projection period (i.e., city or metropolitan annexation is not assumed).

Viewing the results in a broad scope, we find quite contrasting projected scenarios for the two central cities. Between 1970 and 2020, Pittsburgh's central city population of 535 thousand is reduced by −37.6 percent to 334 thousand, whereas the central city of Houston increases its population from 1.2 million to 4.8 million – or 281 percent! However, for both SMSAs the suburbs fare better than the central cities over the same projection period.

Pittsburgh's suburbs do not undergo the substantial loss projected for its central city but sustain a modest increase in population from 1.9 million in 1970 to better than 2.0 million in 2020 (an 8.3 percent gain). Over this period the entire Pittsburgh SMSA sustains a slight loss of −4.8 percent. While the city of

Houston increases its population almost threefold over the 50-year period, the suburbs of this metropolitan area are projected to grow by 441 percent, increasing their 1971 population of 772 thousand to greater than 4.1 million. Overall, the entire Houston SMSA is projected to increase its population by 341 percent during the 50-year period.

Figure 8 displays graphically the trends in these changes for each period over the 50-year span. The patterns for Pittsburgh show that the rate of central city decline is not constant over the period but is most accentuated over the first three periods. The rate of suburban population change is not high for any single period but is positive for all periods except 1990–1995, 1995–2000, and 2015–2020.

The plots of Houston's city and suburb growth stand in sharp contrast to those of Pittsburgh, which indicate extremely high rates of growth for all projection periods. It is noteworthy that the combined population of Houston's city and suburbs is actually less than that for Pittsburgh during the base year of the projection (2.04 million versus 2.4 million in 1970). In the final year of the projection period, however, Houston's 9.04 million population dwarfs the 2.3 million population projected for the Pittsburgh SMSA. The plot makes plain that this high level of growth accruing in the Houston SMSA is shared by both its city and suburb areas. Yet the suburbs benefit more greatly from the total redistribution process, particularly during the earlier periods of the 50-year span.

The changing city and suburb shares of the total metropolitan population represent another dimension of these illustrative projections. The projected shares in Table 19 indicate that both SMSAs would continue to undergo a suburban deconcentration of their population if 1965–1970 rates continued over the period 1970–2020. Indeed this would be expected to follow from the observed intrametropolitan mobility rates (Table 18) alone. For Pittsburgh, this means that the central city will become reduced to less than 15 percent of the total metropolitan population. In Houston the city share is reduced from 62.3 percent to 53.8 percent. Although these reductions are projected to occur over the course of a 50-year span, the Table 19 data show that in both instances, much of the change will take place in the initial 20 years of the projection period.

Finally, as part of the projection process, it is possible to decompose city and suburb net movement for each period into components of net migration (the algebraic sum of interregional in- and out-migration streams) and net mobility (the algebraic sum of the intrametropolitan city-to-suburb and suburb-to-city mobility streams). These data are presented in Table 20 for the cities and suburbs of Pittsburgh and Houston. They make clear that the base period city–suburb redistribution processes (observed in Table 16) are to some degree replicated in each 5-year projection period. Hence intrametropolitan residential mobility streams lead to city net loss and suburban net gain for both SMSAs in each period, whereas net inter-labor market migration streams bring about opposite effects in the two SMSAs: net losses in Pittsburgh's city and suburbs and net gains in Houston's city and suburbs.

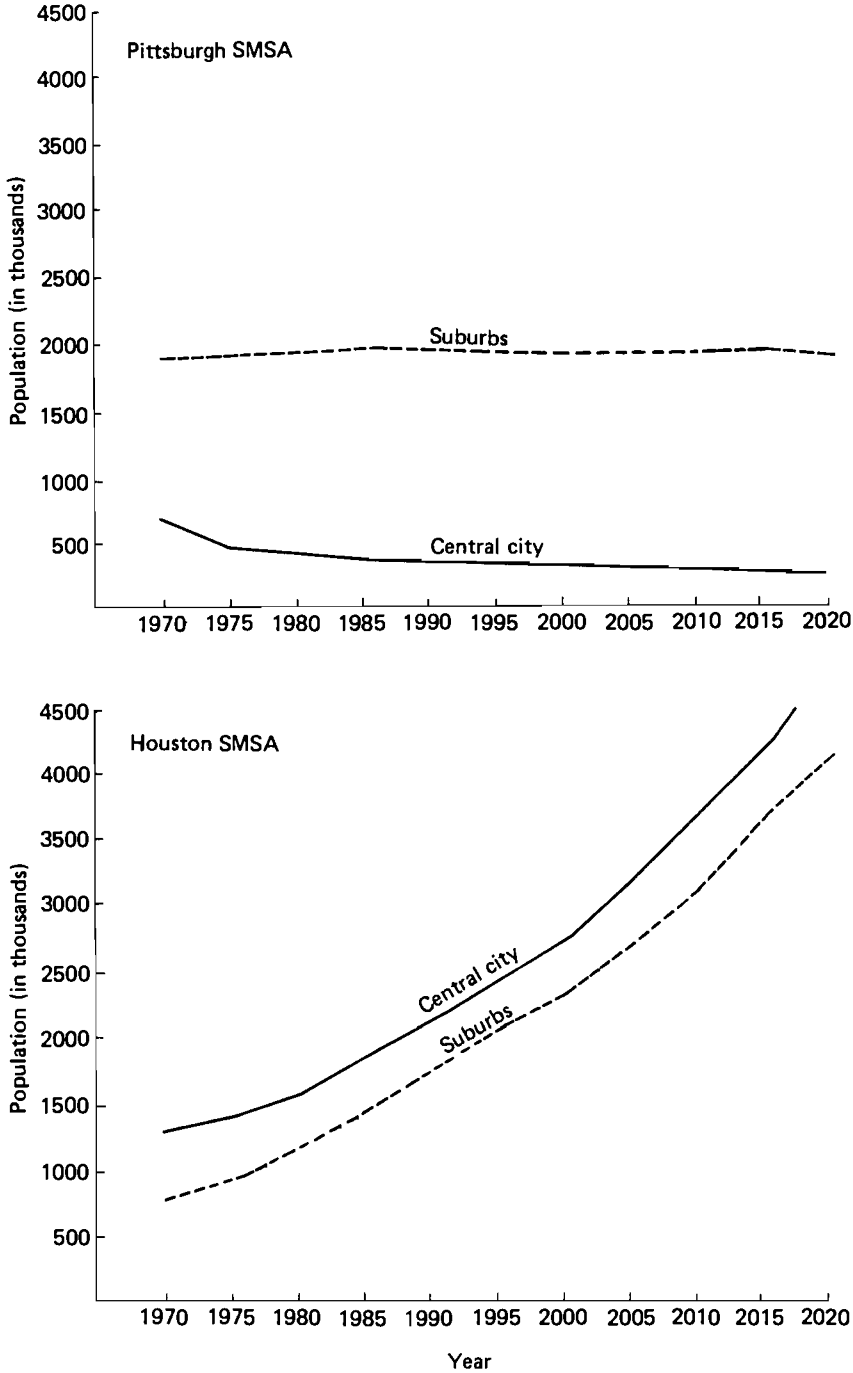

FIGURE 8 Projected population sizes for the cities and suburbs of the Pittsburgh and Houston SMSAs: 1970–2020.

TABLE 19 Projected metropolitan area population sizes and city and suburb shares for the Pittsburgh and Houston SMSAs: 10-year intervals between 1970 and 2020.

SMSA, population size, and city and suburb shares	Years					
	1970	1980	1990	2000	2010	2020
Pittsburgh SMSA						
Size (in thousands)						
Total	2 455	2 398	2 379	2 339	2 339	2 337
Population shares						
City	21.8	18.4	16.2	15.1	14.6	14.3
Suburb	78.2	81.6	83.8	84.9	85.4	85.7
Total	100.0	100.0	100.0	100.0	100.0	100.0
Houston SMSA						
Size (in thousands)						
Total	2 048	2 770	3 805	5093	6 818	9 042
Population shares						
City	62.3	57.4	55.1	54.1	54.0	53.8
Suburb	37.7	42.6	44.9	45.9	46.0	46.2
Total	100.0	100.0	100.0	100.0	100.0	100.0

The Table 20 data demonstrate convincingly that inter-labor market migration stream exchanges are most responsible for the different long-term city growth and city–suburb redistribution scenarios projected for Pittsburgh and Houston. Houston's high rate of city growth (as plotted in Figure 8) is heavily dependent on net in-migration *vis-à-vis* other labor markets. Moreover, its rate of city–suburb deconcentration (shown in Table 19) is moderated by its large number of SMSA in-migrants, who are less prone than local residents to select suburban destinations (see Table 18).

From the perspective of the projection analysis framework, Houston's city (and suburb) growth advantage draws from its success in attracting interregional migrants to the entire labor market area (the interregional exchange stage). This establishes a continual reservoir of population that will more than compensate for the city "flight" of local residents (in the intraregional allocation stage). In the Pittsburgh SMSA this reservoir of in-migrants is appreciably smaller than in Houston. The chances for future population gains in Pittsburgh's central city must depend more heavily upon attracting into (or retaining within) the city existing metropolitan residents. Its observed 1965–1970 intrametropolitan mobility rates, however, like those of Houston, imply continued redistribution out of the city in each 5-year projection period.

TABLE 20 Projected residential mobility and migration contributions to city and suburb population sizes for the Pittsburgh and Houston SMSAs: 5-year periods between 1970 and 2020.

SMSA and components of change	Periods 1970–1975	1975–1980	1980–1985	1985–1990	1990–1995	1995–2000	2000–2005	2005–2010	2010–2015	2015–2020
Pittsburgh SMSA										
City										
Net mobility and migration	–57 728	–46 643	–40 020	–34 440	–28 778	–24 661	–22 504	–21 408	–20 640	–19 649
Net mobility within SMSA	–41 750	–36 222	–32 902	–29 288	–24 872	–22 526	–21 624	–21 100	–20 438	–19 625
Net migration out of SMSA	–15 978	–10 421	–7 118	–5 153	–3 906	–2 134	–880	–307	–202	–23
Suburb										
Net mobility and migration	–18 504	–27 922	–29 439	–31 632	–41 164	–45 842	–46 913	–46 329	–47 161	–48 863
Net mobility within SMSA	41 750	36 222	32 902	29 288	24 872	22 526	21 624	21 100	20 438	19 625
Net migration out of SMSA	–60 254	–64 144	–62 341	–60 920	–66 036	–68 369	–68 536	–67 429	–67 599	–68 489
Houston SMSA										
City										
Net mobility and migration	45 890	78 501	106 214	127 102	151 305	186 197	223 204	258 004	291 272	331 644
Net mobility within SMSA	–62 790	–62 027	–66 870	–74 172	–79 576	–84 822	–94 002	–108 001	–126 112	–144 803
Net migration out of SMSA	108 690	140 528	173 084	201 273	230 881	271 020	317 206	366 005	417 384	476 447
Suburb										
Net mobility and migration	136 452	141 610	157 096	175 743	188 351	203 401	228 726	265 238	307 177	350 186
Net mobility within SMSA	62 790	62 027	66 870	74 172	79 576	84 822	94 002	108 001	126 112	144 803
Net migration out of SMSA	73 662	79 583	90 226	101 571	108 774	118 578	134 723	157 237	181 065	205 383

The foregoing projections are intended to be illustrative of the city–suburb redistribution dynamics occurring in a declining industrial metropolitan area (Pittsburgh) and one which is growing fairly rapidly (Houston). The projections are based on observed migration, fertility, and mortality data for the 1965–1970 period and are subject to the assumptions of the projection methodology discussed above and in Appendix E. Also, the findings presented here for Pittsburgh and Houston are not exactly the same as those obtained in corresponding analyses of other "declining" and "growing" US SMSAs (Frey, forthcoming). Nevertheless these projections serve to point out the utility of examining city–suburb population redistribution as a case of intraregional population redistribution within a single labor market area region (an SMSA) and as a product of both intraregional residential mobility and inter-labor market region migration streams.

5 CONCLUSION

Over the past decade and a half, the demographic processes that have led to long-standing US settlement patterns seem to have taken new turns. The pervasive westward movement of population that has dominated interregional redistribution in the nation during most of its 205-year history can no longer be seen as a "filling-in of the frontier". This movement to the West is now complemented by an equally prominent movement to the South in response to significant new economic growth in these regions – which, together, have come to be known as the Sunbelt. The second noteworthy change involves an apparent curtailment of the metropolitanization process. For the first time ever, the nation's nonmetropolitan population is growing faster than its metropolitan population, and it is clearly no longer valid to assume that nonmetropolitan areas are "lagging" areas. Finally, recent trends have shown that the suburbanization of residents that occurs within metropolitan areas takes on a strikingly different form in growing metropolitan areas in the Sunbelt than in declining metropolitan areas in the Northeast and North Central regions. The general slowdown in growth that has recently characterized the latter two regions has been most devastating for their large central cities, which have generally sustained high levels of population loss.

The newly evolving redistribution processes become even more significant in the context of lower fertility levels. With a reduced plane of nationwide natural increase and a relatively low level of immigration, internal migration across regions, metropolitan areas, and localities has become the dominant component of population redistribution. Net in-migration and population growth in some areas will necessarily result in net out-migration and population loss in others. In contrast to the situation that existed during the post-World War II baby boom, one can no longer expect high levels of fertility to cushion migration losses in declining areas.

These new redistribution processes are not necessarily harmful. The locational categories that are sustaining greater gains from this redistribution – the

South, small towns, nonmetropolitan areas – were previously considered to be lagging areas that continually lost population to the highly industrialized older regions and metropolitan areas. Hence many analysts have viewed the recent reversals as a generally healthy phenomenon directed to a more balanced development of the nation's regions.

The precise causes of these new redistribution processes are difficult to pinpoint. They can, in some measure, be attributed to broad societal changes: the transformation from an economy dependent on centrally located heavy industrial installations to a greater emphasis on services and light industry; continuing technological innovations that contribute to more extensive, less costly transportation and communication networks; and a general rise in the standard of living, which permits a larger share of the population to respond to the changing locations of opportunities via migration, residential mobility, and commuting. More specific explanations for the recent deconcentration phenomenon have been linked to its economic incentives for industry – to the lower costs of resources and labor and to the more favorable tax rates that generally prevail in smaller, less congested locations of the Sunbelt and nonmetropolitan areas. Finally, a series of nationwide attitude surveys have shown a decided preference among Amercian residents for living in a low density, uncongested environment (Zuiches and Fuguitt 1972).

Despite the fact that the newly emerging redistribution trends augur toward a more balanced pattern of population and economic growth across US regions, metropolitan areas, and towns, they are not the result of any concerted federal government effort to direct population redistribution in this manner. While it is true that the complex of location-specific government programs have indirectly affected national redistribution patterns in largely unintended and conflicting ways, the US government has never enacted an official population policy that held as an explicit goal the attainment of specific population growth or distribution targets, as has been the case in other industrialized nations (Sundquist 1975). Such a policy would be viewed as a severe infringement on the highly valued right of the individual to move or stay as he pleases. And past proposals to rectify mismatches between workers and employment opportunities in lagging regions tended to favor bringing "jobs to the people" over moving "people to the jobs".

The current federal posture towards population distribution seems to be one of accommodating individuals and places to general demographic patterns rather than one of influencing those patterns. The following passage from a recent report on metropolitan and nonmetropolitan policy prepared for the President's Commission for a National Agenda for the Eighties (1980, pp. 100, 101) is illustrative:

> The limits to what a federal urban policy effort can achieve are defined by several factors. First, recognition should be made of the near immutability of the technological, economic, social, and demographic trends that herald the emergence of a postindustrial society

> and that are responsible for the transformation of our nation's settlements and life within them. These major formative trends are likely to continue not only through the coming decade, but also well into the next century. Major deflection or reversal of these broad-gauge trends is not likely to result from purposive government action. Clearly, on the basis of these trends, a federal policy of active anticipation, accommodation, and adjustment makes more sense than efforts to retard or reverse them. The efforts to revitalize those communities whose fortunes are adversely affected principally by the inadvertent consequences of past public policies are entirely justified, but these instances are judged to be rare. It is far more judicious to recognize that the major circumstances that characterize our nation's settlements have not been and will not be significantly dependent on what the federal government does or does not do.

The growth and internal redistribution of the US population, nevertheless, holds important consequences for policy making at all levels of government – federal, state, and local. Representation in the US Congress, the country's main legislative body, is directly related to an area's population size as determined at the most recent US census, so that the political influence of each region, state, metropolitan area, and city increases or decreases along with its population size. Funds and services for many federal programs are allocated to state and local governments on the basis of their populations. And at the local level, city and community governments rely heavily on property taxes to finance basic municipal sources of their residents. The heavy out-migration of a city's residents can lead to "tax base erosion" and lower levels of service for residents left behind whereas unanticipated in-migration may bring about demands for government services that the local government cannot absorb in the short term.

The current low levels of nationwide population growth, coupled with unexpected new directions in the internal redistribution process, will pose difficult choices for policy makers in their attempt to "anticipate, accommodate, and adjust" to the changing spatial dimensions of US population growth and decline. The short run *processes* of demographic change can be fairly well monitored through survey, census, and registration data that are routinely collected by US statistical agencies. However, it is information on the long-term *aggregate distributional consequences* of these processes that is both most needed and most difficult to assess. Although high rates of in-migration were sustained by nonmetropolitan areas, the Sunbelt regions, and cities and suburbs of selected fast-growing metropolitan areas since 1970, 1980 census data show that greater than 75 percent of the US population still lives in metropolitan areas, that 48 percent lives outside of the Sunbelt, and that the central city of the New York metropolitan area houses more people than the entire metropolitan areas surrounding Houston and Dallas combined. These statistics emphasize the fact that there is a great deal of inertia involved in aggregate population redistribution and that currently observed reversals in migration and fertility processes are not quickly translated into a dramatically different national population distribution.

The multiregional demographic methods that were employed in the analytic chapters of this volume constitute important tools for evaluating the long-term redistribution implications associated with migration, fertility, and mortality processes observed at a given point in time. The section 3 analysis of redistribution across the four US census regions shows that the early 1970s schedule of south- and west-directed migration rates would not result in a significant long-term reallocation in the nation's regional population distribution, but that the Sunbelt regions would continue to make slight gains over time. The section 4 analysis of intraregional city–suburb redistribution in the Pittsburgh and Houston SMSAs shows that, in the long run, the fate of central city population change depends more on the capacity of the entire metropolitan area to attract inter-labor market migrants than on the capacity of the central city itself to attract intrametropolitan residential movers.

These analyses of interregional and intrametropolitan redistributions, prepared for the IIASA Comparative Migration and Settlement Study, constitute only two of many possible redistribution analyses that can be undertaken by applying the powerful multiregional demographic methodology to migration, fertility, and mortality statistics, which are regularly made available by the US Census Bureau and the National Center for Vital Statistics. It is hoped that as these statistical agencies continue to release updated trend data on the components of US population change, demographers will continue to expand upon the multiregional and intraregional analyses presented here. This should yield an increasingly precise picture of just how far the newly evolving US settlement patterns depart from those that have been observed over most of the nation's history.

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APPENDIXES

Appendix A

OBSERVED POPULATION, NUMBERS OF BIRTHS, DEATHS, AND MIGRANTS, DISAGGREGATED BY AGE AND REGION: 1970

APPENDIX A

Observed population characteristics.

region n.east

age	population	births	deaths	migration from n.east to n.east	n.centr.	south	west
0	3991155.	0.	18280.	0.	21500.	34750.	16750.
5	4598870.	0.	1862.	0.	22250.	43500.	17750.
10	4760108.	1868.	1564.	0.	16250.	29000.	18250.
15	4319751.	107668.	4040.	0.	12000.	25250.	15000.
20	3695722.	300834.	4752.	0.	31500.	68250.	36250.
25	3167984.	248842.	3945.	0.	23500.	46500.	27250.
30	2678284.	110600.	4404.	0.	15750.	35250.	11250.
35	2694395.	47290.	6393.	0.	11038.	15801.	9334.
40	3029781.	12632.	10680.	0.	7962.	13449.	7416.
45	3111549.	774.	17091.	0.	4031.	10315.	5771.
50	2918178.	0.	25487.	0.	2719.	10435.	4229.
55	2621429.	0.	35407.	0.	1484.	11446.	4302.
60	2254113.	0.	46182.	0.	1516.	13304.	4198.
65	1803083.	0.	54950.	0.	459.	11427.	2906.
70	1435711.	0.	66837.	0.	440.	5457.	1858.
75	999203.	0.	71934.	0.	263.	3274.	1115.
80	585908.	0.	61392.	0.	88.	1092.	372.
85	375479.	0.	63389.	0.	0.	0.	0.
total	49040708.	830508.	498589.	0.	172750.	378500.	184001.

region n.centr.

age	population	births	deaths	migration from n.centr. to n.east	n.centr.	south	west
0	4837268.	0.	23149.	14500.	0.	58750.	40250.
5	5696243.	0.	2391.	14750.	0.	61250.	43250.
10	5965440.	2678.	2161.	11750.	0.	51250.	25750.
15	5402978.	170860.	5971.	14500.	0.	50500.	29250.
20	4382524.	399636.	6078.	34500.	0.	88500.	70750.
25	3664711.	280666.	4743.	18500.	0.	65750.	51750.
30	3117407.	119340.	4855.	9000.	0.	34500.	24500.
35	3008922.	49830.	6708.	8418.	0.	29051.	20322.
40	3276073.	14456.	11359.	6082.	0.	23449.	16678.
45	3309386.	878.	17862.	4117.	0.	11954.	8036.
50	3059407.	0.	25783.	2633.	0.	10796.	6464.
55	2754367.	0.	35786.	571.	0.	9562.	6431.
60	2369513.	0.	46190.	429.	0.	9938.	6569.
65	1912867.	0.	54894.	1151.	0.	10166.	4477.
70	1537213.	0.	67971.	1027.	0.	5463.	3207.
75	1132593.	0.	77763.	617.	0.	3278.	1924.
80	689585.	0.	70024.	206.	0.	1093.	642.
85	455166.	0.	77195.	0.	0.	0.	0.
total	56571668.	1038344.	540883.	142751.	0.	525250.	360250.

region south

age	population	births	deaths	migration from n.east	migration from n.centr.	south to south	south to west
0	5389233.	0.	31099.	33000.	65750.	0.	48500.
5	6227912.	0.	3000.	29500.	55250.	0.	57500.
10	6508350.	5970.	3045.	23250.	31500.	0.	52500.
15	6069949.	257432.	7644.	24750.	43000.	0.	41250.
20	5275729.	465460.	8272.	73500.	124750.	0.	101500.
25	4166153.	287352.	6824.	41750.	68250.	0.	51750.
30	3555505.	122930.	7456.	16250.	27500.	0.	36750.
35	3438676.	53224.	10115.	14766.	15673.	0.	22948.
40	3622962.	14942.	15842.	10484.	11327.	0.	17052.
45	3599656.	1036.	24558.	8548.	9856.	0.	14206.
50	3266214.	0.	32483.	5952.	6894.	0.	9294.
55	2981929.	0.	44560.	4295.	5086.	0.	6229.
60	2650466.	0.	55002.	3955.	4164.	0.	5271.
65	2206608.	0.	66347.	3856.	5774.	0.	2131.
70	1642483.	0.	72258.	3413.	5542.	0.	1733.
75	1114156.	0.	73860.	2048.	3325.	0.	1040.
80	644677.	0.	63113.	683.	1108.	0.	347.
85	434709.	0.	67862.	0.	0.	0.	0.
total	62795372.	1208346.	593340.	300000.	484749.	0.	470001.

region west

age	population	births	deaths	migration from n.east	migration from n.centr.	west to south	west to west
0	2936681.	0.	13687.	14000.	33750.	39250.	0.
5	3433222.	0.	1463.	12000.	26000.	41000.	0.
10	3555570.	1236.	1361.	7000.	18750.	32250.	0.
15	3277670.	108748.	3968.	4750.	19500.	28000.	0.
20	3017046.	252944.	4536.	31250.	57750.	72500.	0.
25	2478145.	178044.	3491.	17750.	33250.	49500.	0.
30	2079240.	74936.	3475.	9000.	17750.	22500.	0.
35	1964858.	29900.	4298.	6315.	14810.	18838.	0.
40	2052138.	7922.	7222.	4435.	11440.	13912.	0.
45	2095348.	458.	11159.	2439.	6190.	10212.	0.
50	1860219.	0.	15094.	1561.	4560.	6788.	0.
55	1615303.	0.	20394.	1281.	2412.	9267.	0.
60	1342692.	0.	24852.	969.	2088.	6733.	0.
65	1069067.	0.	28753.	1082.	2091.	3805.	0.
70	828424.	0.	33521.	788.	1755.	2470.	0.
75	588882.	0.	37252.	473.	1053.	1482.	0.
80	364141.	0.	34465.	158.	351.	494.	0.
85	245547.	0.	38509.	0.	0.	0.	0.
total	34804200.	654188.	287500.	115251.	253500.	359001.	0.

Appendix B

OBSERVED DEMOGRAPHIC RATES: 1970

B.1 Observed Rates of Fertility, Mortality, and Out-migration

B.2 Single-region Life Tables for Each of the Four US Regions

LEGEND

- $p(x)$: probability of survival from age x to age $x + 5$
- $q(x)$: probability that an individual of age x dies before reaching age $x + 5$
- $l(x)$: number surviving at exact age x, of 100000 born
- $d(x)$: number dying between ages x and $x + 5$, of 100000 born
- $ll(x)$: number of years lived between ages x and $x + 5$ per unit born
- $m(x)$: age-specific death rate
- $s(x)$: survivorship proportion – proportion of people x to $x + 4$ years old that will survive to be $x + 5$ to $x + 9$ years old, 5 years later
- $t(x)$: number of years expected to be lived beyond age x by a newborn baby
- $e(x)$: expectation of life at age x – number of years expected to be lived beyond age x by a person of age x

APPENDIX B.1 Observed rates of fertility, mortality, and out-migration.

Mortality rates.

age	n.east	n.centr.	south	west
0	0.004580	0.004786	0.005771	0.004661
5	0.000405	0.000420	0.000482	0.000426
10	0.000329	0.000362	0.000468	0.000383
15	0.000935	0.001105	0.001259	0.001211
20	0.001286	0.001387	0.001568	0.001503
25	0.001245	0.001294	0.001638	0.001409
30	0.001644	0.001557	0.002097	0.001671
35	0.002373	0.002229	0.002942	0.002187
40	0.003525	0.003467	0.004373	0.003519
45	0.005493	0.005397	0.006822	0.005326
50	0.008734	0.008427	0.009945	0.008114
55	0.013507	0.012992	0.014943	0.012625
60	0.020488	0.019493	0.020752	0.018509
65	0.030476	0.028697	0.030067	0.026895
70	0.046553	0.044217	0.043993	0.040464
75	0.071991	0.068659	0.066292	0.063259
80	0.104781	0.101545	0.097899	0.094647
85	0.168822	0.169597	0.156109	0.156829
gross	2.435830	2.378174	2.337099	2.218197
crude	0.010167	0.009561	0.009449	0.008260
m.age	77.1704	77.2288	76.1325	76.9626

Fertility rates.

age	n.east	n.centr.	south	west
0	0.	0.	0.	0.
5	0.	0.	0.	0.
10	0.000392	0.000449	0.000917	0.000348
15	0.024925	0.031623	0.042411	0.033178
20	0.081401	0.091189	0.088227	0.083838
25	0.078549	0.076586	0.068973	0.071846
30	0.041295	0.038282	0.034575	0.036040
35	0.017551	0.016561	0.015478	0.015217
40	0.004169	0.004413	0.004124	0.003860
45	0.000249	0.000265	0.000288	0.000219
50	0.	0.	0.	0.
55	0.	0.	0.	0.
60	0.	0.	0.	0.
65	0.	0.	0.	0.
70	0.	0.	0.	0.
75	0.	0.	0.	0.
80	0.	0.	0.	0.
85	0.	0.	0.	0.
gross	1.242655	1.296837	1.274963	1.222732
crude	0.016935	0.018354	0.019243	0.018796
m.age	26.6444	26.1490	25.6030	26.0216

Out-migration rates.

age	migration from n.east to: total	n.east	n.centr.	south	west
0	0.018290	0.	0.005387	0.008707	0.004197
5	0.018157	0.	0.004838	0.009459	0.003860
10	0.013340	0.	0.003414	0.006092	0.003834
15	0.012096	0.	0.002778	0.005845	0.003472
20	0.036799	0.	0.008523	0.018467	0.009809
25	0.030698	0.	0.007418	0.014678	0.008602
30	0.023242	0.	0.005881	0.013161	0.004200
35	0.013425	0.	0.004097	0.005864	0.003464
40	0.009515	0.	0.002628	0.004439	0.002448
45	0.006465	0.	0.001295	0.003315	0.001855
50	0.005957	0.	0.000932	0.003576	0.001449
55	0.006574	0.	0.000566	0.004366	0.001641
60	0.008437	0.	0.000673	0.005902	0.001862
65	0.008204	0.	0.000255	0.006337	0.001612
70	0.005402	0.	0.000306	0.003801	0.001294
75	0.004656	0.	0.000263	0.003277	0.001116
80	0.002649	0.	0.000150	0.001864	0.000635
85	0.	0.	0.	0.	0.
gross	1.119523	0.	0.247018	0.595757	0.276747
crude	0.014993	0.	0.003523	0.007718	0.003752
m.age	31.0200	0.	25.3113	33.5944	30.5737

age	migration from n.centr. to: total	n.east	n.centr.	south	west
0	0.023464	0.002998	0.	0.012145	0.008321
5	0.020935	0.002589	0.	0.010753	0.007593
10	0.014877	0.001970	0.	0.008591	0.004317
15	0.017444	0.002684	0.	0.009347	0.005414
20	0.044210	0.007872	0.	0.020194	0.016144
25	0.037111	0.005048	0.	0.017941	0.014121
30	0.021813	0.002887	0.	0.011067	0.007859
35	0.019207	0.002798	0.	0.009655	0.006754
40	0.014105	0.001856	0.	0.007158	0.005091
45	0.007284	0.001244	0.	0.003612	0.002428
50	0.006502	0.000861	0.	0.003529	0.002113
55	0.006014	0.000207	0.	0.003472	0.002335
60	0.007147	0.000181	0.	0.004194	0.002772
65	0.008257	0.000602	0.	0.005315	0.002340
70	0.006308	0.000668	0.	0.003554	0.002086
75	0.005138	0.000545	0.	0.002894	0.001699
80	0.002815	0.000299	0.	0.001585	0.000931
85	0.	0.	0.	0.	0.
gross	1.313151	0.176541	0.	0.675024	0.461586
crude	0.018176	0.002523	0.	0.009285	0.006368
m.age	29.9880	27.6286	0.	30.7077	29.8378

APPENDIX B.1 *Continued.*

age	migration from total	n.east	south to n.centr.	south	west
0	0.027323	0.006123	0.012200	0.	0.008999
5	0.022841	0.004737	0.008871	0.	0.009233
10	0.016479	0.003572	0.004840	0.	0.008067
15	0.017957	0.004077	0.007084	0.	0.006796
20	0.056817	0.013932	0.023646	0.	0.019239
25	0.038825	0.010021	0.016382	0.	0.012422
30	0.022641	0.004570	0.007734	0.	0.010336
35	0.015525	0.004294	0.004558	0.	0.006673
40	0.010727	0.002894	0.003126	0.	0.004707
45	0.009059	0.002375	0.002738	0.	0.003946
50	0.006778	0.001822	0.002111	0.	0.002845
55	0.005235	0.001440	0.001706	0.	0.002089
60	0.005052	0.001492	0.001571	0.	0.001989
65	0.005330	0.001747	0.002617	0.	0.000966
70	0.006507	0.002078	0.003374	0.	0.001055
75	0.005756	0.001838	0.002984	0.	0.000933
80	0.003316	0.001059	0.001719	0.	0.000538
85	0.	0.	0.	0.	0.
gross	1.380843	0.340368	0.536309	0.	0.504167
crude	0.019982	0.004777	0.007720	0.	0.007485
m.age	28.3667	30.4297	28.4414	0.	26.8946

age	migration from total	n.east	west to n.centr.	south	west
0	0.029625	0.004767	0.011493	0.013365	0.
5	0.023010	0.003495	0.007573	0.011942	0.
10	0.016312	0.001969	0.005273	0.009070	0.
15	0.015941	0.001449	0.005949	0.008543	0.
20	0.053529	0.010358	0.019141	0.024030	0.
25	0.040555	0.007163	0.013417	0.019975	0.
30	0.023687	0.004329	0.008537	0.010821	0.
35	0.020339	0.003214	0.007537	0.009587	0.
40	0.014515	0.002161	0.005575	0.006779	0.
45	0.008992	0.001164	0.002954	0.004874	0.
50	0.006940	0.000839	0.002451	0.003649	0.
55	0.008023	0.000793	0.001493	0.005737	0.
60	0.007291	0.000722	0.001555	0.005015	0.
65	0.006527	0.001012	0.001956	0.003559	0.
70	0.006051	0.000951	0.002118	0.002982	0.
75	0.005108	0.000803	0.001788	0.002517	0.
80	0.002754	0.000434	0.000964	0.001357	0.
85	0.	0.	0.	0.	0.
gross	1.446002	0.228114	0.498880	0.719007	0.
crude	0.020910	0.003311	0.007284	0.010315	0.
m.age	29.0784	28.4189	28.1433	29.9364	0.

APPENDIX B.2 Single-region life tables for each of the four US regions.

Northeast.

age	population number	population - % -	births number	births - % -	deaths number	deaths - % -	arrivals number	arrivals - % -	departures number	departures - % -	observed rates (x 1000) birth	death	inmig	outmig	net mig
0	3991155.	8.14	0.	0.	18280.	3.67	61500.	11.02	73000.	9.93	0.	4.580	15.409	18.290	-2.881
5	4598870.	9.38	0.	0.	1862.	0.37	56250.	10.08	83500.	11.36	0.	0.405	12.231	18.157	-5.925
10	4760108.	9.71	1868.	0.22	1564.	0.31	42000.	7.53	63500.	8.64	0.392	0.329	8.823	13.340	-4.517
15	4319751.	8.81	107668.	12.96	4040.	0.81	44000.	7.89	52250.	7.11	24.925	0.935	10.186	12.096	-1.910
20	3695722.	7.54	300834.	36.22	4752.	0.95	139250.	24.96	136000.	18.50	81.401	1.286	37.679	36.799	0.879
25	3167984.	6.46	248842.	29.96	3945.	0.79	78000.	13.98	97250.	13.23	78.549	1.245	24.621	30.698	-6.076
30	2678284.	5.46	110600.	13.32	4404.	0.88	34250.	6.14	62250.	8.47	41.295	1.644	12.788	23.242	-10.454
35	2694395.	5.49	47290.	5.69	6393.	1.28	29499.	5.29	36173.	4.92	17.551	2.373	10.948	13.425	-2.477
40	3029781.	6.18	12632.	1.52	10680.	2.14	21001.	3.76	28827.	3.92	4.169	3.525	6.932	9.515	-2.583
45	3111549.	6.34	774.	0.09	17091.	3.43	15104.	2.71	20117.	2.74	0.249	5.493	4.854	6.465	-1.611
50	2918178.	5.95	0.	0.	25487.	5.11	10146.	1.82	17383.	2.36	0.	8.734	3.477	5.957	-2.480
55	2621429.	5.35	0.	0.	35407.	7.10	6147.	1.10	17232.	2.34	0.	13.507	2.345	6.574	-4.229
60	2254113.	4.60	0.	0.	46182.	9.26	5353.	0.96	19018.	2.59	0.	20.488	2.375	8.437	-6.062
65	1803083.	3.68	0.	0.	54950.	11.02	6089.	1.09	14792.	2.01	0.	30.476	3.377	8.204	-4.827
70	1435711.	2.93	0.	0.	66837.	13.41	5228.	0.94	7755.	1.05	0.	46.553	3.641	5.402	-1.760
75	999203.	2.04	0.	0.	71934.	14.43	3138.	0.56	4652.	0.63	0.	71.991	3.141	4.656	-1.515
80	585908.	1.19	0.	0.	61392.	12.31	1047.	0.19	1552.	0.21	0.	104.781	1.787	2.649	-0.862
85	375479.	0.77	0.	0.	63389.	12.71	0.	0.	0.	0.	0.	168.822	0.	0.	0.
tot	49040708.	100.00	830508.	100.00	498589.	100.00	558002.	100.00	735251.	100.00					
gross											1.243	2.436	0.823	1.120	
crude(x1000)											16.935	10.167	11.378	14.993	-3.614
m.age		33.52		25.84		66.22		23.87		25.78	26.64	77.17	28.21	31.02	
e(0)												70.99			

APPENDIX B.2 *Continued.*

table - single region life table n.east mortality level = 70.99

age	p(x)	q(x)	l(x)	d(x)	ll(x)	m(x)	s(x)	t(x)	e(x)
0	0.977359	0.022641	100000.	2264.	4.943397	0.004580	0.987550	70.9917	70.9917
5	0.997978	0.002022	97736.	198.	4.881852	0.000405	0.998168	66.0483	67.5784
10	0.998359	0.001641	97538.	160.	4.872908	0.000329	0.996848	61.1664	62.7102
15	0.995335	0.004665	97378.	454.	4.857548	0.000935	0.994465	56.2935	57.8092
20	0.993592	0.006408	96924.	621.	4.830662	0.001286	0.993692	51.4360	53.0685
25	0.993793	0.006207	96303.	598.	4.800189	0.001245	0.992805	46.6053	48.3946
30	0.991812	0.008188	95705.	784.	4.765655	0.001644	0.990017	41.8051	43.6813
35	0.988206	0.011794	94921.	1119.	4.718077	0.002373	0.985385	37.0395	39.0213
40	0.982529	0.017471	93802.	1639.	4.649120	0.003525	0.977761	32.3214	34.4571
45	0.972908	0.027092	92163.	2497.	4.545728	0.005493	0.965193	27.6723	30.0254
50	0.957264	0.042736	89666.	3832.	4.387507	0.008734	0.946215	23.1266	25.7918
55	0.934672	0.065328	85834.	5607.	4.151523	0.013507	0.919154	18.7390	21.8317
60	0.902552	0.097448	80227.	7818.	3.815890	0.020488	0.881611	14.5875	18.1829
65	0.858410	0.141590	72409.	10252.	3.364132	0.030476	0.827504	10.7716	14.8761
70	0.791500	0.208500	62156.	12960.	2.783831	0.046553	0.748842	7.4075	11.9175
75	0.694946	0.305054	49197.	15008.	2.084648	0.071991	0.649804	4.6237	9.3983
80	0.584846	0.415154	34189.	14194.	1.354613	0.104781	0.874352	2.5390	7.4264
85	0.	1.000000	19995.	19995.	1.184408	0.168822	0.	1.1844	5.9234

net reproduction rate 1.193374

net migraproduction rate 1.017215

North Central.

age	population number	population - % -	births number	births - % -	deaths number	deaths - % -	arrivals number	arrivals - % -	departures number	departures - % -	observed rates (x 1000) birth	death	inmig	outmig	net mig
0	4837268.	8.55	0.	0.	23149.	4.28	121000.	13.28	113500.	11.04	0.	4.786	25.014	23.464	1.550
5	5696243.	10.07	0.	0.	2391.	0.44	103500.	11.36	119250.	11.60	0.	0.420	18.170	20.935	-2.765
10	5965440.	10.54	2678.	0.26	2161.	0.40	66500.	7.30	88750.	8.63	0.449	0.362	11.148	14.877	-3.730
15	5402978.	9.55	170860.	16.46	5971.	1.10	74500.	8.18	94250.	9.17	31.623	1.105	13.789	17.444	-3.655
20	4382524.	7.75	399636.	38.49	6078.	1.12	214000.	23.49	193750.	18.84	91.189	1.387	48.830	44.210	4.621
25	3664711.	6.48	280666.	27.03	4743.	0.88	125000.	13.72	136000.	13.23	76.586	1.294	34.109	37.111	-3.002
30	3117407.	5.51	119340.	11.49	4855.	0.90	61000.	6.70	68000.	6.61	38.282	1.557	19.568	21.813	-2.245
35	3008922.	5.32	49830.	4.80	6708.	1.24	41521.	4.56	57791.	5.62	16.561	2.229	13.799	19.207	-5.407
40	3276073.	5.79	14456.	1.39	11359.	2.10	30729.	3.37	46209.	4.49	4.413	3.467	9.380	14.105	-4.725
45	3309386.	5.85	878.	0.08	17862.	3.30	20077.	2.20	24107.	2.34	0.265	5.397	6.067	7.284	-1.218
50	3059407.	5.41	0.	0.	25783.	4.77	14173.	1.56	19893.	1.93	0.	8.427	4.633	6.502	-1.870
55	2754367.	4.87	0.	0.	35786.	6.62	8982.	0.99	16564.	1.61	0.	12.992	3.261	6.014	-2.753
60	2369513.	4.19	0.	0.	46190.	8.54	7768.	0.85	16936.	1.65	0.	19.493	3.278	7.147	-3.869
65	1912867.	3.38	0.	0.	54894.	10.15	8324.	0.91	15794.	1.54	0.	28.697	4.352	8.257	-3.905
70	1537213.	2.72	0.	0.	67971.	12.57	7737.	0.85	9697.	0.94	0.	44.217	5.033	6.308	-1.275
75	1132593.	2.00	0.	0.	77763.	14.38	4641.	0.51	5819.	0.57	0.	68.659	4.098	5.138	-1.040
80	689585.	1.22	0.	0.	70024.	12.95	1547.	0.17	1941.	0.19	0.	101.545	2.243	2.815	-0.571
85	455166.	0.80	0.	0.	77195.	14.27	0.	0.	0.	0.	0.	169.597	0.	0.	0.
tot	56571668.	100.00	1038344.	100.00	540883.	100.00	910999.	100.00	1028251.	100.00					
gross											1.297	2.378	1.134	1.313	
crude(x1000)											18.354	9.561	16.103	18.176	-2.073
m.age		32.28		25.17		66.01		22.64		24.27	26.15	77.23	27.58	29.99	
e(0)												71.26			

APPENDIX B.2 *Continued.*

table - single region life table n.centr. mortality level = 71.26

age	p(x)	q(x)	l(x)	d(x)	ll(x)	m(x)	s(x)	t(x)	e(x)
0	0.976355	0.023645	100000.	2364.	4.940888	0.004786	0.987000	71.2637	71.2637
5	0.997903	0.002097	97636.	205.	4.876658	0.000420	0.998047	66.3229	67.9290
10	0.998190	0.001810	97431.	176.	4.867133	0.000362	0.996342	61.4462	63.0665
15	0.994490	0.005510	97255.	536.	4.849327	0.001105	0.993792	56.5791	58.1763
20	0.993090	0.006910	96719.	668.	4.819221	0.001387	0.993319	51.7297	53.4848
25	0.993550	0.006450	96050.	620.	4.787022	0.001294	0.992899	46.9105	48.8396
30	0.992243	0.007757	95431.	740.	4.753027	0.001557	0.990586	42.1235	44.1404
35	0.988915	0.011085	94690.	1050.	4.708281	0.002229	0.985881	37.3705	39.4659
40	0.982813	0.017187	93641.	1609.	4.641804	0.003467	0.978133	32.6622	34.8803
45	0.973372	0.026628	92031.	2451.	4.540303	0.005397	0.966151	28.0204	30.4466
50	0.958732	0.041268	89581.	3697.	4.386619	0.008427	0.948135	23.4801	26.2111
55	0.937081	0.062919	85884.	5404.	4.159106	0.012992	0.922559	19.0935	22.2317
60	0.907062	0.092938	80480.	7480.	3.837022	0.019493	0.887588	14.9343	18.5565
65	0.866119	0.133881	73001.	9773.	3.405695	0.028697	0.835859	11.0973	15.2017
70	0.800921	0.199079	63227.	12587.	2.846680	0.044217	0.759151	7.6916	12.1651
75	0.706997	0.293003	50640.	14838.	2.161059	0.068659	0.660640	4.8449	9.5674
80	0.595071	0.404929	35802.	14497.	1.427682	0.101545	0.879892	2.6839	7.4964
85	0.	1.000000	21305.	21305.	1.256206	0.169597	0.	1.2562	5.8963

net reproduction rate 1.243228

net migraproduction rate 1.200544

South.

age	population number	- % -	births number	- % -	deaths number	- % -	arrivals number	- % -	departures number	- % -	observed rates (x 1000) birth	death	inmig	outmig	net mig
0	5389233.	8.58	0.	0.	31099.	5.24	132750.	10.51	147250.	11.74	0.	5.771	24.632	27.323	-2.691
5	6227912.	9.92	0.	0.	3000.	0.51	145750.	11.54	142250.	11.34	0.	0.482	23.403	22.841	0.562
10	6508350.	10.36	5970.	0.49	3045.	0.51	112500.	8.91	107250.	8.55	0.917	0.468	17.285	16.479	0.807
15	6069949.	9.67	257432.	21.30	7644.	1.29	103750.	8.22	109000.	8.69	42.411	1.259	17.092	17.957	-0.865
20	5275729.	8.40	465460.	38.52	8272.	1.39	229250.	18.15	299750.	23.89	88.227	1.568	43.454	56.817	-13.363
25	4166153.	6.63	287352.	23.78	6824.	1.15	161750.	12.81	161750.	12.89	68.973	1.638	38.825	38.825	0.
30	3555505.	5.66	122930.	10.17	7456.	1.26	92250.	7.31	80500.	6.42	34.575	2.097	25.946	22.641	3.305
35	3438676.	5.48	53224.	4.40	10115.	1.70	63690.	5.04	53387.	4.25	15.478	2.942	18.522	15.525	2.996
40	3622962.	5.77	14942.	1.24	15842.	2.67	50810.	4.02	38863.	3.10	4.124	4.373	14.024	10.727	3.298
45	3599656.	5.73	1036.	0.09	24558.	4.14	32481.	2.57	32610.	2.60	0.288	6.822	9.023	9.059	-0.036
50	3266214.	5.20	0.	0.	32483.	5.47	28019.	2.22	22140.	1.76	0.	9.945	8.578	6.778	1.800
55	2981929.	4.75	0.	0.	44560.	7.51	30275.	2.40	15610.	1.24	0.	14.943	10.153	5.235	4.918
60	2650466.	4.22	0.	0.	55002.	9.27	29975.	2.37	13390.	1.07	0.	20.752	11.309	5.052	6.257
65	2206608.	3.51	0.	0.	66347.	11.18	25398.	2.01	11761.	0.94	0.	30.067	11.510	5.330	6.180
70	1642483.	2.62	0.	0.	72258.	12.18	13390.	1.06	10688.	0.85	0.	43.993	8.152	6.507	1.645
75	1114156.	1.77	0.	0.	73860.	12.45	8034.	0.64	6413.	0.51	0.	66.292	7.211	5.756	1.455
80	644677.	1.03	0.	0.	63113.	10.64	2679.	0.21	2138.	0.17	0.	97.899	4.156	3.316	0.839
85	434709.	0.69	0.	0.	67862.	11.44	0.	0.	0.	0.	0.	156.109	0.	0.	0.
tot	62795372.	100.00	1208346.	100.00	593340.	100.00	1262751.	100.00	1254750.	100.00					
gross											1.275	2.337	1.466	1.381	
crude(x1000)											19.243	9.449	20.109	19.982	0.127
m.age		31.92		24.52		63.03		25.31		22.98	25.60	76.13	31.95	28.37	
e(0)												69.90			

APPENDIX B.2 *Continued.*

table - single region life table south mortality level = 69.90

age	p(x)	q(x)	l(x)	d(x)	ll(x)	m(x)	s(x)	t(x)	e(x)
0	0.971557	0.028443	100000.	2844.	4.928894	0.005771	0.984388	69.9043	69.9043
5	0.997594	0.002406	97156.	234.	4.851944	0.000482	0.997629	64.9754	66.8776
10	0.997663	0.002337	96922.	226.	4.840440	0.000468	0.995696	60.1235	62.0328
15	0.993723	0.006277	96696.	607.	4.819604	0.001259	0.992959	55.2830	57.1722
20	0.992191	0.007809	96089.	750.	4.785672	0.001568	0.992018	50.4634	52.5176
25	0.991844	0.008156	95338.	778.	4.747472	0.001638	0.990711	45.6777	47.9112
30	0.989570	0.010430	94561.	986.	4.703374	0.002097	0.987496	40.9303	43.2847
35	0.985400	0.014600	93574.	1366.	4.644561	0.002942	0.981912	36.2269	38.7146
40	0.978373	0.021627	92208.	1994.	4.560551	0.004373	0.972482	31.5823	34.2512
45	0.966460	0.033540	90214.	3026.	4.435053	0.006822	0.959098	27.0218	29.9530
50	0.951481	0.048519	87188.	4230.	4.253652	0.009945	0.940020	22.5867	25.9057
55	0.927974	0.072026	82958.	5975.	3.998516	0.014943	0.915163	18.3331	22.0993
60	0.901358	0.098642	76983.	7594.	3.659296	0.020752	0.881834	14.3346	18.6205
65	0.860173	0.139827	69389.	9702.	3.226892	0.030067	0.833194	10.6753	15.3847
70	0.801830	0.198170	59687.	11828.	2.688628	0.043993	0.763484	7.4484	12.4791
75	0.715662	0.284338	47859.	13608.	2.052725	0.066292	0.670232	4.7598	9.9455
80	0.606753	0.393247	34251.	13469.	1.375803	0.097899	0.967597	2.7070	7.9036
85	0.	1.000000	20782.	20782.	1.331223	0.156109	0.	1.3312	6.4058

net reproduction rate 1.213106

net migraproduction rate 1.255053

West.

age	population number	- % -	births number	- % -	deaths number	- % -	arrivals number	- % -	departures number	- % -	observed rates (x 1000) birth	death	inmig	outmig	net mig
0	2936681.	8.44	0.	0.	13687.	4.76	105500.	10.40	87000.	11.95	0.	4.661	35.925	29.625	6.300
5	3433222.	9.86	0.	0.	1463.	0.51	118500.	11.68	79000.	10.86	0.	0.426	34.516	23.010	11.505
10	3555570.	10.22	1236.	0.19	1361.	0.47	96500.	9.51	58000.	7.97	0.348	0.383	27.141	16.312	10.828
15	3277670.	9.42	108748.	16.62	3968.	1.38	85500.	8.43	52250.	7.18	33.178	1.211	26.086	15.941	10.144
20	3017046.	8.67	252944.	38.67	4536.	1.58	208500.	20.56	161500.	22.19	83.838	1.503	69.107	53.529	15.578
25	2478145.	7.12	178044.	27.22	3491.	1.21	130750.	12.89	100500.	13.81	71.846	1.409	52.761	40.555	12.207
30	2079240.	5.97	74936.	11.45	3475.	1.21	72500.	7.15	49250.	6.77	36.040	1.671	34.869	23.687	11.182
35	1964858.	5.65	29900.	4.57	4298.	1.49	52604.	5.19	39963.	5.49	15.217	2.187	26.772	20.339	6.434
40	2052138.	5.90	7922.	1.21	7222.	2.51	41146.	4.06	29787.	4.09	3.860	3.519	20.050	14.515	5.535
45	2095348.	6.02	458.	0.07	11159.	3.88	28013.	2.76	18841.	2.59	0.219	5.326	13.369	8.992	4.377
50	1860219.	5.34	0.	0.	15094.	5.25	19987.	1.97	12909.	1.77	0.	8.114	10.744	6.940	3.805
55	1615303.	4.64	0.	0.	20394.	7.09	16962.	1.67	12960.	1.78	0.	12.625	10.501	8.023	2.478
60	1342692.	3.86	0.	0.	24852.	8.64	16038.	1.58	9790.	1.35	0.	18.509	11.945	7.291	4.653
65	1069067.	3.07	0.	0.	28753.	10.00	9514.	0.94	6978.	0.96	0.	26.895	8.899	6.527	2.372
70	828424.	2.38	0.	0.	33521.	11.66	6798.	0.67	5013.	0.69	0.	40.464	8.206	6.051	2.155
75	588882.	1.69	0.	0.	37252.	12.96	4079.	0.40	3008.	0.41	0.	63.259	6.927	5.108	1.819
80	364141.	1.05	0.	0.	34465.	11.99	1361.	0.13	1003.	0.14	0.	94.647	3.738	2.754	0.983
85	245547.	0.71	0.	0.	38509.	13.39	0.	0.	0.	0.	0.	156.829	0.	0.	0.
tot	34804200.	100.00	654188.	100.00	287500.	100.00	1014252.	100.00	727752.	100.00					
gross											1.223	2.218	2.008	1.446	
crude(x1000)											18.796	8.260	29.142	20.910	8.232
m.age		31.69		25.10		64.10		23.80		23.76	26.02	76.96	29.21	29.08	
e(0)												71.82			

APPENDIX B.2 *Continued.*

table - single region life table west mortality level = 71.82

age	p(x)	q(x)	l(x)	d(x)	ll(x)	m(x)	s(x)	t(x)	e(x)
0	0.976965	0.023035	100000.	2304.	4.942412	0.004661	0.987296	71.8227	71.8227
5	0.997872	0.002128	97696.	208.	4.879626	0.000426	0.997980	66.8803	68.4572
10	0.998088	0.001912	97489.	186.	4.869768	0.000383	0.996028	62.0007	63.5979
15	0.993965	0.006035	97302.	587.	4.850428	0.001211	0.993240	57.1309	58.7149
20	0.992511	0.007489	96715.	724.	4.817640	0.001503	0.992745	52.2805	54.0562
25	0.992981	0.007019	95991.	674.	4.782689	0.001409	0.992332	47.4628	49.4453
30	0.991678	0.008322	95317.	793.	4.746015	0.001671	0.990406	42.6801	44.7771
35	0.989122	0.010878	94524.	1028.	4.700480	0.002187	0.985858	37.9341	40.1319
40	0.982557	0.017443	93496.	1631.	4.634005	0.003519	0.978178	33.2336	35.5457
45	0.973722	0.026278	91865.	2414.	4.532883	0.005326	0.967069	28.5996	31.1324
50	0.960236	0.039764	89451.	3557.	4.383610	0.008114	0.949737	24.0668	26.9051
55	0.938804	0.061196	85894.	5256.	4.163279	0.012625	0.925606	19.6831	22.9157
60	0.911548	0.088452	80637.	7133.	3.853556	0.018509	0.893640	15.5199	19.2465
65	0.873995	0.126005	73505.	9262.	3.443692	0.026895	0.847072	11.6663	15.8715
70	0.816268	0.183732	64243.	11803.	2.917057	0.040464	0.776103	8.2226	12.7993
75	0.726896	0.273104	52439.	14321.	2.263936	0.063259	0.680770	5.3056	10.1175
80	0.617314	0.382686	38118.	14587.	1.541219	0.094647	0.973518	3.0416	7.9795
85	0.	1.000000	23531.	23531.	1.500405	0.156829	0.	1.5004	6.3764

net reproduction rate 1.171596

net migraproduction rate 1.331207

Total US.

age	population number	population - % -	births number	births - % -	deaths number	deaths - % -	arrivals number	arrivals - % -	departures number	departures - % -	observed rates (x 1000) birth	death	inmig	outmig	net mig
0	17154338.	8.44	0.	0.	86215.	4.49	420750.	11.23	420750.	11.23	0.	5.026	24.527	24.527	0.
5	19956248.	9.82	0.	0.	8716.	0.45	424000.	11.32	424000.	11.32	0.	0.437	21.246	21.246	0.
10	20789468.	10.23	11752.	0.31	8131.	0.42	317500.	8.48	317500.	8.48	0.565	0.391	15.272	15.272	0.
15	19070348.	9.38	644708.	17.28	21623.	1.13	307750.	8.22	307750.	8.22	33.807	1.134	16.138	16.138	0.
20	16371021.	8.06	1418874.	38.03	23638.	1.23	791000.	21.12	791000.	21.12	86.670	1.444	48.317	48.317	0.
25	13476993.	6.63	994904.	26.66	19003.	0.99	495500.	13.23	495500.	13.23	73.822	1.410	36.766	36.766	0.
30	11430436.	5.62	427806.	11.47	20190.	1.05	260000.	6.94	260000.	6.94	37.427	1.766	22.746	22.746	0.
35	11106851.	5.47	180244.	4.83	27514.	1.43	187314.	5.00	187314.	5.00	16.228	2.477	16.865	16.865	0.
40	11980954.	5.90	49952.	1.34	45103.	2.35	143686.	3.84	143686.	3.84	4.169	3.765	11.993	11.993	0.
45	12115939.	5.96	3146.	0.08	70670.	3.68	95675.	2.55	95675.	2.55	0.260	5.833	7.897	7.897	0.
50	11104018.	5.46	0.	0.	98847.	5.15	72325.	1.93	72325.	1.93	0.	8.902	6.513	6.513	0.
55	9973028.	4.91	0.	0.	136147.	7.09	62366.	1.66	62366.	1.66	0.	13.652	6.253	6.253	0.
60	8616784.	4.24	0.	0.	172226.	8.97	59134.	1.58	59134.	1.58	0.	19.987	6.863	6.863	0.
65	6991625.	3.44	0.	0.	204944.	10.67	49325.	1.32	49325.	1.32	0.	29.313	7.055	7.055	0.
70	5443831.	2.68	0.	0.	240587.	12.53	33153.	0.89	33153.	0.89	0.	44.194	6.090	6.090	0.
75	3834834.	1.89	0.	0.	260809.	13.58	19892.	0.53	19892.	0.53	0.	68.011	5.187	5.187	0.
80	2284311.	1.12	0.	0.	228994.	11.92	6634.	0.18	6634.	0.18	0.	100.246	2.904	2.904	0.
85	1510901.	0.74	0.	0.	246955.	12.86	0.	0.	0.	0.	0.	163.449	0.	0.	0.
tot	203211920.	100.00	3731386.	100.00	1920312.	100.00	3746004.	100.00	3746004.	100.00					
gross											1.265	2.357	1.313	1.313	
crude(x1000)											18.362	9.450	18.434	18.434	0.
m.age		32.37		25.10		64.86		24.04		24.04	26.07	76.84	29.46	29.46	
e(0)												70.84			

APPENDIX B.2 *Continued.*

table - single region life table usa mortality level = 70.84

age	p(x)	q(x)	l(x)	d(x)	ll(x)	m(x)	s(x)	t(x)	e(x)
0	0.975183	0.024817	100000.	2482.	4.937957	0.005026	0.986358	70.8414	70.8414
5	0.997819	0.002181	97518.	213.	4.870595	0.000437	0.997932	65.9034	67.5806
10	0.998046	0.001954	97306.	190.	4.860524	0.000391	0.996198	61.0328	62.7229
15	0.994347	0.005653	97115.	549.	4.842046	0.001134	0.993579	56.1723	57.8407
20	0.992806	0.007194	96566.	695.	4.810955	0.001444	0.992890	51.3302	53.1554
25	0.992975	0.007025	95872.	674.	4.776750	0.001410	0.992094	46.5193	48.5224
30	0.991207	0.008793	95198.	837.	4.738985	0.001766	0.989456	41.7425	43.8480
35	0.987690	0.012310	94361.	1162.	4.689019	0.002477	0.984541	37.0036	39.2148
40	0.981353	0.018647	93200.	1738.	4.616532	0.003765	0.976351	32.3145	34.6724
45	0.971255	0.028745	91462.	2629.	4.507357	0.005833	0.963965	27.6980	30.2837
50	0.956459	0.043541	88833.	3868.	4.344935	0.008902	0.945477	23.1906	26.1060
55	0.933995	0.066005	84965.	5608.	4.108037	0.013652	0.919905	18.8457	22.1806
60	0.904820	0.095180	79357.	7553.	3.779005	0.019987	0.885165	14.7377	18.5714
65	0.863443	0.136557	71804.	9805.	3.345044	0.029313	0.834516	10.9587	15.2620
70	0.801013	0.198987	61998.	12337.	2.791491	0.044194	0.760251	7.6136	12.2804
75	0.709363	0.290637	49661.	14433.	2.122235	0.068011	0.663652	4.8221	9.7100
80	0.599212	0.400788	35228.	14119.	1.408425	0.100246	0.916965	2.6999	7.6641
85	0.	1.000000	21109.	21109.	1.291476	0.163449	0.	1.2915	6.1181

net reproduction rate 1.209916

net migraproduction rate 1.198496

Appendix C

MULTIREGIONAL LIFE TABLE

C.1 Expected Number of Survivors at Exact Age x
C.2 Life Expectancy by Region of Birth
C.3 Life Expectancy by Region of Residence

APPENDIX C.1 Expected number of survivors at exact age x.

age / initial region of cohort n.east

age	total	n.east	n.centr.	south	west
0	100000.	100000.	0.	0.	0.
5	97723.	89280.	2546.	3937.	1959.
10	97522.	81584.	4595.	7662.	3681.
15	97354.	76436.	5874.	9759.	5286.
20	96869.	71947.	6866.	11459.	6597.
25	96216.	60983.	10130.	15494.	9609.
30	95575.	53362.	12205.	18333.	11674.
35	94752.	47953.	13468.	20627.	12704.
40	93597.	45127.	13921.	21336.	13213.
45	91876.	42844.	13980.	21641.	13412.
50	89264.	40763.	13859.	21211.	13430.
55	85386.	38169.	13409.	20649.	13158.
60	79753.	34721.	12548.	19988.	12496.
65	72127.	30224.	11315.	18985.	11603.
70	62217.	25117.	9747.	17139.	10214.
75	49769.	19551.	7911.	13935.	8371.
80	35240.	13396.	5671.	10071.	6103.
85	21088.	7771.	3405.	6137.	3774.

age / initial region of cohort n.centr.

age	total	n.east	n.centr.	south	west
0	100000.	0.	100000.	0.	0.
5	97624.	1446.	87078.	5390.	3710.
10	97417.	2598.	78796.	9391.	6633.
15	97235.	3408.	73500.	12175.	8152.
20	96688.	4439.	67748.	14684.	9817.
25	96001.	7501.	56855.	18136.	13508.
30	95342.	9029.	49532.	21016.	15764.
35	94531.	9419.	45773.	22455.	16884.
40	93398.	10037.	42416.	23565.	17380.
45	91678.	10289.	39797.	24056.	17537.
50	89071.	10299.	37980.	23467.	17325.
55	85235.	9994.	35729.	22681.	16831.
60	79668.	9286.	32811.	21715.	15855.
65	72167.	8257.	29007.	20294.	14609.
70	62434.	7091.	24462.	18094.	12787.
75	50150.	5725.	19338.	14645.	10442.
80	35722.	4049.	13546.	10540.	7586.
85	21507.	2393.	8024.	6409.	4682.

age   initial region of cohort   south
***   *********************************

age	total	n.east	n.centr.	south	west
0	100000.	0.	0.	100000.	0.
5	97188.	2763.	5413.	85047.	3965.
10	96959.	4527.	8553.	76513.	7366.
15	96745.	5674.	9950.	71200.	9920.
20	96159.	6885.	11778.	65773.	11723.
25	95437.	10605.	17134.	52412.	15287.
30	94731.	12287.	19196.	46479.	16770.
35	93859.	12436.	19767.	43730.	17926.
40	92662.	12920.	19576.	41961.	18205.
45	90876.	13046.	19195.	40449.	18186.
50	88180.	12960.	18878.	38322.	18019.
55	84272.	12518.	18165.	36090.	17500.
60	78641.	11641.	16955.	33628.	16417.
65	71161.	10361.	15223.	30544.	15033.
70	61490.	8865.	13126.	26433.	13066.
75	49389.	7129.	10659.	20986.	10613.
80	35223.	5027.	7641.	14874.	7682.
85	21253.	2966.	4586.	8969.	4732.

age   initial region of cohort   west
***   *********************************

age	total	n.east	n.centr.	south	west
0	100000.	0.	0.	0.	100000.
5	97679.	2201.	5145.	5881.	84452.
10	97470.	3606.	7908.	10213.	75741.
15	97280.	4347.	9520.	13037.	70376.
20	96702.	4962.	11146.	15199.	65394.
25	95987.	8465.	16004.	19233.	52285.
30	95307.	10183.	18037.	22118.	44969.
35	94478.	10612.	18911.	23354.	41600.
40	93346.	11175.	19151.	24316.	38705.
45	91619.	11378.	19052.	24676.	36514.
50	89015.	11314.	18786.	24136.	34779.
55	85201.	10934.	18125.	23294.	32847.
60	79654.	10182.	16920.	22426.	30126.
65	72209.	9069.	15205.	20964.	26971.
70	62556.	7782.	13104.	18555.	23115.
75	50397.	6270.	10621.	14977.	18530.
80	36051.	4427.	7601.	10760.	13263.
85	21827.	2614.	4557.	6537.	8119.

APPENDIX C.2 Life expectancy by region of birth.

age — initial region of cohort n.east

age	total	n.east	n.centr.	south	west
0	71.08402	41.72749	8.18820	13.15777	8.01057
5	67.68236	37.85765	8.31390	13.36368	8.14713
10	62.81631	33.55529	8.14793	13.09381	8.01927
15	57.92054	29.55540	7.89317	12.66910	7.80288
20	53.19797	25.87388	7.60388	12.18494	7.53526
25	48.54193	22.59549	7.21386	11.56729	7.16530
30	43.85108	19.75621	6.67805	10.76014	6.65667
35	39.21005	17.25455	6.05863	9.82563	6.07125
40	34.66310	14.98130	5.40183	8.82605	5.45392
45	30.26563	12.86821	4.74384	7.82196	4.83161
50	26.07808	10.90319	4.10296	6.85072	4.22122
55	22.14896	9.08733	3.49091	5.93625	3.63447
60	18.53660	7.44423	2.92376	5.08163	3.08698
65	15.23225	5.98028	2.40579	4.26811	2.57807
70	12.26020	4.70907	1.94266	3.49641	2.11206
75	9.70145	3.64313	1.54153	2.81002	1.70677
80	7.67042	2.80783	1.21350	2.26548	1.38362
85	6.14050	2.18288	0.95197	1.86439	1.14125

age — initial region of cohort n.centr.

age	total	n.east	n.centr.	south	west
0	71.07962	5.84480	39.89208	14.68605	10.65669
5	67.74854	5.95001	36.07210	14.90541	10.82102
10	62.88716	5.85888	31.89195	14.55775	10.57858
15	58.00033	5.71546	28.03606	14.03054	10.21828
20	53.31463	5.54495	24.54265	13.41550	9.81153
25	48.67812	5.27368	21.47338	12.65678	9.27428
30	43.99735	4.87670	18.83219	11.71764	8.57082
35	39.35346	4.43067	16.47332	10.66854	7.78093
40	34.80042	3.96363	14.31255	9.56610	6.95814
45	30.40625	3.48371	12.33912	8.44693	6.13649
50	26.22299	3.00783	10.51726	7.36030	5.33760
55	22.29072	2.54801	8.82868	6.33803	4.57600
60	18.67379	2.12105	7.29485	5.38779	3.87010
65	15.35471	1.73374	5.91152	4.49245	3.21699
70	12.35867	1.38945	4.69209	3.65563	2.62151
75	9.77348	1.09094	3.65792	2.91897	2.10564
80	7.71139	0.84761	2.83398	2.33539	1.69441
85	6.15564	0.65904	2.19970	1.90875	1.38815

age initial region of cohort south

age	total	n.east	n.centr.	south	west
0	70.50226	7.73190	11.94552	39.52089	11.30395
5	67.46995	7.88456	12.15194	35.90440	11.52904
10	62.62316	7.71520	11.82049	31.82339	11.26408
15	57.75644	7.46871	11.36854	28.07684	10.84235
20	53.09325	7.18772	10.87293	24.68685	10.34575
25	48.47560	6.78389	10.19775	21.77753	9.71642
30	43.81856	6.23039	9.31507	19.33019	8.94291
35	39.20209	5.62972	8.36373	17.10685	8.10178
40	34.67637	5.01839	7.41034	15.01598	7.23167
45	30.30872	4.40269	6.48940	13.04397	6.37267
50	26.15907	3.80001	5.60842	11.20958	5.54106
55	22.25604	3.22039	4.76953	9.52184	4.74428
60	18.67080	2.68300	3.99461	7.98740	4.00580
65	15.37047	2.19203	3.28402	6.57248	3.32194
70	12.39468	1.75514	2.64793	5.28964	2.70198
75	9.81913	1.37560	2.09273	4.18540	2.16540
80	7.76263	1.06602	1.63549	3.32338	1.73773
85	6.22198	0.82660	1.27233	2.70329	1.41976

age initial region of cohort west

age	total	n.east	n.centr.	south	west
0	71.15323	6.56556	11.64443	15.23917	37.70407
5	67.78438	6.66522	11.78941	15.45073	33.87902
10	62.92479	6.53059	11.47995	15.07116	29.84308
15	58.04239	6.33890	11.05440	14.50298	26.14610
20	53.37476	6.13615	10.58629	13.85979	22.79253
25	48.75351	5.83212	9.95799	13.06617	19.89722
30	44.08353	5.38459	9.13611	12.07471	17.48812
35	39.44860	4.88161	8.23863	10.97746	15.35091
40	34.89631	4.35727	7.31910	9.83376	13.38619
45	30.50705	3.82403	6.41465	8.68231	11.58607
50	26.32632	3.29859	5.53960	7.56540	9.92272
55	22.39305	2.79344	4.70454	6.51239	8.38268
60	18.77839	2.32521	3.93224	5.53093	6.99000
65	15.45667	1.89842	3.22543	4.59895	5.73387
70	12.45604	1.51793	2.59181	3.72928	4.61702
75	9.85799	1.18711	2.04019	2.96562	3.66507
80	7.78606	0.91775	1.58845	2.36102	2.91884
85	6.23070	0.70937	1.23105	1.91843	2.37185

APPENDIX C.3 Life expectancy by region of residence.

age	region of residence at age x		n.east		
***	*************************************				
	total	n.east	n.centr.	south	west
0	71.08402	41.72749	8.18820	13.15777	8.01057
5	67.68832	40.84627	7.28475	12.21012	7.34717
10	62.82857	39.00417	6.32351	10.91358	6.58731
15	57.93130	36.21154	5.66763	10.11582	5.93632
20	53.19233	33.16441	5.16561	9.45369	5.40862
25	48.51542	33.78391	3.66542	7.20884	3.85726
30	43.79019	33.76642	2.40232	5.19759	2.42386
35	39.12661	32.69015	1.44275	3.31357	1.68014
40	34.55098	30.09105	0.81107	2.50272	1.14614
45	30.10974	26.91284	0.43206	1.95834	0.80649
50	25.86823	23.39980	0.26450	1.61776	0.58618
55	21.90064	19.98137	0.16097	1.31194	0.44636
60	18.24130	16.81873	0.10658	1.00024	0.31575
65	14.91794	14.04027	0.04972	0.63627	0.19168
70	11.94160	11.50300	0.02882	0.30324	0.10654
75	9.41157	9.18769	0.01358	0.15606	0.05424
80	7.43117	7.35683	0.00414	0.05227	0.01793
85	5.92341	5.92341	0.00000	0.00000	0.00000

age	region of residence at age x		n.centr.		
***	*************************************				
	total	n.east	n.centr.	south	west
0	71.07962	5.84480	39.89209	14.68604	10.65669
5	67.76663	5.30614	39.21971	13.48958	9.75120
10	62.92219	4.75405	37.30129	12.15464	8.71220
15	58.04802	4.35598	34.38209	11.14687	8.16308
20	53.37427	3.87570	31.74917	10.17042	7.57898
25	48.77275	2.50459	32.67643	7.87375	5.71799
30	44.11512	1.58927	33.19486	5.51192	3.81907
35	39.46629	1.08711	31.67903	3.98775	2.71240
40	34.90052	0.63452	29.79581	2.68554	1.78465
45	30.47740	0.36202	27.21391	1.78194	1.11953
50	26.24605	0.20609	23.80216	1.39135	0.84644
55	22.26833	0.11294	20.43442	1.06987	0.65110
60	18.59039	0.09495	17.20924	0.81514	0.47107
65	15.22886	0.08503	14.29433	0.56060	0.28890
70	12.18382	0.05283	11.68302	0.28017	0.16779
75	9.57871	0.02538	9.33260	0.13839	0.08234
80	7.50102	0.00798	7.42185	0.04478	0.02641
85	5.89632	-0.00000	5.89632	0.00000	0.

age region of residence at age x south

age	total	n.east	n.centr.	south	west
0	70.50226	7.73190	11.94552	39.52089	11.30395
5	67.42799	7.07381	10.67300	39.12160	10.55957
10	62.54313	6.43883	9.54084	37.10961	9.45385
15	57.65096	5.98119	8.99042	34.17208	8.50727
20	52.96284	5.52035	8.25624	31.36399	7.82226
25	48.22291	3.80256	5.49299	33.23503	5.69233
30	43.48182	2.41594	3.22782	33.72038	4.11768
35	38.83044	1.78197	2.08523	32.26788	2.69537
40	34.31391	1.19214	1.44798	29.88105	1.79273
45	29.98134	0.83416	1.05476	26.89887	1.19355
50	25.90945	0.58011	0.75595	23.83459	0.73880
55	22.08942	0.41863	0.56751	20.64837	0.45491
60	18.60393	0.32039	0.45319	17.54850	0.28185
65	15.36450	0.23917	0.37949	14.60526	0.14058
70	12.46112	0.16166	0.26522	11.94340	0.09084
75	9.93361	0.08426	0.13796	9.66455	0.04684
80	7.89851	0.02811	0.04571	7.80923	0.01546
85	6.40578	0.00000	0.	6.40578	0.

age region of residence at age x west

age	total	n.east	n.centr.	south	west
0	71.15323	6.56556	11.64443	15.23917	37.70407
5	67.81278	5.82870	10.31338	14.00636	37.66435
10	62.98110	5.18222	9.29087	12.60189	35.90612
15	58.12101	4.82809	8.61391	11.58432	33.09469
20	53.48443	4.61353	7.93223	10.75461	30.18407
25	48.98134	3.07191	5.66538	8.18454	32.05951
30	44.43323	1.94029	3.91697	5.61785	32.95813
35	39.86972	1.25289	2.77108	4.15752	31.68824
40	35.35983	0.75796	1.76535	2.89243	29.94409
45	31.00159	0.45650	1.04855	2.06737	27.42917
50	26.80800	0.31632	0.71066	1.54467	24.23635
55	22.84112	0.23500	0.47108	1.22175	20.91329
60	19.19536	0.17166	0.35819	0.76484	17.90067
65	15.83789	0.12757	0.26520	0.43055	15.01458
70	12.77946	0.07568	0.16847	0.24422	12.29109
75	10.10801	0.03737	0.08335	0.12249	9.86480
80	7.97662	0.01168	0.02594	0.03890	7.90011
85	6.37635	-0.00000	0.00000	-0.00000	6.37635

Appendix D

MULTIREGIONAL POPULATION PROJECTIONS AND STABLE EQUIVALENT POPULATION, TOTAL POPULATION: 1970–2020

LEGEND

m.ag: mean age of population
sha: percentage of population in each region
lam: intrinsic growth ratio
r: intrinsic growth rate

APPENDIX D

Multiregional population projections.

year 1970

population

age	total	n.east	n.centr.	south	west
0	17154338.	3991155.	4837268.	5389233.	2936681.
5	19956248.	4598870.	5696243.	6227912.	3433222.
10	20789468.	4760108.	5965440.	6508350.	3555570.
15	19070348.	4319751.	5402978.	6069949.	3277670.
20	16371021.	3695722.	4382524.	5275729.	3017046.
25	13476993.	3167984.	3664711.	4166153.	2478145.
30	11430436.	2678284.	3117407.	3555505.	2079240.
35	11106851.	2694395.	3008922.	3438676.	1964858.
40	11980954.	3029781.	3276073.	3622962.	2052138.
45	12115939.	3111549.	3309386.	3599656.	2095348.
50	11104018.	2918178.	3059407.	3266214.	1860219.
55	9973028.	2621429.	2754367.	2981929.	1615303.
60	8616784.	2254113.	2369513.	2650466.	1342692.
65	6991625.	1803083.	1912867.	2206608.	1069067.
70	5443831.	1435711.	1537213.	1642483.	828424.
75	3834834.	999203.	1132593.	1114156.	588882.
80	2284311.	585908.	689585.	644677.	364141.
85	1510901.	375479.	455166.	434709.	245547.
total	203211952.	49040708.	56571668.	62795372.	34804200.

percentage distribution

age	total	n.east	n.centr.	south	west
0	8.4416	8.1385	8.5507	8.5822	8.4377
5	9.8204	9.3777	10.0691	9.9178	9.8644
10	10.2304	9.7064	10.5449	10.3644	10.2159
15	9.3845	8.8085	9.5507	9.6662	9.4175
20	8.0561	7.5360	7.7469	8.4015	8.6686
25	6.6320	6.4599	6.4780	6.6345	7.1202
30	5.6249	5.4613	5.5105	5.6620	5.9741
35	5.4656	5.4942	5.3188	5.4760	5.6455
40	5.8958	6.1781	5.7910	5.7695	5.8962
45	5.9622	6.3448	5.8499	5.7324	6.0204
50	5.4643	5.9505	5.4080	5.2014	5.3448
55	4.9077	5.3454	4.8688	4.7486	4.6411
60	4.2403	4.5964	4.1885	4.2208	3.8578
65	3.4406	3.6767	3.3813	3.5140	3.0717
70	2.6789	2.9276	2.7173	2.6156	2.3802
75	1.8871	2.0375	2.0020	1.7743	1.6920
80	1.1241	1.1947	1.2190	1.0266	1.0463
85	0.7435	0.7656	0.8046	0.6923	0.7055
total	100.0000	100.0000	100.0000	100.0000	100.0000
m.ag	32.3664	33.5177	32.2785	31.9241	31.6852
sha	100.0000	24.1328	27.8388	30.9014	17.1270

year 1975

population

age	total	n.east	n.centr.	south	west
0	19788476.	4344006.	5580634.	6285792.	3578045.
5	16920322.	3857439.	4764670.	5277049.	3021164.
10	19914970.	4474207.	5598765.	6235180.	3606817.
15	20710424.	4669093.	5836371.	6486276.	3718684.
20	18948012.	4280473.	5334405.	5858304.	3474829.
25	16254525.	3640141.	4378769.	5056094.	3179521.
30	13370420.	3023415.	3595478.	4160813.	2590714.
35	11309884.	2572352.	3032555.	3563931.	2141045.
40	10934894.	2625116.	2895991.	3424541.	1989246.
45	11697381.	2932724.	3157846.	3550151.	2056660.
50	11679383.	2974016.	3174060.	3466435.	2064871.
55	10498810.	2716291.	2868213.	3122435.	1791872.
60	9174617.	2349631.	2500298.	2806096.	1518592.
65	7627630.	1934183.	2063449.	2410064.	1219934.
70	5835280.	1467842.	1579249.	1873146.	915043.
75	4139222.	1066606.	1161179.	1262427.	649010.
80	2545255.	645265.	745247.	750886.	403858.
85	2097553.	510794.	605599.	625521.	355639.
total	213447072.	50083600.	58872780.	66215140.	38275552.

percentage distribution

age	total	n.east	n.centr.	south	west
0	9.2709	8.6735	9.4791	9.4930	9.3481
5	7.9272	7.7020	8.0932	7.9696	7.8932
10	9.3302	8.9335	9.5099	9.4165	9.4233
15	9.7028	9.3226	9.9135	9.7958	9.7156
20	8.8771	8.5467	9.0609	8.8474	9.0785
25	7.6152	7.2681	7.4377	7.6359	8.3069
30	6.2640	6.0367	6.1072	6.2838	6.7686
35	5.2987	5.1361	5.1510	5.3824	5.5938
40	5.1230	5.2415	4.9191	5.1718	5.1972
45	5.4802	5.8557	5.3638	5.3615	5.3733
50	5.4718	5.9381	5.3914	5.2351	5.3948
55	4.9187	5.4235	4.8719	4.7156	4.6815
60	4.2983	4.6914	4.2469	4.2378	3.9675
65	3.5735	3.8619	3.5049	3.6397	3.1872
70	2.7338	2.9308	2.6825	2.8289	2.3907
75	1.9392	2.1297	1.9724	1.9066	1.6956
80	1.1925	1.2884	1.2659	1.1340	1.0551
85	0.9827	1.0199	1.0287	0.9447	0.9292
total	100.0000	100.0000	100.0000	100.0000	100.0000
m.ag	32.7134	33.8670	32.4763	32.4783	31.9755
sna	100.0000	23.4642	27.5819	31.0218	17.9321
lam	1.050367	1.021266	1.040676	1.054459	1.099739
r	0.009828	0.004209	0.007974	0.010606	0.019015

APPENDIX D *Continued.*

year 1980

population

age	total	n.east	n.centr.	south	west
0	22223464.	4824871.	6326685.	6934909.	4136998.
5	19518264.	4220754.	5502248.	6147488.	3647774.
10	16885314.	3755656.	4690096.	5284457.	3155106.
15	19839150.	4392952.	5488371.	6214994.	3742834.
20	20577550.	4628337.	5767476.	6281078.	3900660.
25	18813446.	4209997.	5258829.	5677989.	3666632.
30	16125838.	3495072.	4306863.	5044307.	3279596.
35	13229430.	2912323.	3504903.	4170599.	2641605.
40	11134625.	2516234.	2923136.	3544504.	2150751.
45	10675493.	2546715.	2797620.	3347563.	1983595.
50	11275488.	2805230.	3030567.	3414603.	2025089.
55	11042917.	2770085.	2977437.	3312359.	1983036.
60	9658839.	2435288.	2604481.	2939814.	1679256.
65	8122335.	2016935.	2178125.	2552271.	1375004.
70	6366943.	1575220.	1704462.	2045355.	1041907.
75	4438493.	1092123.	1195589.	1435073.	715708.
80	2748238.	689131.	765287.	849146.	444674.
85	2339844.	562660.	654791.	727969.	394423.
total	225015696.	51449588.	61676964.	69924480.	41964648.

percentage distribution

age	total	n.east	n.centr.	south	west
0	9.8764	9.3779	10.2578	9.9177	9.8583
5	8.6742	8.2037	8.9211	8.7916	8.6925
10	7.5041	7.2997	7.6043	7.5574	7.5185
15	8.8168	8.5384	8.8986	8.8882	8.9190
20	9.1449	8.9959	9.3511	8.9827	9.2951
25	8.3609	8.1828	8.5264	8.1202	8.7374
30	7.1665	6.7932	6.9829	7.2139	7.8151
35	5.8793	5.6605	5.6827	5.9644	6.2948
40	4.9484	4.8907	4.7394	5.0690	5.1252
45	4.7443	4.9499	4.5359	4.7874	4.7268
50	5.0110	5.4524	4.9136	4.8833	4.8257
55	4.9076	5.3841	4.8275	4.7371	4.7255
60	4.2925	4.7333	4.2228	4.2043	4.0016
65	3.6097	3.9202	3.5315	3.6500	3.2766
70	2.8296	3.0617	2.7635	2.9251	2.4828
75	1.9725	2.1227	1.9385	2.0523	1.7055
80	1.2214	1.3394	1.2408	1.2144	1.0596
85	1.0399	1.0936	1.0616	1.0411	0.9399
total	100.0000	100.0000	100.0000	100.0000	100.0000
m.ag	32.6954	33.7806	32.2883	32.6741	31.9989
sha	100.0000	22.8649	27.4101	31.0754	18.6497
lam	1.054199	1.027274	1.047631	1.056020	1.096383
r	0.010556	0.005382	0.009306	0.010901	0.018403

year 1985

population

age	total	n.east	n.centr.	south	west
0	23518764.	5098661.	6702783.	7226393.	4490928.
5	21920326.	4691722.	6229720.	6803491.	4195394.
10	19477820.	4124482.	5418054.	6150134.	3785151.
15	16820984.	3689347.	4602960.	5268068.	3260609.
20	19711724.	4365290.	5444180.	6019762.	3882492.
25	20431426.	4555060.	5691560.	6111141.	4073666.
30	18664842.	4039915.	5137774.	5701927.	3785226.
35	15955767.	3378711.	4203626.	5052557.	3320873.
40	13024462.	2854720.	3383502.	4148969.	2637271.
45	10870233.	2447424.	2826697.	3461755.	2134356.
50	10289933.	2439833.	2688948.	3214107.	1947046.
55	10660668.	2614348.	2844127.	3258830.	1943364.
60	10159786.	2484931.	2704883.	3116969.	1853003.
65	8551799.	2091092.	2269739.	2674561.	1516406.
70	6781103.	1643397.	1799979.	2166374.	1171353.
75	4843890.	1172491.	1291053.	1566848.	813498.
80	2948650.	706450.	789294.	963073.	489833.
85	2530600.	601050.	672891.	822542.	434117.
total	237162800.	52998920.	64701776.	73727504.	45734588.

percentage distribution

age	total	n.east	n.centr.	south	west
0	9.9167	9.6203	10.3595	9.8015	9.8195
5	9.2427	8.8525	9.6284	9.2279	9.1734
10	8.2128	7.7822	8.3739	8.3417	8.2763
15	7.0926	6.9612	7.1141	7.1453	7.1294
20	8.3115	8.2366	8.4143	8.1649	8.4892
25	8.6149	8.5946	8.7966	8.2888	8.9072
30	7.8701	7.6226	7.9407	7.7338	8.2765
35	6.7278	6.3751	6.4969	6.8530	7.2612
40	5.4918	5.3864	5.2294	5.6274	5.7665
45	4.5834	4.6179	4.3688	4.6953	4.6668
50	4.3388	4.6036	4.1559	4.3594	4.2573
55	4.4951	4.9328	4.3957	4.4201	4.2492
60	4.2839	4.6886	4.1805	4.2277	4.0516
65	3.6059	3.9455	3.5080	3.6276	3.3157
70	2.8593	3.1008	2.7820	2.9384	2.5612
75	2.0424	2.2123	1.9954	2.1252	1.7787
80	1.2433	1.3330	1.2199	1.3063	1.0710
85	1.0670	1.1341	1.0400	1.1157	0.9492
total	100.0000	100.0000	100.0000	100.0000	100.0000
m.ag	32.6291	33.5644	32.0697	32.8045	32.0538
sha	100.0000	22.3471	27.2816	31.0873	19.2840
lam	1.053983	1.030114	1.049043	1.054388	1.089836
r	0.010515	0.005934	0.009576	0.010592	0.017205

APPENDIX D *Continued.*

year 1990

population

age	total	n.east	n.centr.	soutn	west
0	23442928.	5048945.	6644662.	7168655.	4580667.
5	23198280.	4957954.	6598685.	7108571.	4533070.
10	21874932.	4587258.	6129539.	6821332.	4336804.
15	19403440.	4063647.	5319129.	6127064.	3893599.
20	16712878.	3670915.	4576104.	5103639.	3362220.
25	19571646.	4309499.	5394633.	5858421.	4009093.
30	20270098.	4372814.	5563909.	6149507.	4183869.
35	18468386.	3904828.	4997747.	5731915.	3833897.
40	15708535.	3320396.	4061768.	5025649.	3300722.
45	12715213.	2780340.	3274971.	4052745.	2607156.
50	10477512.	2348906.	2718784.	3321301.	2088521.
55	9728457.	2276487.	2526355.	3062060.	1863556.
60	9807946.	2346364.	2584716.	3062444.	1814422.
65	8996148.	2135122.	2358520.	2833429.	1669077.
70	7140700.	1704434.	1876546.	2270487.	1289233.
75	5160301.	1223803.	1363980.	1659866.	912651.
80	3218828.	758677.	852648.	1051437.	556066.
85	2720996.	616493.	694528.	931990.	477985.
total	248617248.	54426888.	67537224.	77340520.	49312608.

percentage distribution

age	total	n.east	n.centr.	soutn	west
0	9.4293	9.2766	9.8385	9.2690	9.2890
5	9.3309	9.1094	9.7704	9.1913	9.1925
10	8.7986	8.4283	9.0758	8.8199	8.7945
15	7.8045	7.4662	7.8758	7.9222	7.8957
20	6.7223	6.7447	6.7757	6.5989	6.8182
25	7.8722	7.9180	7.9876	7.5748	8.1300
30	8.1531	8.0343	8.2383	7.9512	8.4844
35	7.4284	7.1744	7.4000	7.4113	7.7747
40	6.3184	6.1007	6.0141	6.4981	6.6935
45	5.1144	5.1084	4.8491	5.2401	5.2870
50	4.2143	4.3157	4.0256	4.2944	4.2353
55	3.9130	4.1827	3.7407	3.9592	3.7791
60	3.9450	4.3110	3.8271	3.9597	3.6794
65	3.6185	3.9229	3.4922	3.6636	3.3847
70	2.8722	3.1316	2.7785	2.9357	2.6144
75	2.0756	2.2485	2.0196	2.1462	1.8507
80	1.2947	1.3939	1.2625	1.3595	1.1276
85	1.0945	1.1327	1.0284	1.2050	0.9693
total	100.0000	100.0000	100.0000	100.0000	100.0000
m.ag	32.7159	33.4583	32.0589	33.0384	32.2905
sha	100.0000	21.8918	27.1651	31.1083	19.8347
lam	1.048298	1.026943	1.043823	1.049005	1.078234
r	0.009434	0.005317	0.008578	0.009568	0.015065

year 1995

population

age	total	n.east	n.centr.	south	west
0	23362444.	4926308.	6589134.	7191026.	4655977.
5	23123582.	4912638.	6547268.	7058390.	4605285.
10	23150268.	4847473.	6491861.	7140695.	4670237.
15	21791404.	4521510.	6014102.	6806800.	4448991.
20	19278508.	4069916.	5291914.	5928794.	3987885.
25	16594065.	3630011.	4545398.	4968034.	3450622.
30	19417046.	4143964.	5284531.	5894848.	4093703.
35	20056864.	4227734.	5414601.	6188462.	4226068.
40	18182660.	3837120.	4818780.	5714753.	3812007.
45	15335483.	3239204.	3933830.	4908535.	3253914.
50	12255985.	2670800.	3151837.	3888539.	2544810.
55	9905834.	2194498.	2555699.	3161715.	1993922.
60	8950285.	2045225.	2297964.	2871860.	1735235.
65	8684762.	2017172.	2254745.	2779809.	1633036.
70	7513012.	1741699.	1951319.	2403681.	1416312.
75	5435097.	1269696.	1422634.	1739923.	1002844.
80	3430186.	792163.	901095.	1114013.	622915.
85	2972374.	662166.	750407.	1017473.	542328.
total	259439872.	55749300.	70217120.	80777352.	52696096.

percentage distribution

age	total	n.east	n.centr.	south	west
0	9.0050	8.8365	9.3839	8.9023	8.8355
5	8.9129	8.8120	9.3243	8.7381	8.7393
10	8.9232	8.6951	9.2454	8.8400	8.8626
15	8.3994	8.1104	8.5650	8.4266	8.4427
20	7.4308	7.3004	7.5365	7.3397	7.5677
25	6.3961	6.5113	6.4733	6.1503	6.5482
30	7.4842	7.4332	7.5260	7.2976	7.7685
35	7.7308	7.5835	7.7112	7.6611	8.0197
40	7.0084	6.8828	6.8627	7.0747	7.2339
45	5.9110	5.8103	5.6024	6.0766	6.1749
50	4.7240	4.7907	4.4887	4.8139	4.8292
55	3.8182	3.9364	3.6397	3.9141	3.7838
60	3.4498	3.6686	3.2727	3.5553	3.2929
65	3.3475	3.6183	3.2111	3.4413	3.0990
70	2.8959	3.1242	2.7790	2.9757	2.6877
75	2.0949	2.2775	2.0261	2.1540	1.9031
80	1.3222	1.4209	1.2833	1.3791	1.1821
85	1.1457	1.1878	1.0687	1.2596	1.0292
total	100.0000	100.0000	100.0000	100.0000	100.0000
m.ag	32.9351	33.5213	32.2209	33.3276	32.6649
sha	100.0000	21.4883	27.0649	31.1353	20.3115
lam	1.043531	1.024297	1.039680	1.044438	1.068613
r	0.008522	0.004801	0.007783	0.008696	0.013272

APPENDIX D *Continued.*

year 2000

population

age	total	n.east	n.centr.	south	west
0	24366898.	5024941.	6879038.	7526271.	4936648.
5	23044040.	4803326.	6499596.	7074129.	4666990.
10	23075724.	4805071.	6444585.	7094809.	4731260.
15	23061888.	4777695.	6369151.	7135263.	4779778.
20	21651086.	4533517.	5976196.	6601572.	4539802.
25	19141296.	4055928.	5259290.	5762749.	4063331.
30	16462959.	3493680.	4458030.	4999025.	3512224.
35	19212780.	4010354.	5148486.	5931614.	4122327.
40	19746704.	4155139.	5222475.	6174311.	4194779.
45	17751406.	3743053.	4660473.	5589423.	3758458.
50	14781681.	3115058.	3787403.	4708966.	3170254.
55	11587545.	2496874.	2964064.	3701873.	2424734.
60	9113849.	1973717.	2325562.	2962565.	1852005.
65	7925910.	1760318.	2006739.	2600879.	1557973.
70	7253438.	1646563.	1866585.	2355438.	1384852.
75	5720060.	1298466.	1480349.	1841275.	1099969.
80	3613806.	822091.	940156.	1167886.	683672.
85	3169894.	691507.	793154.	1078093.	607139.
total	270680992.	57207300.	73081336.	84306152.	56086192.

percentage distribution

age	total	n.east	n.centr.	south	west
0	9.0021	8.7837	9.4129	8.9273	8.8019
5	8.5134	8.3964	8.8936	8.3910	8.3211
10	8.5251	8.3994	8.8184	8.4155	8.4357
15	8.5200	8.3515	8.7152	8.4635	8.5222
20	7.9987	7.9247	8.1775	7.8305	8.0943
25	7.0715	7.0899	7.1965	6.8355	7.2448
30	6.0821	6.1071	6.1001	5.9296	6.2622
35	7.0979	7.0102	7.0449	7.0358	7.3500
40	7.2952	7.2633	7.1461	7.3237	7.4792
45	6.5581	6.5430	6.3771	6.6299	6.7012
50	5.4609	5.4452	5.1824	5.5856	5.6525
55	4.2809	4.3646	4.0558	4.3910	4.3232
60	3.3670	3.4501	3.1822	3.5141	3.3021
65	2.9281	3.0771	2.7459	3.0850	2.7778
70	2.6797	2.8782	2.5541	2.7939	2.4691
75	2.1132	2.2698	2.0256	2.1840	1.9612
80	1.3351	1.4370	1.2865	1.3853	1.2190
85	1.1711	1.2088	1.0853	1.2788	1.0825
total	100.0000	100.0000	100.0000	100.0000	100.0000
m.ag	33.1345	33.5927	32.3671	33.5704	33.0118
sha	100.0000	21.1346	26.9991	31.1459	20.7204
lam	1.043328	1.026153	1.040791	1.043686	1.064333
r	0.008483	0.005163	0.007996	0.008552	0.012470

year 2005

population

age	total	n.east	n.centr.	south	west
0	25951778.	5301153.	7346777.	7976095.	5327751.
5	24034698.	4910102.	6786950.	7401191.	4936457.
10	22996316.	4704820.	6401281.	7105884.	4784333.
15	22987608.	4737180.	6325342.	7092603.	4832482.
20	22913400.	4790618.	6327727.	6933796.	4861259.
25	21497002.	4524217.	5931504.	6433157.	4608125.
30	18989968.	3919664.	5158050.	5792355.	4119899.
35	16289770.	3382778.	4346134.	5030074.	3530784.
40	18915676.	3944144.	4969682.	5918146.	4083704.
45	19278532.	4053672.	5051895.	6041574.	4131392.
50	17110990.	3599354.	4482689.	5367135.	3661813.
55	13975694.	2914558.	3562783.	4482160.	3016193.
60	10661583.	2246938.	2698041.	3468745.	2247860.
65	8071674.	1700924.	2031843.	2679744.	1659163.
70	6620875.	1438872.	1663606.	2199702.	1318695.
75	5523221.	1228344.	1416929.	1802945.	1075003.
80	3804664.	841227.	978805.	1235582.	749050.
85	3341692.	717722.	827659.	1130289.	666022.
total	282965152.	58956288.	76307696.	88091184.	59609988.

percentage distribution

age	total	n.east	n.centr.	south	west
0	9.1714	8.9917	9.6278	9.0544	8.9377
5	8.4939	8.3284	8.8942	8.4017	8.2813
10	8.1269	7.9802	8.3888	8.0665	8.0261
15	8.1238	8.0351	8.2893	8.0514	8.1068
20	8.0976	8.1257	8.2924	7.8712	8.1551
25	7.5970	7.6738	7.7731	7.3028	7.7305
30	6.7111	6.6484	6.7595	6.5754	6.9114
35	5.7568	5.7378	5.6955	5.7101	5.9231
40	6.6848	6.6899	6.5127	6.7182	6.8507
45	6.8130	6.8757	6.6204	6.8583	6.9307
50	6.0470	6.1051	5.8745	6.0927	6.1430
55	4.9390	4.9436	4.6690	5.0881	5.0599
60	3.7678	3.8112	3.5357	3.9377	3.7709
65	2.8525	2.8851	2.6627	3.0420	2.7834
70	2.3398	2.4406	2.1801	2.4971	2.2122
75	1.9519	2.0835	1.8569	2.0467	1.8034
80	1.3446	1.4269	1.2827	1.4026	1.2566
85	1.1810	1.2174	1.0846	1.2831	1.1173
total	100.0000	100.0000	100.0000	100.0000	100.0000
m.ag	33.2788	33.6169	32.4585	33.7595	33.2842
sha	100.0000	20.8352	26.9672	31.1315	21.0662
lam	1.045382	1.030573	1.044147	1.044896	1.062828
r	0.008877	0.006023	0.008640	0.008784	0.012187

APPENDIX D *Continued.*

year 2010

population

age	total	n.east	n.centr.	south	west
0	27244676.	5551167.	7717629.	8322860.	5653021.
5	25598066.	5184462.	7246295.	7851029.	5316280.
10	23984900.	4816537.	6684573.	7432192.	5051599.
15	22908422.	4643534.	6285681.	7100283.	4878924.
20	22839562.	4753392.	6289002.	6896777.	4900393.
25	22750358.	4781525.	6279123.	6772030.	4917680.
30	21327104.	4375631.	5813349.	6475090.	4663033.
35	18790166.	3804436.	5028007.	5824564.	4133160.
40	16037872.	3328114.	4197123.	5018775.	3493860.
45	18467204.	3849460.	4809728.	5791008.	4017008.
50	18583274.	3898250.	4859691.	5803048.	4022285.
55	16178660.	3367397.	4213874.	5113230.	3484159.
60	12859361.	2624591.	3243713.	4198922.	2792135.
65	9443248.	1937645.	2358208.	3136925.	2010469.
70	6744099.	1392458.	1685541.	2264122.	1401977.
75	5043310.	1074863.	1264623.	1681740.	1022084.
80	3674502.	796202.	937298.	1209207.	731795.
85	3521547.	734634.	861882.	1195667.	729365.
total	295996320.	60914296.	79775344.	92087456.	63219224.

percentage distribution

age	total	n.east	n.centr.	south	west
0	9.2044	9.1131	9.6742	9.0380	8.9419
5	8.6481	8.5111	9.0834	8.5256	8.4093
10	8.1031	7.9071	8.3792	8.0708	7.9906
15	7.7394	7.6231	7.8792	7.7104	7.7175
20	7.7162	7.8034	7.8834	7.4894	7.7514
25	7.6860	7.8496	7.8710	7.3539	7.7788
30	7.2052	7.1833	7.2871	7.0315	7.3760
35	6.3481	6.2456	6.3027	6.3250	6.5378
40	5.4183	5.4636	5.2612	5.4500	5.5266
45	6.2390	6.3195	6.0291	6.2886	6.3541
50	6.2782	6.3996	6.0917	6.3017	6.3624
55	5.4658	5.5281	5.2822	5.5526	5.5112
60	4.3444	4.3087	4.0661	4.5597	4.4166
65	3.1903	3.1809	2.9561	3.4065	3.1802
70	2.2784	2.2859	2.1129	2.4587	2.2176
75	1.7038	1.7646	1.5852	1.8262	1.6167
80	1.2414	1.3071	1.1749	1.3131	1.1576
85	1.1897	1.2060	1.0804	1.2984	1.1537
total	100.0000	100.0000	100.0000	100.0000	100.0000
m.ag	33.4295	33.6403	32.5664	33.9590	33.5442
sha	100.0000	20.5794	26.9515	31.1110	21.3581
lam	1.046052	1.033211	1.045443	1.045365	1.060547
r	0.009005	0.006534	0.008888	0.008873	0.011757

year 2015

population

age	total	n.east	n.centr.	south	west
0	28024626.	5681101.	7928810.	8547815.	5866899.
5	26873484.	5430010.	7611443.	8201266.	5630767.
10	25545030.	5088658.	7135562.	7889071.	5431740.
15	23893152.	4759423.	6564196.	7424894.	5144640.
20	22760782.	4670951.	6255260.	6899052.	4935518.
25	22677026.	4748658.	6245819.	6740759.	4941791.
30	22570600.	4625036.	6153661.	6824429.	4967475.
35	21102804.	4249094.	5664982.	6515819.	4672910.
40	18499562.	3749493.	4855441.	5810251.	4084378.
45	15657629.	3248945.	4063207.	4911051.	3434427.
50	17801260.	3702908.	4628194.	5562386.	3907773.
55	17571018.	3647184.	4568601.	5530193.	3825040.
60	14886911.	3032043.	3834321.	4794674.	3225873.
65	11390768.	2265098.	2835906.	3795661.	2494102.
70	7891267.	1587492.	1957258.	2649827.	1696691.
75	5138990.	1041762.	1282127.	1729967.	1085134.
80	3356865.	697450.	837427.	1126969.	695019.
85	3403311.	695478.	825502.	1169872.	712458.
total	309045088.	62920784.	83247712.	96123952.	66752640.

percentage distribution

age	total	n.east	n.centr.	south	west
0	9.0681	9.0290	9.5244	8.8925	8.7890
5	8.6957	8.6299	9.1431	8.5320	8.4353
10	8.2658	8.0874	8.5715	8.2072	8.1371
15	7.7313	7.5641	7.8851	7.7243	7.7070
20	7.3649	7.4235	7.5140	7.1772	7.3937
25	7.3378	7.5470	7.5027	7.0126	7.4031
30	7.3033	7.3506	7.3920	7.0996	7.4416
35	6.8284	6.7531	6.8050	6.7786	7.0003
40	5.9860	5.9591	5.8325	6.0445	6.1187
45	5.0665	5.1635	4.8809	5.1091	5.1450
50	5.7601	5.8850	5.5595	5.7867	5.8541
55	5.6856	5.7965	5.4880	5.7532	5.7302
60	4.8171	4.8188	4.6059	4.9880	4.8326
65	3.6858	3.5999	3.4066	3.9487	3.7363
70	2.5534	2.5230	2.3511	2.7567	2.5418
75	1.6629	1.6557	1.5401	1.7997	1.6256
80	1.0862	1.1085	1.0059	1.1724	1.0412
85	1.1012	1.1053	0.9916	1.2170	1.0673
total	100.0000	100.0000	100.0000	100.0000	100.0000
m.ag	33.6164	33.7183	32.7288	34.1828	33.8118
sha	100.0000	20.3597	26.9371	31.1035	21.5996
lam	1.044084	1.032940	1.043527	1.043833	1.055892
r	0.008628	0.006482	0.008521	0.008580	0.010877

APPENDIX D *Continued.*

year 2020

population

age	total	n.east	n.centr.	south	west
0	28705152.	5759584.	8114701.	8774683.	6056184.
5	27642842.	5559873.	7821669.	8425743.	5835556.
10	26817818.	5330325.	7494755.	8247235.	5745504.
15	25447298.	5030619.	7006073.	7885176.	5525430.
20	23739070.	4799978.	6533281.	7211814.	5193997.
25	22598728.	4679838.	6217969.	6737012.	4963909.
30	22497846.	4595483.	6123575.	6795259.	4983529.
35	22333300.	4491695.	5996748.	6871739.	4973119.
40	20776540.	4189195.	5469596.	6503124.	4614624.
45	18060874.	3664392.	4700487.	5684627.	4011367.
50	15093035.	3125717.	3910569.	4717212.	3339538.
55	16831718.	3465162.	4351960.	5300864.	3713732.
60	16168419.	3284096.	4157313.	5187334.	3539676.
65	13187138.	2616505.	3350061.	4338443.	2882129.
70	9520029.	1857539.	2354563.	3205124.	2102803.
75	6014492.	1188580.	1489529.	2024516.	1311867.
80	3422146.	676759.	849423.	1158801.	737163.
85	3113664.	609515.	737890.	1089916.	676341.
total	321970112.	64924856.	86680160.	100158616.	70206464.

percentage distribution

age	total	n.east	n.centr.	south	west
0	8.9155	8.8712	9.3617	8.7608	8.6262
5	8.5855	8.5635	9.0236	8.4124	8.3120
10	8.3293	8.2100	8.6464	8.2342	8.1837
15	7.9036	7.7484	8.0827	7.8727	7.8703
20	7.3731	7.3931	7.5372	7.2004	7.3982
25	7.0189	7.2081	7.1735	6.7263	7.0704
30	6.9876	7.0782	7.0646	6.7845	7.0984
35	6.9365	6.9183	6.9182	6.8609	7.0836
40	6.4529	6.4524	6.3101	6.4928	6.5729
45	5.6095	5.6441	5.4228	5.6756	5.7137
50	4.6877	4.8144	4.5115	4.7097	4.7567
55	5.2277	5.3372	5.0207	5.2925	5.2897
60	5.0217	5.0583	4.7962	5.1791	5.0418
65	4.0958	4.0301	3.8649	4.3316	4.1052
70	2.9568	2.8611	2.7164	3.2000	2.9952
75	1.8680	1.8307	1.7184	2.0213	1.8686
80	1.0629	1.0424	0.9800	1.1570	1.0500
85	0.9671	0.9388	0.8513	1.0882	0.9634
total	100.0000	100.0000	100.0000	100.0000	100.0000
m.ag	33.8440	33.8625	32.9389	34.4297	34.1090
sha	100.0000	20.1649	26.9218	31.1080	21.8053
lam	1.041822	1.031851	1.041232	1.041974	1.051741
r	0.008194	0.006271	0.008081	0.008223	0.010089

The stable equivalent population.

age	total	n.east	n.centr.	south	west
0	19995214.	3769535.	5701326.	6118026.	4406327.
5	19012078.	3582408.	5420918.	5814223.	4194531.
10	18289076.	3408017.	5144589.	5637318.	4099152.
15	17562520.	3261669.	4868757.	5435767.	3996328.
20	16820342.	3204570.	4669188.	5097035.	3849549.
25	16098688.	3142526.	4470973.	4802893.	3682295.
30	15395935.	2959391.	4223606.	4664948.	3547990.
35	14685235.	2786692.	3967118.	4527011.	3404414.
40	13937370.	2659563.	3692615.	4358530.	3226662.
45	13116776.	2512765.	3445765.	4113475.	3044771.
50	12188585.	2336618.	3196643.	3809446.	2845878.
55	11110116.	2112056.	2897822.	3499952.	2600287.
60	9856033.	1836636.	2542481.	3164670.	2312246.
65	8418136.	1531187.	2142104.	2759779.	1985066.
70	6784856.	1213598.	1713797.	2247747.	1609713.
75	4988683.	878933.	1257120.	1656094.	1196536.
80	3206267.	552193.	803049.	1069599.	781425.
85	2877377.	466128.	682315.	997082.	731852.
total	224343312.	42214484.	60840188.	69773600.	51515020.

percentage distribution

age	total	n.east	n.centr.	south	west
0	8.9128	8.9295	9.3710	8.7684	8.5535
5	8.4745	8.4862	8.9101	8.3330	8.1423
10	8.1523	8.0731	8.4559	8.0794	7.9572
15	7.8284	7.7264	8.0025	7.7906	7.7576
20	7.4976	7.5912	7.6745	7.3051	7.4727
25	7.1759	7.4442	7.3487	6.8835	7.1480
30	6.8627	7.0104	6.9421	6.6858	6.8873
35	6.5459	6.6013	6.5206	6.4881	6.6086
40	6.2125	6.3001	6.0694	6.2467	6.2635
45	5.8467	5.9524	5.6636	5.8955	5.9105
50	5.4330	5.5351	5.2542	5.4597	5.5244
55	4.9523	5.0032	4.7630	5.0162	5.0476
60	4.3933	4.3507	4.1789	4.5356	4.4885
65	3.7523	3.6272	3.5209	3.9553	3.8534
70	3.0243	2.8748	2.8169	3.2215	3.1247
75	2.2237	2.0821	2.0663	2.3735	2.3227
80	1.4292	1.3081	1.3199	1.5330	1.5169
85	1.2826	1.1042	1.1215	1.4290	1.4207
total	100.0000	100.0000	100.0000	100.0000	100.0000
m.ag	34.2062	33.9284	33.2782	34.7606	34.7789
sha	100.0000	18.8169	27.1192	31.1013	22.9626
lam	1.037376	1.037376	1.037376	1.037376	1.037376
r	0.007339	0.007339	0.007339	0.007339	0.007339

Appendix E

METHODOLOGY FOR INTRAREGIONAL CITY–SUBURB POPULATION PROJECTIONS

APPENDIX E.1 THE LINKAGE BETWEEN INTRAREGIONAL CITY–SUBURB PROJECTIONS AND MULTIREGIONAL POPULATION PROJECTIONS

The purpose of this section is to specify a population projection model that links Frey's (1978, 1979a, forthcoming) model of intraregional city–suburb redistribution within a single metropolitan area region to the multiregional redistribution model advanced by Rogers (1975) and Willekens and Rogers (1978) for purposes of producing population projections that are consistent both within and across regions. According to this combined model, the metropolitan area is assumed to be a self-contained labor market region that is part of a nationwide system of labor market regions. Intrametropolitan city–suburb redistribution is therefore seen to be a function of two distinct types of movement processes: inter-labor market migration as specified in the multiregional model and local residential mobility, which occurs within the boundaries of the metropolitan area.

The discussion that follows is intended to accompany the nontechnical treatment in text sections 4.1 and 4.2 and is divided into three parts. In E.1.1 the fundamental equations required for projecting intraregional city–suburb redistribution within a single metropolitan area are presented, while not taking explicit account of the nationwide multiregional redistribution process. Subsection E.1.2 explicates the equations associated with the multiregional projection process, discusses their relationship to the single-region intraregional redistribution equations in E.1.1, and introduces a matrix model of projection that combines both earlier approaches. Subsection E.1.3 introduces an alternative specification for this matrix model of projection that decomposes intraregional *stream mobility rates* into residents' *mobility incidence rates* and movers' *destination propensity rates.* This distinction is analogous to that made between "the resident's decision to move" and "the mover's choice of destination" in the mobility decision-making literature and has proved to be analytically useful in empirical studies of intraregional redistribution (Frey 1978, 1979a, forthcoming).

E.1.1 Intraregional City–Suburb Redistribution within a Single Metropolitan Area

Following Frey's (1978, 1979a, forthcoming) analytic framework, the basic equations used to project intraregional city–suburb redistribution within a single metropolitan area i are as follows:*

$$
\begin{aligned}
K_{i.c}^{(t+1)}(x+5) = {} & s(x)K_{i.c}^{(t)}(x) - s(x)K_{i.c}^{(t)}(x)m_{i.co}(x) \\
& - s(x)[K_{i.c}^{(t)}(x) - K_{i.c}^{(t)}(x)m_{i.co}(x)]\hat{m}_{i.cs}(x) \\
& + s(x)[K_{i.s}^{(t)}(x) - K_{i.s}^{(t)}(x)m_{i.so}(x)]\hat{m}_{i.sc}(x) + s(x)K_{i.o}^{(t)}(x)p_{i.oc}(x) \qquad (1)
\end{aligned}
$$

*The notation used in eqs. (1) and (2) and their alternative specification as eqs. (24) and (25) in subsection E.1.2 differs slightly from that employed in Frey's (1978, 1979a) presentation of this analytic framework. In the earlier specification (see eqs. (7) and (8) in Frey 1978 or eqs. (1) and (2) in Frey 1979a), population totals were represented by the letter P rather than the present K, in-migrants to the metropolitan area were represented by the factor M_o rather than by the present $K_{i.o}^{(t)}$, and there was not an explicit subscript i designation for the metropolitan area or an (x) designation for each age class.

$$K_{i.s}^{(t+1)}(x+5) = s(x)K_{i.s}^{(t)}(x) - s(x)K_{i.s}^{(t)}(x)m_{i.so}(x)$$

$$- s(x)[K_{i.s}^{(t)}(x) - K_{i.s}^{(t)}(x)m_{i.so}(x)]\,\hat{m}_{i.sc}(x)$$

$$+ s(x)[K_{i.c}^{(t)}(x) - K_{i.c}^{(t)}(x)m_{i.co}(x)]\,\hat{m}_{i.cs}(x) + s(x)K_{i.o}^{(t)}(x)p_{i.os}(x) \qquad (2)$$

$$\text{for } 0 \leqslant x \leqslant z-5$$

These are employed to compute end-of-period (time $t + 1$) city and suburb populations for age categories 5–9, 10–14, . . . z (such that z is the uppermost open-ended age category, e.g., 75 and over), given beginning-of-period (time t) populations for age categories 0–4, 5–9, . . . $z-5$ where

$K_{i.c}^{(t)}(x)$ is the city population within metropolitan area i, age x to $x + 4$ at time t

$K_{i.s}^{(t)}(x)$ is the suburb population within metropolitan area i, age x to $x + 4$ at time t

$s(x)$ is the survival rate (proportion of the population ages x to $x + 4$ at time t, that is alive at time $t + 1$)

$m_{i.co}(x)$ is the metropolitan out-migration rate for city residents (proportion of city residents of metropolitan area i, ages x to $x + 4$ at time t and surviving to time $t + 1$, that resides outside of metropolitan area i at time $t + 1$)

$m_{i.so}(x)$ is the metropolitan out-migration rate for suburb residents (proportion of suburb residents of metropolitan area i, ages x to $x + 4$ at time t and surviving to time $t + 1$, that resides outside of metropolitan area i at time $t + 1$)

$\hat{m}_{i.cs}(x)$ is the city-to-suburb mobility rate for city residents (proportion of city residents of metropolitan area i, ages x to $x + 4$ at time t, surviving to time $t + 1$ and not migrating out of the metropolitan area, that resides in the suburbs of metropolitan area i at time $t + 1$)

$\hat{m}_{i.sc}(x)$ is the suburb-to-city mobility rate for suburb residents (proportion of suburb residents of metropolitan area i, ages x to $x + 4$ at time t, surviving to time $t + 1$ and not migrating out of the metropolitan area, that resides in the city of metropolitan area i at time $t + 1$)

$s(x)K_{i.o}^{(t)}(x)$ are the surviving in-migrants to metropolitan area i (sum of all residents outside of metropolitan area i, ages x to $x + 4$ at time t, that survive and reside in metropolitan area i at time $t + 1$)

$p_{i.oc}(x)$ is the city destination propensity rate for in-migrants to metropolitan area i (proportion of in-migrants to metropolitan area i, ages x to $x + 4$ at time t and surviving to time $t + 1$, that resides in the city at time $t + 1$)

$p_{i.os}(x)$ is the suburb destination propensity rate for in-migrants to metropolitan area i (proportion of in-migrants to metropolitan area i, ages x to $x + 4$ at time t and surviving to time $t + 1$, that resides in the suburbs at time $t + 1$)

The equations used to compute end-of-period city and suburb populations for age category 0–4 are presented below.

Equations (1) and (2) show city–suburb redistribution to result from both an exchange of interregional migration streams that lead into and out of the metropolitan area region and the exchange of intraregional city-to-suburb and suburb-to-city mobility streams. Taken term by term, eq. (1) shows the end-of-period city population to equal the surviving beginning-of-period city population that has been reduced by the out-migration from the city to regions outside the metropolitan area and the intrametropolitan city-to-suburb mobility stream and that has been incremented by the intrametropolitan suburb-to-city mobility stream and in-migration to the city from regions outside the metropolitan area. In the same way, eq. (2) shows the end-of-period suburb population equal to the beginning-of-period suburb population after subtracting out-migrants from the suburbs to regions outside the metropolitan area and intrametropolitan suburb to city movers and after adding intrametropolitan city-to-suburb movers and in-migrants to the suburbs from regions outside the metropolitan area.

The rates and populations at risk in eqs. (1) and (2) can best be understood from the perspective of the two-stage redistribution sequence of interregional exchange and intraregional allocation discussed in section 4.1 and depicted in Figure 7. The interregional exchange of migrants affects this single metropolitan area region as rates of metropolitan out-migration ($m_{i.\mathrm{co}}$ and $m_{i.\mathrm{so}}$) are applied to the beginning-of-period city and suburb populations, respectively, while the (surviving) number of metropolitan in-migrants from other regions is represented by the quantity $s(x)K_{i.\mathrm{o}}^{(t)}(x)$.

From the perspective of the metropolitan area i, the interregional exchange ends by producing three at-risk populations to be allocated to city and suburb destinations, which can be specified as follows:

$$s(x)[K_{i.\mathrm{c}}^{(t)}(x) - K_{i.\mathrm{c}}^{(t)}(x)m_{i.\mathrm{co}}(x)]$$

$$s(x)[K_{i.\mathrm{s}}^{(t)}(x) - K_{i.\mathrm{s}}^{(t)}(x)m_{i.\mathrm{so}}(x)]$$

$$s(x)K_{i.\mathrm{o}}^{(t)}(x)$$

The first two at-risk populations represent the beginning-of-period city and suburb populations, respectively, that did not out-migrate from the metropolitan area during the interregional exchange stage, and the third is the surviving population of individuals who in-migrated into the metropolitan area during that stage.

In the second, intraregional allocation stage of the redistribution process, the three at-risk populations listed above will be allocated to city and suburb destinations by intrametropolitan residential mobility rates and destination propensity rates. To the first two at-risk populations are applied rates of city-to-suburb mobility and suburb-to-city mobility $\hat{m}_{i.\mathrm{cs}}(x)$ and $\hat{m}_{i.\mathrm{sc}}(x)$, respectively, yielding the following streams of (surviving) intrametropolitan movers:

$$s(x)[K_{i.\mathrm{c}}^{(t)}(x) - K_{i.\mathrm{c}}^{(t)}(x)m_{i.\mathrm{co}}(x)]\,\hat{m}_{i.\mathrm{cs}}(x)$$

$$s(x)[K_{i.s}^{(t)}(x) - K_{i.s}^{(t)}(x)\, m_{i.so}(x)]\, \hat{m}_{i.sc}(x)$$

Finally, city and suburb destination propensity rates $p_{i.oc}(x)$ and $p_{i.os}(x)$ are applied to the (surviving) population of metropolitan in-migrants, yielding the following numbers of migrants into the city and suburbs, respectively:

$$s(x)K_{i.o}^{(t)}\, p_{i.oc}(x)$$

$$s(x)K_{i.o}^{(t)}\, p_{i.os}(x)$$

The city–suburb redistribution process, as modeled here, is recognized to be one of redistribution across subregions (i.e., the city and suburbs) in a self-contained labor market region. Population change that occurs within each subregion is influenced by the two distinctly different types of movement: inter-labor market migration streams and local residential mobility streams. It is assumed that the size of migration streams that enter and leave the metropolitan area are part of an interregional network of streams whose magnitudes are likely to be influenced by the attributes of their "origin" and "destination" labor market regions. Hence the magnitudes of parameters $m_{i.co}(x)$ and $m_{i.so}(x)$ should be influenced by the labor market attributes of metropolitan area i as an origin, and it is reasonable to model $m_{i.co}(x) = m_{i.so}(x)$ where both rates are equivalent to the out-migration rate for metropolitan residents of age x. The assumption also underlies the specification of a single metropolitan in-migration parameter $K_{i.o}^{(t)}(x)$, which is likely to be influenced by the labor market attributes of metropolitan area i as a destination.

In contrast, the magnitudes of the intrametropolitan residential mobility streams and the local destination selections of metropolitan in-migrants are likely to be influenced by attributes of city and suburban subregions as relevant origins and destinations. Hence the volume of in-migrants to an SMSA's city or suburb should be influenced by the attributes of that subregion as a destination (through its influence on $p_{i.oc}(x)$ or $p_{i.os}(x)$) despite the fact that the total number of in-migrants $K_{i.o}^{(t)}(x)$ is influenced by the attributes of the metropolitan area as a destination. The magnitudes of parameters $\hat{m}_{i.cs}(x)$ and $\hat{m}_{i.sc}(x)$ should be influenced solely by intrametropolitan city and suburb origin and destination attributes. (In subsection E.1.3 a more refined parameterization of the intrametropolitan redistribution is introduced.)

One final aspect of the redistribution equations regards the different conditionalities associated with migration and residential mobility rates. It can be seen from eqs. (1) and (2) that the movement rates for all streams are conditional on surviving (not dying) over the period. Rates of survival and out-migration are therefore multiplicative products of the survival rate $s(x)$ and a migration rate where, for convenience of exposition, survival rates are assumed to be equivalent for all resident and mover groups. The intrametropolitan residential mobility rates $\hat{m}_{i.cs}(x)$ and $\hat{m}_{i.sc}(x)$, however, are conditional on not migrating out of metropolitan area i as well as on survival during the period. Given that an individual is able to make only one movement transition over the period, it is assumed that a local residential move is not substitutable to an inter-labor market migratory move. The individual, then, is at risk of moving locally only if an interregional move was not taken.

It is a straightforward matter to begin the city–suburb projection process with eqs. (1) and (2). Given initial year values for city and suburb populations in age classes 0–4, 5–9, . . . z–5 and values for parameters $s(x)$, $m_{i.\text{co}}(x)$, $m_{i.\text{so}}(x)$, $\hat{m}_{i.\text{cs}}(x)$, $\hat{m}_{i.\text{sc}}(x)$, $K_{i.\text{o}}^{(t)}(x)$, $p_{i.\text{oc}}(x)$, and $p_{i.\text{os}}(x)$, eqs. (1) and (2) will yield the projected end-of-period city and suburb populations in age classes 5–9, 1–14, . . . z. Assuming the availability of age-specific fertility rates $f_i(x)$ for metropolitan area i, the end-of-period city and suburb populations ages 0–4 ($x = 0$) can be estimated as follows:

$$K_{i.\text{c}}^{(t+1)}(0) = \sum_{x=10}^{45} \{2.5s(0)[f_i(x)K_{i.\text{c}}^{(t)}(x) + f_i(x+5)K_{i.\text{c}}^{(t+1)}(x+5)]\} \tag{3}$$

$$K_{i.\text{s}}^{(t+1)}(0) = \sum_{x=10}^{45} \{2.5s(0)[f_i(x)K_{i.\text{s}}^{(t)}(x) + f_i(x+5)K_{i.\text{s}}^{(t+1)}(x+5)]\} \tag{4}$$

where

$s(0)$ is the survival rate of births (proportion of persons born between time t and $t + 1$ that survive to age 0–4 at time $t + 1$)

$f_i(x)$ is the fertility rate (the average annual number of births born to persons age x to $x + 4$ in metropolitan area i)

Because the end-of-period values $K_{i.\text{c}}^{(t+1)}(x)$ and $K_{i.\text{s}}^{(t+1)}(x)$ for all age classes x can be used as beginning-of-period values $K_{i.\text{c}}^{(t)}(x)$ and $K_{i.\text{s}}^{(t)}(x)$ for the next period, eqs. (1), (2), (3), and (4) can be employed repeatedly to project city and suburb populations for as many periods as desired.

It must be understood, however, that these equations do not comprise a "closed system" of redistribution – an exhaustive system of regions with a full matrix of movement stream transition rates between each pair so that end-of-period populations for all regions could be projected from their beginning-of-period populations. Rather, the city–suburb redistribution model discussed above is an "open" one. While it is affected by migration streams that connect metropolitan area i to regions outside its boundaries (through parameters $m_{i.\text{cs}}(x)$, $m_{i.\text{sc}}(x)$, and $K_{i.\text{o}}^{(t)}(x)$), it does not explicitly incorporate these outside regions into the projection process and does not necessarily yield projections that are consistent with a closed process that does incorporate them. This open, single metropolitan area model does have the practical advantage of permitting calculation of intrametropolitan city–suburb projections without requiring migration rates to be specified for all interregional streams in a multiregional system. Assuming such rates can be specified, however, the next subsection explicates how this model can be linked to a closed projection process by treating metropolitan area i as one region in the multiregional redistribution model developed by Rogers (1975).

E.1.2 Combining Intraregional City–Suburb Redistribution with the Multiregional Model

The Rogers (1975) multiregional projection process as specified in Willekens and Rogers (1978, pp. 56–62), assumes redistribution across a closed system of n regions with age-specific populations represented by the following vector:

$$K^{(t)}(x) = \begin{bmatrix} K_1^{(t)}(x) \\ K_2^{(t)}(x) \\ \cdot \\ \cdot \\ \cdot \\ K_n^{(t)}(x) \end{bmatrix}$$

such that

$K^{(t)}(x)$ is the column vector of population totals for n regions of ages x to $x + 4$ at time t with elements $K_i^{(t)}(x)$
$K_i^{(t)}(x)$ is the population total for region i of ages x to $x + 4$ at time t

The process can be represented by the following equations:

$$K^{(t+1)}(x + 5) = \mathbf{S}(x)K^{(t)}(x) \qquad \text{for } 0 < x < z{-}5 \tag{5}$$

and

$$K^{(t+1)}(0) = \sum_{10}^{45} \mathbf{B}(x)K^{(t)}(x) \tag{6}$$

where

$\mathbf{S}(x)$ is an $n \times n$ matrix of survival and out-migration rates with elements $S_{ij}(x)$
$S_{ij}(x)$ is the proportion of residents in region i, ages x to $x + 4$ at time t, that is alive and resides in region j at time $t + 1$
$\mathbf{B}(x)$ is the $n \times n$ matrix of births and survival rates with elements $B_{ij}(x)$
$B_{ij}(x)$ is the average number of babies born between time t and $t + 1$ to residents in region i, ages x to $x + 4$ at time t, that are alive and reside in region j at time $t + 1$

Alternatively, the projection process can be represented by the generalized Leslie matrix as in Willekens and Rogers (1978, pp. 56–59).

If one views metropolitan area i in the previous section as one of the n labor market regions in a closed nationwide system, it is possible to specify links between parameters $m_{i.\text{co}}(x)$, $m_{i.\text{so}}(x)$, and $K_{i.\text{o}}^{(t)}(x)$ in eqs. (1) and (2) and the elements of $\mathbf{S}(x)$ in eq. (5). We assume, as in eqs. (1) and (2), that the same age-specific survival rates $s(x)$ hold for all regional resident and mover subgroups.*

*The assumption that age-specific survival rates will be equivalent among all regional resident and mover subgroups is made throughout this presentation for convenience of exposition and because it is a reasonable one to make for most developed nations. It is nevertheless possible to respecify the equations to allow different regional and subgroup survival rates at age x by replacing each scalar $s(x)$ with an appropriate matrix $\mathbf{S}(x)$.

For our purposes here, $\mathbf{S}(x)$ can be specified as

$$\mathbf{S}(x) = \mathbf{m}(x)s(x) \tag{7}$$

where

$s(x)$ is the survival rate expressed in scalar form (as in eqs. (1) and (2))
$\mathbf{m}(x)$ is an $n \times n$ matrix of interregional migration rates with elements $m_{ij}(x)$
$m_{ij}(x)$ is the proportion of residents in region i, ages x to $x + 4$ at time t and surviving to time $t + 1$, that resides in region j at time $t + 1$

The following relationships between the two models can then be established:

Metropolitan Area Model in eqs. (1) and (2)	Multiregional Model in eq. (5)	
$m_{i.\mathrm{co}}(x)$	$\equiv \sum_{j=1, j \neq i}^{n} m_{ij}(x)$	(8)
$m_{i.\mathrm{so}}(x)$	$\equiv \sum_{j=1, j \neq i}^{n} m_{ij}(x)$	(9)
$s(x)K_{i.\mathrm{o}}^{(t)}$	$\equiv \sum_{j=1, j \neq i}^{n} s(x)K_j^{(t)}(x)m_{ji}(x)$	(10)

which will yield end-of-period values for $K_{i.\mathrm{c}}^{(t+1)}(x)$ and $K_{i.\mathrm{s}}^{(t+1)}(x)$ in eqs. (1) and (2) that are consistent with end-of-period values $\mathbf{K}^{(t+1)}(x + 5)$ in eq. (5) for end-of-period age classes 5–9, 10–14, . . . z.

Assuming that the same age-specific survival rates $s(x)$ hold for all regional resident and mover subgroups, one can estimate $\mathbf{B}(x)$ in eq. (6) as

$$\mathbf{B}(x) = 2.5s(0)[\mathbf{F}(x) + \mathbf{F}(x + 5)\mathbf{S}(x)] \tag{11}$$

where

$s(0)$ is the survival rate of births expressed in scalar form (as in eqs. (3) and (4))
$\mathbf{F}(x)$ is an $n \times n$ matrix of fertility rates with diagonal elements $f_i(x)$
$f_i(x)$ is the average annual number of births to persons x to $x + 4$ in region i

Hence, given the ability to estimate parameters $\mathbf{F}(x)$ and $\mathbf{m}(x)$ (for the multiregional system of n regions), parameters $\hat{m}_{i.\mathrm{cs}}(x)$, $\hat{m}_{i.\mathrm{sc}}(x)$, $p_{i.\mathrm{oc}}(x)$, and $p_{i.\mathrm{os}}(x)$ (for metropolitan area i), and survival parameter $s(x)$, eqs. (1), (2), (3), (4), (5), and (6) can be employed to compute a consistent set of intrametropolitan and interregional projections for any desired number of projection periods.

It is possible to combine both of the redistribution models described above into a single matrix model of redistribution across n regions where each region can be seen as a metropolitan area comprised of a city and suburb subregion. The matrix of age-specific population totals for this system can be specified as

$$\bar{K}^{(t)}(x) = \begin{bmatrix} \bar{K}_1^{(t)}(x) \\ \bar{K}_2^{(t)}(x) \\ \cdot \\ \cdot \\ \cdot \\ \bar{K}_n^{(t)}(x) \end{bmatrix}$$

and

$$\bar{K}_i^{(t)}(x) = \begin{bmatrix} K_{i.c}^{(t)}(x) \\ K_{i.s}^{(t)}(x) \\ K_{i.o}^{(t)}(x) \end{bmatrix}$$

where

$\bar{K}^{(t)}(x)$ is the column vector of population totals for n regions and their subregions, for ages x to $x + 4$

$\bar{K}_i^{(t)}(x)$ is the column vector of subregional populations of region i, for ages x to $x + 4$ with elements $K_{i.c}^{(t)}, K_{i.s}^{(t)}$, and $K_{i.o}^{(t)}$

$K_{i.c}^{(t)}$ is the city population of region (or metropolitan area) i at time t

$K_{i.s}^{(t)}$ is the suburb population of region (or metropolitan area) i at time t

$K_{i.o}^{(t)}$ are the in-migrants to region (or metropolitan area) i (initially assigned a 0 value in the projection process)

and the equation used for the projection of end-of-period population totals of age classes 5–9, 10–14, . . . x is:

$$\bar{K}^{(t+1)}(x + 5) = \bar{\mathbf{S}}(x)\bar{K}^{(t)}(x) \qquad \text{for } 0 \leqslant x \leqslant z{-}5 \tag{12}$$

where

$\bar{\mathbf{S}}(x)$ is a $3n \times 3n$ matrix of survival and out-migration rates with elements $\bar{S}_{i.x,j.y}$

$\bar{S}_{i.x,j.y}(x)$ is the proportion of residents in region i and subregion x, ages x to $x + 4$ at time t, that is alive and resides in region j and subregion y at time $t + 1$ (where subregions x and y can equal c, s, or o)

such that $\bar{\mathbf{S}}(x)$ is defined as

$$\bar{\mathbf{S}}(x) = [\hat{\mathbf{p}}(x) + \hat{\mathbf{m}}(x)]\,\overline{\mathbf{m}}(x)s(x) \tag{13}$$

where

$s(x)$ is the survival rate expressed in scalar form
$\bar{\mathbf{m}}(x)$ is a $3n \times 3n$ matrix of interregional migration rates (specified below in terms of rates $m_{ij}(x)$ defined in eq. (7))
$\hat{\mathbf{m}}(x)$ is a $3n \times 3n$ matrix of intraregional mobility rates (specified below in terms of the rates $\hat{m}_{i.cs}(x)$ and $\hat{m}_{i.sc}$ defined in eqs. (1) and (2))
$\hat{\mathbf{p}}(x)$ is a $3n \times 3n$ matrix of destination propensity rates for interregional in-migrants (specified below in terms of the rates $p_{i.oc}$ and $p_{i.os}$ defined in eqs. (1) and (2))

When (for simplicity) it is assumed that $n = 2$ regions, the elements of $\bar{\mathbf{m}}(x)$, $\hat{\mathbf{m}}(x)$, and $\hat{\mathbf{p}}(x)$ can be specified as

$$\bar{\mathbf{m}}(x) = \left[\begin{array}{ccc|ccc} 1-\sum\limits_{j\neq 1} m_{1j}(x) & 0 & 0 & 0 & 0 & 0 \\ 0 & 1-\sum\limits_{j\neq 1} m_{1j}(x) & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & m_{21}(x) & m_{21}(x) & 0 \\ \hline 0 & 0 & 0 & 1-\sum\limits_{j\neq 2} m_{2j}(x) & 0 & 0 \\ 0 & 0 & 0 & 0 & 1-\sum\limits_{j\neq 2} m_{2j}(x) & 0 \\ m_{12}(x) & m_{12}(x) & 0 & 0 & 0 & 0 \end{array}\right]$$

where rates $m_{ij}(x)$ are elements of matrix $\mathbf{m}(x)$ defined in eq. (7)

$$\hat{\mathbf{m}}(x) = \left[\begin{array}{ccc|ccc} 1-\hat{m}_{1.cs}(x) & \hat{m}_{1.sc}(x) & 0 & 0 & 0 & 0 \\ \hat{m}_{1.cs}(x) & 1-\hat{m}_{1.sc}(x) & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 1-\hat{m}_{2.cs}(x) & \hat{m}_{2.sc}(x) & 0 \\ 0 & 0 & 0 & \hat{m}_{2.cs}(x) & 1-\hat{m}_{2.sc}(x) & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{array}\right]$$

where rates $\hat{m}_{i.cs}(x)$ and $\hat{m}_{i.sc}(x)$ are defined in eqs. (1) and (2) and

$$\hat{\mathrm{p}}(x) = \left[\begin{array}{ccc|ccc} 0 & 0 & p_{1.oc}(x) & 0 & 0 & 0 \\ 0 & 0 & p_{1.os}(x) & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 & p_{2.oc}(x) \\ 0 & 0 & 0 & 0 & 0 & p_{2.os}(x) \\ 0 & 0 & 0 & 0 & 0 & 0 \end{array}\right]$$

where rates $p_{i.os}(x)$ and $p_{i.oc}(x)$ are defined in eqs. (1) and (2).

To show how the projection process in eq. (12) is consistent with the models presented earlier, it is employed here for a simplified two-region system with beginning-of-period values $K_{1.c}^{(t)}(x)K_{1.s}^{(t)}(x)$ and $K_{2.c}^{(t)}(x)K_{2.s}^{(t)}(x)$ such that

$$\overline{K}^{(t)}(x) = \left[\begin{array}{c} K_{1.c}^{(t)}(x) \\ K_{1.s}^{(t)}(x) \\ 0 \\ \hline K_{2.c}^{(t)}(x) \\ K_{2.s}^{(t)}(x) \\ 0 \end{array}\right]$$

(where vector elements $K_{1.o}^{(t)}(x)$ and $K_{2.o}^{(t)}(x)$ are assigned initial values of 0).

It is significant to note that the expression equivalent to $\overline{\mathrm{S}}(x)$, $[\hat{\mathrm{p}}(x) + \hat{\mathrm{m}}(x)]\,\overline{\mathrm{m}}(x)\,s(x)$, can be decomposed into two multiplicative factors where each represents a different stage of the two-stage redistribution process discussed in the previous section. One can represent the projection process in eqs. (12) and (13) as follows:

$$\overline{K}^{(t+1)}(x+5) = [\hat{\mathrm{p}}(x) + \hat{\mathrm{m}}(x)]\,[\overline{\mathrm{m}}(x)s(x)]\,\overline{K}^{(t)}(x) \qquad (14)$$

so that the factor $\overline{\mathrm{m}}(x)s(x)$ represents the interregional exchange stage wherein streams of migrants become redistributed across regions. The intraregional allocation stage is then represented by the factor $\hat{\mathrm{p}}(x) + \hat{\mathrm{m}}(x)$, which both redistributes non-migrating residents to intraregional destinations via residential mobility streams and allocates regional in-migrants to city and suburb destinations.

If one first pre-multiplies the two-region population sector $\overline{K}^{(t)}(x)$ by the interregional exchange factor $\overline{\mathrm{m}}(x)s(x)$, the following vector results:

$$[\overline{\mathrm{m}}(x)s(x)]\overline{K}^{(t)}(x) = \left[\begin{array}{c} s(x)K_{1.c}^{(t)}(x)[1 - \sum\limits_{j\neq 1} m_{1j}(x)] \\ s(x)K_{1.s}^{(t)}(x)[1 - \sum\limits_{j\neq 1} m_{1j}(x)] \\ \sum\limits_{j\neq 1} s(x)K_{j}^{(t)} m_{j1}(x) \\ \hline s(x)K_{2.c}^{(t)}(x)[1 - \sum\limits_{j\neq 2} m_{2j}(x)] \\ s(x)K_{2.s}^{(t)}(x)[1 - \sum\limits_{j\neq 2} m_{2j}(x)] \\ \sum\limits_{j\neq 2} s(x)K_{j}^{(t)} m_{j2}(x) \end{array}\right] = \left[\begin{array}{c} s(x)K_{1.c}^{(t)}(x)[1 - m_{1.co}(x)] \\ s(x)K_{1.s}^{(t)}(x)[1 - m_{1.so}(x)] \\ s(x)K_{1.o}^{(t)}(x) \\ \hline s(x)K_{2.c}^{(t)}(x)[1 - m_{2.co}(x)] \\ s(x)K_{2.s}^{(t)}(x)[1 - m_{2.so}(x)] \\ s(x)K_{2.o}^{(t)}(x) \end{array}\right] \tag{15}$$

The right-most version of this vector is presented in the notation of the single metropolitan area eqs. (1) and (2) (see translation eqs. (8), (9), (10)) and shows that this vector identifies, for each region, the three at-risk populations that are subject to be allocated to city and suburb destinations in the intraregional allocation stage of the redistribution process.

To complete the process, one can pre-multiply this vector by the intraregional allocation factor $\hat{\mathrm{p}}(x) + \hat{\mathrm{m}}(x)$ to obtain the vector, $\overline{K}^{(t+1)}(x + 5)$, where

$$\left[\begin{array}{c} K_{1.c}^{(t+1)}(x) \\ K_{1.s}^{(t+1)}(x) \\ K_{1.o}^{(t+1)}(x) \\ \hline K_{2.c}^{(t+1)}(x) \\ K_{2.s}^{(t+1)}(x) \\ K_{2.o}^{(t+1)}(x) \end{array}\right] = \left[\begin{array}{c} s(x)K_{1.c}^{(t)}(x)[1 - m_{1.co}]\,[1 - \hat{m}_{1.cs}(x)] + s(x)K_{1.s}^{(t)}(x)[1 - m_{1.so}]\,\hat{m}_{1.sc}(x) + s(x)K_{1.o}^{(t)}p_{1.oc} \\ s(x)K_{1.s}^{(t)}(x)[1 - m_{1.so}]\,[1 - \hat{m}_{1.sc}(x)] + s(x)K_{1.c}^{(t)}(x)[1 - m_{1.co}]\,\hat{m}_{1.cs}(x) + s(x)K_{1.o}^{(t)}p_{1.os} \\ 0 \\ \hline s(x)K_{2.c}^{(t)}(x)[1 - m_{2.co}]\,[1 - \hat{m}_{2.cs}(x)] + s(x)K_{2.s}^{(t)}(x)[1 - m_{2.so}]\,\hat{m}_{2.sc}(x) + s(x)K_{2.o}^{(t)}p_{2.oc} \\ s(x)K_{2.s}^{(t)}(x)[1 - m_{2.so}]\,[1 - \hat{m}_{2.sc}(x)] + s(x)K_{2.s}^{(t)}(x)[1 - m_{2.co}]\,\hat{m}_{2.cs}(x) + s(x)K_{2.o}^{(t)}p_{2.os} \\ 0 \end{array}\right] \tag{16}$$

These resulting expressions for the end-of-period population totals $K_{1.c}^{(t+1)}(x+5)$, $K_{1.s}^{(t+1)}(x+5)$ and $K_{2.c}^{(t+1)}(x+5)$, $K_{2.s}^{(t+1)}(x+5)$ are algebraically equivalent to eqs. (1) and (2) of the single metropolitan area redistribution model in subsection E.1.1. This illustrates the equivalence of the intraregional city–suburb redistribution process, which occurs in Frey's (1978, 1979a) single metropolitan area model, to that in the combined intra- and interregional model as specified in eq. (12).

The redistribution that occurs in the combined model is also consistent with the Rogers (1975) multiregional model. Keeping in mind the equivalences in eqs. (8), (9), and (10), as well as the fact that $p_{i.oc} + p_{i.os} = 1$, one can combine the eq. (14) expressions for $K_{1.c}^{(t+1)}(x+5)$, $K_{1.s}^{(t+1)}(x+5)$, $K_{2.c}^{(t+1)}(x+5)$, and $K_{2.s}^{(t+1)}(x+5)$ to yield the following:

$$K_{1.c}^{(t+1)}(x+5) + K_{1.s}^{(t+1)}(x+5) = [K_{1.c}^{(t)}(x) + K_{1.s}^{(t)}(x)]\,[1 - m_{12}(x)] + [K_{2.c}^{(t)}(x) + K_{2.s}^{(t)}(x)]\,m_{21}(x) \qquad (17)$$

$$K_{2.c}^{(t+1)}(x+5) + K_{2.s}^{(t+1)}(x+5) = [K_{2.c}^{(t)}(x) + K_{2.s}^{(t)}(x)]\,[1 - m_{21}(x)] + [K_{1.c}^{(t)}(x) + K_{1.s}^{(t)}(x)]\,m_{12}(x) \qquad (18)$$

Given the obvious identity that $K_i^{(t)}(x) = K_{i.c}^{(t)}(x) + K_{i.s}^{(t)}(x)$, the above expressions are exactly equivalent to those that would be obtained from the multiregional eq. (5) in a two-region system of initial population totals $K_1^{(t)}(x)$ and $K_2^{(t)}(x)$.

The second of the two equations that comprise the combined model's projection process projects end-of-period population totals for the 0–4 age class

$$\bar{K}^{(t+1)}(0\text{–}4) = \sum_{10}^{45} \bar{\mathbf{B}}(x)\bar{K}^{(t)}(x) \qquad (19)$$

where

$\bar{\mathbf{B}}(x)$ is a $3n \times 3n$ matrix of birth and survival rates with elements $\bar{B}_{i.x,j.y}$

$\bar{B}_{i.x,j.y}$ is the average number of babies born between time t and $t+1$ to residents in region i and subregion x, ages x to $x+4$ at time t, who are alive and reside in region j and subregion y at time $t+1$ (where subregions x and y can be c, s, or o)

such that $\bar{\mathbf{B}}(x)$ is defined as

$$\bar{\mathbf{B}}(x) = 2.5s(0)[\bar{\mathbf{F}}(x) + \bar{\mathbf{F}}(x+5)\bar{\mathbf{S}}(x)] \qquad (20)$$

where

$s(0)$ is the survival rate of births expressed in scalar terms (as in eqs. (3) and (4))

$\bar{\mathbf{F}}(x)$ is a $3n \times 3n$ matrix of fertility rates (specified below in terms of elements defined in eq. (11))

The fertility assumption made in the combined model is that the city and suburb subregions of each region will exhibit the same fertility rates as the region. Hence the $\bar{\mathbf{F}}(x)$ matrix for an illustrative $n = 2$ region model is specified as follows:

$$\bar{\mathbf{F}}(x) = \left[\begin{array}{ccc|ccc} f_1(x) & 0 & 0 & 0 & 0 & 0 \\ 0 & f_1(x) & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & f_2(x) & 0 & 0 \\ 0 & 0 & 0 & 0 & f_2(x) & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{array}\right]$$

where rates $f_i(x)$ are defined in eq. (11).

When one applies eq. (19) to the same two-region model, the following vector results:

$$\left[\begin{array}{c} K_{1.c}^{(t+1)}(0) \\ K_{1.s}^{(t+1)}(0) \\ K_{1.o}^{(t+1)}(0) \\ \hline K_{2.c}^{(t+1)}(0) \\ K_{2.s}^{(t+1)}(0) \\ K_{2.o}^{(t+1)}(0) \end{array}\right] = \left[\begin{array}{c} \sum_{10}^{45} 2.5s(0)[f_1(x)K_{1.c}^{(t)}(x) + f_1(x+5)K_{1.c}^{(t+1)}(x+5)] \\ \sum_{10}^{45} 2.5s(0)[f_1(x)K_{1.s}^{(t)}(x) + f_1(x+5)K_{1.s}^{(t+1)}(x+5)] \\ 0 \\ \hline \sum_{10}^{45} 2.5s(0)[f_2(x)K_{2.c}^{(t)}(x) + f_2(x+5)K_{2.c}^{(t+1)}(x+5)] \\ \sum_{10}^{45} 2.5s(0)[f_2(x)K_{2.s}^{(t)}(x) + f_2(x+5)K_{2.s}^{(t+1)}(x+5)] \\ 0 \end{array}\right] \tag{21}$$

The expressions shown here for the end-of-period population totals $K_{1.c}^{(t+1)}(0)$, $K_{1.s}^{(t+1)}(0)$ and $K_{2.c}^{(t+1)}(0)$, $K_{2.s}^{(t+1)}(0)$ are algebraically equivalent to their counterparts in the single metropolitan area model (in eqs. (3) and (4)) and in the multiregional model (eq. (6)). Together the combined model eqs. (12) and (19) constitute a single matrix model that projects intraregional city–suburb population change consistently with Frey's (1978, 1979a, forthcoming) single metropolitan area model and projects interregional redistribution on a nationwide system of regions consistent with the Rogers (1975) multiregional model.

An important feature of the combined model, as specified in eqs. (12) and (19), is its identification of two distinct types of population movement processes: (1) interregional migration streams between distinct labor market regions (represented by the matrix $\overline{\mathrm{m}}(x)$) and (2) processes that affect redistribution within the labor market region – intrametropolitan residential mobility streams and the intrametropolitan destination propensities of in-migrants to the metropolitan area (represented by the matrices $\hat{\mathrm{m}}(x)$ and $\hat{\mathrm{p}}(x)$, respectively). This model, therefore, structures the redistribution process in a manner consistent with previous migration literature that has shown the former processes to respond to region-specific origin and destination attributes (e.g., wage levels and availability goals); destinations respond to attributes of subareas within the region (e.g., residential amenities and availability of housing).

Another advantage of this model lies in its relatively modest data requirements. In order to estimate the matrices $\overline{\mathrm{m}}(x)$, $\hat{\mathrm{m}}(x)$, and $\hat{\mathrm{p}}(x)$, it is not necessary to know the full matrix of mobility streams from each $i.x$ subregion of origin to every other $j.y$ subregion of destination during the period of observation. Hence the model provides a theoretically defensible means of spatial "aggregation" in the projection of subareal populations (see Rogers 1976).

Finally, it should be emphasized that while the notation presented here for the combined intra- and interregional projection model is tailored to a regional system wherein each region (metropolitan area) is comprised of two subregions (a city and its suburbs), these are not necessary constraints. It remains a straightforward exercise to expand the notation for a system that allows any number of subregions within a region (representing, for example, neighborhoods), such that it is not necessary for all regions to have an equal number of subregions.

E.1.3 An Alternative Specification of the Combined Model

This section introduces a further refinement to the intraregional residential mobility stream parameters of the single metropolitan area projection model discussed in subsection E.1.1 and proposes an alternative specification for eqs. (1) and (2) of that model, as well as for eq. (12) of the combined intra- and interregional projection model discussed in the previous section.

The refinement is based on Frey's (1978, 1979a, forthcoming) decomposition of the intrametropolitan residential mobility stream rate into multiplicative component rates: (1) the *mobility incidence rate*, which is applied to an at-risk population of *residents*, and (2) the *destination propensity rate*, which is applied to an at-risk population of *movers*. This decomposition can be illustrated by assuming an intraregional mobility stream between a hypothetical origin subregion A to a hypothetical destination subregion B. This A to B mobility stream rate can be decomposed into two component rates as follows:

$$\text{A \textit{to} B \textit{mobility stream rate}} = \begin{array}{c}\textit{Mobility incidence}\\ \textit{rate for } \text{A} \textit{ residents}\end{array} \times \begin{array}{c}\text{B-}\textit{destination propensity}\\ \textit{rate for } \text{A-}\textit{origin movers}\end{array}$$

or

$$\frac{\begin{array}{c}\textit{Number of } \text{A} \textit{ residents}\\ \textit{that move to } \text{B}\end{array}}{\textit{Number of } \text{A} \textit{ residents}} = \frac{\begin{array}{c}\textit{Number of } \text{A} \textit{ residents}\\ \textit{that move anywhere}\end{array}}{\textit{Number of } \text{A} \textit{ residents}} \times \frac{\begin{array}{c}\textit{Number of } \text{A} \textit{ residents}\\ \textit{that move to } \text{B}\end{array}}{\begin{array}{c}\textit{Number of } \text{A} \textit{ residents}\\ \textit{that move anywhere}\end{array}}$$

The mobility incidence rate measures the incidence, or degree of occurrence, at which residents move from one dwelling unit to another within the same labor market without regard to the location of the destination dwelling unit. Therefore, even moves within subregion A are included in the numerator of the above mobility incidence rate. The destination propensity rate measures the propensity, or tendency, for intraregional movers to select a destination dwelling unit in a given location (in this case, subregion B). As defined by Frey (1978, 1979a, forthcoming) a destination propensity rate must always be applied to an at-risk population of movers or migrants, while a mobility incidence rate must be applied to an at-risk population of residents.

The theoretical rationale for decomposing the stream mobility rate into those two multiplicative component rates draws from the literature on individual residential mobility decision making, which indicates that the activity of moving residentially (within the same labor market) from one dwelling unit to another should not be viewed as a single process. Rather, the residential move consists of a sequence of two general decision-making processes that can be labelled as the resident's "decision to move" and the mover's "choice of destination", where each is shown to be affected by different individual, housing, and areal influences. (See Speare et al. 1975, Chapter 7 for a review of this literature). The mobility incidence rate and destination propensity rate, defined above, can be considered as aggregate analogs of the "decision to move" and "choice of destination" decision-making processes. Frey (1978, forthcoming) has demonstrated empirically the analytic utility of separating the residential mobility stream rate into these two component rates.*

In light of the above discussion, one can specify an alternative version of the single metropolitan area model presented in subsection E.1.1 by decomposing the intrametropolitan mobility stream rates $\hat{m}_{i.\mathrm{cs}}(x)$ and $\hat{m}_{i.\mathrm{sc}}(x)$ into component mobility incidence rates and destination propensity rates

$$\hat{m}_{i.\mathrm{cs}}(x) = i_{i.\mathrm{c}}(x) p_{i.\mathrm{cs}}(x) \tag{22}$$

$$\hat{m}_{i.\mathrm{sc}}(x) = i_{i.\mathrm{s}}(x) p_{i.\mathrm{sc}}(x) \tag{23}$$

where

$\hat{m}_{i.\mathrm{cs}}(x)$ is the city-to-suburb mobility rate for city residents (as defined in eqs. (1) and (2))

*This decomposition into component rates is particularly appropriate in the analysis of intra-labor market residential mobility because intra-labor market residential mobility incidence rates in all areas largely reflect individuals' life-cycle transitions and accompanying moves. Age-specific mobility incidence rates are, therefore, not greatly affected by areal influences and can conveniently be treated as an independent parameter. Alternatively, mover's destination propensity rates are heavily influenced by areal attributes because they represent the outcome of a selection process that weighs the relative attractiveness of each subarea within the labor market region as a possible "destination". Frey's (1978) analysis of city-to-suburb mobility stream rates in 59 large US SMSAs shows that two-thirds of the inter-SMSA variation in these stream rates are attributable to inter-SMSA variation in their component destination propensity rates.

It seems less justifiable to decompose inter-labor market migration rates on the above grounds because the entire migration process represents more of a cost-benefit decision that weighs the relative labor market attributes of the "origin" and "destination" regions. Liaw and Bartels's (1981) decomposition of inter-labor market migration stream rates in the Netherlands shows significant areal influences on both component rates.

$i_{i.c}(x)$ is the mobility incidence rate for city residents (proportion of city residents of metropolitan area i, ages x to $x + 4$ at time t, surviving to time $t + 1$ and not migrating out of the metropolitan area, that resides in a different dwelling unit in metropolitan area i at time $t + 1$)

$p_{i.cs}(x)$ is the suburb destination propensity rate for city-origin movers (proportion of city residents of metropolitan area i ages x to $x + 4$ at time t, surviving and residing in a different metropolitan area i dwelling unit at time $t + 1$, that resides in the suburbs at time $t + 1$)

$\hat{m}_{i.sc}(x)$ is the suburb-to-city mobility rate for suburb residents (as defined in eqs. (1) and (2))

$i_{i.s}(x)$ is the mobility incidence rate for suburb residents (proportion of suburb residents of metropolitan area i, ages x to $x + 4$ at time t, surviving to time $t + 1$ and not migrating out of the metropolitan area, that resides in a different dwelling unit in metropolitan area i, at time $t + 1$)

$p_{i.sc}(x)$ is the city destination propensity rate for suburb origin movers (proportion of suburb residents of metropolitan area i, ages x to $x + 4$ at time t, surviving and residing in a different metropolitan area i dwelling unit at time $t + 1$, that resides in the city at time $t + 1$)

so that alternative specifications of eqs. (1) and (2) are

$$\begin{aligned} K_{i.c}^{(t+1)}(x+5) = {} & s(x)K_{i.c}^{(t)}(x) - s(x)K_{i.c}^{(t)}(x)m_{i.co}(x) \\ & - s(x)[K_{i.c}^{(t)}(x) - K_{i.c}^{(t)}(x)m_{i.co}(x)]\, i_{i.c}(x)p_{i.cs}(x) \\ & + s(x)[K_{i.s}^{(t)}(x) - K_{i.s}^{(t)}(x)m_{i.so}(x)]\, i_{i.s}(x)p_{i.sc}(x) \\ & + s(x)K_{i.o}^{(t)}(x)p_{i.oc}(x) \end{aligned} \tag{24}$$

$$\begin{aligned} K_{i.s}^{(t+1)}(x+5) = {} & s(x)K_{i.s}^{(t)}(x) - s(x)K_{i.s}^{(t)}(x)m_{i.so}(x) \\ & - s(x)[K_{i.s}^{(t)}(x) - K_{i.s}^{(t)}(x)m_{i.so}(x)]\, i_{i.s}(x)p_{i.sc}(x) \\ & + s(x)[K_{i.c}^{(t)}(x) - K_{i.c}^{(t)}(x)m_{i.co}(x)]\, i_{i.c}(x)p_{i.cs}(x) \\ & + s(x)K_{i.o}^{(t)}(x)p_{i.os}(x) \qquad \text{for } 0 \leqslant x \leqslant z-5 \end{aligned} \tag{25}$$

With this specification of the intrametropolitan city–suburb redistribution process, it is possible to view the intrametropolitan allocation stage of the process as one in which three "pools of movers" are allocated to city and suburb destinations with appropriate destination propensity rates. The sizes of the first two of these pools are determined by applying mobility incidence rates $i_{i.c}$ and $i_{i.s}$ to their respective at-risk city and suburb resident populations, yielding pools of city-origin intrametropolitan movers and suburb-origin intrametropolitan movers. The third pool is the population of in-migrants from outside of the metropolitan area so that the three mover pools can be specified as

$$s(x)[K_{i.c}^{(t)}(x) - K_{i.c}^{(t)}(x)m_{i.co}(x)]\, i_{i.c}$$

$$s(x)[K_{i.s}^{(t)}(x) - K_{i.s}^{(t)}(x)m_{i.so}(x)]\, i_{i.s}$$

$$s(x)K_{i.o}^{(t)}(x)$$

The allocation of these movers and migrants to city and suburb destinations then proceeds by applying appropriate destination propensity rates to each pool: $p_{i.cs}(x)$ (to city-origin movers), $p_{i.sc}(x)$ (to suburb-origin movers), and $p_{i.oc}(x)$ and $p_{i.os}(x)$ (to in-migrants to the metropolitan area).

It is possible, as well, to specify an alternative to the combined matrix model of intra- and interregional redistribution in subsection E.1.2 by respecifying the matrix $\bar{\mathbf{S}}(x)$ in eq. (12) as follows:

$$\bar{\mathbf{S}}(x) = \{\mathbf{p}(x)\mathbf{i}(x) + [\mathbf{I} - \mathbf{i}(x)]\}\bar{\mathbf{m}}(x)s(x) \tag{26}$$

where

$s(x)$ is the survival rate expressed in scalar form
$\bar{\mathbf{m}}(x)$ is a $3n \times 3n$ matrix of interregional migration rates (as defined in eq. (13))
$\mathbf{i}(x)$ is a $3n \times 3n$ matrix of intraregional mobility incidence rates (specified below in terms of rates $i_{i.c}(x)$ and $i_{i.s}(x)$ defined in eqs. (22) and (23))
$\mathbf{p}(x)$ is a $3n \times 3n$ matrix of destination propensity rates for intraregional movers and interregional in-migrants (specified below in terms of rates $p_{i.cs}(x)$ and $p_{i.sc}(x)$ in eqs. (22) and (23), and rates $p_{i.oc}(x)$ and $p_{i.oc}(x)$ in eqs. (1) and (2))
$\mathbf{I}$ is a $3n \times 3n$ identity matrix with 1 in each diagonal element, 0 in all other elements

When it is assumed that $n = 2$ regions, the elements of $\mathbf{i}(x)$ and $\mathbf{p}(x)$ can be specified as

$$\mathbf{i}(x) = \left[\begin{array}{ccc|ccc} i_{1.c}(x) & 0 & 0 & 0 & 0 & 0 \\ 0 & i_{1.s}(x) & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & i_{2.c}(x) & 0 & 0 \\ 0 & 0 & 0 & 0 & i_{2.s}(x) & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{array}\right]$$

where values $i_{i.c}(x)$ and $i_{i.s}(x)$ are defined in eqs. (22) and (23) and

$$
\mathbf{p}(x) = \left[\begin{array}{ccc|ccc}
1 - p_{1.cs}(x) & p_{1.sc}(x) & p_{1.oc}(x) & 0 & 0 & 0 \\
p_{1.cs}(x) & 1 - p_{1.sc}(x) & p_{1.os}(x) & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 \\
\hline
0 & 0 & 0 & 1 - p_{2.cs}(x) & p_{2.sc}(x) & p_{2.oc}(x) \\
0 & 0 & 0 & p_{2.cs}(x) & 1 - p_{2.sc}(x) & p_{2.os}(x) \\
0 & 0 & 0 & 0 & 0 & 0
\end{array}\right]
$$

where rates $p_{i.cs}(x)$ and $p_{i.sc}(x)$ are defined in eqs. (22) and (23), and rates $p_{i.oc}(x)$ and $p_{i.os}(x)$ are defined in eqs. (1) and (2) so that unlike $\hat{\mathbf{p}}(x)$ in eq. (26), which only allocates metropolitan in-migrants to city and suburb destinations, the $\mathbf{p}(x)$ allocates city-origin movers, suburb-origin movers, and metropolitan in-migrants to city and suburb destinations.

The two stage redistribution process can now be represented by an equation that is comparable to eq. (14)

$$\bar{K}^{(t+1)}(x + 5) = \{\mathbf{p}(x)\mathbf{i}(x) + [\mathbf{I} - \mathbf{i}(x)]\}[\bar{\mathbf{m}}(x)s(x)]\bar{K}^{(t)}(x) \tag{27}$$

As in the earlier equation, the interregional exchange stage of the process is represented by the factor $\bar{\mathbf{m}}(x)s(x)$, which redistributes migrants from one region to another. The intraregional allocation stage, however, can now be viewed as the sum of two factors. The factor $\mathbf{I} - \mathbf{i}(x)$ identifies those subregional (city and suburb) residents that do not undertake a residential move and reside in the same dwelling unit at the end of the period. The second factor $\mathbf{p}(x)\mathbf{i}(x)$ both identifies residential movers among the subregional population (through $\mathbf{i}(x)$) and redistributes those movers as well as regional in-migrants to city and suburb destinations at the end of the period (through $\mathbf{p}(x)$).

It is significant that this representation of intra- and interregional redistribution treats the allocation of residential movers to *intra*regional destinations, in the same way as the allocation of regional in-migrants to these destinations and identifies a single matrix destination propensity rate $\mathbf{p}(x)$ for this purpose. Frey (1979a, forthcoming) has shown that the destination propensity rates of each of these mover and migrant groups respond to the same attributes of regional subareas, or in other words, that both intraregional movers and regional in-migrants are influenced by the same areal attributes in their choice of destination within the region. The identification of destination propensity rates in this manner is also useful from a modeling perspective. This specification allows the researcher to perform several projection simulations based on alternative sets of destination propensity rates for $\mathbf{p}(x)$ while keeping constant rates of mobility incidence $\mathbf{i}(x)$ and interregional migration $\bar{\mathbf{m}}(x)$. (See Frey 1980 for an example of this type of investigation.)

One disadvantage of this new specification of the combined intra- and interregional redistribution model is its greater data requirements. In order to estimate the intraregional mobility incidence rates and destination propensity rates, it is necessary to have data that distinguish (a) non-mobile individuals, (b) movers within the subregion (city or suburb), and (c) movers across intraregional subregions. (The earlier model requires only a distinction between (a) + (b), and (c).) However, since age-specific mobility incidence rates show fairly similar patterns across all regions, a researcher may wish to estimate $\mathbf{i}(x)$ by attributing *nationwide* mobility incidence rates to all (city and suburb) subregions and estimate age-specific destination propensity rates $\mathbf{p}(x)$ on the basis of region-specific surveys of recent movers.

APPENDIX E.2 DATA AND PARAMETER ESTIMATION FOR PITTSBURGH AND HOUSTON PROJECTIONS

The current unavailability of migration data for a nationwide system of US labor market areas precludes undertaking projections of intrametropolitan city–suburb redistribution using either variant of the combined intra- and interregional redistribution model presented in subsections E.1.2 and E.1.3. The projections for the Pittsburgh and Houston metropolitan areas in section 4 of the text are, therefore, based on the single metropolitan area model methodology presented in subsection E.1.1.

The data used to calculate the mobility and migration parameters for eqs. (1) and (2) are estimated from special tabulations of the 1970 US Census that classify individuals' 1970 and reported 1965 residence locations in the Pittsburgh and Houston metropolitan areas as follows:

Resident of metropolitan area's central city in 1970
1. Residing in same dwelling unit in 1965
2. Residing in different dwelling unit, same central city in 1965
3. Residing in suburbs of same metropolitan area in 1965
4. Residing outside the same metropolitan area in 1965

Resident of metropolitan area's suburbs in 1970

5. Residing in same dwelling unit in 1965
6. Residing in different dwelling unit, same suburb in 1965
7. Residing in central city of same metropolitan area in 1965
8. Residing outside the same metropolitan area in 1965

9. Residing outside of metropolitan area in 1970, residing in metropolitan area in 1965

The above classification is restricted to individuals ages 5 and over in 1970 and is further disaggregated into age categories 5–9, 10–14, . . . 70–74, 75+.

Adjustments were made for individuals, ages 5 and over, who lived in a different 1965 dwelling unit but did not report (NR) its location; adjustments were also made for estimated census underenumerations. NRs with 1970 central city residence were allocated to categories (2), (3), and (4) according to the distribution of individuals in the same metropolitan area of similar race, age, and years of school who did report their 1965 residence location. NRs with 1970 suburb residences were allocated to categories (6), (7), and (8) in a like manner. Reported totals of category (9) were adjusted upward on the basis of race, age, and years of school. NR-to-reported ratios were computed from a nationwide matrix of individuals who did not report their 1965 residence location (US Bureau of the Census, 1973, Tables 1–14). Finally, all populations were adjusted (generally upward) to compensate for estimated census underenumeration by age and race (US Bureau of the Census, 1975b, Table G-1).

The adjusted tabulations (1) through (9) for Pittsburgh and Houston were used to compute the following mobility and migration parameters for eqs. (1) and (2) for each beginning-of-period age group where $x = 0, 5, \ldots 65, 70+$

$$m_{i.\text{co}}(x) = (9)/[(1) + (2) + (3) + (5) + (6) + (7) + (9)]$$

$$m_{i.\text{so}}(x) = (9)/[(1) + (2) + (3) + (5) + (6) + (7) + (9)]$$

$$\hat{m}_{i.\text{cs}}(x) = (7)/[(1) + (2) + (7)]$$

$$\hat{m}_{i.\text{sc}}(x) = (3)/[(5) + (6) + (3)]$$

$$p_{i.\text{oc}}(x) = (4)/[(4) + (8)]$$

$$p_{i.\text{os}}(x) = (8)/[(4) + (8)]$$

$$s(x)K_{i.\text{o}}^{1965}(x) = [(4) + (8)]$$

The actual age-specific values for Pittsburgh and Houston are shown in Table E1. (Because of the nature of data employed in these projections, the interpretation of x in eqs. (1) and (2) changes for the estimates of the uppermost age category (when $x + 5 = 75+$) as follows: $x = 70+$ for populations $K_{i.\text{c}}^{(t)}(x)$, $K_{i.\text{s}}^{(t)}(x)$, $K_{i.\text{o}}^{(t)}(x)$; and x pertains to the transition between ages 70+ at time t to ages 75+ at time $t + 1$ for parameters $s(x)$, $m_{i.\text{co}}(x)$, $m_{i.\text{so}}(x)$, $\hat{m}_{i.\text{cs}}(x)$, $\hat{m}_{i.\text{sc}}(x)$, $p_{i.\text{oc}}(x)$, $p_{i.\text{os}}(x)$. For all other age categories, the parameters correspond to the definitions in eqs. (1) and (2).)

For projection purposes, the value $s(x)K_{i.\text{o}}^{1965}(x)$ is not simply inserted into eqs. (1) and (2) for each successive period $t, t + 1$. Rather, the value $K_{i.\text{o}}^{(t)}(x)$ is determined by multiplying the beginning-of-period metropolitan populations of age x by the following ratio:

$$\frac{s(x)K_{i.\text{o}}^{1965}(x)}{s(x)[K_{i.\text{c}}^{1965}(x) + K_{i.\text{s}}^{1965}(x)]} = [(4) + (8)]/[(1) + (2) + (3) + (5) + (6) + (7) + (9)]$$

such that

$$K_{i.\text{o}}^{(t)}(x) = \left\{\frac{s(x)K_{i.\text{o}}^{1965}(x)}{s(x)[K_{i.\text{c}}^{1965}(x) + K_{i.\text{s}}^{1965}(x)]}\right\} [K_{i.\text{c}}^{(t)}(x) + K_{i.\text{s}}^{(t)}(x)]$$

TABLE E1 Observed rates of migration and intrametropolitan mobility for the Pittsburgh and Houston SMSAs: 1965–1970.

SMSA and age category at beginning of period (x to $x + 4$)	Metropolitan out-migration rates for residents of: City $m_{i.co}(x)$	Suburbs $m_{i.so}(x)$	In-migrants to the metropolitan area $s(x)K_{i.o}^{(t)}(x)$	Destination propensity rates for in-migrants to metropolitan area: City dest. $p_{i.oc}(x)$	Suburb dest. $p_{i.os}(x)$	City-to-suburb mobility rate $\hat{m}_{i.cs}(x)$	Suburb-to-city mobility rate $\hat{m}_{i.sc}(x)$
Pittsburgh SMSA							
0–4	0.1119	0.1119	21 360	0.1227	0.8773	0.0202	0.0172
5–9	0.0812	0.0812	15 602	0.1017	0.8983	0.0141	0.0096
10–14	0.1276	0.1276	16 009	0.2960	0.7040	0.0111	0.0199
15–19	0.2855	0.2855	27 886	0.3690	0.6390	0.2286	0.0565
20–24	0.2088	0.2088	30 799	0.2314	0.7686	0.3825	0.0402
25–29	0.1412	0.1412	15 471	0.1921	0.8079	0.2950	0.0209
30–34	0.0904	0.0904	10 403	0.1411	0.8589	0.1978	0.0169
35–39	0.0846	0.0846	9 852	0.1406	0.8594	0.1528	0.0101
40–44	0.0458	0.0458	6 852	0.1441	0.8559	0.1168	0.0084
45–49	0.0435	0.0435	4 766	0.1747	0.8253	0.0879	0.0102
50–54	0.0447	0.0447	2 986	0.2615	0.7385	0.0715	0.0091
55–59	0.0431	0.0431	2 529	0.1894	0.8106	0.0860	0.0112
60–64	0.0575	0.0575	2 246	0.2747	0.7253	0.0553	0.0104
65–69	0.0551	0.0551	1 782	0.2631	0.7369	0.0930	0.0141
70+	0.0506	0.0506	2 375	0.1482	0.8513	0.1339	0.0143
Houston SMSA							
0–4	0.1435	0.1435	49 575	0.5499	0.4501	0.1544	0.0859
5–9	0.1131	0.1131	38 278	0.5592	0.4408	0.1175	0.0659
10–14	0.1507	0.1507	32 490	0.6387	0.3613	0.0918	0.0777
15–19	0.2539	0.2539	61 388	0.7028	0.2972	0.1395	0.2313
20–24	0.1961	0.1961	62 866	0.6221	0.3779	0.2005	0.1698
25–29	0.1722	0.1722	36 154	0.5647	0.4353	0.1656	0.1081
30–34	0.1173	0.1173	26 113	0.5566	0.4434	0.1265	0.0814
35–39	0.1212	0.1212	22 611	0.6033	0.3967	0.1112	0.0544
40–44	0.0801	0.0801	16 042	0.6021	0.3979	0.0815	0.0672
45–49	0.0797	0.0797	10 481	0.6109	0.3891	0.0658	0.0682
50–54	0.0723	0.0723	7 201	0.6393	0.3607	0.0590	0.0515
55–59	0.0699	0.0699	5 151	0.6173	0.3827	0.0532	0.0462
60–64	0.0736	0.0736	3 759	0.5400	0.4600	0.0434	0.0470
65–69	0.0722	0.0722	3 062	0.6515	0.3485	0.0504	0.0378
70+	0.0701	0.0701	4 583	0.6895	0.3105	0.0272	0.0490

TABLE E2 City–suburb projections for the Pittsburgh and Houston SMSAs: 1970, 1995, and 2020.

	Pittsburgh SMSA						Houston SMSA					
	City			Suburbs			City			Suburbs		
Age category	1970	1995	2020	1970	1995	2020	1970	1995	2020	1970	1995	2020
0–4	36 323	36 718	35 418	146 968	170 828	173 049	122 437	243 954	487 869	74 983	181 505	368 606
5–9	42 974	32 750	30 592	178 899	180 243	177 491	133 518	225 514	437 016	90 121	199 234	393 523
10–14	45 969	31 339	27 553	199 069	187 950	178 776	130 613	208 578	394 208	87 777	197 597	383 008
15–19	50 186	32 646	28 398	173 276	169 992	162 862	115 292	185 651	356 248	70 695	163 911	324 400
20–24	45 516	33 711	31 621	118 356	126 365	127 923	113 663	200 547	412 883	53 738	126 672	267 011
25–29	30 809	24 447	27 275	111 062	116 140	131 916	104 394	205 652	441 627	63 366	148 598	321 814
30–34	23 884	25 201	23 528	98 477	143 595	138 513	82 271	219 901	415 621	54 384	187 103	357 386
35–39	24 584	25 314	21 961	106 398	160 204	144 063	77 793	210 367	388 886	51 354	193 760	362 735
40–44	31 696	22 129	19 163	131 591	150 226	137 130	81 528	177 716	331 829	50 163	170 953	323 493
45–49	34 478	17 858	16 247	138 398	123 739	122 070	76 228	141 860	274 894	44 013	132 649	261 687
50–54	34 873	14 563	13 211	129 334	99 320	99 641	60 543	111 284	232 529	35 440	99 397	212 355
55–59	33 561	12 516	15 105	110 764	78 092	109 888	53 682	77 585	225 730	30 701	66 180	202 450
60–64	29 807	12 610	14 978	87 960	73 691	107 256	43 436	61 195	183 919	24 131	49 966	163 926
65–69	23 755	15 099	12 564	63 754	76 210	83 815	30 180	51 964	128 998	16 282	40 081	114 694
70–74	19 498	13 160	8 314	49 999	61 258	52 639	21 418	36 838	77 934	10 990	27 138	68 117
75+	27 877	15 642	8 509	75 403	72 836	55 882	28 930	40 198	73 124	14 411	24 889	53 360

or

$$s(x)K_{i.o}^{(t)}(x) = \left\{ \frac{s(x)K_{i.o}^{1965}(x)}{s(x)[K_{i.c}^{1965}(x) + K_{i.s}^{1965}(x)]} \right\} s(x)[K_{i.c}^{(t)}(x) + K_{i.s}^{(t)}(x)] \tag{28}$$

when one assumes the same survival rate $s(x)$ to hold for each mover and nonmover subgroup.

The above estimation procedure for $s(x)K_{i.o}^{(t)}(x)$ is necessary because the single metropolitan area projection model is an "open" model, not linked to a closed system of labor market regions, which provides estimates of regional in-migrants for each period on the basis of an interregional matrix of migration stream rates (as described in subsections E.1.2 and E.1.3). The $s(x)K_{i.o}^{(t)}(x)$ estimation procedure in eq. (28) assumes a constant ratio of period metropolitan in-migrants to the beginning-of-period metropolitan population at that age, based on the ratio observed over the 1965–1970 period.

The final parameters required for projection eqs. (1), (2), (3), and (4) are age-specific survival rates $s(x)$ and regional fertility rates $f(x)$. For both Pittsburgh and Houston metropolitan area projections, the former rates were obtained from the national life table presented in Appendix B.2, while the later rates were assumed to be nationwide fertility rates reported in Appendix B.1. The accompanying Table E2 shows initial 1970 age-specific population totals for the central city and suburbs of each metropolitan area, as well as projected age-specific totals for the years 1995 and 2020. A listing of the projected totals for each 5-year period 1970–2020 is available from the authors upon request.

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