WORKING PAPER 332

AN INTEGRATED MODEL OF MIGRATION FLOWS AND POPULATION CHANGE FOR A SYSTEM OF UK METROPOLITAN AND NON-METROPOLITAN REGIONS : A FRAMEWORK

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Abstract

The paper outlines a framework for research into processes of spatial population change. Recent patterns of change for a twenty zone system covering the UK are described, and metropolitan-non-metropolitan shifts are revealed to be much more important than North-South shifts. Levels of national and local mobility, age-group migration propensities and distribution patterns are described for the study set of zones. As a tool for consistent description and population projection, a system of populations accounts, accounts based models and data estimation tasks is outlined. Linked to this accounting framework are a set of alternative migration models. A scheme for exploring the sensitivity of the zonal population projections to alternative accounts based and migration models is proposed.

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Introduction

Over the past intercensal period (1971-1981) national population growth in the United Kingdom (UK) has almost ceased. The population grew by only 150,000 in the 1971-81 decade or only 0.28 of one per cent. However, just as much relative redistribution took place as in the previous intercensal decade (1961-1971).

The proportional distribution of the UK population among regions shifted slightly more between 1961 and 1971 than between 1971 and 1981.* Migration has continued to redistribute a zero natural increase national population among its constituent parts.

There is a long history of interest in migration and its quantitative modelling (Stillwell, 1980b). An equivalent interest in regional population change (Rees, 1981b) has been present for the past two decades. These two streams of work are rarely brought together. The ambition of this paper is to bring the two together and to integrate a model of interregional migration within a population accounting model. Formally, this simply involves connecting the two models by using the population outputs of the accounts model as the population inputs of the migration model, and then inputting the migration model predictions into the accounts based model (Figure 1). The attraction of forging the connection is to link, for a multi-regional system, the population and economic systems, by using various economic indicators in the migration model destination attractiveness terms.

However, we are also concerned with the value of such a system for projection purposes, and therefore need to evaluate the results of the integration against those of a purely demographic model as well as exploring the consequences of using alternative migration models.

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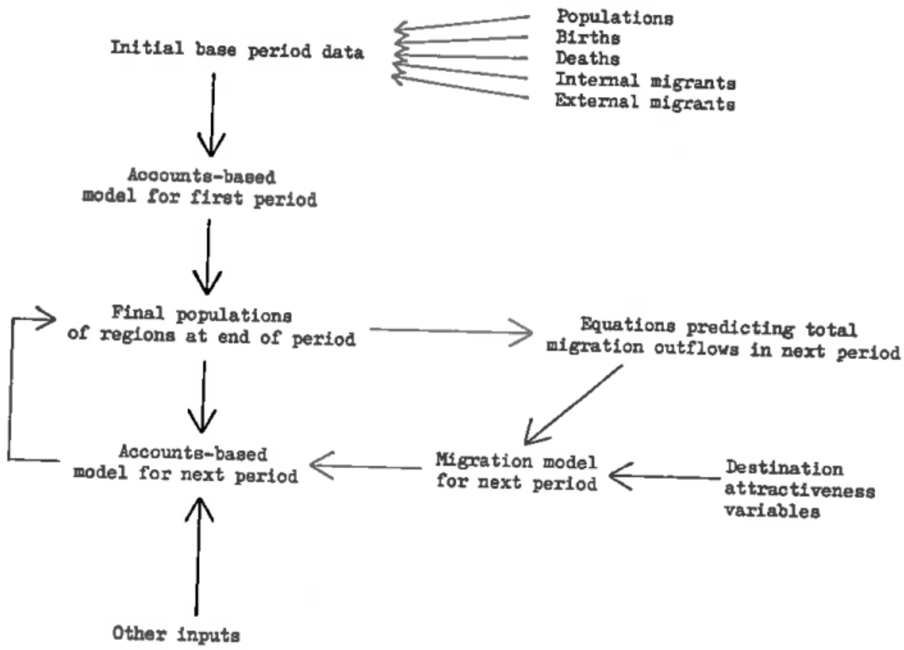
*The index of dissimilarity between the 1961 and 1971 distribution of population among twenty regions was 1.8; between 1971 and 1981, the value of the index was 4.3, indicating an increase in the pace of relative redistribution of the population.

FIGURE 1. The connections between the accounts based and migration models in a population projection system.



To carry out such a programme of model integration and tests we need a good information system over several time periods, and the construction of such a system proved to be more difficult than at first anticipated. Section 4 of the paper gives a detailed description of the information system constructed and the data estimation methods used. Prior to that description, however, we justify our selection of study zones by outlining the interesting light they shed on spatial population change in the UK over the period since 1961. Particular attention is focussed on the migration patterns of 1966-71 (the last period for which a full matrix of age disaggregated migration flows for the study regions is available).

In the fifth section of the paper, the alternative demographic projection models are outlined, which we hope to test out once the information system construction is complete. This section also outlines an associated set of migration models to be tested. The final section of the paper outlines how the two sets of models are to be brought together.

The paper thus constitutes a design for research rather than a report on results. These we hope to report on in a second companion paper.

2. Description of patterns of population change for the study set of zones

2.1 Choice of the study set of zones

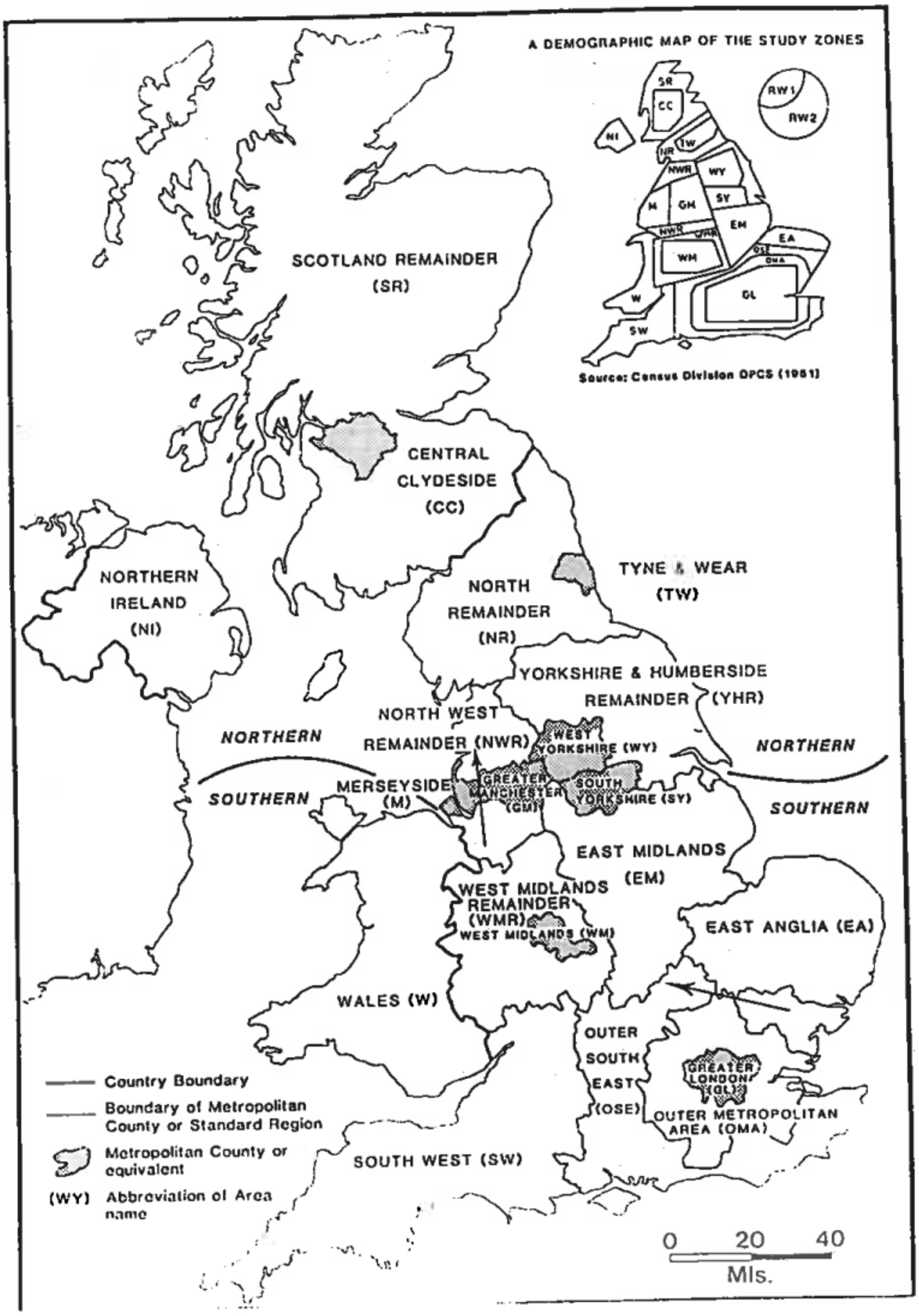
In studying spatial population change a choice has to be made from among the possible sets of areal units within a given universe. Many alternatives have been used in the past in the UK.

Standard economic regions and subregions were used in the Department of the Environment (1971) study; standard regions were used in the study by Rees (1979a); counties were adopted by Stillwell (1979); functional urban regions were adopted in the urban change project Kennett, 1980); and local government districts by Martin, Voorhees and Bates (1981). Finer scale units are clearly of great interest to geographers and planners, though normally this has meant the sacrifice of age and sex detail for the components of population change, or ignoral of treatment of particular components (the Martin, Voorhees and Bates study is an exception in this respect).

Ideally, we would have liked to have worked with the Martin, Voorhees and Bates set of local government units using their data base. This, however, we considered beyond current capabilities in terms of purchase and release of unpublished data and size of the computing problems involved. The standard regions were convenient to work with given a wealth of published data series and previous experience. However, the standard region set obscures one of the important dimensions of population change over the last two intercensal decades (1961-71, 1971-81), namely the shift from densely populated urban cores to the more sparsely settled rural areas (Census Division, OPCS, 1981 on England and Wales; Rees, 1982 on Wales).

We therefore chose to work with the set of metropolitan counties, region remainders and regions without metropolitan counties shown in Figure 2, some twenty zones in all that exhaustively divide the territory of the United Kingdom. A key advantage of such a set is that very many demographic components are available in age disaggregated detail at this level in published form (e.g. OPCS 1975-81 and OPCS 1978); and with such a set it is possible to separate

FIGURE 2. The study set of zones



North-South population shifts from metropolitan core-region remainder shifts.

2.2 Zonal population changes, 1961-81

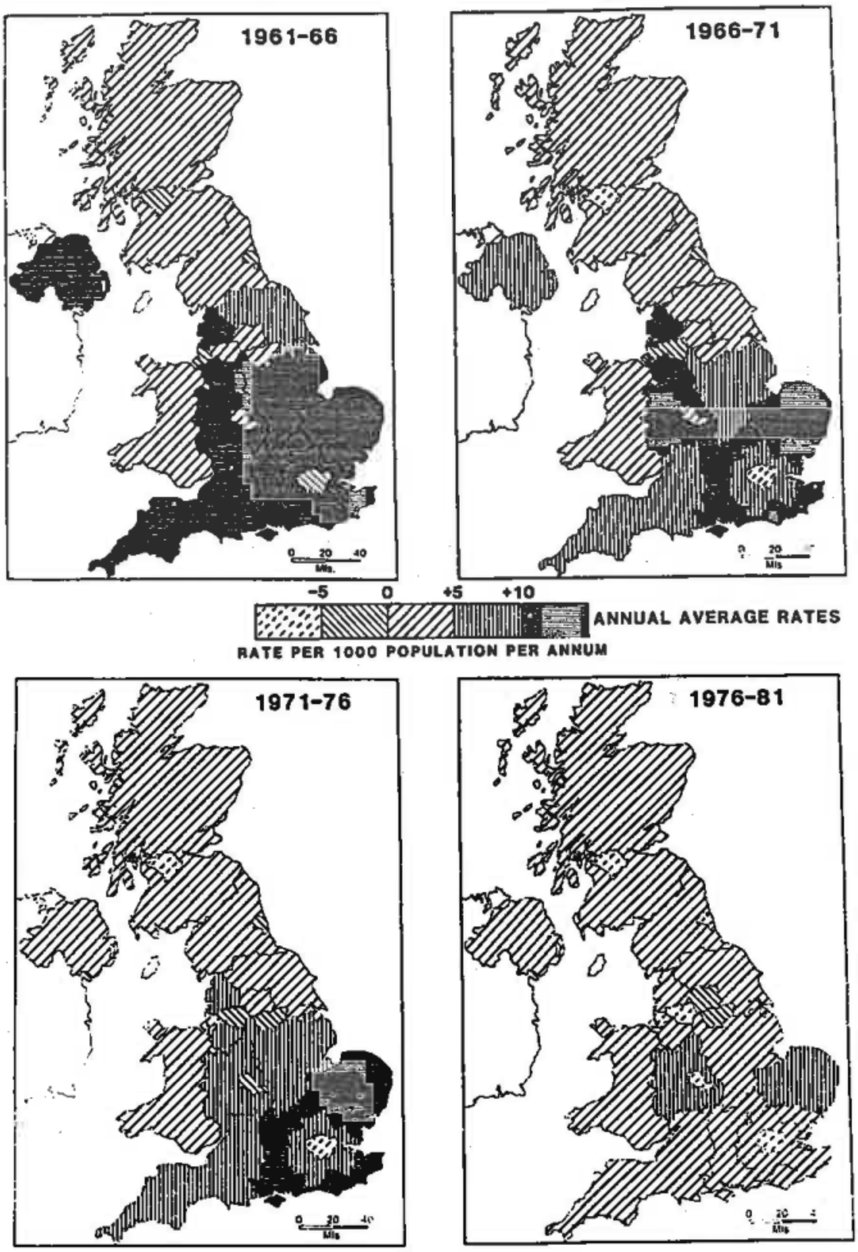
After a moderate rise during the 1961-71 decade, the UK population has become almost stationary, gaining only 156 thousand between the 1971 and 1981 censuses, having been according the OPCS (Office of Population Censuses and Surveys) estimates, higher than at either census in mid-decade (see Table A1 for detailed figures on the UK population and the study zones).

The rate of population change slowed nationally from 6.5 per 1000 in the 1961-66 quinquennium to -0.9 in the 1976-81 quinquennium. This cessation of growth was due in major part to a decline in fertility over the period and in minor part to an increase in net emigration and to a marginal increase in the death rate (see Rees, 1979a, 1982 for details). This cessation of growth did not, however, prevent moderate population shifts taking place. Thus, the four fastest growing zones (Outer South East, East Anglia, Outer Metropolitan Area, West Midlands Remainder) increased their populations by 23-27 per cent, whereas the fastest declining zones (Greater London, Central Clydeside, Merseyside and Tyne and Wear) saw their populations shrink by 8-16 per cent.

If we utilize the preliminary results of the 1981 census (OPCS, 1981) and make some interpolative estimates for zonal populations on April 25/26 in 1966 and 1976, it is possible to construct tables of population stocks (Table A1), population changes (Table A2) and population change rates (Table A3) for the four quinquennia up to Census date 1981. The latter are mapped, in annual average form, in Figure 3. What patterns do the maps show?

Let us, for the moment, leave aside the general pattern of falling rates, and the special circumstances of particular zones. Two patterns would seem to be present : a North/South contrast and a metropolitan county/non-metropolitan zone contrast. Zones north of a Dee-Wash line grew less or declined more than zones south of the line, with the major exceptions of the metropolitan areas of the West Midlands and Greater London. In both North and South metropolitan counties

FIGURE 3. Patterns of population change, U.K. zones, 1961-81.



registered declines or only small increases in population. In a detailed analysis of population changes between 1971 and 1981, the Census Division of OPCS (1981) argues that the metropolitan/ non-metropolitan pattern is dominant. In both the 1971-76 and 1976-81 five year periods the metropolitan zones all showed population decreases, the non-metropolitan zones all exhibited population increase (Figure 3).

2.3 An analysis of spatial variance

Table 1 rearranges the population change rates into summary two by two tables for each quinquennium so that the effect of each pattern can be seen more clearly. The difference in growth rates between metropolitan and non-metropolitan zones has been 2-4 times that between Northern and Southern zones. When an analysis of variance is carried out (Table 2) with the population change rates in the twenty zones as the dependent variables and "region" status, "metro" status the independent, classifactory variables, the results affirm the almost complete dominance of the metropolitan/non-metropolitan pattern. Over the two decades from 1961, the dominance of the metropolitan/non-metropolitan pattern increases as the overall variance decreases.

2.4 Components of change

Before we can interpret the pattern of population shifts, we must establish whether they are due to the migration or due to differences in the rate at which zonal populations die or give birth. There are a number of statistical difficulties involved in constructing components of change tables (see section 4 of the paper) for all four quinquennia which we have so far examined, so that attention is focussed for the present on the components of change for the most recent period 1976-81, which are the easiest to assemble (see Table A.4).

Figure 4 shows the pattern of crude birth rates, crude death rates, natural increase rates and net migration rates for the 20 study zones. The first point to note is that the range of variation on the first three indicators is relatively small compared with that on net migration. The range for birth rates lay between 11.4 (South West) and 13.1 (Central Clydeside), with the exception of Northern Ireland where the birth rate

TABLE 1. Population change rates classified by type of zone, U.K.1961-81 and deviation from the U.K. mean.

1961-66	Metropolitan zones	Non-Metropolitan zones	Totals
North zones	0.4 (-6.1)	5.7 (-0.8)	2.9 (-3.6)
South zones	-2.9 (-9.4)	14.5 (+8.0)	8.8 (+2.3)
Totals	1.2 (-5.3)	11.7 (+5.2)	6.5

1966-71	Metropolitan zones	Non-Metropolitan zones	Totals
North zones	-1.8 (-5.7)	6.1 (+2.2)	2.0 (-1.9)
South zones	-6.3 (-9.9)	10.1 (+6.2)	5.0 (+1.1)
Totals	-4.0 (-7.9)	8.9 (+5.0)	3.9

1971-76	Metropolitan zones	Non-Metropolitan zones	Totals
North zones	-4.4 (-5.9)	3.7 (+2.2)	-0.4 (-1.9)
South zones	-9.0 (-10.5)	7.5 (+6.0)	2.7 (+1.2)
Totals	-6.6 (-8.1)	6.4 (+4.9)	1.5

1976-81	Metropolitan zones	Non-Metropolitan zones	Totals
North zones	-6.7 (-5.8)	0.9 (+1.8)	-2.9 (-2.0)
South zones	-9.4 (-8.5)	3.9 (+4.8)	2.2 (+3.1)
Totals	-8.0 (-7.1)	3.0 (+3.9)	-0.9

Source: Table A.3

Deviations from the U.K. mean are shown in parentheses

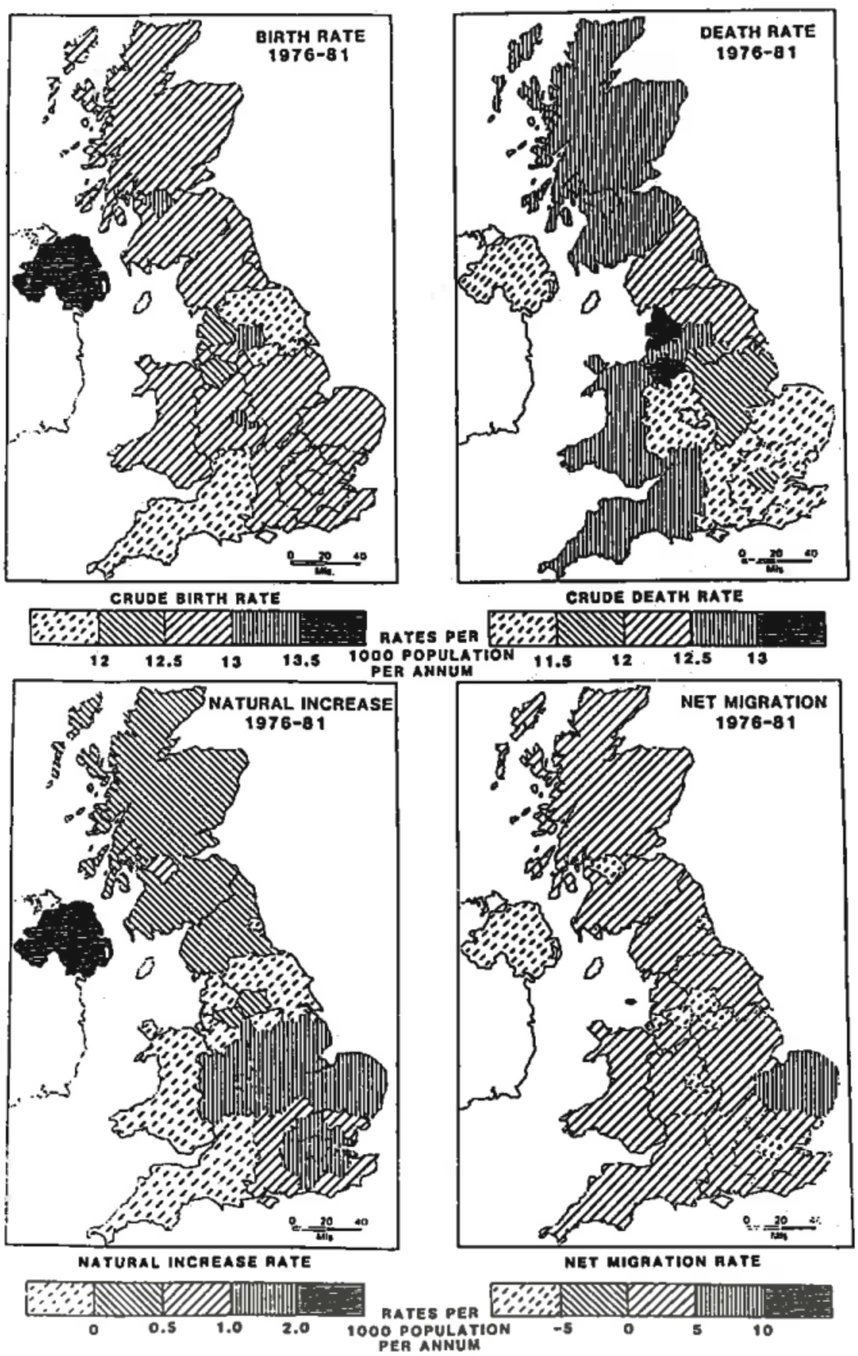
TABLE 2. Analysis of variance of population change rates of UK zones by macro-region and metropolitan/non-metropolitan status, 1961-81

Source of variation	Sums of squared deviations	Degrees of freedom	Mean squared deviations	F	Significance of F
1961-66					
Main effects	627.7	2	313.9	12.2	.001
Region (North/South)	79.0	1	79.0	3.1	.099
Metro (Metro/Non-Metro)	368.0	1	369.0	14.3	.002
2-way interactions*	78.1	1	78.1	3.0	.101
Explained	705.8	3	235.3	9.1	.001
Residual	411.9	16	25.7	Multiple R^2 = .562	
Total	1117.7	19	58.8		
1966-71					
Main effects	567.8	2	283.9	13.5	.000
Region	18.2	1	18.2	0.9	.365
Metro	430.2	1	430.2	20.5	.000
2-way interactions*	27.3	1	27.3	1.3	.271
Explained	595.1	3	198.4	9.5	.001
Residual	335.4	16	21.0	Multiple R^2 = .601	
Total	930.5	19	49.0		
1971-76					
Main effects	629.9	2	315.0	19.2	.000
Region	18.8	1	18.8	1.1	.300
Metro	480.8	1	480.8	29.3	.000
2-way interactions*	52.3	1	52.3	3.2	.093
Explained	682.2	3	227.4	13.9	.000
Residual	262.4	16	16.4	Multiple R^2 = .667	
Total	944.6	19	49.7		
1976-81					
Main effect	497.9	2	248.9	53.0	.000
Region	8.2	1	8.2	1.8	.204
Metro	398.4	1	398.4	84.9	.000
2-way interactions*	29.4	1	29.4	6.2	.024
Explained	527.3	3	175.8	37.4	.000
Residual	75.1	16	4.7	Multiple R^2 = .827	
Total	602.4	19	31.7		

The analysis of variance was computed using the ANOVA sub-program in the Statistical Package for the Social Sciences suite (Nie et al, 1975), Chapter 22, 'Analysis of variance and covanance: sub-programs anova and oneway.' The classical approach was used, giving each factor (region status, metro status) equal weight in assessing its effect.

* Region x metro. Regions = (1) Northern (2) Southern (see Figure 1)
Metro = (1) Metropolitan (2) Non-metropolitan

FIGURE 4. Components of growth rates, U.K. zones, 1976-81.



was 17.4 per thousand. The cell means in our 2 × 2 classification (Table 3) show little or no variation. The death rates show some tendency to increase from south east to north west, though Northern Ireland's death rate is lower because of the more youthful age structure. Only the net migration rate pattern closely parallels the population change pattern.

The correlation coefficient between net migration and population change rates is 0.961 whereas between natural increase and population change it is only 0.139. Only the net migration rates show significant spatial patterning by our region-metro classification (Table 4). Our conclusion must be that the important demographic component influencing population change is migration.

2.5 Net migration patterns

Net migration is the net balance between much larger gross inflows and outflows of migrants, and further attention in later sections of the paper will concentrate on these gross migration streams. But, as Table 5's statistics reveal, net flows can be very substantial and their absolute levels make up, for example, 41% of the gross flows for migration within the U.K. Note that external migration plays an important role, in general, reducing the gains that zones make through internal (within country) migration, or in reducing the losses as some of the principal metropolitan areas (Greater London, West Midlands) are gainers of migrants from abroad. In fact, the net losses to and net gains from abroad are made to different parts of the world. Approximate estimates of migration between the U.K. and richer parts of the world (RW(1) in Table 5) and between the U.K. and the poorer parts of the world show that almost all zones lose migrants to the former and gain migrants from the latter.

If we work out the net migration flows between all of our study zones from the five year migration tables for 1966-71 from the 1971 Census (OPCS, 1978), and arrange them, as in Table 5, in order of the number of positive or gaining net migration flows, then an interesting pattern emerges. This ordering of zones predicts most of the net gains and losses between them. A zone loses migrants to all those above it on the list, and gains migrants from all those below it on the list. There

TABLE 3. Mean values of the components of growth rates for the region-metro classes and deviations from the UK mean, 1976-81

Birth Rates 1976-81	Metropolitan zones	Non-metropolitan zones	Totals
North zones	12.7 (+ 0.1)	13.2 (+ 0.6)	13.0 (+ 0.4)
South zones	12.9 (+ 0.3)	12.3 (- 0.3)	12.4 (- 0.2)
Totals	12.8 (+ 0.2)	12.5 (- 0.1)	12.6
Death Rates 1976-81	**Metropolitan zones**	**Non-metropolitan zones**	**Totals**
North zones	12.7 (+ 0.7)	12.3 (+ 0.3)	12.5 (+ 0.5)
South zones	11.7 (- 0.3)	11.6 (- 0.4)	11.7 (- 0.3)
Totals	12.2 (+ 0.2)	11.8 (- 0.2)	12.0
Natural increase rates 1976-81	**Metropolitan zones**	**Non-metropolitan zones**	**Totals**
North zones	0.1 (- 0.6)	0.9 (+ 0.2)	0.5 (- 0.2)
South zones	1.2 (+ 0.5)	0.6 (- 0.1)	0.8 (+ 0.1)
Totals	0.6 (- 0.1)	0.7 (0.0)	0.7
Net migration rates 1976-81	**Metropolitan zones**	**Non-metropolitan zones**	**Totals**
North zones	- 6.8 (- 5.2)	0.1 (+ 1.7)	-3.3 (- 1.7)
South zones	-10.6 (- 9.0)	3.3 (+ 4.9)	-0.6 (+ 1.0)
Totals	- 8.6 (- 7.0)	2.3 (+ 3.9)	-1.6

Deviations from the UK mean are given in parentheses

TABLE 4. Analysis of variance of components of growth of UK zones by macro-region and metropolitan/non-metropolitan status, 1976-81

Source of variation	Sums of squared deviations	Degrees of freedom	Mean squared deviations	F	Significance of F
Birth rate					
Main effects	1.8	2	0.9	0.6	.556
Region	1.7	1	1.7	1.2	.289
Metro	0.3	1	0.3	0.2	.641
2 way interaction*	1.8	1	1.8	1.3	.279
Explained	3.6	3	1.2	0.8	.499
Residual	23.0	16	1.4	Multiple R^2 = .066	
Total	26.6	19	1.4		
Death rate					
Main effects	3.4	2	1.7	3.8	.046
Region	2.4	1	2.4	5.2	.037
Metro	0.2	1	0.2	0.5	.488
2 way interaction*	0.3	1	0.3	0.6	.464
Explained	3.7	3	1.2	2.7	.081
Residual	7.3	16	0.5	Multiple R^2 = .312	
Total	11.0	19	0.6		
Natural increase rate					
Main effects	1.5	2	0.7	0.3	.769
Region	0.0	1	0.0	0.0	.911
Metro	1.2	1	1.2	0.4	.528
2 way interaction*	3.1	1	3.1	1.1	.304
Explained	4.6	3	1.5	0.6	.652
Residual	44.5	16	2.8	Multiple R^2 = .030	
Total	49.2	19	2.6		
Net migration rate					
Main effects	446.5	2	223.3	32.0	.000
Region	6.8	1	6.8	1.0	.337
Metro	359.1	1	359.1	51.5	.000
2 way interaction*	50.7	1	50.7	7.3	.016
Explained	497.3	3	165.8	23.8	.000
Residual	111.6	16	1.0	Multiple R^2 = .733	
Total	608.8	19	32.0		

TABLE 5. The zones arranged in hierarchical order according to the number of net inflows of migrants, 1966-71, and net migrant estimates (1000's)

Zone	No. of net inflows	Internal[c] migrants			External[d] migrants			Total migrants		
		In	Out	Net	In	Out	Net	In	Out	Net
Rest of the World (1)[a,e]	20	-	-	-	963	466	497	963	466	497
South West	19	381	248	133	72	98	-25	453	345	108
East Anglia	18	180	106	74	50	71	-21	230	177	53
Outer South East	16	591	352	239	103	101	2	694	454	241
North West Remainder	15	229	148	81	25	35	- 9	255	183	72
East Midlands	15	253	208	45	55	69	-14	308	277	31
Outer Metropolitan Area	14	687	512	175	115	148	-34	802	661	141
West Midlands Remainder	12	237	179	58	22	35	-12	259	214	46
Wales	12	130	124	7	21	32	-11	152	156	- 4
Greater London	11	383	856	-473	289	251	39	673	1107	-434
Yorkshire & Humberside Remainder	10	125	111	14	20	28	- 8	145	138	6
North Remainder	9	123	123	0	15	31	-16	137	153	- 16
Scotland Remainder	8	162	151	12	42	71	-29	205	221	- 17
Greater Manchester	8	126	174	- 49	38	41	- 3	163	215	- 52
West Yorkshire	7	97	117	- 20	31	29	1	128	147	- 18
West Midlands	6	115	211	- 96	53	41	11	168	252	- 84
Merseyside	4	66	136	- 70	14	32	-18	81	169	- 88
South Yorkshire	3	55	86	- 31	10	22	-12	64	107	- 43
Tyne and Wear	2	51	87	- 36	8	22	-14	59	109	- 51
Central Clydeside	1	62	115	- 53	16	55	-39	78	170	- 92
Northern Ireland	0	28	38	- 10	16	12	4	44	49	- 5
Rest of World (2)[b,e]	3	-	-	-	258	548	-290	258	548	-290
United Kingdom		4083	4083	0	1015	1222	-207	1015	1222	-207
Absolute numbers (U.K. only)				1676			322			1602

Source: Computed from tables in OPCS (1978) for 5 year migrants.

Notes

[a] Includes "Channel Islands and Isle of Man", "Old Commonwealth", "EEC" and "other" countries as country of origin (immigrants) in OPCS (1978) tables, and the nearest equivalents in the IPS tables (emigrants).

[b] Includes "Irish Republic", "New Commonwealth", "Rest of Europe" in OPCS (1978) tables, and the nearest equivalents in the IPS tables (emigrants). Emigrant numbers are the author's estimates (see Rees, 1981 for details of techniques).

[c] Internal = migration within U.K. [d] External = migration to or from U.K.

[e] The RW(1) and RW(2) estimates are approximate only.

are some 231 ($\frac{1}{2} \times 22 \times 21$) net flows involved among the 20 study zones and the two parts of the rest of the world, and of these only 13 depart from this simple hierarchical ordering*.

The hierarchy generally places non-metropolitan zones above metropolitan, except for Greater London which is placed higher than several of the Northern non-metropolitan zones. We can follow Ravenstein's (1885) example, and plot the patterns of gains and losses on a series of maps, one for each zone as centre (Figure 5). The bottom zone in the hierarchy is Northern Ireland, which our estimates (but see the footnote) suggest loses migrants to all other zones. Central Clydeside loses to all zones except Northern Ireland. Tyne and Wear gains from Northern Ireland, Central Clydeside, and the poorer part of the rest of the world. South Yorkshire gains from these zones and from Tyne and Wear but loses to all the others bar the poorer part of the rest of the world. Merseyside shows net inflows from the zones below it in the hierarchy, but shows slight gains from the poorer part of the rest of the world. West Midlands, West Yorkshire and Greater Manchester exhibit gains from other metropolitan areas lower in the hierarchy, from Northern Ireland and the poorer part of the rest of the world. Then follow a trio of Northern region remainders gaining particularly from their metropolitan counties. Greater London shows the pattern of gains from all other metropolitan zones and all northern zones except the North West remainder, and losses to all southern non-metropolitan zones. Wales shows four departures from the pure hierarchic pattern, gaining from the North West and West Midlands remainders (as a result of retirement migration) and losing to the Northern and Scotland remainders.

An ordered sequence of gains and losses then characterises the West Midlands Remainder, the Outer Metropolitan Area, the East Midlands, North West Remainder, Outer South East, East Anglia and the South West. Finally, our estimates indicate that all zones lose to the richer part of the rest of the world (Isle of Man and Channel Islands, Australia, Canada, New Zealand, United States, rest of the Common Market).

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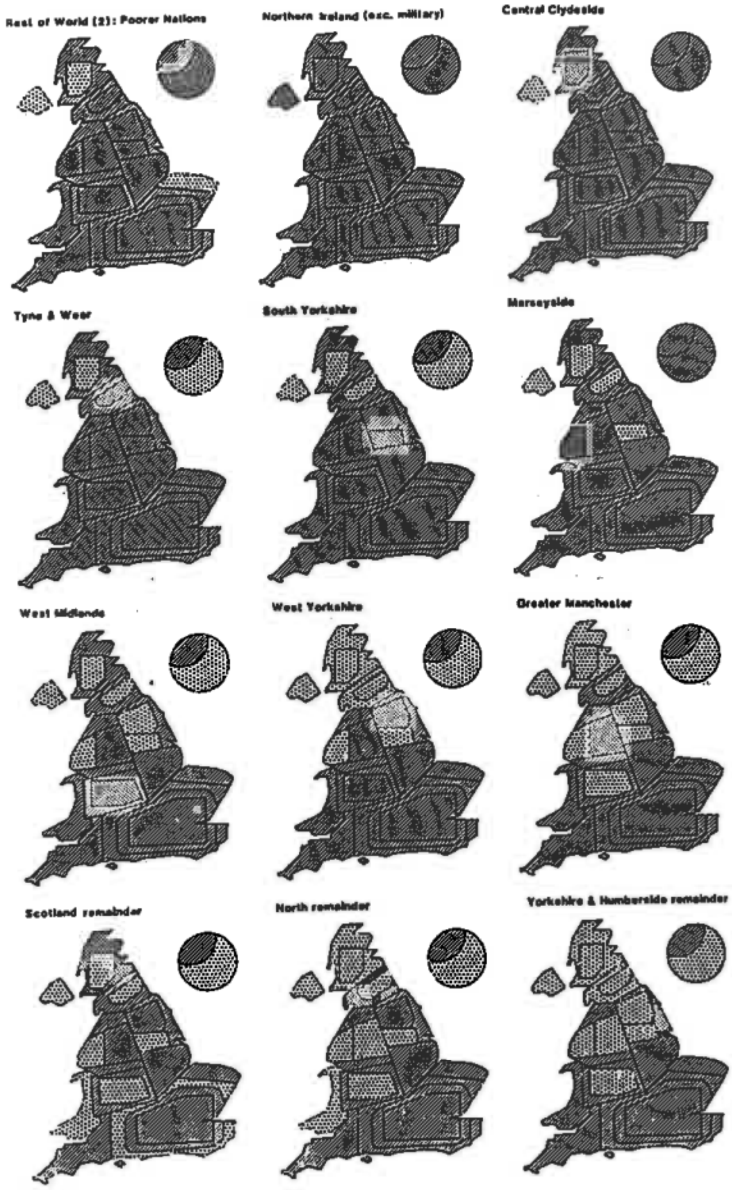
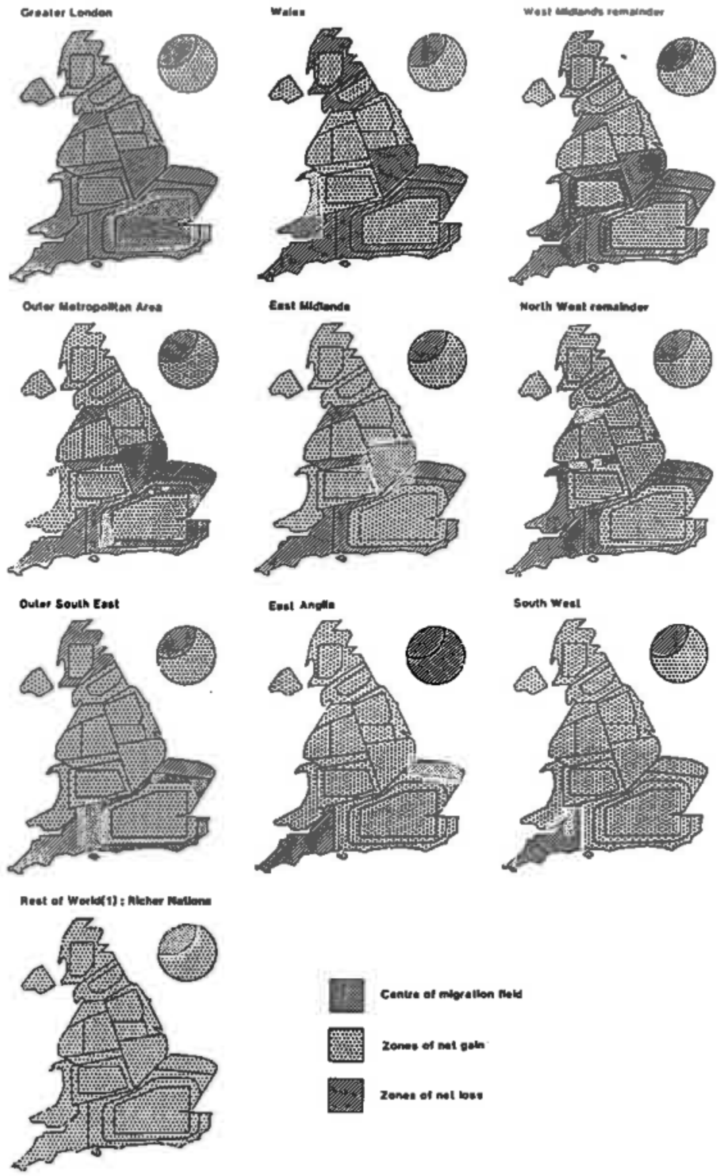
*The placement of Northern Ireland at the bottom of the list depends on the treatment of migrants with unknown origin (General Register Office, Northern Ireland, 1975, Table 1B): these are ignored in the present analysis. They are probably members of the Armed Forces.

FIGURE 5. Net migration fields of U.K. Zones, 1966-71.




Greater London
Wales
West Midlands remainder
Outer Metropolitan Area
East Midlands
North West remainder
Outer South East
East Anglia
South West
Rest of World(1) ; Richer Nations
Centre of migration field
Zones of net gain
Zones of net loss

The migration flows of the 1966-71 thus reveal a common ordered set of residential preferences among the British population, the bases for which need to be explored and incorporated into an explanation for the patterns of population change reported on earlier.

3. Further characteristics of migration patterns

The analysis presented in Section 2 of the paper has demonstrated that contemporary changes in the distribution of the population in the U.K. are influenced primarily by migration rather than by natural change. This dominance seems likely to continue and an improved understanding of the historical flow-generating process continues to provide the focus of much research associated with migration futures. The complexity of the process is compounded by the sparseness of available data and by the uncertainty of exogenous influences, creating circumstances in which migration forecasts are likely to be severely error prone.

Nevertheless, three important characteristics of internal migration can be identified which require representation in a forecasting model: levels of national and local mobility, age-group migration propensities and distribution patterns. Investigation of migration and survival transition data published following the 1971 Census (OPCS, 1978) indicates cross-sectional variations in these characteristics associated with metropolitan counties and non-metropolitan zones, but lack of data for preceding or succeeding periods prohibits consistent time series analysis for this particular system of interest. Zonal systems and data sources alternative to those adopted here are required to illustrate temporal changes in flows and propensities in more detail.

3.1 Variations in levels of national and local mobility

17.8 million respondents to the 1971 Census had moved from their place of usual residence in Great Britain and Northern Ireland during the previous five years. This total, which excludes external flows, represents approximately one third of the population at risk of migration at census date, 1966. Over three quarters of this movement occurred 'within' rather than 'between' individual zones in the metropolitan/non-metropolitan system, a fraction reflected in the respective migration rates of 253 and 75 per thousand population in 1966.

Temporal fluctuations in the national propensity to migrate are influenced by changing macro-economic conditions measured by declining rates of growth in productivity, declining employment opportunities or alterations in the money supply or in the availability of disposable income. While the level of migration in England and Wales increased during the sixties (Table 6), Ogilvy (1979) has used National Health Service Central Register recorded transfers to show that there has been subsequent decline in the 1970's. The degree of fluctuation over time depends upon the type of migration concerned. Inter-regional migrants tend to be job-based and are likely to be more affected by macro-economic change than intra-regional migrants who tend to be home-based; consequently the former are proportionately more mobile during periods of boom or when general levels are increasing, and less mobile in periods of recession or when levels are declining.

Table 6 shows that rates of immigration into England and Wales from outside Great Britain increased between the two five year intercensal periods in the sixties. Although the factors influencing external migration rates are likely to be quite different from those which determine rates of internal migration, statistics derived from the International Passenger Survey (OPCS, Quarterly) presented in Table 7 suggest that, in a fashion similar to internal levels of mobility, rates of immigration and emigration declined during the seventies.

At the subnational level, spatial variation exists in gross out- and inmigration propensities according to relative prosperity or zonal 'attractiveness' measured using socio-economic indicators and influenced by policy initiatives. Unlike internal net migration rates, for which there is a clear out pattern of losses from all the metropolitan counties and gains by all the non-metropolitan regions, the patterns of variation in gross out- and inmigration rates are more obscure and less closely related to region type or location.

The gross rates for 1966-71 have been ranked and mapped in Figure 6. Intra-zonal and external flows are included in the rates presented in 6A and 6B and excluded from the rates in 6C and 6D. The metropolitan zones of Central Clydeside, Greater London, Tyne and Wear, West Yorkshire and the West Midlands have the highest rates of total outmigration together

TABLE 6. Levels of five-year migration in England and Wales, 1961-71; Standard Regions.

	Type of migration (rate per thousand population at census date).			
	Within England and Wales	Inter-regional in England and Wales*	Intra-regional in England and Wales*	Into England and Wales from outside G.B.
1961-66	308.7	38.6	270.2	18.9
1966-71	319.2	43.9	275.2	20.0
% change	+ 3.4	+13.7	+ 1.9	+ 5.8

Source: Migration Summary Tables Part 1 (GRO, 1968)
Migration Tables, Part 1 (OPCS, 1974).

* Figures have not been adjusted for regional boundary changes between 1966 and 1971.

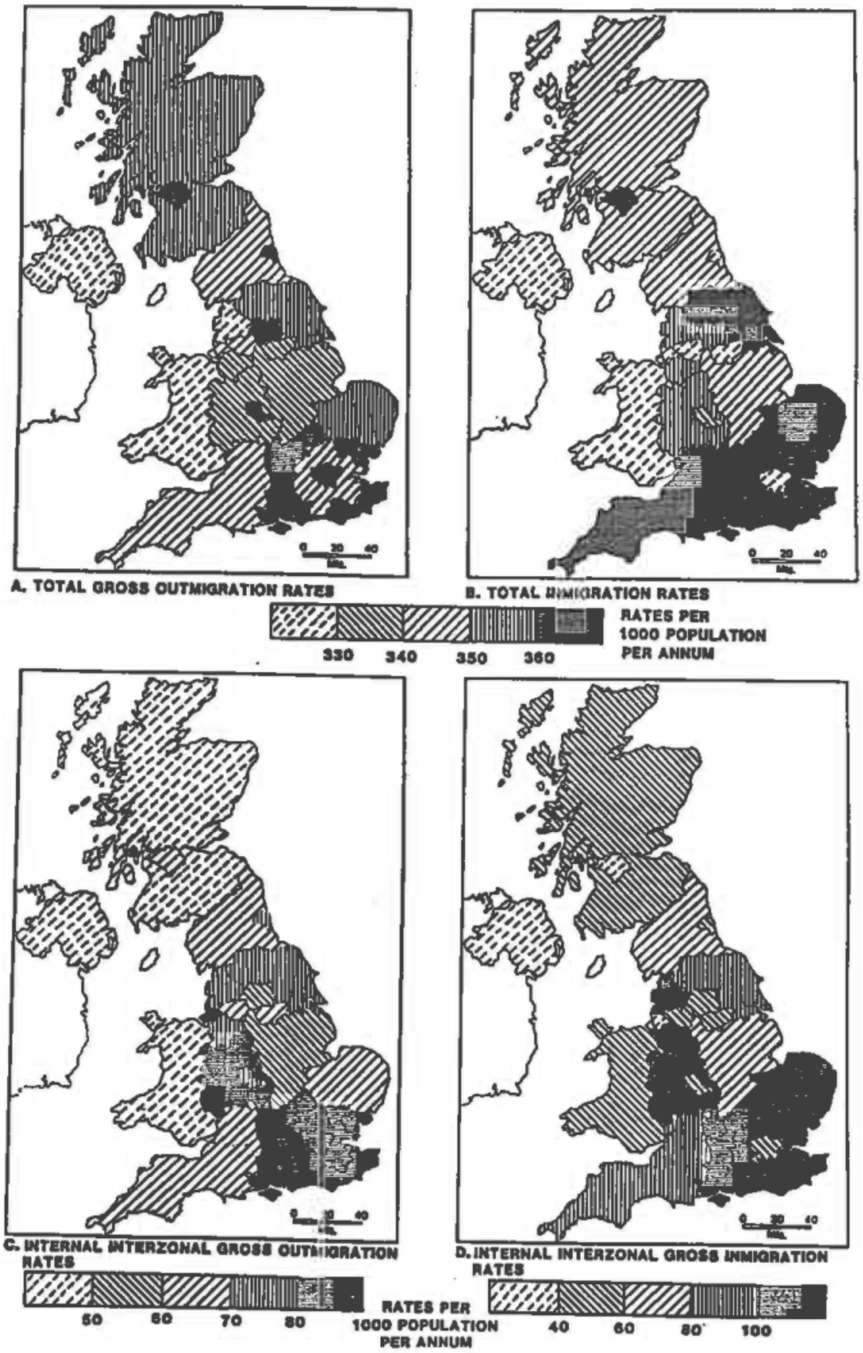
TABLE 7. U.K. External Migration, 1966-80

Year	Immigrants to U.K.	Emigrants from U.K.	U.K. Immigration Rate	U.K. Emigration Rate
	(Thousands)		(Rates/1000 population*)	
1966	219	302	4.0	5.5
67	225	309	4.1	5.6
68	222	278	4.0	5.1
69	206	293	3.7	5.3
70	226	291	4.1	5.3
71	200	240	3.6	4.3
72	222	233	4.0	4.2
73	196	246	3.5	4.3
74	184	269	3.3	4.8
75	197	238	3.5	4.3
76	191	210	3.4	3.8
77	163	209	2.9	3.7
78	187	192	3.3	3.4
79	195	189	3.5	3.4
1980	174	229	3.1	4.1

Source: IPS Statistics (OPCS, Quarterly)

* Populations used for rate calculations are U.K. mid year estimates.

FIGURE 6. Gross out-and in-migration rate patterns, 1966-71.



with the Outer South East, while Merseyside, Greater Manchester and South Yorkshire experience rates that are lower than those for East Anglia and the region remainders of Yorkshire and Humberside, the North and Scotland, as well as the Outer Metropolitan Area and the South West. The initial group, with the exception of Greater London have relatively high rates of intra-regional migration and when these are omitted, Central Clydeside and West Yorkshire in particular receive much lower rankings. The Outer Metropolitan Area, which maintained the lowest rate of intra-regional migration in the system, and also Merseyside appear in the top category of zones ranked according to their gross inter-regional outmigration rates along with the regional remainders of the South East and the West Midlands.

Differences in the gross rate patterns between the two definitions are less dramatic for inmigration than for outmigration. The majority of metropolitan counties experience relatively low rates of total inmigration except for Central Clydeside which belongs to the same group as the Outer South East, the Outer Metropolitan Area, East Anglia and the South West, and West Yorkshire which has rates of total inmigration of roughly the same magnitude as the other region remainders.

Internal gross inmigration rates turn out to be significantly higher than corresponding outmigration rates for zones in the top two categories mapped in Figure 6, yet considerably lower than outmigration in the lower categories. The major differences in the two sets of inmigration rate patterns involve Central Clydeside whose rate ranking falls dramatically when intra-regional migrations are excluded, and Greater London and Wales, whose rankings improve. Northern Ireland records the lowest rates of both out- and inmigration regardless of which flows are included.

Fluctuations in 'regional' levels of mobility during the sixties can be identified when ratios are defined to compare rates for the two quinquennia, 1961-66 and 1966-71 (Table 8). Increases in gross migration propensities are evident for all regions except the North and Scotland, whose gross outmigration rates showed marginal decline. While outmigration rate increases varied from 22% (East Midlands) to 9% (Wales), growth in inmigration rates experienced by all the regions, ranged down from 40% (Scotland) to 1% (West Midlands). The inmigration rate increased more sharply than the outmigration rate in four regions: East Anglia, Wales, the North and Scotland.

TABLE 8. Ratios based on quinquennial 'transitions' data and biennial 'moves' data, illustrating changes in regional gross migration rates

Region	Outmigration Ratio * 1966-71/ 1961-66	Inmigration Ratio* 1966-71/ 1961-66	Region	Outmigration Ratio** 1977-79/ 1971-73	Inmigration Ratio** 1977-79/ 1971-73
East Midlands	1.22	1.13	Wales	0.98	0.88
Yorks & Humbs	1.19	1.07	North West	0.95	0.86
North West	1.18	1.10	East Anglia	0.92	0.85
South East	1.16	1.11	West Midlands	0.91	0.84
West Midlands	1.11	1.01	South West	0.91	0.82
South West	1.11	1.10	East Midlands	0.90	0.83
East Anglia	1.10	1.20	North	0.89	0.80
Wales	1.09	1.14	Yorks & Humbs	0.88	0.85
North	0.99	1.19	Scotland	0.83	0.90
Scotland	0.98	1.40	South East	0.82	0.98

Sources
* Ratio based on quinquennial 'transitions' rates (Stillwell, 1980a)
** Ratios based on biennial 'moves' rates (Bates, 1982)

In contrast to the trends of the sixties, all regions showed declining levels of gross otumigration and inmigration during the following decades according to ratios (Table 8) defined using biennial NHSCR-transfer recorded moves for 1971-73 and 1977-79 (Bates, 1982). Apart from Scotland and the South East, the level of decline was more pronounced for inmigration than outmigration. The largest decline in outmigration rate was experienced by the South East (18%) and the inmigration rate decline was most apparent in the North (20%).

3.2 Age group differentials in migration propensities

Migration propensities also vary according to age, and Figure 7 illustrates the 5 year rates of internal intra- and inter-zonal migration in the metropolitan/non-metropolitan system. The initial decline in the propensity to migrate over the first two age groups evident from both schedules, is followed by the labour force peak in the 25-29 age group (average age 25) and subsequent decline with increasing age. The retirement peak at age group 65-69 is more pronounced for inter-regional migration. The age-specific inter-regional migration rates show substantial variation from zone to zone. The range of values around each age group rate (Figure 8) is consistently wider for inmigration than outmigration suggesting that inmigration rates are more likely to be influenced by changing conditions than outmigration rates. Age-specific migration rates for each region can be summed to provide gross migraproduction rates, indicating general levels of mobility which are directly proportional to the total volume of migration involved. Whereas gross migraproduction rates may show significant fluctuation over time, the shape of the migration schedule is likely to be preserved although lowering the retirement age would have the effect of shifting the retirement peak to the left.

Three types of zone can be classified on the basis of the pattern of age group net migration balances for 1966-71. The first category contains those metropolitan counties experiencing net losses in all age groups: Tyne and Wear, South Yorkshire, West Yorkshire, Greater Manchester, Merseyside, West Midlands and Central Clydeside. The second group includes those non-metropolitan regions which gain migrants on

FIGURE 7 Rates of migration within and between internal zones, 1966-71, disaggregated by 5 year age group.

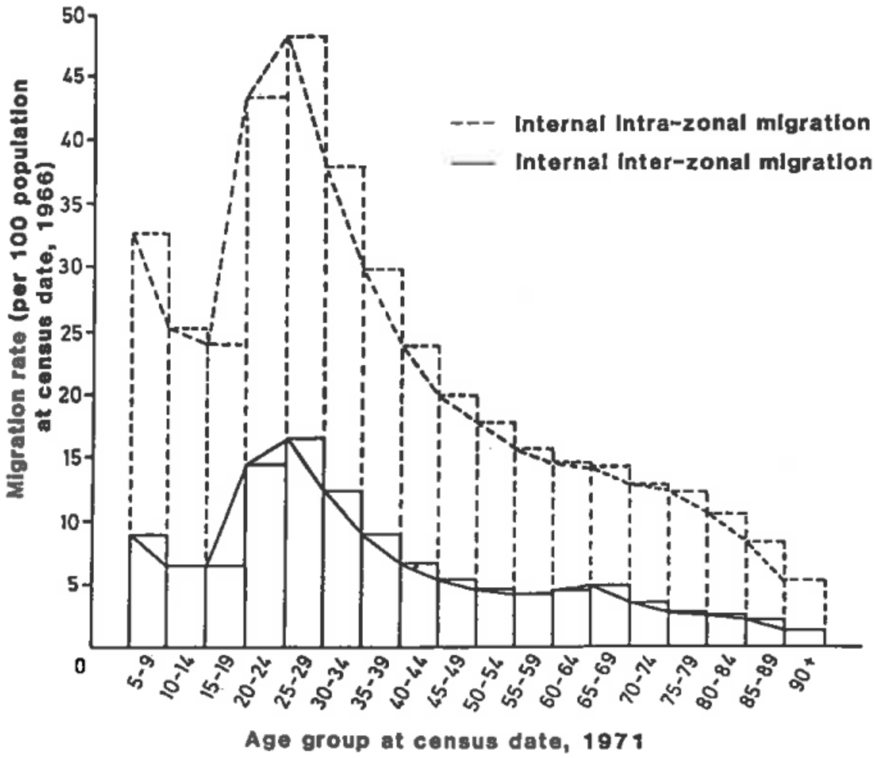
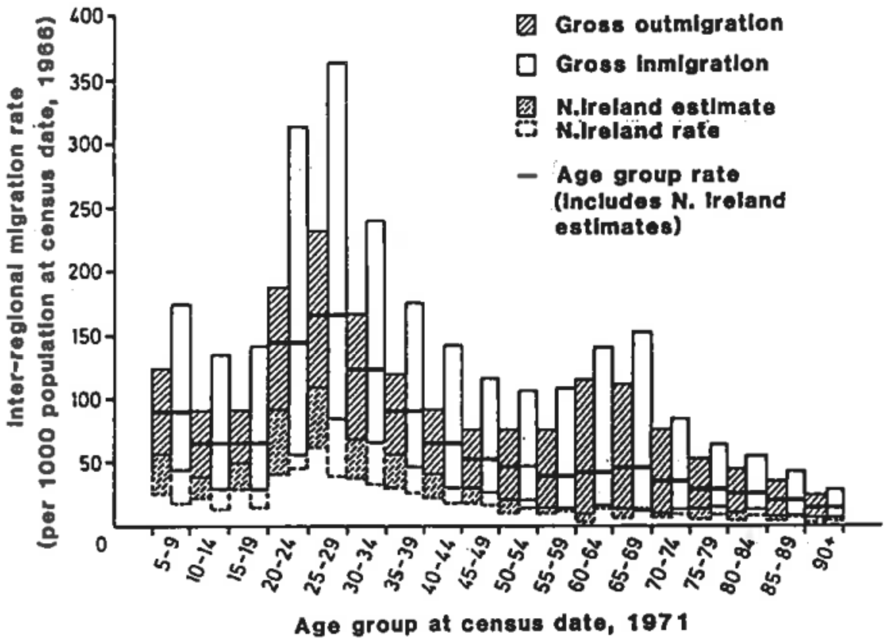


FIGURE 8 Variance in gross out-migration and in-migration rates (between zones), 1966-71, disaggregated by five year age group.



balance in each age group: the remainders of the North West and West Midlands, the East Midlands, East Anglia, the Outer South East and the South West. The third category contains zones whose net migration profiles are neither entirely positive nor entirely negative across the range of age groups. While Greater London experiences net losses in all age groups except 20-24, the Outer Metropolitan Area gains migrants in all age groups except 60-69. Two other subgroups can be identified; the first includes the region remainders of Yorkshire and Humberside and Scotland with net losses in the highly mobile labour force age range 15-29, and the second contains the remainder of the Northern Region and also Wales, whose net migration balances show net losses in the age ranges 10-29 and 75+, and gains elsewhere. Northern Ireland has been excluded from the classification because age-group inmigration flows from the other regions to Northern Ireland were obtained by estimation rather than observation.

3.3 Spatial variation in migration streams

The previous classification provides a broad summary of the distribution of migrants between destinations which is dependent upon the type of zone, the relative location of origins and destinations and the age of the migrant involved. Persons in the highly mobile age groups are likely to move to metropolitan counties and to Greater London in particular to obtain employment. Table 9 shows that a higher percentage of migrants aged 15-29 moved between rather than within zones and they are therefore liable to move over relatively long distances. On the other hand, children up to age 15 tend to move with their parents aged 30-45, over relatively short distances and not necessarily for job change reasons. A higher percentage of these persons move intra-zonally and the process of suburbanisation involving increased commuting distances has been a common feature of the 60's and 70's. Retirement migration will have a distinctive distribution which focusses on certain inland or coastal destinations. Table 9 indicates a higher percentage of the 60+ age group migrating within zones rather than between them, but a finer scale is required to observe the patterns in detail.

Distribution patterns will fluctuate over time according to changes in the relative attractiveness of origins and destinations. The South East has always been at the hub of migration activity both as a recipient and as

TABLE 9. Internal migration within the zonal system for broad age groups, 1966-71

Age Group	Total	Inter-Zonal	Intra-Zonal
	%	%	%
5-14	18.6	17.3	19.0
15-29	33.6	36.4	32.8
30-59	35.5	34.6	35.8
60+	12.3	11.7	12.4
TOTAL MIGRATION	17,845,934	4,083,219	13,762,715

Source: OPCS (1978)

a generating region. While dispersal from the South East increased during the 60's, counteracting the inward drift from elsewhere, one of the features of change in the 70's has been the decline in rates of out-migration from the South East, reducing net gains in certain regions and increasing net losses in others (Ogilvy, 1982; Bates, 1982).

Previous studies have shown that there is a strong friction of distance effect on migration and Stillwell (1978) has identified regional variations in age group migration propensities over distance which are independent of location. Further results comparing inter-county migrations between 1961-66 and 1966-71 (Stillwell, 1979) suggest that for the majority of counties in England and Wales, both out- and in-migration propensities to move over distance increased as mean out- and in-migration lengths were extended.

3.4 The next steps

What we have presented in this section are a series of vignettes describing the recent spatial history of the British population. However, these vignettes do not constitute a systematic description of population change. Great gaps yawn in the description - the components of growth were presented for 1976-81 only; the migration patterns primarily for 1966-71; the picture was one for the whole population only, not its different groups; and so on. Before we can proceed to explanation and projection of the population change patterns, we need to build up a more systematic description using population accounts as our framework. These and their associated data gap-filling techniques are discussed in the next section of the paper.

4. An accounting and data estimation framework

4.1 The aim

The intention is to construct, for the study set of 20 zones together with one Rest of the World zone, population accounts spanning the last three quinquennia up to the 1981 census in order to show how the population stocks of 1966 were transformed into those of 1981. These accounts will be disaggregated by age groups because of the vital connection between all demographic processes and age. The age groups are 0-4, 5-9, 10-14, ..., 80-84 and 85 and over. Sex disaggregation, though interesting, is not considered vital as men and women do most things together or in parallel!

The reasons for wishing to build population accounts for three periods were

(i) the need to look at a time series of accounts if reasonable forecasts were to be made;

(ii) the need to link together two censuses and to verify the accounts building procedure; and

(iii) to develop a proper age disaggregation of migrant information.

This latter requirement forced inclusion of the 1966-71 period into the series as this is the last period for which detailed migration information is published. A major alternative to constructing quinquennial accounts would be to construct annual accounts for say 1970-71, 1975-76 and 1980-81 using the one year migrant tables from the 1971 Census, and in the future, from the 1981 Census. However, this would fail to meet the second requirement (linkage and verification), and raise operation difficulties (concerning single year of age disaggregation or age interval, time interval considerations). We will, however, attempt to construct 1966-71 accounts with five year age groups using adjusted (multiplied by 5) 1970-71 migration rates to explore the consequences of using one-year census migration measures compared with five year.

4.2 Age disaggregated population accounts

The concepts of population accounts have been developed by the Cambridge economist Richard Stone (Stone, 1971, 1975) and by Rees and Wilson (1977). The reader is referred to the latter book and subsequent papers (Rees, 1979b, 1980) for a full exposition of the full theory underpinning population accounts. Here a simplified description is provided of population accounts for cohorts.

4.2.1 Notation

The accounts matrix is a two dimensional array of population numbers classified into cells according to their initial states in a time interval (the row classes) and their final states in a time interval (the column classes), with other states such as sex or, in this paper, age cohort, constant over the time interval.

General notation for population

K : a count of people

Initial life states

v : general label for initial life-state of which there are two:-

b : birth in a time interval

e : existence at the start of a time interval

Final life states

w : general label for final life-state of which there are two:-

s : survival at the end of a time interval

d : death in a time interval

Constant states

a : age cohort label. There are a = 1, ..., A cohorts. Persons remain in the age cohort for a time interval and are transferred to the next, assuming survival, at the start of the next time interval. They remain members of the same cohort of persons born in the same set of birth dates throughout.
This age cohort definition represents a return to that suggested by Stone (1971).

Other constant (or fairly constant) states could also be specified: sex, race or ethnic status for example, although over several periods interaction may take place.

Time labels

t : start point of time interval

T : length of time interval

t+T : end point of time interval

These labels are generally not made explicit as most accounting equations refer to a single period t to t + T.

Initial and final states of interest

In this paper we use:-

i : initial region label for region at start of time interval

j : final region label for region at end of time interval

There are i,j = 1, ..., N internal regions of interest and R is the label used for the external region or 'rest of the world'.

People can move freely among these region states. Note that we could use the labels i and j to refer to other kinds of states amongst which people can move more or less freely such as illness states or income groups.

Thus, although accounts are defined and discussed in this paper as referring to regional age-cohort disaggregated populations, these are only one of the many sorts of population that could be described using accounting theory.

4.2.2 The accounts variables

At the most general level, two accounts variables can be defined, survivors and non-survivors.

$K_a^{v(i)s(j)}$: persons of age cohort a either born in region i or in existence in region i who survive in region j at the end of the period (survivors)

$K_a^{v(i)d(j)}$: persons of age cohort a either born in region i or in existence in region i who die in region j before the end of the time interval (non-survivors)

If these variables are summed over final and initial states we obtain the row and column sums of the accounts:

$K_a^{v(i)*(*)}$: row sums of the accounts matrix

$K_a^{*(*)s(j)}$: column sums for survivors of the accounts matrix

$K_a^{*(*)d(j)}$: column sums for non-survivors of the accounts matrix

4.2.3 The accounts matrix and table

These variables can be arranged in a matrix with 2n columns and n rows, where n is the number of regions being studied (Figure 9). When row sums and columns are added to the accounts matrix, an accounts table is formed.

The accounts table becomes of real interest only when we define the set of regions being studied to include an external zone that receives or sends all the population flows which the internal regions send to 'the rest of the world'. Then we can interpret the row sums for the internal regions as the initial populations of the regions or the births totals in those regions.

Figure 10 shows a four region accounts table in which the last region is the external zone that closes the system being studied together with a numerical example. In these accounts the population transitions within the rest of the world are ignored and set to zero. The row sums of these accounts can be interpreted as initial populations of the regions (in the example: 125605, 1409274, 3058068) except for the last (113704) in which the total refers to the sum of all surviving and non-surviving immigrants to the internal system. The column sums for survivors are the final populations of the regions in the time interval (in the example: 135051, 1356147, 3016295), except for the last which refers to the total of surviving emigrants from all the internal regions (177998). The non-survivors totals refer to deaths recorded in the internal regions (530, 5708, 14525) except for the rest of the world total which refers to non-surviving emigrants (397).

4.3 Components of the accounts

In order to make estimates of the numbers of persons experiencing the transitions laid out in an accounts table, we need to identify

FIGURE 9. <u>The structure of a population accounts table for age cohort a</u>

Initial states \ Final states		Region of survival (s) at time t + T				Region of death (d), t to t + T				Totals
		1	2 ...	j ...	n	1	2 ...	j ...	n	*
Initial state (v): existence (e) or birth Region of origin	1	$K_a^{v(1)s(1)}$	$K_a^{v(1)s(2)}$ ...	$K_a^{v(1)s(j)}$ ...	$K_a^{v(1)s(n)}$	$K_a^{v(1)d(1)}$	$K_a^{v(1)d(2)}$ ...	$K_a^{v(1)d(j)}$ ...	$K_a^{v(1)d(n)}$	$K_a^{v(1)*(*)}$
	2	$K_a^{v(2)s(1)}$	$K_a^{v(2)s(2)}$ ...	$K_a^{v(2)s(j)}$ ...	$K_a^{v(2)s(n)}$	$K_a^{v(2)d(1)}$	$K_a^{v(2)d(2)}$ ...	$K_a^{v(2)d(2)}$ ...	$K_a^{v(2)d(n)}$	$K_a^{v(2)*(*)}$
		⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	i	$K_a^{v(i)s(1)}$	$K_a^{v(i)s(2)}$ ...	$K_a^{v(i)s(j)}$ ...	$K_a^{v(i)s(n)}$	$K_a^{v(i)d(1)}$	$K_a^{v(i)d(2)}$	$K_a^{v(i)d(j)}$ ...	$K_a^{v(i)d(n)}$	$K_a^{v(i)*(*)}$
		⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	n	$K_a^{v(n)s(1)}$	$K_a^{v(n)s(2)}$ ...	$K_a^{v(n)s(j)}$ ...	$K_a^{v(n)s(n)}$	$K_a^{v(n)d(1)}$	$K_a^{v(n)d(2)}$ ...	$K_a^{v(n)d(j)}$ ...	$K_a^{v(n)d(n)}$	$K_a^{v(n)*(*)}$
totals	*	$K_a^{v(x)s(1)}$	$K_a^{v(x)s(2)}$ ...	$K_a^{v(x)s(j)}$ ...	$K_a^{v(*)s(n)}$	$K_a^{v(x)d(1)}$	$K_a^{v(x)d(2)}$	$K_a^{v(*)d(j)}$	$K_a^{v(*)d(n)}$	$K_a^{v(*)*(*)}$

FIGURE 10. **The structure of an accounts matrix for three internal regions and one external: 0-4 cohort, Great Britain, 1966-71**

Initial state \ Final state		Region of survival at time t + T				Region of death, t to t + T				Totals
		1	2	3	4	1	2	3	4	
Existence in region of origin	East Anglia 1	108108	5739	6880	4366	475	12	16	9	125605
	South East 2	11171	1249289	58934	84055	23	5487	141	174	1419274
	Rest of Britain 3	8869	52833	2892219	89577	18	109	14228	214	3058068
	Rest of World 4	6900	48268	58283	0	14	100	140	0	113704
Totals		135048	1356129	3016316	177998	530	5708	14525	397	4706651

those items of information which can be acquired from official demographic sources (or estimated fairly reliably from such sources) and which will need to be estimated by means of 'model' equations (guesses as to their likely size) or by means of accounting equations (that is, as residuals in the row or column in which they appear, all other items being known).

To do this the variables are classified into further component parts. These components are shown in Figure 11 in words using the four region accounts of Figure 10 as the framework.

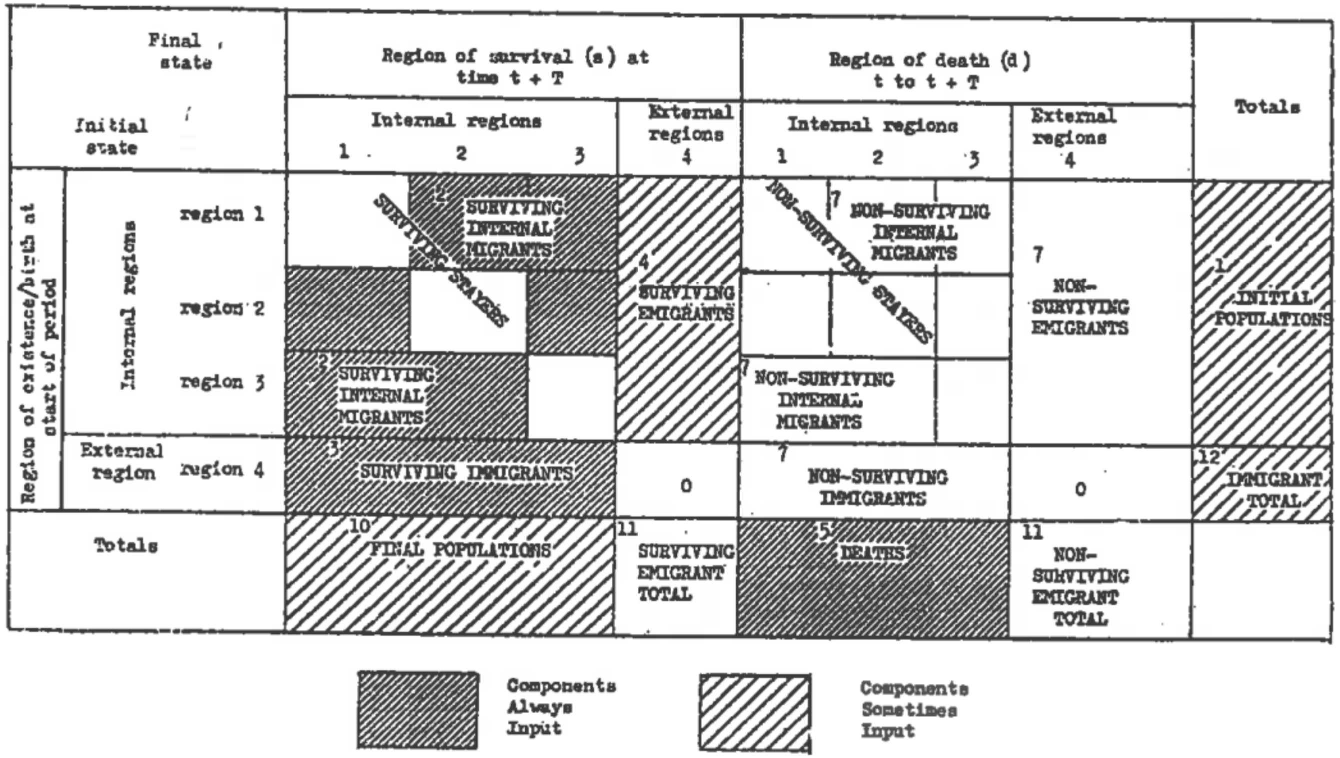
Some twelve components are identified, all of which must be estimated to complete any accounts table, though one, the populations at risk, do not appear as such in the table. Each component can be estimated in one of a number of different ways. For example, non-surviving internal migrants could be estimated using one of three hypotheses: that migrants die at the rate observed in their region of destination; that migrants die at the rate observed in their region of origin; or that migrants die at a rate intermediate between that of their origin and their destination regions.

4.4 General features of the accounts based model

The combination of choices for estimating items in each component constitutes an accounts based model. Not all choice combinations are allowed but there are a great many resultant accounts based models. The detailed equations involved for each component are not given here, but may be assembled from those described in Rees (1981a). All will have the following features, however:-

(1) The populations of the regions are input externally. The initial populations may be derived from population census data or population estimate series or they may simply be the final populations of the previous modelling period (if forecasting is being carried out). The final populations may be derived from population census data or population estimate series or they may simply be the initial populations of the next modelling period (if backcasting is being carried out). Either initial populations or final populations or both may be input.

Figure 11. Components of the accounts



(2) Surviving internal migrant flows will be either derived from census data or registration sources and input as flows or they will be estimated by inputting migration rates and multiplying these by the initial population serving as the population at risk. Or they may be estimated by a separate migration model and then input.

(3) Surviving external migrant flows (immigrants and emigrants) will be either input from census or registration or survey data sources. If emigrant estimates are unavailable, they may be derived by inputting both initial and final populations and immigrant flows. Rates may be substituted for flow inputs and multiplied by one of a variety of populations at risk instead.

(4) Deaths totals for the regions will be input in either flows or rates form. If in rates form deaths flows will be estimated by multiplying by an appropriate population at risk.

(5) Non-surviving migrants are then estimated using regional death rates and the surviving migrant flow estimates in model equations assuming either migrants die at the death rate of region of origin (non-surviving internal migrants and emigrants), or that they die at the death rate of region of destination (non-surviving internal migrants and immigrants) or that they die at a rate averaging origin and destination mortality (non-surviving internal migrants).

(6) Non-surviving stayers are then computed normally as residuals in their columns (that is, as the difference between total deaths in a region and the sum of in-migrant non-survivors).

(7) Surviving stayers are then computed as residuals from the row accounting equation or from the column accounting equation depending on the availability of initial or final regional populations and the users' choice.

(8) Regional populations, either final or initial, which remain unknown are then computed from the appropriate column or row accounting equation.

(9) The accounts matrix will then be re-estimated using revised

values of the populations at risk involved as many times as are required for the accounts matrix to converge on a stable solution.

(10) The converged accounts may be adjusted to new or unused information about the marginal totals using standard balancing factor procedures, after first ensuring that the marginal constraints are themselves consistent.

4.5 A births model

In order to utilize an accounts based model for projection a births model is required. Births are generated by this model and are aggregated to represent the 'initial population' of the infant cohort. Accounts for the infant cohort are built in very much the same fashion as accounts for existing age cohorts except that several different options for some components are available and that the 'fraction of a period exposed to risk' factor in the population at risk equation is one half rather than one.

The births model either inputs births disaggregated by age cohort from data sources or inputs age cohort specific birth rates which are multiplied by the population at risk specified by the user. The age cohort classified births are summed before being used as the row totals (for internal regions) in the infant accounts.

4.6 Modes of use of the accounts based model

Initially, the accounts based model was designed either as an historical model in which all inputs were of known population stock or flow quantities or as a projection model in which all components besides initial populations were input as forecast rates. However, a much wider set of modes of use can be envisaged with the current accounts based model. These are set out in Figure 12.

If reasonable estimates of the numbers of people in each flow component input are available for a past time period, the resulting accounts are known as historical (the first row of the table in Figure 12). If no constraints (external estimates for the accounts table marginals) are applied the accounts are unconstrained. If the final population stocks are the ones available then the backcast model must be used. If both initial and final populations are known then constrained

FIGURE 12. __Modes of use of the accounts based model__

Time Horizon	Knowledge of Flow Components	State of knowledge of stocks components		
		Initial population stocks only	Final population stocks only	Constraints (inc both initial and final population stocks)
Past	All flow data inputs are known	historical unconstrained	historical unconstrained backcast	historical constrained
Past	Only some flow data inputs are known	estimated unconstrained	estimated unconstrained backcast	estimated constrained
Present ⟶ Future	All flow data inputs are projected	projected un-constrained (forecast)	projected un-constrained backcast	projected constrained (target)

historical accounts will be prepared.

For one or more time intervals between the present and the period for which all input data are available, only some of input components may be known. In this situation estimated flows or rates may have to be input and the resulting accounts called 'estimated'. If the time interval being studied is wholly in the future then the accounts produced are referred to as projected as the inputs will all be forecast rather than known. In certain circumstances the analyst may wish to fix the population stocks, and the accounts based model may be used to estimate the relevant matrices of change that would match the target populations. All projected versions of the accounts based model may be used with fixed or variable inputs of rates or flows.

4.7 Data estimation framework

4.7.1 General problems

Some six components of the accounts are required for input to an accounts based model: populations (initial and final in a period), births, deaths, internal migrants, immigrants and emigrants. Figure 13 sets out the sequence of data sets that have to be estimated, and the degree of estimation (interpolation) that is required for each component.

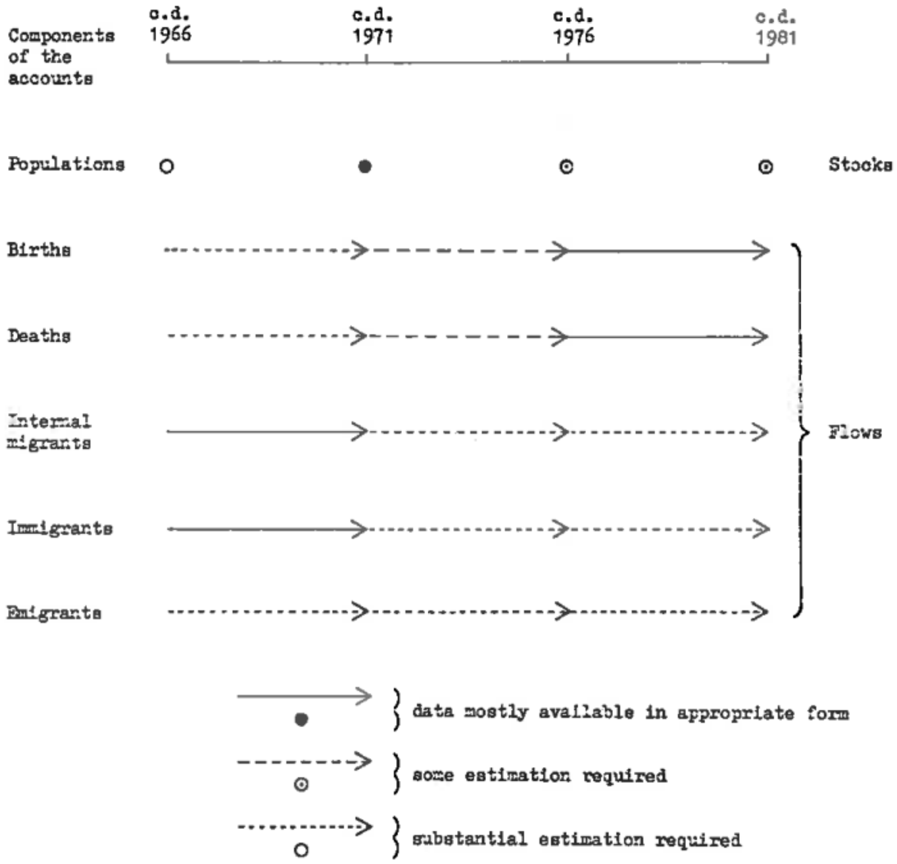
The original intention of our research was to construct very general data estimation procedures and computer programs that could be used in any British context. This proved to be infeasible, and instead the preparation of the data inputs requires some 18 separate estimation exercises and associated computer programs.

Four general problems had to be faced in the estimation exercises:

(i) The age disaggregation of input component had to be improved to that of the accounts model, which consisted of five year age groups from 0-4 years through 80-84 years plus the last, 85 years or more in age. The age disaggregation of flow data had to be adjusted to a cohort basis (see Rees 1981).

(ii) The area definition of the data inputs had to be transformed to those of the study set of zones. The main difficulties in this respect were the result of local government reorganization in 1974-75 and affected data for years prior

FIGURE 13. Degrees of estimation of accounts components required



to that date. Other problems were in assembling statistics for non-administrative zones such as Central Clydeside and the Outer Metropolitan Area.

(iii) Under- or over-enumeration in the data series had to be dealt with. This was a particular problem in estimating census date 1966 populations, and in reconciling census and International Passenger Survey immigrant estimates.

(iv) The time point or period to which the data applied had to be adjusted for. The periods chosen were tied to the dates of censuses rather than to mid-year (June 30/July 1) points because of our desire to link census population stocks explicitly.

The estimations were carried out in the main on published Office of Population Censuses and Surveys (OPCS) data: in many instances better unpublished data were probably available, but expensive in money and time. Should OPCS ever take up the methodology for their own use, the data base could be improved. The data estimations carried out are briefly reviewed.

4.7.2 Population stocks

No published figures disaggregated by age were available for the study zones for census date 1966, since the areal units used then were rather different (e.g. conurbations rather than metropolitan counties). However, estimates of the total population at mid-year 1965 and 1966 were available on approximately the right basis (OPCS, 1975). The procedure used was to apply regional transformation coefficients to the Census 1966 age disaggregated populations (Table 10) and then to constrain those figures to an interpolated estimate of post-April 1, 1974 areas this procedure ensured that errors in estimating the regional transformation coefficients were compensated for and that the underenumeration of the 1966 Census numbers was corrected for.

Population stocks for census date 1971 were assembled by addition of the relevant county or district statistics given in the county volumes for areas as constituted on 1st April 1974 (OPCS, 1976, Table 8).

TABLE 10 Coefficients used in transforming 1966 census populations to a new areal base.

Post-1974 Zones		1966 Census Zones
Tyne & Wear	=	Tyneside Conurbation + .1623 Northern Remainder
North Remainder	=	.7282 Northern Remainder.
South Yorkshire	=	.3972 Yorkshire & Humberside Remainder + .0029 East Midlands.
West Yorkshire	=	West Yorkshire Conurbation + .1164 Yorkshire & Humberside Remainder
Yorkshire & Humberside Remainder	=	.1095 Northern Remainder + .4322 Yorkshire & Humberside Remainder
Greater Manchester	=	South East Lancashire Conurbation + .1173 North West Remainder.
Merseyside	=	Merseyside Conurbation + .1253 North West Remainder.
North West Remainder	=	.6959 North West Remainder.
East Midlands	=	.0542 Yorkshire & Humberside Remainder + .0265 North West Remainder + .9971 East Midlands.
West Midlands	=	West Midlands Conurbation + .1495 West Midlands Remainder.
West Midlands Remainder	=	.8505 West Midlands Remainder.
East Anglia	=	East Anglia.
Greater London	=	Greater London.
Outer Metropolitan Area	=	Outer Metropolitan Area.
Outer South East	=	.9563 South East Remainder.
South West	=	.0437 South East Remainder + South West.
Wales	=	Wales.
Central Clydeside	=	Central Clydeside + .0517 Scotland Remainder.
Scotland Remainder	=	.9483 Scotland Remainder.
Northern Ireland	=	Northern Ireland.

Population stocks for assumed census date 1976 (25/26th April) were computed by linearly interpolating between the June 30th 1975 and June 30th 1976 population estimates (OPCS, 1977) for metropolitan counties and standard regions, computing region remainders by subtraction, and adding up the population estimates for constituent districts to make up the Central Clydeside figures.

Population stocks for Census 1981 are estimated, for the time being, before publication of the full county reports, by disaggregating published preliminary estimates (OPCS, 1981) by the age group proportions of the 1980 estimates. These estimates can be replaced by the full Census figures when these are published.

4.7.3 Births

For the years 1976 to 1979, births by age group of mother for most of the study zones are given in the OPCS Fertility and Marriage Series, the Registrar General for Scotland's Annual Returns and the Registrar General for Northern Ireland's Annual Returns. For the Outer Metropolitan Area, total births statistics must be assembled from the Local Authority Vital Statistics and disaggregated using Rest of South East figures. For 1980 and the first half of 1981, figures from the OPCS Vital Statistics Monitor (Nos. 81/4, 82/1) are available though not by age of mother, and deconsolidation proportions based on 1979 statistics will be applied. Once the vectors of live births by age of mother for each zone are assembled they need further deconsolidation and reaggregation into age cohort form using national single year of age birth statistics.

For the two earlier periods additional data transformation is needed using coefficients such as those used for the 1966 population stocks, but adjusted to take into account discrepancies revealed in the constraining procedure.

4.7.4 Deaths

Similar methods for the preparation of zonal deaths data will be employed. There is the extra need to move from a ten-year to five-year age group basis using national data. Then the quinquennial age groups need to be deconsolidated from a single classification by age group at death to a double classification by age group at death and at start of time interval thus;

$$K_{aa}^{*(*)d(j)} = C_{aa} \; K_{*a}^{*(*)d(j)} \qquad (1)$$

$$K_{aa+1}^{*(*)d(j)} = C_{aa+1} \; K_{*a+1}^{*(*)d(j)} \qquad (2)$$

and then reaggregated to age cohort form

$$K_{a*}^{*(*)d(j)} = K_{aa}^{*(*)d(j)} + K_{aa+1}^{*(*)d(j)} \qquad (3)$$

The coefficients C_{aa} + C_{aa+1} will be derived from single year of age national data.

4.7.5 Internal migrants

For the first period, 1966-71, internal migrant data is available in virtually the correct form for input to an accounts based model from OPCS (1978), Table 2B, for all flows between zones within the UK except for out-migrants to Northern Ireland, which are estimated by applying deconsolidation proportions based on total out migration to other zones in Great Britain to totals of migration to Northern Ireland, themselves estimated from figures in the General Register Office, Northern Ireland (1974) Migration tables. Infant migrants (those aged 0-4 at Census date 1971) are estimated by the following equation:-

$$K_{*0-4}^{b(i)s(j)} = K_{*5-9}^{e(i)s(j)}(5) \; \frac{\frac{5}{4} K_{*1-4}^{e(i)s(j)}(1)}{K_{*5-9}^{e(i)s(j)}(1)} \times 0.5 \qquad (4)$$

where the bracketed term (1) refers to the one year migrant numbers, the (5) to five year migrant numbers. Migrants in age categories 75-79, 80-84, 85-89 and 90 + are estimated by applying population proportions at Census 1971 to the last migrant age group 75 +.

Methods of updating the 1966-71 migration matrix to 1971-76 and 1976-81 will depend on obtaining suitable data from OPCS from the National Health Service Central Register (NHSCR) migration recording system. Such data were used in the Martin, Voorhees and Bates (1981) study to adjust the 1970-71 matrix using RAS balancing factor methods. They have been compared with census recorded migration by Ogilvy (1980), and have been analysed for national and regional trends in Ogilvy (1979, 1982) respectively.

The Martin, Voorhees and Bates method of updating is a classic factoring process in which the detailed Census 1971 migration matrix for 1970-71 (the one year matrix is used in their study) is constrained to the marginal out-migration totals for later years (Figure 14A) and gross in-migration estimates are generated by summation of the column values. However, they also utilize a methodology of factoring the rows and columns of the 1970-71 matrix so that it is possible to satisfy, to a certain level of tolerance, certain net migration constraints for individual regions or region sets, although this presupposes the availability of net migration estimates. The main problem with this method is that it mixes two types of migration measure. The Census migrant figures are of the transition type, whereas the NHSCR figures are of the movement type (see Ledent and Rees, 1980; Rees and Willekens,1981 for full discussion of concepts). Ogilvy (1980) has shown that the latter statistics are numerically 10 to 20% greater than the former. This accords with what one would expect theoretically: the NHSCR measure counts all moves; the Census measure misses out multiple moves within the time interval of measurement.

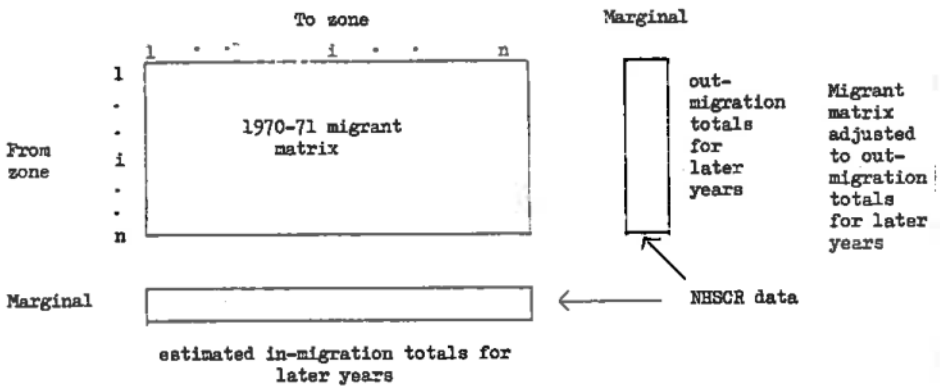
An alternative method of updating using the NHSCR movement data would be to construct standardized time series (setting 1970-71 = 100, say) and apply these ratios to census based out-migration rates disaggregated by age, and then distribute them across destinations according to NHSCR destination probabilities (Figure 14B). The exact details of the updating method need further specification.

4.7.6 Immigration and emigration

Similar problems attend the updating of census based immigration data. The International Passenger Survey (IPS) based data series measures all immigrations by migrants intending to stay for at least a year (OPCS, 1977-1981), and whereas the Census counts only those who stay to the end of the 5 year measurement period. The IPS count is thus higher (though not by much) than the census measure. Updating through use of secular time series is therefore indicated, using as

FIGURE 14. Methods of updating internal migration data for UK zones

A. The Martin, Voorhees and Bates method



B. Alternative method proposed

Migrants (1971-76)	=	Population (1971)	x	Estimated migration rate (1971-76)
Estimated migration rate (1971-76)	=	Origin region out-migration rate (1966-71)	x	Secular shift between 1966-71 and 1971-76 in NHSCR mobility rates
			x	Destination probabilities based on NHSCR data
Migrants (1976-81)	=	Population (1976)	x	Migration rate (1976-81)
Estimated migration rate (1976-81)	=	Origin region out-migration rate (1966-71)	x	Secular shift between 1966-71 and 1976-81 in NHSCR mobility rates
			x	Destination probabilities based on NHSCR data

much regional detail as the IPS tables allow.

For emigration reliance must be placed on the IPS tables, possibly adjusted downwards to allow for the difference in measure, and age disaggregated by applying deconsolidation proportions based on total out-migration to other zones in Great Britain.

4.8 Review

We have only sketched in briefest outline the considerable volume of work that has to go into preparation of the input data for population accounts for a meaningful set of study zones. The effort, however, is justified in that only thus can a sound description of recent population trends be established, and only thus can a solid foundation for population forecasting be attempted.

5. Forecasting models

If we are to use our population accounts as a base for forecasting the population, we must firstly carry out sensitivity tests before secondly exploring alternative futures. The next sub-section (5.1) of the paper sets out the sensitivity tests that will be carried out. This is then followed by a discussion of alternative migration model approaches (Section 5.2), holding constant the mortality and fertility scenarios explored.

5.1 Sensitivity tests using accounts-based models

Using the flexible accounts based model (ABM) program (Rees, 1981a) it is possible to explore

(i) the degree to which data inputs for the various components are consistent with each other;
(ii) the degree to which projections are sensitive to the way in which the zonal system is closed; and
(iii) the degree to which projections are sensitive to the model form adopted.

5.1.1 Options in the construction of accounts

There is a large variety of accounts based models that can be used to construct accounts, depending on the data components (as in Figure 12) available. Four are relevant in the present context:

(i) forecast unconstrained
(ii) backcast unconstrained
(iii) forecast constrained
(iv) backcast constrained

All four ABMs require input of surviving internal migrants, surviving emigrants, surviving immigrants, and deaths data. They differ in the role accorded to the population stocks and other marginals. In the forecast unconstrained ABM, initial populations are input but not final. A comparison of model generated and end of period populations provide a test of the consistency of data inputs. This consistency can be assured by constraining the initial estimates to marginal totals including both initial and final populations. The row marginals and column marginals must be themselves made equal in total by distributing the difference appropriately, usually to the surviving and non-surviving emigrant totals.

The final populations rather than the initial are used in the backcast unconstrained ABM and the initial populations are generated by the model. This might be appropriate for periods such as 1966-71 and 1976-81 where the initial populations are not as reliably estimated as they might be. Again the data inputs can be made consistent using marginals including both initial and final populations as constraints.

Each of these ABMs would be used for one of the periods and projections employing constant rates carried out over the medium term (say to 2021) to gauge the differences generated by initial treatment of the data base. Experience to date with a much smaller three region system (East Anglia, South East, Rest of Britain) suggest that results will not be affected very much.

5.1.2 Options in the closure of the system

Here we can recognise three methods for dealing with population transfers between our study zones and the rest of the world:

(i) they can be ignored - the 'closed' option;
(ii) they can be included as flows or rates in the model - the 'semi-closed' option; or
(iii) the rest of the world can be included as if it were just another study zone - the 'open' option.

Commonsense suggests that option (i) is untenable. Option (iii) leads to difficulties in that it is unrealistic to attempt to treat international migrant flows, subject as they are to direct legislative and administrative control at origin and/or destination, in the same fashion as flows internal to a country which are subject to governmental influence only indirectly. However, it would be useful to demonstrate the effect of choosing the semi-closed option.

5.1.3 Options in the type of model for forecasting

Each migrant term in the forecast version of the ABM can be modelled using rates multiplied by populations at risk or flows specified exogeneously; the term can be included as a gross or a net flow. If we distinguish three types of migration - internal migration, immigration, and emigration - then we can generate 4^3 types of model. Only a selection of these will be experimented with.

(i) The model in which all migration types are treated as a net flow. This is the official subnational population forecasting model.

(ii) The model in which internal migration is modelled using rates and external migration is treated as a net flow. This is similar to Martin, Voorhees and Bates model prepared for the Department of the Environment.

(iii) the model in which internal migration and emigration are modelled using rates and immigration is treated as a flow. This is the model employed by Rees (1977, 1979) in a study for the East Anglia Economic Planning Council.

(iv) The model in which all migration terms are treated as flows, the internal terms being derived from an exogenous migration model and the external terms being modelled as flows.

These model runs should indicate the degree of sensitivity for our 20 zone system to model choice, using the same data base and forecasting assumptions for each model. A scientific comparison of their merits and demerits is then possible.

5.2 Migration models: historical and forecasting models

Various migration models representing a diversity of methodological approaches have been developed in recent years and utilised as theoretical frameworks with which to investigate historical migration behaviour and to project future scenarios. Progress has been relatively modest as far as the integration of analytic migration models with multi-regional population estimation and projection models (Baxter and Williams, 1978) is concerned. Gilje and Campbell (1973) constructed an integrated model for the GLC, and recent work for the Department of the Environment by Martin, Voorhees and Bates (1981) has involved improvements to the methodology for producing net migration assumptions which are required by the OPCS multi-regional cohort survival model for generating sub-national projections. The multi-regional accounts-based models discussed in Section 4 normally require matrices of age-disaggregated inter-regional migration rather than net migration estimates and this section of the paper contains a theoretical discussion of methods that we intend to use in obtaining sets of alternative projections.

An important requirement of a projection methodology is for the user to be able to experiment in such a fashion that it is possible to observe the consequences on the distribution of the population of making different assumptions about future trends in migration or of incorporating policy-related variables where appropriate. This experimentation suggests the need for a suite of migration models based on alternative structural characteristics, data estimation techniques, aggregation arrangements and methods of handling intra-regional flows, infant mobility or external migration. A broad distinction can be drawn between 'single-stage' and 'two-stage' models. The former are represented by a simple age-disaggregated transition rates model in which $\tilde{M}_a^{ij}$, the projected migration flow between zone i and zone j of persons in age group a, is estimated as a function of m_a^{ij}, the migration rate observed for a previous historical period, and $\tilde{P}_a^i$, the age group population at the commencement of the projection period. The model equation is

$$\tilde{M}_a^{ij} = m_a^{ij}\tilde{P}_a^i \qquad (5)$$

where the symbol ~ indicates that the variable is associated with a projection period.

Transition rates are usually calculated with an origin region population at the start of the historical period, although admission rates can be defined when the appropriate population is unavailable, as in the case of immigration from the rest of the world. This type of model is popular in forecasting (Joseph, 1975) because the only information necessary is the set of transition rates and the population totals for the projection periods, which can be derived using separate estimation techniques (Section 4.7.2). Results based on equation (5) are often used as the standard against which other projections are compared since the underlying hypothesis is that the pattern of projected migration will conform with that in the historical period upon which the rates are based. Although there is evidence of historical dependence created by the existence of family contacts and business associations (Hagerstrand, 1957), the assumption of constant transition coefficients in Markov-based models of this type is often too restrictive, particularly when the historical and projection periods are not consecutive.

Two-stage models involve firstly, the generation of gross migration projections and secondly, the distribution of gross flows between zones. A number of probabilistic and deterministic techniques have been developed enabling users to prepare rates-based or policy-based or policy-related sets of projections. In certain cases, the structure of the model or the nature of the data necessitates aggregation of migration flows across age groups with subsequent disaggregation before input to the population model. Thus, in addition to gross flows and distribution modelling, there is the requirement to model migration age schedules. The following discussion articulates a number of techniques and points to certain problems in their usage.

5.2.1 Gross migration models

It has been argued that gross migration is influenced by both national and local factors. Time series information in section 3.1 indicates that pronounced changes in national migration levels can occur as a result of fluctuations in the economy or perhaps due to changing technology, massive infusion of capital into house-building and road construction, or due to dramatic fluctuations in the cost of fuel energy. Ideally, a projection model should be sensitive to the likely effects on migration of changes in these variables. In practice, lack of consistent published data prohibits causal analysis and consequently alternative strategy is that based on assumptions that past trends will continue in the future. In the simplest case for example, a measure of change in the national migration propensity between two periods (t, t+T) and (t+T,t+2T) may be derived as:

$$\hat{g} = \frac{\sum_{a}\sum_{i}\sum_{j} M_a^{ij}(t,t+T)}{\sum_{a}\sum_{i} P_a^i(t)} \Big/ \frac{\sum_{a}\sum_{i}\sum_{j} M_a^{ij}(t+T,t+2T)}{\sum_{a}\sum_{i} P_a^i(t+T)} \qquad (6)$$

providing a national migration propensity multiplier which might be applied to gross out- and inmigration rates for a projection period. In contrast, a user may wish to experiment with different assumptions about changes in national migration propensities.

At the local level, variations in regional gross flows have been observed and projections of either out- or inmigration, or both, can be prepared which may reflect historical rates on the one hand or which may be related to socio-economic variables on the other. The gros outmigration-based model proposed by Martin, Vorhees and Bates (1981) uses historical outmigration rates defined as

$$o_a^i(t,t+T) \;=\; O_a^i(t,t+T)/P_a^i(t) \qquad (7)$$

as the basis of age-specific outmigration flow projections:

$$\bar{O}_a^i \;=\; o_a^i(t,t+T)\bar{P}_a^i \qquad (8)$$

although their rates are standardised by the gross migra-production rate (the sum of all age-specific rates) for the region to allow for different volumes of regional outmigration. The projected gross outmigration flows are then aggregated into broad age groups for distribution between regions. Historical rates of gross outmigration can be adjusted for changes in the national level of mobility by applying the multiplier defined in equation (6):

$$o_a^i \;=\; \hat{g}o_a^i(t,t+T) \qquad (9)$$

Gross inmigration projections for age group a are produced by using admission rates defined as

$$d_a^j(t,t+T) \;=\; D_a^j(t,t+T)/P_a^j(t+T) \qquad (10)$$

where the at risk population stocks refer to those persons in age group a in zone j at the end of the historical or projection periods. Admission rates are particularly useful when the end of a projection period coincides with a census date since population estimation by interpolation is avoided.

The results of numerous deterministic analyses indicate considerable disparity in the emphasis placed on particular 'push' and 'pull' variables acting as stimulants to migration. However, there is some concensus amongst analysts that gross migration is influenced by changing employment levels. Rates of inmigration will tend to be influenced by changes in the distribution of employment opportunities measured by fluctuations in the numbers in employment in different zones. The relationship between regional inmigration rates and changing employment levels in Britain has been demonstrated by Donovan (1971) and Stillwell (1980) using regression techniques, and Morrison and Relles (1975) have developed a forecasting model for the USA based on the relationship between residuals from the inmigration time series trend and residuals from the trend in employment. In the absence of time series gross migration data in Britain and in the event of the calibration of a regression model being impossible, one approach to allow for the effects of shifts in employment change would be to adjust the historical gross inmigration rates for those persons in labour force age groups by applying an age-group employment share change multiplier defined as

$$\tilde{e}_a^j = \frac{\tilde{E}_a^j(t)}{\tilde{E}_a^*(t)} \bigg/ \frac{\tilde{E}_a^j(t+T)}{\tilde{E}_a^*(t+T)} \tag{11}$$

where $\tilde{E}_a^j(t)/\tilde{E}_a^*(t)$ represent the proportion of total employment of those in age group a to be found in region j at the start of the projection period;

and $\tilde{E}_a^j(t+T)/\tilde{E}_a^*(t+T)$ represents the proportion at the end of the projection period.

although the lack of employment data disaggregated by age might result in aggregated age group multipliers being used.

A gross inmigration model based on the historical rate adjusted for changing national mobility and regional employment share change, would have the form:

$$\bar{D}_a^j = d_a^j \hat{g} \tilde{e}_a^j \tilde{P}_a^j \tag{12}$$

incorporating a non-age-specific employment shift multiplier, $\bar{e}_*^j$, if age group employment data were unavailable. The formulation of a gross migration projection model based on a multiplicative relationship between independent variables is presented as a methodological alternative to the more familiar econometric formulations in which an additive structure is adopted and where additional parameters estimated using regression analysis, have explanatory significance. Models with multiplicative structures have been used quite widely in dynamical systems theory.

5.2.2 Model migration schedules

Empirical regularities in schedules of observed age-specific migration rates have enabled Rogers, Raquillet and Castro (1978) to formulate a model schedule consisting of four components as illustrated in Figure 15: a pre labour force negative exponential curve, a labour force curve, a post labour force curve and a constant curve representing the underlying minimum level of migration propensity.

The model equation for a 'full' schedule is

$$\begin{aligned} M_x &= a_1 \exp(-\alpha_1 x) \\ &+ a_2 \exp(-\alpha_2(x-\mu_2) - \exp(-\lambda_2(x-\mu_2))) \\ &+ a_3 \exp(-\alpha_3(x-\mu_3) - \exp(-\lambda_3(x-\mu_3))) \\ &+ c \end{aligned} \tag{13}$$

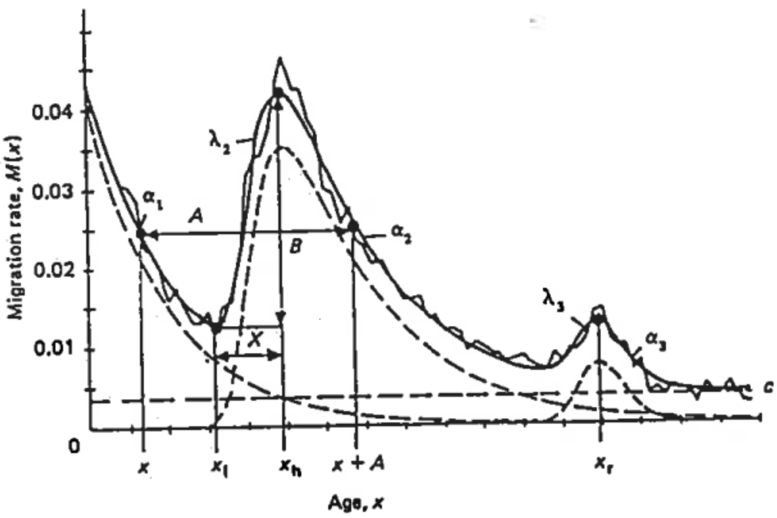
where the original age notation, x, is retained.

The parameters a_1, a_2, a_3 and c reflect the level of the schedule and the remaining parameters (Figure 15) determine its profile, with μ_2 and μ_3 indicating the mean age position of the two double exponential curves. A 'reduced' model can be calibrated which omits the second double exponential term and may be sufficient for the metropolitan/non-metropolitan data since a retirement migration peak is not always significant.

FIGURE 15. The model migration schedule (Rogers and Castro, 1981)

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

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



The purpose of modelling migration schedules is to smooth out the random variations which are found in measuring the propensity to migrate on the basis of one set of data, and then to use the model functions in projection. Bracken and Bates (1981) have developed a classification of areas in England and Wales on the basis of the shape of their migration profiles and Martin, Voorhees and Bates (1981) use group profiles to project age-specific out-migration flows and to disaggregate projected in-migration flows for single years of age.

A non-linear least squares procedure is required to estimate the model parameters and while Rogers *et.al.* adopt a modified Levenburg-Marquardt algorithm, Bates and Bracken (1981) prefer to fit a reparameterized model using a maximum likelihood, modified Newton method. One problem which has arisen in attempting to fit a non-linear least squares curve to the metropolitan/non-metropolitan data is the small number of age groups. Preliminary work suggests that a cubic spline function would enable interpolated values to be added to the initial data points, although further exploratory work is required.

5.2.3 Distribution modelling

The distribution of migrants between origin and destination areas can be achieved in several different ways, depending upon the amount of information that is known (the extent of constraint) and according to the users desire to incorporate policy-related information. The problem of sparse data matrices normally means that age-specific migration streams require aggregation, although this is less of a problem with 5 year than 1 year data. Typical broad age groups would be persons in the most mobile age range (15-29), those aged over 60, and the remainder, although complete aggregation may be necessary.

Growth factor methods have been shown to be valuable when projections are short term (Stillwell, 1979). When both gross out- and in-migration flows for the projection period are available, they can be distributed on the basis of the migration distribution associated with the previous historical period. A doubly constrained growth factor model for migrants in broad age group A may be expressed as:

$$\tilde{M}_A^{ij} = \tilde{a}_A^i \tilde{b}_A^j \tilde{g}_A^{ij} M_A^{ij} \tag{14}$$

where the growth factor is:

$$\tilde{g}^{ij} = \frac{\tilde{O}_A^i}{O_A^i} \cdot \frac{\tilde{D}_A^j}{D_A^j} \tag{15}$$

such that the constraints

$$\tilde{O}_A^i = \sum_j \tilde{M}_A^{ij} \tag{16}$$

and

$$\tilde{D}_A^j = \sum_i \tilde{M}_A^{ij} \tag{17}$$

and ensured by the inclusion of balancing factors defined as:

$$\tilde{a}_A^i = \tilde{O}_A^i / \sum_j \tilde{b}_A^j \tilde{g}_A^{ij} M_A^{ij} \tag{18}$$

and

$$\tilde{b}_A^j = \tilde{D}_A^j / \sum_i \tilde{a}_A^i \tilde{g}_A^{ij} M_A^{ij} \tag{19}$$

This model factors the historical matrix according to the product of the ratio between the historical and projected out and inmigration totals.

The availability of NHSCR recorded transfer data suggests the possibility of incorporating changes evident in the distribution of 'moves' during particular projection periods. The conceptual difference between 'moves' and 'transitions' data does not preclude the use of this updated information altogether and alternative methods of estimation have been discussed in section 4.7.5.

An alternative modelling style is that based on the gravity principle in which measures of origin and destination attractiveness and distance are integrated into a model equation which can be constrained to achieve varying degrees of internal consistency. Entropy maximising models of this type require historical calibration prior to projection and computer programs are available to generate best-fit parameters associated with observed data sets (Stillwell, 1981).

In the situation where projections have been generated for both gross out- and inmigration, projected inter-regional migration streams for broad age group A would be generated using a doubly constrained spatial interaction model of the form:

$$\tilde{M}_A^{ij} = \tilde{a}_A^i \tilde{b}_A^j \tilde{O}_A^i \tilde{D}_A^j f(d^{ij}) \tag{20}$$

where $\tilde{a}_A^i$ and $\tilde{b}_A^j$ are balancing factors derived iteratively which ensure that constraint equations (16) and (17) are satisifed, and where $f(d^{ij})$ is a distance decay function of negative power or exponential form with a parameter, β, measuring the rate of decline of migration with distance. The measurement of distance is conventionally achieved by using road mileages between zone centroids. However, the shape of certain zones in the metropolitan / non-metropolitan system and the desire to include Northern Ireland and the rest of the world demands an alternative method of measurement. In addition, intra-zonal flows may be included. Consequently a proxy measure of distance such as the reciprocal of the observed flow in the historical period might be adopted. Spatial interaction models of this type can be used for projection with a generalised decay parameter or with a set of zone-specific parameters if significant improvements in fit are evident from the historical calibrations.

In circumstances where either gross outmigration or inmigration flows have been projected, singly constraint variants of the family of spatial interaction models can be used for distribution. When out-migration projections are available, an attraction-constrained model is applicable which has the form:

$$\tilde{M}_a^{ij} = \tilde{a}_A^i \tilde{O}_A^i \tilde{W}_A^j f(d^{ij}) \tag{21}$$

where $\tilde{W}_A^j$ is a variable representing the destination attractiveness in the projection period.

The attractiveness factor in the outmigration-constrained case may be a measure of employment opportunities created or an index of the new dwellings completed in the destination zone during the projection period. Other variables may be supplied as attractiveness factors if specific policy-sensitive distributions are required.

Several methods for modelling migration have been outlined. Our intention is to investigate the effects of adopting different models and to examine the results of using different combinations of techniques in the preparation of migration projections.

6. An integrated population-migration forecasting model

We are not as yet in a position to put forward one model that integrates the accounts based framework of population analysis and the spatial interaction framework of migration analysis. The intention is to explore the outcomes of using alternative models in both frameworks, comparing alternatives against a fixed base run. Our analysis will thus differ from the usual comparison of alternative scenarios in forecasting (Rees, 1977) or previous work on comparing alternative disaggregation or decomposition schemes (Rogers, 1976): it will be a comparison of alternative models holding constant the scenario of demographic and related rates and holding constant the level of aggregation.

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Abbreviations

OPCS = Office of Population Censuses and Surveys
HMSO = Her Majesty's Stationery Office

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TABLE A1. Populations of United Kingdom Zones, 1961-81.

Zone and class	Population (1000's) at census date in:				
	1961	1966	1971	1976	1981
Central Clydeside	1,979	1,954	1,903	1,810	1,713
Tyne and Wear	1,244	1,227	1,212	1,185	1,143
West Yorkshire	2,005	2,053	2,068	2,075	2,038
South Yorkshire	1,303	1,319	1,323	1,318	1,302
Greater Manchester	2,720	2,741	2,729	2,689	2,595
Merseyside	1,718	1,698	1,657	1,580	1,513
TOTAL, Metropolitan-North zones	10,969	10,992	10,892	10,657	10,304
Scotland Remainder	3,200	3,248	3,326	3,395	3,404
Northern Ireland	1,425	1,474	1,536	1,538	1,543
North Remainder	1,876	1,898	1,930	1,939	1,954
Yorkshire & Humberside Remainder	1,373	1,435	1,465	1,501	1,514
North West Remainder	1,991	2,096	2,211	2,290	2,298
TOTAL, Non-Metropolitan North Zones	9,865	10,151	10,468	10,663	10,713
TOTAL North Zones	20,834	21.143	21,320	21,320	21,017
West Midlands	2,732	2,753	2,793	2,749	2,645
Greater London	7,992	7,818	7,452	7,043	6,696
TOTAL Metropolitan South Zones	10,724	10,571	10,245	9,792	9,341
East Midlands	3,321	3,492	3,633	3,732	3,807
West Midlands Remainder	2,026	2,186	2,317	2,418	2,492
East Anglia	1,470	1,571	1,669	1,799	1,865
Outer Metropolitan Area	4,344	4,972	5,152	5,292	5,379
Outer South East	3,656	3,909	4,325	4,566	4,654
South West	3,689	3,913	4,081	4,250	4,326
Wales	2,644	2,693	2,731	2,767	2,790
TOTAL, Non-Metropolitan South Zones	21,150	22,736	23,908	24,824	25,313
TOTAL, South Zones	31,874	33,307	34,153	34,616	34,654
TOTAL, Metropolitan Zones	21,693	21,563	21,137	20,449	19,645
TOTAL, Non-Metropolitan Zones	31,015	32,887	34,376	35.487	36,026
United Kingdom	52,709	54,450	55,515	55,936	55,671

Sources: 1961, 1971, 1981 Census Populations: OPCS (1981)
1966: estimated from mid-year 1965 and 1966 mid-year population estimates (OPCS, 1974).
1976: estimated from mid-year 1975 and 1976 mid-year population estimates (OPCS, 1976,77).
Central Clydeside figures for 1961 and 1966 are adjusted for a major redefinition consequent on local government reorganization (April, 1975).

TABLE A2. Population change, United Kingdom Zones, 1961-81.

Zone and class	Population change (1000's)			
	1961-66	1966-71	1971-76	1976-81
Central Clydeside	- 25	- 51	- 93	- 97
Tyne and Wear	- 17	- 15	- 27	- 42
West Yorkshire	48	15	7	- 37
South Yorkshire	16	4	- 5	- 16
Greater Manchester	21	- 12	- 40	- 94
Merseyside	- 20	- 41	- 77	- 67
TOTAL, Metropolitan North Zones	23	-100	-235	-353
Scotland Remainder	48	78	69	9
Northern Ireland	49	62	2	5
North Remainder	22	32	9	15
Yorkshire & Humberside Remainder	62	30	36	13
North West Remainder	105	115	79	8
TOTAL, Non-Metropolitan North Zones	286	317	195	50
TOTAL, North Zones	309	217	- 40	-303
West Midlands	21	40	- 44	-104
Greater London	-174	-366	-409	-347
TOTAL, Metropolitan South Zones	-153	-326	-453	-451
East Midlands	171	141	99	75
West Midlands Remainder	160	131	101	74
East Anglia	101	98	130	66
Outer Metropolitan Area	628	180	140	87
Outer South East	253	416	241	88
South West	224	168	169	76
Wales	49	38	36	23
TOTAL, Non-Metropolitan South Zones	1,586	1,172	916	489
TOTAL, South Zones	1,433	846	463	38
TOTAL, Metropolitan Zones	-130	-426	-688	-804
TOTAL, Non-Metropolitan Zones	1,872	1,489	1,111	539
United Kingdom	1,741	1,065	421	-265

Source: Computed from Table 1.

TABLE A3. Population change rates, annual equivalent (per 1000 population) United Kingdom Zones, 1961-81.

Zone and class	Population change rate (PCR)			
	1961-66	1966-71	1971-76	1976-81
Central Clydeside	- 2.5	- 5.3	-10.0	-11.0
Tyne and Wear	- 2.7	- 2.5	- 4.5	- 7.2
West Yorkshire	4.7	1.5	0.7	- 3.6
South Yorkshire	2.4	0.6	- 0.8	- 2.4
Greater Manchester	1.5	- 0.9	- 3.0	- 7.1
Merseyside	- 2.3	- 4.9	- 9.5	- 8.7
TOTAL, Metropolitan North Zones	0.4	- 1.8	- 4.4	- 6.7
Scotland Remainder	3.0	4.7	4.1	0.5
Northern Ireland	6.8	8.2	0.3	0.6
North Remainder	2.3	3.3	0.9	1.5
Yorkshire & Humberside Remainder	8.8	4.1	4.9	1.7
North West Remainder	10.3	10.7	7.0	0.7
TOTAL, Non-Metropolitan North Zones	5.7	6.1	3.7	0.9
TOTAL, North Zones	2.9	2.0	- 0.4	- 2.9
West Midlands	1.5	2.9	- 3.2	- 7.7
Greater London	- 4.4	- 9.6	-11.3	-10.1
TOTAL, Metropolitan South Zones	- 2.9	- 6.3	- 9.0	- 9.4
East Midlands	10.0	7.9	5.4	4.0
West Midlands Remainder	15.2	11.6	8.5	6.0
East Anglia	13.3	12.1	15.0	7.2
Outer Metropolitan Area	27.0	7.1	5.4	3.3
Outer South East	13.4	20.2	10.8	3.8
South West	11.8	8.4	8.1	3.5
Wales	3.7	2.8	2.6	1.7
TOTAL, Non-Metropolitan South Zones	14.5	10.1	7.5	3.9
TOTAL, South Zones	8.8	5.0	2.7	2.2
TOTAL, Metropolitan Zones	1.2	- 4.0	- 6.6	- 8.0
TOTAL, Non-Metropolitan Zones	11.7	8.9	6.4	3.0
United Kingdom	6.5	3.9	1.5	- 0.9

Notes

PCR = 1000 x ((P(t+5) - P(t))/5)/½(P(t)+P(t+5))) where P = population and t = point in time.

Source: Tables 1 and 2.

TABLE A4. Components of growth, annual equivalent rates per 1,000 population, United Kingdom Zones, 1961-81.

Zone and class	Components of growth, 1976-81			
	Birth rate	Death rate	Nat. Incr. Rate	Net Migr. Rate
Central Clydeside	13.1	12.5	0.6	-11.6
Tyne and Wear	12.5	12.9	-0.3	- 6.9
West Yorkshire	13.0	12.7	0.3	- 3.9
South Yorkshire	11.8	11.9	-0.2	- 2.3
Greater Manchester	12.9	12.8	0.2	- 7.3
Merseyside	12.5	12.9	-0.4	- 8.3
TOTAL, Metropolitan North Zones	12.7	12.7	0.1	- 6.8
Scotland Remainder	12.7	12.5	0.2	0.4
Northern Ireland	17.4	10.9	6.5	- 5.8
North Remainder	12.8	12.4	0.4	1.1
Yorkshire & Humberside Remainder	11.8	12.2	-0.4	2.1
North West Remainder	12.3	13.0	-0.7	1.4
TOTAL, Non-Metropolitan North Zones	13.2	12.3	0.9	0.1
TOTAL, North Zones	13.0	12.5	0.5	- 3.3
West Midlands	13.0	11.3	1.6	- 9.3
Greater London	12.8	11.8	1.0	-11.1
TOTAL, Metropolitan South Zones	12.9	11.7	1.2	-10.6
East Midlands	12.6	11.5	1.2	2.8
West Midlands Remainder	12.5	10.8	1.7	4.3
East Anglia	12.6	11.2	1.3	5.9
Outer Metropolitan Area	12.6	11.2	1.5	1.8
Outer South East	12.0	11.2	0.8	3.0
South West	11.4	12.8	-1.4	4.9
Wales	12.5	12.8	-0.3	1.9
TOTAL, Non-Metropolitan South Zones	12.3	11.6	0.6	3.3
TOTAL, South Zones	12.4	11.7	0.8	- 0.6
TOTAL, Metropolitan Zones	12.8	12.2	0.6	- 8.6
TOTAL, Non Metropolitan Zones	12.5	11.8	0.7	2.3
United Kingdom	12.6	12.0	0.7	- 1.6

Computed from series FM, M, VS and PP series OPCS statistics.