J. R. Statist. Soc. A (2002)
165, *Part* 3, *pp.* 435–464

Cross-national comparison of internal migration: issues and measures

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[Received September 2000. Revised October 2001]

Summary. Our objectives are to identify the issues that researchers encounter when measuring internal migration in different countries and to propose key indicators that analysts can use to compare internal migration at the 'national' level. We establish the benefits to be gained by a rigorous approach to cross-national comparisons of internal migration and discuss issues that affect such comparisons. We then distinguish four dimensions of internal migration on which countries can be compared and, for each dimension, identify a series of summary measures. We illustrate the issues and measures proposed by comparing migration in Australia and Great Britain.

Keywords: Australia; Comparative measures; Great Britain; Internal migration

1. Introduction

Compared with fertility and mortality, surprisingly little attention has been given to the way that internal or domestic migration varies between nations. This is not to say that cross-national comparisons do not exist. There are several collections which describe sources of migration data (e.g. Nam *et al.* (1990)) or patterns in different countries (e.g. Rees, Stillwell, Convey and Kupiszewski (1996) and Rees and Kupiszewski (1999a, b)). There are specialized literatures that compare particular aspects of internal migration, the most obvious example being that concerned with counter-urbanization (e.g. Champion (1989) and Fielding (1982)). Attempts have also been made to draw direct comparisons between countries with regard to overall levels of mobility (Long, 1991), distance of migration (Long *et al.*, 1988a), age structures (Rogers *et al.*,

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 0964–1998/02/165435

1978) and other demographic characteristics (Long, 1992). Although this work has contributed valuable insights into cross-national differences in migration, its utility has been diminished by the lack of a rigorous comparative framework. What is needed is a robust series of measures that allow cross-national comparisons of migration to be made across several dimensions.

The dearth of comparative work in the field can be traced to familiar origins: the multi-dimensional nature of migration (Goldstein, 1976), differences in the way that it is measured and problems of spatial and temporal comparability, all of which prejudice a rigorous comparative analysis. However, there are good reasons for attempting more genuine comparisons. First, consistent summary measures of migration calculated for individual countries become more meaningful when placed in a cross-national context. Second, by drawing attention to similarities and differences, cross-national comparisons provide a more rigorous test-bed for migration theorization. Third, such analyses have the potential to provide new insights into the dynamics of migration within individual countries as unusual results may only come to light once comparisons have been made. Fourth, much can be learnt from such comparisons about the nexus between migration and public policy. Finally, there is a persuasive argument that a more structured approach to the analysis of migration might also lead to greater rigour and consistency in empirical research on individual countries and regions.

This paper takes a first step towards these ends by endeavouring to establish a range of measures that can be used to make such comparisons. These are classified in terms of four key dimensions, which together, we argue, provide complementary perspectives on the dynamics of population movements. These dimensions are concerned with the overall intensity of migration, distance of migration, migration connectivity and the effect of migration on the redistribution of populations. For this paper, we restrict the consideration to summary measures that can be calculated at the national level by using only the basic demographic variables, age and sex, although some of the measures proposed employ data for subnational regions. Further work will extend this review to incorporate subnational variations and other characteristics.

The context for this work derives from a broader project which aims to compare migration levels and trends in Britain and Australia in an age–period–cohort framework, and the application of each of the measures is illustrated by using migration data for these two countries. Despite their common language, heritage and traditions, Britain and Australia epitomize many of the general problems that beset cross-national comparisons and we begin by reviewing four general issues that must be addressed in comparisons of this type.

2. Problems of comparability in migration analysis

In some areas of demographic research, common standards for the collection of data and measurement are regarded as a priority. For example, the international classification of diseases was developed to ensure comparability in the collection of deaths data and there are universally agreed measures for the analysis and reporting of both fertility and mortality. Calls have also been made for international comparability in measuring migration (United Nations, 1970) but domestic priorities have generally taken precedence and widespread variations continue to exist. If international comparisons are to be made a vital first step is to identify the nature of these variations and their implications for measuring migration (Rees and Kupiszewski, 1999b). We suggest that four broad groups of problems are apparent. These derive from

(a) the way that migration is measured and the different types of data that result,
(b) issues of temporal comparability,

(c) differences in the coverage of population and quality of data, and
(d) the division of space and the measurement of distance.

Each is discussed in turn.

2.1. Migration data and measurement

Migration may be measured in various ways but the two most common forms of data measure changes of residence either as *transitions* or as *events*. Transition data are typical of the information that is collected in national censuses which identify migrants by comparing their place of usual residence at the time of enumeration (t) with that at a specified earlier date ($t-n$). This time period is usually either 1 year, as in Britain, or 5 years, as in the USA, although some nations, such as Australia and Canada, ask for place of residence at both $t-1$ and $t-5$, and others, such as France, have a different interval length. Transition data have several limitations, perhaps the most serious of which is the failure to identify multiple and return moves, and migrants who are born or who die during the measurement period.

Event data, in contrast, purport to record every move (event) that is made by each individual and therefore include multiple and return migrations as well as moves by the newborn and those immediately before death. Event data are typical of the information that is collected in population registers, such as those maintained in Germany, the Netherlands and Sweden (Langevin *et al.*, 1992). In Britain, although there is no formal population registration system, the National Health Service central registers (NHSCRs) in England and Wales and in Scotland collate information on National Health Service patient re-registration with new doctors to calculate payments to general practitioners.

Population registers therefore capture *moves* (events) whereas censuses capture *movers* (transitions). Registers consequently represent a more complete record of migration over time and the counts that are recorded in registers should thus exceed those from censuses, *ceteris paribus*. Compared with censuses, however, the geographical units for which the data are available are generally much coarser (Boden *et al.*, 1992) and registers often fail to capture information on within-region moves. Moreover, less information about characteristics of migrants is usually available and some groups may be omitted from registration counts altogether. For example, the British NHSCR data exclude prisoners and long-stay psychiatric patients, although they do include students.

Censuses may also differ in key definitions and in the way that some groups are treated with respect to migration. Migration is generally defined as a permanent change in usual residence but usual residence itself may be defined differently between nations. In Australia, for example, a person's place of usual residence is defined as the address where they have lived, or intend to live, for 6 months or more during the census year. In Britain, in contrast, no residence criteria are specified: usual address is simply that address at which the respondent normally resides. Similarly the 1981 British census requested that students living away from home record their home rather than their study address as their usual residence, whereas in the 1991 census both addresses were recorded. In contrast, since 1986, boarders at school or college in Australia have been asked to record the school or college as their usual residence (Australian Bureau of Statistics, 1991). Similar problems arise with other groups such as foreign students, armed forces personnel and diplomats.

Care is also needed when comparing transition data for time periods of different length. Multiplying the number of migrants captured in a 1-year time interval by 5 does not provide a reliable estimate of the number of migrants during the 5-year period. This is because an increasing proportion of moves is made by 'chronic migrants' and the apparent volume of migration therefore grows at a steadily declining rate as the observation interval lengthens (Long and Boertlein, 1990). This is widely recognized as the '1-year–5-year problem' and has attracted sustained attention (Courgeau, 1973a, b; Kitsul and Philipov, 1981). Long and Boertlein (1990) concluded that the difference between the 1-year and 5-year figures equals twice the number of return migrants plus the number of onward migrations. Rogerson (1990) argued that the difference is a product of population heterogeneity and demonstrated that there is no straightforward algebraic solution to comparing 1-year and 5-year migration probabilities. Moreover, whereas event data reveal patterns that are similar to those which are evident from census information for the same period, the width of the interval influences not only the intensity of migration but also the geographic pattern of migration flows and hence population redistribution (Rees, 1977).

Time period difficulties are compounded for migration analyses that are disaggregated by age. Population registers record age at the time that migration occurs whereas censuses record age at the end of the transition interval. Event data are therefore based on a period–age observation plan, whereas transition data reflect a period–cohort framework (Rees and Woods, 1986). Data from the two sources disaggregated by age are therefore not directly comparable. For census measures based on 5-year intervals, it seems reasonable to assume that migration will have occurred, on average, $2\frac{1}{2}$ years earlier, which implies an average age at migration of 2.5 years younger than recorded at the census. This assumes that there is only one migration per transition, or that if multiple migrations occur these are distributed evenly around the midpoint of the interval, on average. Thus, it is the collective of migration events which creates the transition, not the last migration which occurs, on average, after the mid-interval. For single-year transitions, the figure would be 0.5 years. In both cases, seasonal variations in the intensity of migration are ignored. These figures provide the basis for a coarse adjustment to transition data to parallel the age that is recorded in population registers but true comparability can only be achieved by realigning the original observation plans (Bell and Rees, 2000).

Although transition and event data are the most commonly collected forms of information on migration, other types of data include the place of last residence, duration of residence, the number of moves over a given interval and lifetime migration. Although these are arguably richer, particularly if used in combination with transition data (Bell, 1996), they are rarely collected except in specialist surveys and a small number of censuses.

2.2. *Temporal comparability*

Many of the conceptual and measurement problems outlined above become even more complicated when we attempt to make cross-national comparisons of migration patterns through time. Ideally, data are required for the same time intervals but countries differ in the timing and frequency of their censuses, as well as in the time interval for which migration data are collected. Moreover, even coincident timing does not imply identical contexts. The intensity of migration is affected by economic cycles, housing market conditions and Government policy regimes that are unlikely to be in phase in different countries. The British censuses in 1981 and 1991, for example, corresponded with economic nadirs and probably understated the levels of intensity of migration during times of economic buoyancy (Stillwell *et al.*, 1995). NHSCR data reveal considerable volatility in British migration from year to year (Stillwell *et al.*, 1992) whereas the time trend that emerges from the quinquennial Australian census appears to be remarkably stable (Bell, 1995).

More crucial to the broader aims of the research described here is that demographic cycles may not be in phase. Triggered by the Easterlin hypothesis, there is a mounting body of evidence that age structure effects influence not only aggregate levels of mobility (Rogerson, 1987; Plane, 1993) but also the geographic patterns of movement (Plane and Rogerson, 1991) and the timing of migration (Pandit, 1997). An awareness of such effects is crucial to any such comparisons and reliable time series data sets are needed that allow the influence of age, period and cohort influences on migration to be estimated and analysed. The availability of such data varies markedly between nations. In Britain, annual NHSCR data have been made available since mid-1975 whereas in Australia there is no comparable source of event data but transition data for 5-year intervals have been collected at each quinquennial census since 1971, and 1-year interval data are available for all years except 1971 and 1991. A broadly comparable time series can therefore be established (see Bell *et al.* (1999) and Rees *et al.* (2000a)).

2.3. Quality of migration data

Questions of the accuracy of data are critical to migration analysis. This is particularly so when making cross-national comparisons of migration, as any differences that are identified may result from errors in the data, rather than genuine variations in the underlying migration patterns and processes. It is commonly accepted that at least 1 million people were missed in the 1991 British census (Simpson and Dorling, 1994) and the problem for migration analysis is exacerbated by the fact that the undercount was selective of certain groups, such as young adults, ethnic minorities and migrants, in part, perhaps, because of their very mobility. The rate of underenumeration in the 1991 Australian census Australia (1.9%) was not far short of that in Britain (2.2%) and the data suffer similar problems of a selective undercount among the more mobile groups, with rates of 4.1% for males aged 25–29 years and 16.1% among people who were enumerated away from their usual residence (Australian Bureau of Statistics, 1995). Non-response to questions on place of previous residence is also high. At the 1996 Australian census, more than half a million people (3%) failed to indicate their place of usual residence 1 year previously, and for the 5-year question this rose to 4.3% (Bell and Stratton, 1998). When missing data are imputed in one census (as was proposed for the 2001 census in the UK), but not in another (such as those in Australia), this compounds the problems of comparability. Registration data are also subject to error. In Britain, the NHSCR data rely on patients re-registering with a new doctor after moving. Although virtually all British residents are registered with a general practitioner, the elderly and those with young families require health care more often and are therefore better recorded than young single adults, who are more mobile but often delay re-registering (Bone, 1984).

2.4. Division of space and measurement of distance

Although the intensity of migration can be measured at the national level, population movement is inherently spatial. The division of space and the measurement of distance are therefore crucial ingredients. Like all geographical studies, however, the analysis of migration is plagued by the modifiable areal unit problem (MAUP). Two aspects of the MAUP are traditionally recognized: those of scale and of zonation (Wrigley *et al.*, 1996). The former occurs because the same area may be divided into geographies with differing numbers of spatial units. The latter occurs because an area may be divided into the same number of units in a variety of ways. The decision about which geography to use is often made for the researcher because data are usually only available for a limited set of zones defined by the providers of the data. Unfortunately, these administrative units rarely have any functional basis, bearing little relationship to the underlying distribution of socioeconomic variables. Temporal comparisons are further prejudiced by changes over time in the number and shape of the units on which the data are provided and considerable effort may be needed to derive a set of temporally consistent zonal boundaries (see, for example, Blake *et al.* (2000)).

The MAUP takes on particular significance for cross-national comparisons because it is difficult, if not impossible, to identify directly comparable geographies for two or more nations. Differences in the geography for which migration data are available will inevitably affect the results obtained, but in ways that are unpredictable. One solution is to compare migration processes and patterns at a range of spatial scales within each nation. Another approach is to develop a broadly comparable set of regions in each country based around some common functional division of space. In the case of Britain and Australia, for example, an analysis based around 35–40 regions clustered around eight major city cores in each country reveals close similarities but also intriguing differences in patterns of movement and redistribution (Stillwell *et al.*, 2000).

In practice, such comparisons are inevitably affected by differences in geographic size and in the distribution of opportunities within each country. This is especially problematic for a comparison between Australia and Britain since the latter is much smaller in land area and the population is more evenly distributed. An individual in Australia moving between jobs in two cities is forced to move further, because of the distance between the major cities, than a corresponding individual in Britain. This effect might be partly offset by the fact that individuals changing jobs between cities in Britain may choose to commute, rather than to migrate, whereas the likelihood of this in Australia is much smaller. Variations in geographic size, population density and the settlement pattern may therefore lead to differences in spatial behaviour and these, in turn, will be reflected in the resulting measures of migration.

A related problem is the measurement of distance. The distance that individuals move has its own intrinsic interest and some surveys have relied on self-reported measures (Long *et al.*, 1988a, b). However, distance also forms a key input to models of migration flows. For these purposes, it is usually measured as the straight line distance between population-weighted centroids of the origin and destination zones. The distances measured between each pair of places are meant to represent the typical distance that migrants travel. As Boyle and Flowerdew (1997) pointed out, however, this method of distance measurement introduces 'model error'. The average cost faced by a migrant may not be represented well by the intercentroid distance. The problem is most severe for distances measured between nearby places. The reliability of such measures is also influenced by the size and shape of the areal units on which the calculations are based. Contrasting zonal systems used in different countries will therefore inevitably bias the resulting parameter estimates. For example, in a 'doughnut-shaped' region, the geometric and population-weighted centroids will almost certainly lie outside the region itself, probably within the 'hole', and hence dramatically understate the distance moved between the two regions represented by the hole and the body of the doughnut. If population-weighted centroids are available for some more detailed underlying geography, one simple solution is to calculate the distance between regions I and J as the mean of the distances d between their constituent zones, i and j. Thus:

$$D_{IJ} = \sum_{i \in I} \sum_{j \in J} d_{ij}/nm \qquad J \neq I \tag{1}$$

where n and m represent the number of zones in regions I and J respectively.

The shape of the country as a whole may also influence some of the distance calculations. Australia is more regular in shape than Britain where the coastline is highly indented. The straight line distances between some counties in Britain, such as between Cornwall and West Glamorgan, cross substantial bodies of water and these physical barriers mean that the Euclidean distance misrepresents the cost of movement. This problem can be addressed by calculating distances around such physical barriers (Boyle and Flowerdew, 1997) or by using travel times.

Another issue in the calculation of distances is how to handle intraregional moves. In many modelling studies, either the data are not available (as with the British NHSCR registrations) or a decision is made to ignore the flows within regions. One justification is that moves of short distance within areas commonly represent housing adjustment (residential mobility) whereas moves of longer distance between areas are more likely to be motivated by considerations of employment (migration). In practice, however, the geography may be such that some intraregional moves may involve longer distances than those between regions (Boyle *et al.*, 1998). Moreover, excluding intraregional flows will reduce the total number of migrants who are retained within the system and this has been shown (Boyle *et al.*, 1997) to influence the resulting parameter estimates, independent of zonation and scale effects. At the same time, the estimation of within-region migration distances is itself a complex task since the potential for such moves is affected by the shape as well as the size of the regions. Long *et al.* (1988a) and Bell (1995) estimated intraregional distances as equivalent to the radius of a circle of equivalent area but Rogerson (1990) concluded that half the radius is a more accurate estimate. Following the approach described above, if population-weighted centroids are available for a more detailed underlying geography, some refinement is possible by calculating the intraregional distance D for region I as the mean of the distances between its constituent zones ij, but it is still necessary to add a component representing within-zone migration distances by using more elementary methods. Intraregional distances might therefore be estimated as

$$D_{II} = \frac{1}{n_I^2}\left\{\sum_{i\in I}\sum_{\substack{j\in I\\ j\neq i}} d_{ij} + \sum_{i\in I}\frac{\surd(A_i/\pi)}{2}\right\} \tag{2}$$

where A_i represents the area of the zone and n_I is the number of zones within region I.

Cross-national comparisons of distances of migration present further problems if the data refer to time intervals of different length. The longer the transition interval, the greater is the likelihood of multiple moves. If repeat moves are evenly distributed then, on average, they should take a person further from their point of origin. Migration distances would then increase as the transition interval lengthens. Long *et al.* (1988a) found that the median migration distance among people who moved five times or more over a 3-year period was far greater than among those who moved only once. However, this could simply reflect the selective nature of chronic migrants (Newbold and Bell, 2002). Moreover, the cumulative effect of onward movers on the distance of migration could be partly or wholly offset by the fact that longer-distance migrants appear to display a higher propensity to return to their region or dwelling of origin (Bell, 1995). Further research in countries that collect data for more than one interval is needed to establish the precise nature of these effects and the extent to which they prejudice cross-national comparisons.

3. Measures for cross-national comparison

Studies comparing internal migration in different countries have generally focused on a single aspect of mobility, such as the overall incidence of migration, or a particular pattern of redistribution, such as counter-urbanization. However, migration has several dimensions, each of which can be measured in various ways. If cross-national comparisons are to be made, it is important to adopt measures that capture all these dimensions. Studies that rely on a single measure obscure the diversity of the phenomenon and may even be misleading. Here we argue that there are four broad groups of measure, each of which provides a different insight into the migration process. These are

(a) measures of the intensity of migration,
(b) measures of the distance of migration,
(c) measures of migration connectivity and
(d) measures of the effect of migration.

This section describes some measures under each of these headings and discusses their relative strengths, limitations and utility. We examine the problems that are associated with each measure for cross-national studies and suggest that certain measures are more robust for comparative analyses. As stated above, these measures are straightforward in the sense that a single value is calculated at the national level although, for some, the choice of the zonal system for which the measures are calculated will influence the results.

3.1. Measures of the intensity of migration

The first group of measures endeavours simply to capture the overall level, or incidence, of mobility within a country. In this context the term 'migration intensity' coined by van Imhoff and Keilman (1991) is useful since it encompasses both *transition probabilities* and *movement rates*. Intensities of migration can also be computed for individual spatial units, but we focus here on the national picture and confine attention to transition probabilities. A more detailed treatment of the measures discussed in this section is provided in Rees *et al.* (2000b).

3.1.1. Crude migration intensity

The crude migration intensity is the simplest measure of the overall propensity to migrate and is analogous to the crude birth-rate or crude death-rate. Different populations at risk (PARs) are required depending on whether the intensity is being measured using transitions or events. If transition data are used, the crude migration probability (CMP) is computed by expressing the total number of internal migrants (M) in a given time period as a percentage of the PAR (P) as follows:

$$\mathrm{CMP} = 100M/P. \tag{3}$$

In practice, some care is needed in the measurement of both the numerator and the denominator of equation (3). Long (1991) reported crude migration intensities for a number of countries as a percentage of the population at the end of the period and included immigrants in the numerator. By definition, international migrants have changed residence within the transition period and Long's tabulation follows a common form of reporting that has been adopted by many national statistical offices. However, there are several grounds for excluding external migrants from both the numerator and the denominator of equation (3). First, comparable information is not available from censuses for emigrants: including immigrants therefore reveals only part of the picture with respect to international migration. Secondly, their inclusion will tend to prejudice temporal and international comparisons since the results that are obtained will be affected by fluctuations in the level of immigration between countries and over time, thereby potentially obscuring any underlying trends or regularities in domestic migration (Bell and Stratton, 1998). It therefore seems sensible in cross-national studies to confine attention to people who migrated within the country.

In a similar vein, the PAR should ideally be measured at the start, rather than at the end, of the transition interval. However, using the end-of-period population as the PAR has several advantages: first, it ensures consistency in the data since the PAR can often be drawn from the same source as the transition data, i.e. from the census; secondly, it provides for comparability with the numerator of equation (3) since emigrants are automatically excluded and immigrants can be separately identified by their place of residence at $t - n$; thirdly, it excludes people who die within the transition interval (who are also omitted from the numerator). It is important to recognize, however, that measured in this way the CMP represents the probability of migration *conditional on survival and remaining within the country* (Rees *et al.*, 2000b).

Table 1 sets out CMPs computed from the British censuses of 1981 and 1991 and the Australian censuses of 1981 and 1996 (since only interstate data were collected in Australia for the 1-year period at the 1991 census). Expressed as percentages, they suggest that Australians are more migratory overall than Britons, though a direct comparison is only applicable for 1980–1981 where the British intensity is 55% that of the Australian. Table 1 shows how the aggregate CMPs break down into probabilities of migration between a range of zonal systems in the two countries (see Bell *et al.* (1999) for a full discussion of sources of data and regional definitions). The 1326 spatially defined statistical local areas (SLAs) in Australia group into 686 'pseudo'-local-government areas (PLGAs), 69 temporally consistent statistical divisions (TCSDs), 38 city regions and ultimately into eight states and territories, whereas the 10933 wards in Britain aggregate hierarchically into 459 districts, 67 counties and 10 standard regions. City regions are aggregations of family health service authority areas used in recording National Health Service transfers of patients. Although these zonal systems are not directly comparable, they

Table 1. Crude migration probabilities by type of move, Britain† and Australia

Zonal system‡	*Probabilities for Australia for the following periods:*			*Zonal system*	*Probabilities for Britain for the following periods:*	
	1980–1981	*1995–1996*	*1991–1996*		*1980–1981*	*1990–1991*
Between						
States (8)	1.9	1.8	5.1	Standard regions (10)	1.2	1.2
City regions (38)	6.1	5.4	15.6	City regions (35)	—§	1.8
TCSDs (69)	6.9	6.1	17.4	Counties (67)	2.4	2.1
PLGAs (686)	—§§	—§§	24.8	Districts (459)	3.5	3.2
SLAs (1326)	10.7	10.6	28.4	Wards (10933)	—§	6.6
Within						
SLAs	5.6	7.4	14.2	Wards	—§	2.2
All moves*	16.3	18.3	43.1		9.0	8.8

†Britain refers to Great Britain, which is the combination of England, Wales and Scotland.
‡Maps showing the geographical boundaries of TCSDs and city regions in Australia, and family health services authorities and city regions in Britain are given in Bell *et al.* (1999). The construction of Australian TCSDs is discussed in detail in Blake *et al.* (2000), which provides source references to the local government area and SLA boundaries in the 1981 and 1996 censuses of Australia. Maps of county and district boundaries are given in Office of Population Censuses and Surveys (1992). Thematic ward maps for Britain are given in Rees, Kupiszewski and Durham (1996). Full digital boundary information on wards and districts is available on the UKBORDERS service of the EDINA Data Centre, University of Edinburgh (see `http://datalib.ed.ac.uk`).
§Not computed because of changes in the definitions of wards between 1981 and 1991 and current difficulties in accessing the special migration statistics from the 1981 census.
§§Not available.
*Includes moves of undefined type.

do reveal that the increase in intensity of migration in Australia between the early 1980s and the mid-1990s was due to an increase in short-distance mobility (migration within SLAs), offsetting a fall in longer-distance migration, whereas in Britain transitions between districts fell slightly between 1980–1981 and 1990–1991. The Australian data also illustrate the 1-year–5-year problem discussed earlier: 18% of Australians moved between 1995 and 1996 but this rises to just 43.1% for the 5-year period (much lower than 5×18%). A comparison of the 1- and 5-year intensities also offers qualified support for the hypothesis that longer transition intervals imply longer distances of movement. Compared with the 1-year CMPs, 5-year period intensities in Australia were proportionally a little higher for longer-distance migration than for shorter-distance moves.

3.1.2. Standardized migration intensities

Standardization of CMPs eliminates the contaminating effect of variations in the age–sex structure of the population at risk, thereby providing a more accurate basis for comparisons of cross-national differences in migration. Age is more important in this context than sex because age differentials in the propensity for migration are very pronounced whereas sex differentials are generally less significant. The standardized migration probability (SMP) for transition data is calculated as

$$\mathrm{SMP} = 100\left(\sum_a \sum_s m_{as} P_{as}\right) \bigg/ \left(\sum_a \sum_s P_{as}\right) \tag{4}$$

where m_{as} is the migration probability, conditional on survival and staying in the country, for age a and sex s for a country and P_{as} is the PAR for age a and sex s for a standard population at risk of surviving and staying in the country. In the equivalent standardized migration rate for movement data, the migration probability is replaced by a migration occurrence–exposure rate.

Ideally, direct standardization calls for a third population that is intermediate between those of the populations under study (Shryock *et al.*, 1975), which might be represented by an unweighted average. However, since standardized measures have meaning only in relation to the standard population selected, cross-national comparisons may be more meaningful if the population of one of the nations under study is used. When we standardize the CMPs for the total migration in Australia in 1980–1981 and 1995–1996 against the British population at the 1991 census, corrected for underenumeration, the intensity values for the two periods drop from 16.3 and 18.3 to 15.5 and 18.2 respectively. In the case of the 1991–1996 Australian data, the intensity value falls from 43.1 to 40.2. The reduction in mobility due to standardization is only marginal; thus, the younger Australian age structure contributes only a small amount to the higher values suggested by the crude probabilities, but greater differences may be expected between countries whose age structures are further apart.

3.1.3. Gross migraproduction intensity

The gross migraproduction rate (GMR) (Rogers, 1975) is analogous to the gross reproduction rate in fertility analysis and effectively measures the area under the schedule of age-specific migration rates. It is defined as the average number of moves that a person could expect to make in a lifetime if they were subject to the age-specific migration rates of a given year. Here we use the word ‘rate’ because the GMR has become a standard term but recognize that for transition data the GMR is really a gross migraproduction probability defined as

$$\mathrm{GMR} = \sum_{as} m_{as} \tag{5}$$

where m_{as} is the age-specific transition probability for age a for individuals of sex s. Since the rate is computed directly as the sum of age-specific probabilities, the GMR is another way of standardizing for age structure. As Rees *et al.* (2000b) pointed out, it is important to recognize that the GMR is highly sensitive to the starting and stopping ages of the summation. In the 1981 British census transition probabilities were reported only up to age 75 years whereas in Australia the published data extend to age 99 years and over. If the values are harmonized by stopping the summation early in the case of the Australian data and assuming that the probability at the last observed age applies at each subsequent age to a final standard of 90 years and over for Britain, the differential in the GMR between the two countries is significantly reduced (Table 2). Adding an allowance for transitions during the first year of life (assuming transition probabilities equivalent to half those observed for infants aged 0–1 years at the time of the census) further raises the GMRs for both countries by a small amount. Assuming that the age-specific intensities of migration observed in 1980–1981 applied over 90 years, then Australian men would make just over five and Australian women just under five more migrations than their British counterparts (Table 2, last column).

3.1.4. Migration expectancy

Migration expectancy, also termed the net migraproduction rate (Rogers, 1975), can be defined as the average number of moves that a person could expect to make in their lifetime if they were subject to the age-specific migration and mortality rates of a given year. It therefore represents a refinement of the GMR in that it takes account of mortality and is analogous to the net reproduction rate in fertility studies. Migration expectancies were first computed by Wilber (1963) and have been used extensively in national studies (Long, 1970, 1973, 1988; Bell, 1996) but rarely in cross-national comparisons. Their computation requires data from an appropriate life-table:

$$\mathrm{ME}_x = \left(\sum_{y=x}^{y=z} M_y L_y \right) \Big/ l_x \tag{6}$$

where ME_x is the migration expectancy at exact age x, M_y is the age-specific migration probability for ages from y to $y+n$, L_y is the size of the stationary population and l_x is the life-table population at exact age x and z is the last exact age to which the life-table population survives.

Table 2. Gross migraproduction rates by sex for selected age ranges, Britain and Australia

Age range (years) for GMR measure	*Rates for Australia for the following periods:*		*Rates for Britain for the following periods:*		*Australia–Britain differences, 1980–1981*
	1980–1981	*1995–1996*	*1980–1981*	*1990–1991*	
Males					
1–74, ⩾75	11.0	12.9	6.6	6.2	4.4
1–89, ⩾90	12.3	14.3	7.2	6.9	5.1
0–89, ⩾90	12.4	14.4	7.3	7.0	5.1
Females					
1–74, ⩾75	10.9	12.9	6.5	6.2	4.4
1–89, ⩾90	12.2	14.6	7.3	7.0	4.9
0–89, ⩾90	12.4	14.7	7.4	7.1	5.0

Migration expectancies require transition data for a single-year interval. Calculations based on transitions for a 5-year period generate misleading results, implying about 25 lifetime moves in the USA (Bailey and Sly, 1987; Kulkarni and Pol, 1994) compared with around 12 moves when data for a single-year interval are used (Long, 1988). The error has its origins in the 1-year–5-year problem discussed earlier. Since transition data capture only one migration in any given interval, migration expectancies actually indicate the number of years with one or more migrations, rather than the total number of moves. As in the case of the GMR, care is also needed in terms of the starting and stopping ages to be used for computation (Rees *et al.*, 2000b).

Despite these constraints, expectancies have several advantages compared with other measures of the intensity of migration. They are conceptually transparent and intuitively meaningful. They therefore represent that rarest of commodities in demography: a plain language figure which is both statistically valid and readily interpreted by non-specialists (Bell, 1996). They also provide the facility to explore the timing of mobility by using standard life-table techniques (Long, 1988; Bell, 1996). For example, it is possible to compute the median age at migration, or the average number of moves during a person's working years. A third advantage is that the life-table stationary population that is used in the calculations automatically acts as a form of standardization (Wilber, 1963). However, cross-national and temporal comparisons will also be affected by differences in mortality and it therefore makes sense to adopt a standard mortality schedule for comparative purposes. Rees *et al.* (2000b) suggest the adoption of the schedule associated with the collective population of developed countries as defined in 2000 in the United Nations Population Division's *Population Prospects*, but useful insights can also be derived by comparing expectancies based on different mortality schedules.

Table 3 sets out migration expectancies for Australia and Britain using country- and period-specific life-tables and also reports expectancies for both countries and periods based on the mortality pertaining in Britain in 1980–1981. The results confirm the higher level of mobility among Australians of both sexes: in 1980–1981 the British migration expectancies were 40% below their Australian counterparts and by the 1990s the gap appears to have widened further with a substantial rise in the mobility of Australians and a small decline in Britain. Life expectancy in Britain is slightly below that in Australia but Table 3 shows that this variation makes little difference to aggregate mobility: applying British mortality to the Australian data reduces the 1980–1981 migration expectancy for Australian women by just 0.1 moves and there is

Table 3. Migration expectancies by sex, Britain and Australia

Sex	*Expectancies for Australia for the following periods:*		*Expectancies for Britain for the following periods:*		*Australia–Britain differences, 1980–1981*
	1980–1981	*1995–1996*	*1980–1981*	*1990–1991*	
With country and period-specific mortality					
Males	10.7	12.8	6.4	6.2	4.3
Females	11.1	13.6	6.7	6.5	4.4
Based on British mortality, 1980–1981					
Males	10.7	12.4	6.4	6.1	4.3
Females	11.0	13.1	6.7	6.4	4.3

no effective change for Australian men. The analysis also reveals that improved longevity during the 1980s contributed only a small proportion of the observed rise in migration expectancy among Australians and marginally offset the decline in mobility in Britain.

3.1.5. Migration age profile

Although migration expectancies can provide useful insights into the age-related aspects of migration, it is not possible to capture adequately the diversity of the age profile of migration in a single summary measure. Some cross-national comparisons of age-related migration have been made by using model migration schedules (e.g. Rogers *et al.* (1978)). This technique segments the age profile into discrete components that can be summarized mathematically in a series of parameters describing how migration varies with age. Although the numbers of parameters required may vary, depending on the complexity of the migration profile, they effectively measure the relationship between age and migration by reference to three key elements: the rate of rise and fall in the migration curve, the height of the peaks and troughs, and their displacement along the age axis.

Although migration schedules therefore appear to offer an attractive basis for cross-national comparisons, there are some problems. First, deciding the optimum number of parameters that need to be estimated is difficult, as schedules for some countries may be summarized more adequately by using a smaller number than for others. Secondly, fitting schedules requires data that are disaggregated by single years of age. Neither the British nor the Australian censuses provide this information routinely. A third limitation is that the parameters derived from model schedules have no inherent meaning: for example, none of the parameters directly identifies points of inflection in the migration curve. Ultimately, there may be no substitute for the use of selected summary indicators together with a graphical representation of the migration age distribution. The two summary indicators that we suggest for comparison are the intensity of migration at the peak of the labour force curve (PMI) and the corresponding age at which this peak occurs (AP). Table 4 reveals that, whereas the peak intensities are substantially higher in Australia than in Britain, the age at which the peaks occur is remarkably similar in the two countries.

Following Rogers *et al.* (1978) other differences between countries in the age distribution of migration are most readily identified by comparing schedules standardized by dividing age-specific migration probabilities by the GMR, thereby reducing the area under each curve to 1

Table 4. Age profile indicators, Britain and Australia

Sex and indicator	*Indicators for Australia for the following periods:*		*Indicators for Britain for the following periods:*	
	1980–1981	*1995–1996*	*1980–1981*	*1990–1991*
Peak intensity (%) (PMI)				
Males	38.0	40.2	24.6	24.8
Females	41.0	43.5	26.5	27.1
Age at peak (years) (AP)				
Males	23	24	24	23
Females	22	22	22	23

and eliminating differences in the overall intensity of migration. Fig. 1 shows that the Australian and British schedules follow the familiar shape (Rogers and Castro, 1981) characterized by a peak among young adults, a rapid decline in the labour force years and among teenagers, and smaller rises among young children moving with their parents. A comparison at older ages is hampered by the lack of data in Britain, but the available evidence points to rising intensities in old age in both countries. There is also evidence of a secondary peak around the age of retirement in Britain but not in Australia. The major difference between the profiles, however, is the much sharper peak among young adults in the British data. Coupled with relatively higher intensities among young children, this suggests that events such as study, entry to the labour force, partnership and the formation of a family account for a larger proportion of mobility in Britain than in Australia.

3.2. *Measures of distances of migration*

Migration is ultimately a spatial activity involving movement between two discrete locations. Any cross-national comparison must therefore take account of the way that intensities of movement vary across space. What are needed are measures that summarize the effects of distance across the entire migration system. The choices that are available range from simple summaries of the distance moved to the distance decay parameters derived from models of migrant flows. It is in the computation of these measures that the general issues of defining space and distance

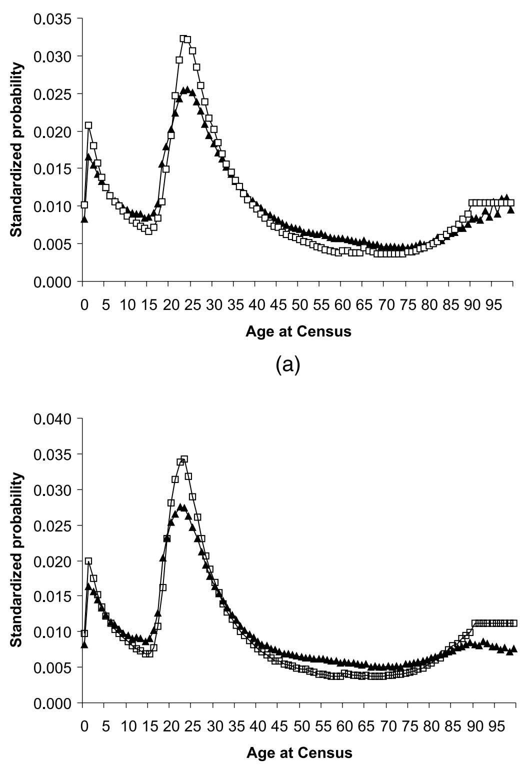

Fig. 1. Standardized migration probability schedules, Britain and Australia, for (a) males and (b) females: ▲, Australia, 1995–1996; □, Great Britain, 1990–1991

discussed earlier come to the fore and it is important to recognize that the choice of spatial units will inevitably influence the results that are obtained.

3.2.1. *Median distance moved*

Perhaps the simplest summary indicator for comparing the distance dimension of internal migration is the median distance moved. The median is clearly preferable to the mean as the distribution of distances is negatively skewed, reflecting the strong distance decay effect which consistently occurs. The median can be calculated simply by locating the midpoint of a cumulative frequency distribution of individuals, sorted according to the distance moved. In the case of countries such as Britain and Australia, such comparisons may be facile, simply because of the inherent difference in geographic size and hence in the opportunity for long-distance movement. Since it is also more sparsely settled, it would be surprising indeed if the median distance moved in Australia was lower than in Britain. Table 5 confirms this expectation. For example, the median migration distance between the 67 counties of Britain in 1990–1991 was 94 km for census migrants (transitions) and 101 km for NHSCR migrations (moves) compared with 177.5 km between 69 TCSD regions of Australia in 1995–1996. Including intrazonal moves reduces the transition-based figures to 27.7 km and 41.4 km respectively. Table 5 also clearly demonstrates the effect of differing geographies on the results obtained: overall, there is a marked fall in the estimates of the median distance of migration as the regional disaggregation increases. An exception occurs in the case of the shift from city regions to TCSDs in Australia because in both cases the median distance of migration falls in the same relatively large origin–destination flow. The evidence on the way that the transition period affects the distance of migration is more equivocal: the median distance for flows between TCSDs was higher for the 5-year period, as expected, reflecting the cumulative effect of multiple moves, but at the city region level the calculated distance was actually lower than for the single-year interval.

Table 5. Median distance moved, Britain and Australia

Country, migration interval and spatial breakdown	*Distance moved (km) excluding intrazonal moves*	*Distance moved (km) including intrazonal moves*
Britain 1990–1991 NHSCR event data		
35 city regions	134.4	101.9†
67 counties	101.0	—‡
Britain 1990–1991 census data		
67 counties	94.0	27.7
459 districts	33.6	6.3
Australia 1995–1996		
38 city regions	248.1	41.4
69 TCSDs	177.5	41.4
Australia 1991–1996		
38 city regions	246.7	41.4
69 TCSDs	181.9	41.4
686 PLGAs	52.1	16.5
1336 SLAs	29.4	5.1

†This figure includes only moves between family health service areas within city regions and not moves within family health service areas.
‡Not available because the NHSCR migration records do not include moves within family health service areas.

3.2.2. Distance decay parameters

Although the median is sensitive to the negative skew of migration, it does not fully capture the nature of the distance decay effect. This can be better achieved by fitting spatial interaction models (SIMs) to matrices of interzonal flows calibrated by using either the entropy maximizing method (Wilson, 1970) or the Poisson regression method (Flowerdew, 1991). Although migration modelling has been undertaken in numerous countries using differing data sets at a variety of spatial scales, it remains a relatively subjective art. In addition to the problems of choosing an appropriate measure of distance, the calculation of intrazonal distances and the MAUP, decisions are needed on the type of model to be used, the independent variables included and the most appropriate distance decay function. Fotheringham and O'Kelly (1989) suggested the use of a power function for longer-distance migration flows and a negative exponential distribution for shorter-distance flows, such as residential mobility.

One alternative is to use a doubly constrained Wilson spatial interaction model in which the distance decay parameter b is calibrated automatically by using an iterative search routine (Stillwell, 1991):

$$M_{ij} = A_i B_j O_i D_j d_{ij}^{-b} \tag{7}$$

where M_{ij} is the migration flow between zone i and zone j, O_i is the total of out-migrants from zone i to all destinations, D_j is the total of in-migrants to zone j from all origins, A_i and B_j are balancing factors to ensure that the predicted flows in each row sum to O_i and the predicted flows in each column sum to D_j and d_{ij} is the distance between the i- and j-zones. If migration flows within zones are available, these may be included in the diagonal element of the matrix and this will necessitate the measurement of intrazonal distances.

Flowerdew (1991) has argued that statistical Poisson SIMs have several beneficial properties in comparison with the type of mathematical models illustrated above; in particular, they are highly flexible, allow the simple introduction of explanatory variables, provide a straightforward goodness-of-fit measure and may be fitted such that they replicate variants of the family of SIMs. A Poisson migration model can be fitted as a generalized linear model as follows:

$$M_{ij} = \exp\left(\sum_k \beta_k X_{ik} + \sum_l \beta_l Y_{jl} + \lambda d_{ij}\right) + \varepsilon_{ij} \tag{8}$$

where M_{ij} has a Poisson distribution whose expected value equals the linear predictor $\exp(\Sigma \beta_k X_{ik} + \Sigma \beta_l Y_{jl} + \lambda d_{ij})$ and ε_{ij} is the error term for the flow from origin i to destination j. The independent explanatory variables are the set of X_{ik}-variables, the origin i-value for attribute k, Y_{jl}-variables, the destination j-value of attribute l, and the d_{ij}-variable, the distance between origin i and destination j. Its regression coefficient λ is interpreted as the measure of distance decay.

In fact the doubly constrained Wilson SIM and the Poisson SIM generate similar distance decay parameters when fitted to Australian and British data. Table 6 reports the values of the doubly constrained Wilson SIM. The distances used in the models have been calculated by using the mean distance method described earlier. The parameters of the spatial interaction models indicate the lower frictional effect of distance on migration between TCSDs in Australia where the mean migration distance in 1995–1996 was over $3\frac{1}{2}$ times that for counties in Britain in 1990–1991. The decay parameter for 5-year transitions is marginally lower and the mean distance of migration is higher than for the single-year data, reflecting the effect of cumulative moves noted above. When intra-TCSD flows are included, the parameters increase to −1.401 and −1.311 for

Table 6. Distance decay parameters, mean migration distances and goodness-of-fit statistics, Britain and Australia†

Country and migration interval	*Distance decay parameter B*	*Mean migration distance (km)*	*Coefficient of determination*
Britain (67 counties), excluding intrazonal flows			
1990–1991 transitions	−1.303	146.1	0.94
1990–1991 events	−1.283	147.3	0.94
Britain (67 counties), including intrazonal flows			
1990–1991 transitions	−2.481	54.8	0.93
1990–1991 events	—‡	—‡	—‡
Australia (69 TCSDs), excluding intrazonal flows			
1995–1996 transitions	−1.065	554.4	0.95
1991–1996 transitions	−1.089	540.1	0.94
Australia (69 TCSDs), including intrazonal flows			
1995–1996 transitions	−1.630	228.7	0.89
1991–1996 transitions	−1.510	254.7	0.90

†The doubly constrained Wilson SIM is used to calibrate the distance parameters. The calibration is achieved by ensuring that the model-predicted average distance of migration is equal to the observed mean migration distance, reported in the table.
‡Not available because the NHSCR migration records do not include moves within family health service areas.

the 1-year and 5-year flows whereas the average distance moved falls to 207.9 km and 235.6 km respectively. The difference in parameters between migration flows based on transitions (from the census) and events (from NHSCR data) in Britain is negligible and all the models fit reasonably well ($R^2 > 0.92$).

3.2.3. *Courgeau's 'K'*

Overall intensities of migration reveal differences in the propensity to move in different spatial settings but, as discussed earlier, cross-national comparisons are confounded by variations in the division of space. For example, there is no clear equivalence between regions or districts in Britain, on the one hand, and states or statistical divisions in Australia, on the other. Even if an endeavour is made to harmonize the zones in different countries on some common framework (such as the city regions employed for Australia and Britain by Stillwell *et al.* (2000)), an interpretation of intensities of migration at subnational levels is therefore problematic. Median distance and measures of distance decay address this spatial dimension, but at the cost of sacrificing information on the overall intensity of migration. One solution, suggested by Courgeau (1973b), derives from the observation that the intensity of migration is directly related to the number of territorial divisions (n) into which a country is divided, such that

$$\mathrm{CMP} = K \log(n^2). \tag{9}$$

Courgeau examined the value of K in countries of differing size and population density, with varying numbers of territorial units of different shapes, and found a clear log-linear relationship. This suggests that fitting a simple regression to values of K computed across a range of zonal systems would deliver a measure of the intensity of migration that is sensitive to distance but independent of variations in the extent of spatial disaggregation. In most countries, however, data are normally available for only a small number of zonal systems, which prejudices the reliability of the regression coefficients. Care is also needed to ensure consistency in cross-national comparisons since the results are sensitive to the base of the logarithms that is employed, and to whether the number of regions is squared. Table 7 sets out coefficients for Australia and

Britain using data for the zonal system set out in Table 1. The results are broadly consistent with the variations in intensity of migration that were observed earlier: the coefficients are higher for Australia than for Britain, and higher for the 5- than for the 1-year interval. However, the high values that were obtained for the intercept when the regression is not forced to pass through the origin suggest that the regression represents a poor fit to the Australian data. A more general weakness of the method for international comparisons is that Courgeau's K, and hence the derivative coefficients, has no intuitive meaning. They do, however, represent the propensity of migrants to overcome the 'relative space' within their country. The index is useful for ranking countries for which no data for comparable spatial units exist.

3.3. Measures of migration connectivity

In any system of interregional migration the magnitude of the flows between different pairs of origins and destinations varies widely. These variations are partly a product of differences in population sizes and the effects of distance decay, but they also reflect the strength of the functional linkages between regions. Measures of the extent to which regions are connected by migration, and the pattern of these linkages, can provide valuable insights into the roles and functions of individual regions within the settlement system (Bell and Maher, 1995). They also provide useful tools for analysing the evolution of settlement patterns and have potential application to population projections (Rogers and Raymer, 1998). Despite this intrinsic interest, however, migration linkages have attracted only sporadic attention in population research. Moreover, there is little agreement on the most suitable measures, or even the appropriate terminology for the phenomenon. Various terms including *spatial connectivity*, *spatial concentration*, *spatial inequality* and *spatial focusing* tend to be used almost interchangeably. In each case, however, what is essentially being measured is the degree of *connection* between places through flows between them. A variety of statistics and indices have been proposed, with varying levels of sophistication. We confine attention here to five such measures, each of which has certain useful properties. Although these measures have generally been used to analyse differences in spatial interaction between regions within countries, in each case it is also possible to compute a national index.

3.3.1. Index of migration connectivity

The index of connectivity I_{MC} represents the simplest of the five measures considered here, in

Table 7. Regression coefficients for Courgeau's K, Britain and Australia†

Country and migration interval	*Regression coefficient, intercept set to 0*	*Regression coefficient, floating intercept*	*Intercept, floating*
Britain			
1980–1981	0.54	0.53	0.12
1990–1991	0.52	0.51	0.11
Australia			
1980–1981	1.52	1.64	−0.64
1995–1996	1.44	1.67	−1.18
1991–1996	3.96	4.38	−2.14

†Computed using natural logarithms and without squaring the number of regions.

that it simply captures the proportion of the total number of potential interregional flows which are non-zero. Define $MC_{ij} = 0$ if the flow from i to j is zero and $MC_{ij} = 1$ otherwise: then

$$I_{MC} = \sum_{i \neq j} \sum_{j \neq i} MC_{ij}/n(n-1). \tag{10}$$

I_{MC} varies within bounds of 0 (indicating no connections between regions) and 1 (indicating some flows between all pairs of regions in the migration system). Although it is straightforward to compute, I_{MC} is a relatively coarse measure that is insensitive to variations in the degree of regional interaction. Moreover, it is strongly influenced by the zonal breakdown that is employed. As Table 8 demonstrates, it is only at high levels of spatial disaggregation that the index assumes values below 1, simply because with a small number of zones there is likely to be at least some migration between all regions.

Table 8. Measures of connectivity, migration inequality and spatial focusing, Britain and Australia†

Zonal system	*Measures for Australia for the following data:*		*Zonal system*	*Measures for Britain for the following data:*	
	1991–1996, census	*1995–1996, census*		*1990–1991, census*	*1990–1991, NHSCR*
Index of migration connectivity, I_{MC}					
States (8)	1.0	1.0	Standard regions (11)	1.0	1.0
City regions (38)	1.0	0.998	City regions (34)	1.0	1.0
TCSDs (69)	0.973	0.946	Counties (67)	0.984	0.984
PLGAs (686)	0.305	—‡	Districts (459)	0.667	—§
Index of migration inequality, I_{MI}					
States	0.443	0.419	Standard regions	0.329	0.319
City regions	0.617	0.604	City regions	0.576	0.559
TCSDs	0.674	0.667	Counties	0.531	0.528
PLGAs	0.830	—‡	Districts	0.648	—§
Total Gini index, G^T					
States	0.604	0.578	Standard regions	0.472	0.464
City regions	0.773	0.763	City regions	0.743	0.733
TCSDs	0.777	0.773	Counties	0.651	0.657
PLGAs	—§§	—§§	Districts	—§§	—§§
Migration-weighted Gini, MWG^A					
States	0.5430	0.5217	Standard regions	0.4230	0.4122
City regions	0.7336	0.7258	City regions	0.6696	0.6452
TCSDs	0.7818	0.7805	Counties	0.6296	0.6205
PLGAs	0.903	—‡	Districts	0.7942	—§
Coefficient of variation, ACV					
States	1.882	1.787	Standard regions	1.732	1.645
City regions	4.721	4.709	City regions	3.623	3.420
TCSDs	5.828	5.890	Counties	3.948	3.721
PLGAs	11.739	—‡	Districts	5.835	—§

†See the text for the formula used to compute each index.
‡No interarea flows matrix was available for PGLAs for 1995–1996.
§No district information is available from the NHSCR migration system.
§§Not computed because there are too many zones (see the text for a discussion of computing times).

3.3.2. *Index of migration inequality*

An alternative measure which partly overcomes these problems is the index of migration inequality, I_{MI}, derived from the family of dissimilarity indices. Here, migration inequality is measured by reference to the difference between the observed distribution of interregional flows M and the expected distribution M'. Thus

$$I_{\mathrm{MI}} = \frac{1}{2} \sum_{i \neq j} \sum_{j \neq i} \left| M_{ij} - M'_{ij} \right|. \tag{11}$$

The expected distribution might simply assume that all interregional flows were of the same magnitude, or it could be based on a hypothetical distribution, such as that derived from a spatial interaction model. Like I_{MC}, I_{MI} varies within the bounds of 0 and 1, with values of 0 indicating that the observed and expected distributions are identical and values closer to 1 denoting greater inequality. In the computations for Australia and Britain, we assume an equal distribution of migrants across flows.

As Table 8 shows, the index is consistently higher in Australia than in Britain, which suggests a more uniform pattern of flows in the latter, or greater inequality of flows in the former. The results also demonstrate that the index is highly sensitive to the scale of spatial disaggregation (as are all the other measures listed in Table 8). However, it is less strongly influenced by the type of data used to measure migration (transition or event), or by the length of the observation period.

Although I_{MI} is sensitive to aggregate variations in the strength of regional interactions, it does not capture the extent to which migration flows are focused on a small number of regions, nor, as Rogers and Raymer (1998) pointed out, does it differentiate between an increase and a decline in the extent of this spatial concentration. Two alternative measures which provide a more accurate indication of the extent of this spatial focusing in a set of migration flows have recently been proposed, the first by Plane and Mulligan (1997) who suggested an adaptation of the Gini index, and the second by Rogers and Raymer (1998) who preferred the coefficient of variation.

3.3.3. *The Gini index*

The Gini index is a well-known measure of concentration (Duncan and Duncan, 1955; White, 1986). As computed by Plane and Mulligan (1997), the Gini index involves a comparison of each interzonal flow (M_{ij}) with every other flow (M_{kl}) in a matrix of interregional migration. Since the index is measuring spatial interaction, the diagonal cells are ignored and the index is computed as half the arithmetic mean of the absolute differences between all pairs of flows, *ij* and *kl*:

$$G^{\mathrm{T}} = \frac{\sum_{i} \sum_{j \neq i} \sum_{k} \sum_{l \neq k} \left| M_{ij} - M_{kl} \right|}{\{(2n(n-1) - 1)\} \sum_{i} \sum_{j \neq i} M_{ij}}. \tag{12}$$

The index varies from 0 when all flows are of equal size (corresponding to no spatial focusing) to 1, when all migrants are found in one single interzonal flow (maximum focusing). Plane and Mulligan (1997) set out the first part of the denominator as $2n(n-1)$ but to ensure that the index can assume the upper limit of 1 this needs to be modified to $2\{n(n-1) - 1\}$. We call this the total Gini index.

A comparison of the total Gini indices in Table 8 delivers the same general picture that is evident from the index of inequality: migration in Australia is consistently more focused than migration in Britain, irrespective of the spatial scale. However, the degree of focusing varies markedly, as does the extent of the differential, with large variations at the state or standard region and TCSD or county levels, but comparatively little difference between the two countries at the level of city regions. The results also emphasize that spatial focusing is fairly insensitive to the length of the transition interval, and that transition and event data offer a similar picture of its overall intensity.

Plane and Mulligan (1997) showed that the total Gini index G^{T} can be decomposed into four component indices, each of which involves the calculation of pairwise differences between selected sets of zones. These are an index for outflows (G^{O}), computed by comparing every outflow from each zone of origin with every other outflow from that origin, which therefore measures the extent to which the destination choices of out-migrants are spatially focused, a corresponding index for in-migration (G^{I}), measured as the mean deviation between the inflow to each destination from one origin compared with the flow from every other origin, an exchange index which compares each off-diagonal flow (M_{ij}) with its counterflow (M_{ji}) and a final, residual, index (G^{R}) representing the focusing that is associated with differences between those flows that are not contained in the in-migration, out-migration or exchange indices.

The total Gini index is comprehensive in that it includes a comparison of each cell with every other cell in the matrix and therefore takes account of all interregional flows in the system. In practice, however, the residual component G^{R} accounts for the overwhelming majority of the total index. At the TCSD level and county levels, for example, the residual component represents 97% of the total Gini score that is recorded in Table 8. Yet, as Plane and Mulligan (1997) acknowledged, this residual component is difficult to interpret. It therefore seems more sensible to confine attention to the inflow and outflow indices. However, the problem that then emerges is that the component indices do not independently have logical limits of 0 and 1.

One solution to this problem is to adopt the approach that Rogers and Raymer (1998) used with the coefficient of variation (see below). In the case of the Gini coefficients, this involves computing an index of concentration for region-specific out-migration as

$$G_i^{\mathrm{O}} = \frac{\sum\limits_{j \neq i} \sum\limits_{l \neq i,j} \left| M_{ij} - M_{il} \right|}{2(n-2) \sum\limits_{j \neq i} M_{ij}}. \tag{13}$$

An equivalent index for in-migration is defined as

$$G_j^{\mathrm{I}} = \frac{\sum\limits_{i \neq j} \sum\limits_{k \neq j,i} \left| M_{ij} - M_{kj} \right|}{2(n-2) \sum\limits_{i \neq j} M_{ij}}. \tag{14}$$

The denominators in each case include the term $n-2$ because the number of comparisons should exclude the diagonal cell in each row and column, and the comparison of each cell with itself. The term is multiplied by 2 because each of the comparisons between the remaining cells in each row or column is performed twice. These calculations result in each origin and destination Gini values having limits of 0 and 1.

Three national or systemwide indices based on these two zone-specific measures can be derived whose values fall between 0 and 1. In each case it is necessary to develop a migration-weighted mean index MWG. In the first case, each origin-specific Gini value is weighted according to the zone of origin's share of total migration and the mean value is computed as

$$\mathrm{MWG^O} = \frac{1}{n}\sum_i G_i^{\mathrm{O}} \frac{\sum_j M_{ij}}{\sum_{ij} M_{ij}}. \tag{15}$$

Likewise, the destination-specific Gini index is weighted according to the zone of destination's share of total migration and the mean of the weighted values is computed as

$$\mathrm{MWG^I} = \frac{1}{n}\sum_j G_j^{\mathrm{I}} \frac{\sum_i M_{ij}}{\sum_{ij} M_{ij}}. \tag{16}$$

The final index is derived as the average of the migration-weighted out-migration and in-migration values as

$$\mathrm{MWG^A} = 0.5(\mathrm{MWG}_i^{\mathrm{O}} + \mathrm{MWG}_j^{\mathrm{I}}) \tag{17}$$

where 0.5 is required to ensure that the combined index varies between 0 and 1.

As well as directing attention to the most significant dimensions of spatial focusing, the migration-weighted Gini index $\mathrm{MWG^A}$ significantly reduces the computational load, compared with the total index G^{T} proposed by Plane and Mulligan (1997). Although in principle the latter can be applied to measure focusing at any spatial scale, it becomes impractical when the number of zones becomes very large (e.g. for the 10000 wards in Great Britain) because of the huge amount of computer time that is needed to make the pairwise comparisons. We estimate that, for a zone system of 400 units which would involve 400^4 comparisons, the time taken to derive the total Gini index would amount to over 300 h on a personal computer. By comparison the number of computations required for $\mathrm{MWG^A}$ is an order of magnitude less, which therefore permits application to much larger matrices. The computational advantage of limiting the calculations to the origin, destination and average Gini indices compared with computing the total Gini index rises exponentially with the number of regions. For 2^6 (128) regions on a fast SUN Ultra workstation and assuming 0.5×10^6 operations per second, we estimate that it would take 1.47×10^{-1} h to compute the total Gini index and 2.29×10^{-3} h to compute the average migration-weighted Gini index; for 2^{14} (16384) regions the corresponding times would be 4.00×10^7 h for G^{T} and 4.89×10^3 h for $\mathrm{MWG^A}$. As a consequence we did not compute the indices for Australian SLAs (1326 units) or British wards (10933 units).

The values of $\mathrm{MWG^A}$ in Table 8 display a pattern which is remarkably similar to that suggested by the other indices: consistently higher levels of spatial focusing in Australia than in Britain, rising values of the $\mathrm{MWG^A}$-measure as the zonal breakdown increases (except at the county level in Britain) and minimal variation between the transition and event data, or between transition data measured over differing length intervals.

3.3.4. Coefficient of variation

An alternative measure of spatial focusing proposed by Rogers and Raymer (1998) is the coefficient of variation (CV), which is calculated simply as the standard deviation divided by the mean of a given set of interzonal migration flows (Allison, 1978):

$$\mathrm{CV} = \frac{\sqrt{\left\{\sum_{i}\sum_{j\neq i}(M_{ij} - \overline{M})^2 \Big/ n(n-1)\right\}}}{\bar{M}}. \tag{18}$$

Rogers and Raymer (1998) computed national indices, ACVs, separately for in- and out-migration by weighting the CV for each origin and destination according to the share of total systemwide migration leaving and entering each zone. A systemwide index is then derived simply by summing the ACVs for in- and out-migration. This is similar to the procedure proposed above to modify Plane and Mulligan's (1997) Gini index.

As well as being computationally much simpler than the Gini indices, Rogers and Raymer (1998) argued that the CV is more sensitive to the extent of primacy in the set of interregional migration flows. The main disadvantage, in the context of international comparisons, is that the CV has no logical limits, which tends to prejudice its interpretation. Nevertheless, as Table 8 reveals, the picture that emerges from the systemwide ACV with respect to spatial focusing in Britain and Australia is similar to that evident from the other indices. The sole exception is that ACV eliminates the apparent anomaly of greater spatial focusing at the city region, than at the county, scale, which is consistently evident in the other measures.

3.4. Measures of migration impact

The final group of measures proposed in this paper endeavours to indicate the extent to which migration acts to transform the pattern of human settlement. Although spatial variations in fertility and mortality persist to varying degrees, in most developed countries internal migration, together with immigration from overseas, is now the predominant mechanism leading to the redistribution of population. Descriptive studies of the effect of migration generally focus on the patterns of net gain and loss in regions and localities. For cross-national comparisons, however, measures are needed that summarize the overall effect of migration in redistributing a population across the entire system of regions. Two suitable candidates are the migration effectiveness index (MEI) and the aggregate net migration rate (ANMR).

3.4.1. Migration effectiveness index

The MEI relates the sum of the absolute value of each zone's net migration balance to the sum of total out-migration and in-migration across all zones. The MEI appears to have been first proposed by Shryock *et al.* (1975) and represents an extension of the migration effectiveness ratio developed for single regions by Thomas (1941). Computationally, the index is defined as

$$\mathrm{MEI} = 100\sum_{i}|D_i - O_i| \Big/ \sum_{i}(D_i + O_i) \tag{19}$$

where D_i is the total inflows to zone i and O_i is the total outflows from zone i. The MEI can assume values between 0 and 100. High values indicate that, overall, migration is an efficient mechanism of population redistribution, generating a large net effect for the given volume of movement. Conversely, low values denote that interzonal flows are more closely balanced, leading to comparatively little redistribution.

The use of the index for cross-national comparisons raises some potential problems, the most significant being its sensitivity to the level of spatial disaggregation. As Table 9 demonstrates, the aggregate migration effectiveness in both Australia and Britain generally falls as the number

Table 9. MEI and net migration rate, Britain and Australia†

Zonal system	*Results for Australia for the following data:*		*Zonal system*	*Results for Britain for the following data:*	
	1991–1996, census	*1995–1996, census*		*1990–1991, census*	*1990–1991, NHSCR*
MEI					
States (8)	20.66	8.69	Standard regions (11)	8.25	6.68
City regions (38)	10.87	5.15	City regions (34)	7.99	5.80
TCSDs (69)	10.14	4.83	Counties (67)	7.63	6.16
PLGAs (686)	10.63	—‡	Districts (459)	7.26	—§
SLAs (1336)	6.08	—‡	Wards (10933)	8.16	—§
Net migration rate					
States	1.05	0.31	Standard regions	0.11	0.12
City regions	1.70	0.56	City regions	0.15	0.15
TSDs	1.77	0.59	Counties	0.16	0.16
PLGAs	2.64	—‡	Districts	0.24	—§
SLAs	1.73	—‡	Wards	0.54	—§

†See the text for the formula used to compute each index.
‡No interarea flows matrix was available for PGLAs or SLAs for 1995–1996.
§No district information is available from the NHSCR migration system.

of zones increases but the value of the MEI varies much more widely in the former. As a result, migration appears to be more efficient as a mechanism for redistributing population between counties and city regions in Britain than in Australia, but at the level of states or standard regions the MEI is higher for Australia. Table 9 also underlines the importance of the type of data and length of observation interval on the results obtained. Migration effectiveness is consistently higher when measured over the 5-year interval because return and onward moves comprise a smaller proportion of all measured transitions than is the case for 1-year data. For similar reasons event data display a lower effectiveness than the corresponding transition data for a single year.

3.4.2. Aggregate net migration rate

The MEI measures the relationship between net and gross migration flows but it does not indicate the overall effect of migration on the settlement pattern. For the latter, we suggest computing an ANMR, effectively changing the denominator in the MEI from the sum of the gross migration flows to the population at risk. Thus

$$\text{ANMR} = 100 \times \frac{1}{2} \sum_i |D_i - O_i| \Big/ \sum_i P_i \tag{20}$$

where P_i is the PAR in region i. As in the case of the MEI, the ANMR represents a logical extension of the more commonly used net migration rate for specific regions. The interpretation of the ANMR in a cross-national context raises problems that are similar to those affecting the MEI as discussed above, notably that the values that it assumes will vary with the level of spatial disaggregation and are susceptible to the MAUP. Thus, as Table 9 shows, the ANMR varies from 0.22% for the 11 standard regions of Britain to 0.32% for the 67 counties, and in Australia from 0.31% for states to 0.59% for TCSDs.

It is important to recognize that, although they are often closely correlated (Rogers and Raymer, 1998), the MEI and the ANMR measure rather different things. The MEI essentially indicates the degree of (a)symmetry or (dis)equilibrium in the network of interregional migration flows whereas the ANMR summarizes the extent of population redistribution arising from the net migration balances. Despite these conceptual differences, it is worth noting that (assuming that the net migration, gross flows and the PAR are measured consistently) the MEI, ANMR and CMP are directly related, such that

$$\mathrm{ANMR} = \mathrm{CMP} \times \mathrm{MEI}/100. \tag{21}$$

This identity facilitates computation since if any of the two measures are known the third can be derived directly. However, equation (21) also underlines the interdependence of migration dynamics and spatial outcomes. Migration effectiveness is independent of the intensity of migration but in combination these two measures dictate the level of population redistribution. It is therefore possible for two countries to display quite different CMPs, as is the case for Britain and Australia, but, if this is offset by compensating migration efficiencies, the net redistribution may be quite similar. Conversely, similar intensities of migration do not necessarily imply corresponding levels of population redistribution. Thus, the intensities of migration in Australia at the TCSD and city region levels are around three times the comparable values for Great Britain (Table 1), but higher effectiveness in Britain reduces the difference measured in terms of the net impact to a factor of 2 in Australia's favour (Table 9). In contrast, the Australian migration intensity at the state level is only 50% above the figure for Britain but marginally lower effectiveness in the latter accentuates the difference between the two countries in terms of redistribution of population.

4. Conclusions and recommendations

We conclude the paper by first reviewing what has been learnt about the particular countries studied and second by summarizing the schema of indices that have been proposed in the paper. Third, we evaluate how far the indices take us in characterizing internal migration. Fourth, we speculate on whether the development of indices for a wider set of countries is a feasible project.

Our comparison of internal migration in Australia and Britain in the early 1980s and 1990s exemplified the indicators selected as well as providing some new insights into migration behaviour in both countries. It appears that Australians have higher propensities to migrate, making double the number of moves that are made by internal migrants in Britain, although the standardized migration rates suggest that Australian males and females both have relatively lower probabilities of moving during their peak labour force ages. Migration distances are much longer in Australia than in Britain and the frictional effect of distance on migration is lower. Migration flows are more geographically concentrated in Australia at the TCSD scale than at the county scale in Britain. Although migration effectiveness is higher in Britain than in Australia, migration in Australia generates a much greater redistribution of population because of its higher intensity.

Before putting forward recommendations about how the indices that were discussed in this paper might be more widely implemented, it is important to revisit the issue of scale. Only a few of the indices proposed are free of the influence of spatial scale, expressed in terms of numbers of regions or their spatial extents: these exceptions are the intensities measured for all migrations within a country, Courgeau's slope index of intensities against numbers of zones and perhaps SIM parameters when intrazone migrations are included. The other indices are heavily influenced by the scale at which they are measured. It may turn out that they also display similar systematic variations of measure with scale to intensities, but further research is needed on that possibility. What recommendations can be made therefore about using the indices? First, we suggest that the measures are used at as many geographical scales as data are available for. Second, where there is the opportunity, researchers should seek to define functionally similar kinds of region in the countries being compared. For Australia and Britain we have defined comparable city regions and their hinterlands, which play the same role in each country as organizers of economic activity and development (Blake *et al.*, 2000; Rees *et al.*, 2001; Stillwell *et al.*, 2000). In the final analysis, scale will always affect international comparisons of internal migration activity: an awareness of this effect is essential in comparative work.

We have argued that to conduct cross-national comparative research on internal migration it is necessary to define and compute a range of robust indicators that measure different dimensions of mobility. This paper has recommended a suite of measures of migration intensity, distance, connectivity and impact that together comprise a toolkit for comparative investigation but which need to be employed with careful attention to the way that migration is measured in the countries concerned, with recognition of the imperfections that are associated with the migration and population data, and with understanding of the spatial division of territory in each case. In particular, it is important to recognize the differences between transition and event data, to ensure that adjustments are made to include infants and other missing groups of migrants, to exclude immigrants and emigrants and to compute crude intensities of migration for each type of migration by using appropriate populations at risk. Care is needed when computing GMRs to ensure that the age ranges and final age groups are consistent and, when computing migration expectancies, to match the method to the age–time plan of observation that is used to compute the intensities of migration. Although comparisons are at their most challenging when indicators are based on overall migration flows between geographical areas of differing size and function, we have identified several measures that reflect interzonal interaction characteristics in aggregate.

Table 10 lists in summary form the battery of 15 national summary indicators of internal migration intensity, distance, connectivity and impact on population that have been proposed for capturing the essential character of internal migration across countries. These indicators can be computed for both transition data and movement data, although for intensity measures different formulae should be used. Table 10 identifies the name of the index, its notational designation and the source formula or method. This is, however, a long list to compute and implement, so in Table 10 we have picked out a minimum set of five indices which will provide comparable information on each of the four dimensions of internal migration level and structure, though they will not encompass all ways in which internal migration systems can differ between countries. *Migration expectancy* measures the intensity of migration and controls for differences in age and sex structure of the populations being studied. The *median distance moved* measure can be computed easily once a good set of interarea distances has been estimated and does not involve the use of models which need sensitive calibration. Although the computation of the average *migration-weighted Gini index* is demanding, it captures the nature of migration connections between places better, we would argue, than the alternatives. Finally, the *MEI* and *ANMR* are included because of their familiarity, ease of computation and ready interpretation. They are both needed to account fully for migration's effect on the population.

We have not attempted in this paper to look at comparisons of characteristics of migrants other than the basic demographic variables of age and sex. Comparisons of other characteristics would inevitably invite similar techniques and introduce more problems relating, for example,

Table 10. Set of indices for cross-national comparison of internal migration†

Index name	*Notational term*	*Equation or source*
Measures of intensity of migration		
Crude migration intensity	CMI (CMP, CMI)	Equation (3)
Standardized migration intensity	SMI (SMP, SMR)	Equation (4)
Gross migraproduction rate	GMR	Equation (5)
Migration expectancy	*ME*	*Equation (6)*
Peak migration intensity	PMI	Fig. 1
Age at peak intensity	API	Fig. 1
Measures of distance of migration		
Median distance moved	*MD*	*50th percentile, text*
Distance decay parameter	b	Equation (7)
Courgeau's index	K	Equation (8)
Measures of migration connectivity		
Index of migration connectivity	I_{MC}	Equation (10)
Index of migration inequality	I_{MI}	Equation (11)
Migration-weighted Gini	MWG^{A}	*Equations (15), (16), (17)*
Coefficient of variation	ACV	Equation (18), text
Measures of migration impact		
Migration effectiveness index	*MEI*	*Equation (19)*
Aggregate net migration rate	*ANMR*	*Equation (20)*

†The indices in italics constitute a minimum list covering the four dimensions of variation in internal migration.

to ethnic and social class definitions, as well as the general issue of changing status with attributes such as labour force and marital status. We have purposely limited our analysis to national indices for certain time periods based on selected systems of subnational zones. Further work is required to examine the sensitivity of these national indices to spatial scale and to expose the extent of spatial variability (within countries) in the measures that have been chosen. Equally, temporal comparisons are needed at both the national and the subnational levels.

How might a proposal to apply this battery of indicators be taken forward to develop a set of internationally comparable measures? First, of course, the ideas presented here must find favour with an international readership of experts on migration. Second, the project will require, for realistic use, the development of an easy-to-use software package. Third, an international organization responsible for producing international demographic statistics on a comparable basis must be persuaded to organize the production of the indices by member countries. The support of the Economic and Social Research Council (UK) for the second ingredient is already in place under the Economic and Social Research Council–Joint Information Systems Committee 2001 census program (award H507 255 155 to Stillwell, Boyle and Duke-Williams on 'Web-based interface to census interaction data'). The authors have confidence that such a project will be attractive to the Council of Europe through its Demographic Committee, given its previous support of comparative work on internal migration in Europe (Rees and Kupiszewski, 1999a). We are also confident that specialists on migration in many countries, if convinced of the value of our research, will be willing to co-operate in the endeavour in the next decade.

Acknowledgements

The research reported here was supported by the Australian Research Council (grant A79803552) and the Economic and Social Research Council (grant R000237375).

References

Allison, P. D. (1978) Measures of inequality. *Am. Sociol. Rev.*, **43**, 865–881.
Australian Bureau of Statistics (1991) *1991 Census Dictionary.* Canberra: Australian Bureau of Statistics.
———(1995) *1991 Census of Population and Housing*, *Data Quality—Undercount.* Canberra: Australian Bureau of Statistics.
Bailey, M. and Sly, D. F. (1987) Metropolitan-nonmetropolitan migration expectancy in the United States, 1965-1980. *Genus*, **53**, no. 3–4, 37–59.
Bell, M. (1995) *Internal Migration in Australia 1986 to 1991*, *Overview Report.* Canberra: Australian Government Publishing Service.
———(1996) How often do Australians move?: alternative measures of population mobility. *J. Aust. Popln Ass.*, **13**, 101–124.
Bell, M. and Maher, C. A. (1995) *Internal Migration in Australia 1986 to 1991*, *the Labour Force.* Canberra: Australian Government Publishing Service.
Bell, M. and Rees, P. (2000) Lexis diagrams in the context of migration: a review and application to British and Australian data. *Wrkshp Lexis in Context: German and Eastern & Northern European Contributions to Demography 1860-1910, Rostock, Aug. 28th–29th.*
Bell, M., Rees, P., Blake, M. and Duke-Williams, O. (1999) An age-period-cohort database of inter-regional migration in Australia and Britain, 1976-96. *Working Paper 99/2.* School of Geography, University of Leeds, Leeds. (Available from `http://www.geog.leeds.ac.uk/wpapers/99-2.pdf`.)
Bell, M. and Stratton, M. (1998) Understanding the 1996 Census migration data. *J. Aust. Popln Ass.*, **15**, 155–169.
Blake, M., Bell, M. and Rees, P. (2000) Creating a temporally consistent spatial framework for the analysis of interregional migration in Australia. *Int. J. Popln Geogr.*, **6**, 155–174.
Boden, P., Stillwell, J. C. H. and Rees, P. H. (1992) How good are the NHSCR data? In *Migration Processes and Patterns*, vol. 2, *Population Redistribution in the United Kingdom* (eds J. C. H. Stillwell, P. H. Rees and P. Boden), pp. 13–27. London: Belhaven.
Bone, M. (1984) *Registration with General Medical Practitioners in Inner London.* London: Her Majesty's Stationery Office.
Boyle, P. and Flowerdew, R. (1997) Improving distance estimates between areal units in migration models. *Geogr. Anal.*, **29**, 93–107.
Boyle, P., Flowerdew, R. and Shen, J. (1997) Multi-collinearity and parameter estimates in gravity models. Unpublished. Department of Geography, University of Wales, Swansea.
Boyle, P., Halfacree, K. and Robinson, V. (1998) *Exploring Contemporary Migration.* London: Longman.
Champion, A. G. (1989) *Counterurbanisation, the Changing Pace and Nature of Population Deconcentration.* London: Arnold.
Courgeau, D. (1973a) Migrants and migrations. *Population*, **28**, 95–128.
———(1973b) Migrations et découpages du territoire. *Population*, **28**, 511–537.
Duncan, O. D. and Duncan, B. (1955) A methodological analysis of segregation indexes. *Am. Sociol. Rev.*, **20**, 210–217.
Fielding, A. J. (1982) Counter-urbanisation in Western Europe. *Progr. Planng*, **17**, 1–52.
Flowerdew, R. (1991) Poisson regression modelling of migration. In *Migration Models, Macro and Micro Approaches* (eds J. C. H. Stillwell and P. Congdon), pp. 92–112. London: Belhaven.
Fotheringham, A. S. and O'Kelly, M. E. (1989) *Spatial Interaction Models*, *Formulations and Applications.* Dordrecht: Kluwer.
Goldstein, S. (1976) Facets of redistribution, research challenges and opportunities. *Demography*, **13**, 423–434.
van Imhoff, E. and Keilman, N. (1991) *LIPRO 2.0, an Application of a Dynamic Demographic Projection Model to Household Structure in the Netherlands.* Amsterdam: Swets and Zeitlinger.
Kitsul, P. and Philipov, D. (1981) The one year/five year migration problem. In *Advances in Multiregional Demography* (ed. A. Rogers), pp. 1–34. Laxenberg: International Institute for Applied Systems Analysis.
Kulkarni, M. and Pol, L. G. (1994) Migration expectancy revisited, results for the 1970s, 1980s and 1990s. *Popln Res. Poly Rev.*, **13**, 195–202.
Langevin, B., Begeot, F. and Pearce, D. (1992) Censuses in the European Community. *Popln Trends*, **68**, 33–36.
Long, J. F. and Boertlein, C. G. (1990) Comparing migration measures having different intervals. *Current Population Reports, Series P-23*, pp. 1–11. Washington DC: US Bureau of the Census.
Long, L. (1970) On measuring geographic mobility. *J. Am. Statist. Ass.*, **65**, 1195–1203.
———(1973) New estimates of migration expectancy in the United States. *J. Am. Statist. Ass.*, **68**, 37–43.
———(1988) *Migration and Residential Mobility in the United States.* New York: Russell Sage Foundation.

———(1991) Residential mobility differences among developed countries. *Int. Regl Sci. Rev.*, **14**, 133–147.
———(1992) Changing residence, comparative perspectives on its relationship to age, sex and marital status. *Popln Stud.*, **46**, 141–158.
Long, L. H., Tucker, C. J. and Urton, W. L. (1988a) Migration distances, an international comparison. *Demography*, **25**, 633–640.
———(1988b) Measuring migration distances, self-reporting and indirect methods. *J. Am. Statist. Ass.*, **83**, 674–678.
Nam, C. B., Serow, W. and Sly, D. (1990) *International Handbook on Internal Migration.* Westport: Greenwood.
Newbold, K. B. and Bell, M. (2002) Return and onwards migration in Canada and Australia, evidence from fixed interval data. *Int. Migrn Rev.*, **35**, 1157–1184.
Office of Population Censuses and Surveys (1992) *1991 Census Definitions Great Britain.* London: Her Majesty's Stationery Office.
Pandit, K. (1997) Demographic cycle effects on migration timing and the delayed mobility effect. *Geogr. Anal.*, **29**, 187–199.
Plane, D. A. (1993) Demographic influences on migration. *Regl Stud.*, **27**, 375–383.
Plane, D. A. and Mulligan, G. F. (1997) Measuring spatial focusing in a migration system. *Demography*, **34**, 251–262.
Plane, D. A. and Rogerson, P. (1991) Tracking the baby boom, the baby bust and the echo generations, how age composition regulates US migration. *Professl Geogr.*, **43**, 416–430.
Rees, P. H. (1977) The measurement of migration from census data and other sources. *Environ. Planng* A, **9**, 247–272.
Rees, P., Bell, M., Blake, M. and Duke-Williams, O. (2000a) Harmonising databases for the cross national study of internal migration: lessons from Australia and Britain. *Working Paper 00/XX.* School of Geography, University of Leeds, Leeds. (Available from `http://www.geog.leeds.ac.uk/wpapers/00-5.pdf`.)
Rees, P., Bell, M., Duke-Williams, O. and Blake, M. (2000b) Problems and solutions in the measurement of migration intensities, Australia and Britain compared. *Popln Stud.*, **54**, 207–222.
Rees, P. and Kupiszewski, M. (1999a) *Internal Migration and Regional Population Dynamics in Europe: a Synthesis.* Strasbourg: Council of Europe Publishing.
———(1999b) Internal migration: what data are available in Europe. *J. Off. Statist.*, **15**, 551–586.
Rees, P. H., Kupiszewski, M. and Durham, H. (1996) Internal migration and regional population dynamics in Europe: United Kingdom case study. *Working Paper 96/20.* School of Geography, University of Leeds, Leeds. (Available from `http://www.geog.leeds.ac.uk/wpapers/92-20.pdf`.)
Rees, P. H., Stillwell, J. C. H., Convey, A. and Kupiszewski, M. (eds) (1996) *Population Migration in the European Union.* Chichester: Wiley.
Rees, P. H. and Woods, R. (1986) Demographic estimation, problems, methods and examples. In *Population Structures and Models* (eds R. Woods and P. H. Rees), pp. 301–343. London: Allen and Unwin.
Rogers, A. (1975) *Introduction to Multiregional Mathematical Demography.* New York: Wiley.
Rogers, A. and Castro, L. J. (1981) Model migration schedules. *Research Report RR-81-30.* International Institute for Applied Systems Analysis, Laxenburg.
Rogers, A., Raquillet, R. and Castro, L. J. (1978) Model migration schedules and their applications. *Environ. Planng* A, **10**, 475–502.
Rogers, A. and Raymer, J. (1998) The spatial focus of US interstate migration flows. *Int. J. Popln Geogr.*, **4**, 63–80.
Rogerson, P. A. (1987) Changes in US national mobility levels. *Professl Geogr.*, **39**, 344–351.
———(1990) Migration analysis using data with time intervals of differing widths. *Pap. Regl Sci. Ass.*, **68**, 97–106.
Shryock, H. S., Siegel, J. S. and Associates (1975) *The Methods and Materials of Demography.* Washington DC: US Bureau of the Census.
Simpson, S. and Dorling, D. (1994) Those missing millions, implications for social statistics of the undercount in the 1991 census. *J. Socl Poly*, **23**, 543–567.
Stillwell, J. C. H. (1991) Spatial interaction models and the propensity to migrate over distance. In *Migration Models, Macro and Micro Approaches* (eds J. C. H. Stillwell and P. Congdon), pp. 34–56. London: Belhaven.
Stillwell, J., Bell, M., Blake, M., Duke-Williams, O. and Rees, P. (2000) A comparison of net migration flows and migration effectiveness in Australia and Britain: part 1, total migration patterns. *J. Popln Res.*, **17**, 17–38.
Stillwell, J. C. H., Duke-Williams, O. and Rees, P. H. (1995) Time series migration in Britain, the context for 1991 Census analysis. *Pap. Regl Sci.*, **74**, 341–359.
Stillwell, J. C. H., Rees, P. H. and Boden, P. (1992) Internal migration trends, an overview. In *Migration Processes and Patterns*, vol. 2, *Population Redistribution in the United Kingdom* (eds J. C. H. Stillwell, P. H. Rees and P. Boden), pp. 28–55. London: Belhaven.
Thomas, D. S. (1941) *Social and Economic Aspects of Swedish Population Movements, 1750-1933.* New York: Macmillan.
United Nations (1970) *Manuals on Methods of Estimating Population*, manual VI, *Methods of Measuring Internal Migration Population Studies.* New York: United Nations.
White, M. J. (1986) Segregation and diversity measures in population distribution. *Popln Index*, **52**, 198–221.
Wilber, G. L. (1963) Migration expectancy in the United States. *J. Am. Statist. Ass.*, **58**, 444–553.

Wilson, A. G. (1970) *Entropy in Urban and Regional Modelling.* London: Pion.
Wrigley, N., Holt, T., Steel, D. and Tranmer, M. (1996) Analysing, modelling, and resolving the ecological fallacy. In *Spatial Analysis, Modelling in a GIS Environment* (eds P. Longley and M. Batty), pp. 23–40. Cambridge: GeoInformation International.