POPULATION, SPACE AND PLACE
Popul. Space Place 2017;23:e2036
Published online 9 June 2016 in Wiley Online Library
(wileyonlinelibrary.com) **DOI**: 10.1002/psp.2036

The Impact of Internal Migration on Population Redistribution: an International Comparison

Philip Rees[1,*], Martin Bell[2], Marek Kupiszewski[3], Dorota Kupiszewska[4], Philipp Ueffing[5], Aude Bernard[2], Elin Charles-Edwards[2] and John Stillwell[1]

[1]*School of Geography, University of Leeds, Leeds, UK*
[2]*Queensland Centre for Population Research, School of Geography, Planning and Environmental Management, University of Queensland, Brisbane, Australia*
[3]*Institute of Geography and Spatial Organization, Polish Academy of Sciences, Warsaw, Poland*
[4]*Independent Consultant, Warsaw, Poland*
[5]*Population Division, Department of Economic and Social Affairs, United Nations, New York, NY USA*

ABSTRACT

We know that internal migration shapes human settlement patterns, but few attempts have been made to measure systematically the extent of population redistribution or make comparisons between countries. Robust comparisons are hampered by limited data access, different space-time frameworks, and inadequate summary statistics. We use new analysis software (IMAGE Studio) to assess the effects of differences in the number and configuration of geographic zones and implement new measures to make comparisons across a large sample of countries, representing 80% of global population. We construct a new Index of Net Migration Impact to measure system-wide population redistribution and examine the relative contributions of migration intensity and effectiveness to cross-national variations. We compare spatial patterns using the slope of a regression between migration and population density across zones in each country to indicate the direction and pace of population concentration. We report correlations between measures of population redistribution and national development and propose a general theoretical model suggesting how internal migration redistributes population across settlement systems during the development process. Copyright © 2016 The Authors Population, Space and Place Published by John Wiley & Sons Ltd.

*Correspondence to: Philip Rees, School of Geography, University of Leeds, Leeds, UK.
E-mail: p.h.rees@leeds.ac.uk

Accepted 14 April 2016

Keywords: internal migration; population redistribution; international comparisons; index of net migration impact; scale effects; migration and development

INTRODUCTION

It has been possible to compare fertility and mortality in national populations across the world since 1950 using comparable indices such as total fertility rate or life expectancy (UN, 2014a). In recent years, progress has also been made in harmonising international migration statistics (UN, 1998; Poulain *et al.*, 2006; Raymer & Willekens, 2008) and in the development of global estimates of international migration flows (Abel & Sander, 2014). In the case of internal migration, movements from place to place within a single country, cross-national comparisons remain a challenge. Bell *et al.* (2002) proposed a suite of 15 measures designed to capture four discrete dimensions of internal migration for comparisons between countries. Until recently, implementation has been constrained by the lack of readily accessible data for a global sample of countries.

A repository of internal migration data assembled under the Internal Migration Around the GlobE (IMAGE) project has now established the foundation of internal migration and population statistics needed to advance this agenda. Building on an inventory of migration data collections for 193 UN member states (Bell *et al.*, 2015a), an international team of researchers has assembled internal migration data covering 135 countries (Bell *et al.*, 2014) and built a bespoke software platform, the IMAGE Studio, to compute multiple migration indicators using flexible geographies (Daras, 2014; Stillwell *et al.*, 2014). Papers have explored methodological issues (Bell *et al.*, 2013a) and made cross-national comparisons of overall internal migration intensities (Bell *et al.*, 2013b, 2015b) and migration age profiles (Bernard *et al.*, 2014a, 2014b; Bernard & Bell, 2015), globally as well as for selected regions and group of countries (Bell *et al.*, 2012; Charles-Edwards *et al.*, 2016).

The current paper focuses on the spatial impact of internal migration on population redistribution, arguably the most visible and significant aspect of human population movement. The aim of the paper is to explore both the substantive and methodological dimensions of this phenomenon. The key substantive question concerns the role of internal migration in transforming settlement systems, particularly in terms of population concentration and deconcentration, and the way the transformation varies over space and time. Key methodological issues are how to select appropriate measures of internal migration that capture the impact of population shifts, how urban and rural populations are defined, and how to handle the spatial frameworks on which the analysis is based. As with all geographical problems, the analysis of migration data for different zonal systems is affected by the modifiable areal unit problem (MAUP) (Openshaw, 1984). When different numbers, sizes, and shapes of zones are chosen for analysis of internal migration in any country, different results are generated.

We focus on samples drawn from 91 countries covering all continents, representing 80% of the world's population. In the section on the Role of Internal Migration in Population Distribution, we review previous literature and outline a theoretical framework for understanding the role of migration in population redistribution within countries. In the section on Data on Internal Migration, we discuss the difficulties for cross-national comparison arising from differences in data types, observation intervals and territorial geographies, and the problems of access to data. In the section on System-Wide Indicators of Migration Impact, we use the flexible geographies available through the IMAGE Studio to examine the effects of scale and zone design on measures of migration impact. Building on the work of Bell *et al.* (2002), we then propose a new summary measure, the index of net migration impact (INMI), to capture the system-wide impact of migration on population redistribution. We apply the INMI to compare migration impacts across 71 countries, distinguishing the relative contributions of migration intensity and effectiveness, and explore the links to various measures of national development. The sections on Rural-Urban Migration and Net Internal Migration and Population Density examine the patterns of redistribution, focusing first on the role of internal migration in urbanisation. Few countries collect data in a form that clearly allows rigorous measurement and comparison of rural–urban movements so we turn attention to finer levels of spatial scale, focusing on the links between net migration and population density. For selected countries, we also explore temporal trends. The Conclusions section discusses our findings in the context of national development and the urban transition.

THE ROLE OF INTERNAL MIGRATION IN POPULATION REDISTRIBUTION

Perhaps the single most significant aspect of internal migration is that it alters the spatial distribution of population. Internal migration sits alongside births, deaths, and international migration in shaping population change, but as the first demographic transition runs its course and as spatial differentials in vital rates diminish, internal migration plays an increasingly important role. Analysis of the drivers and dynamics of internal migration is critical to understanding the progressive shifts in the pattern of human settlement across the globe. International migration plays an important role in adding to populations in metropolises in the developed world but makes a minor contribution to population redistribution in less developed countries. There are important linkages between internal and international migration in global cities (Sassen-Koob, 1984) through substitution of domestic labour and the migration of immigrants to other parts of the national settlement system (Frey, 1979, 2015). The population accounts needed to distinguish the

DOI: 10.1002/psp

roles of internal and international migration that have been created for European regions (De Beer *et al.*, 2010), but they are not available for most countries of the world.

The role of internal migration in population redistribution was studied by Ravenstein (1885), who explored the flows of lifetime migrants recorded in the 1871 and 1881 censuses of Great Britain and Ireland. He showed how internal migration from rural areas was essential to the growth of industrial cities and towns in Britain, where mortality was high. The lifetime migration measures used by Ravenstein cumulate migration experience over many decades in the 19th century, which saw industrialisation and urbanisation. Equivalent processes have since occurred in countries across the world, so that, by 2011, half of the world's population lived in cities (UN, 2014b). Dyson (2010) argues that urbanisation, like fertility decline, is an inevitable consequence of the fall in mortality that triggered the demographic transition. Keyfitz (1980) demonstrates that city growth is mediated by a complex interplay between natural increase and net migration, but rural to urban migration remains the pivotal process in many countries. For example, in China, rural outmigration has underpinned the massive growth of coastal cities since the 1980s, compensating for falling fertility in urban areas (Shen & Spence, 1996).

There is also a longstanding pattern of migration outwards from city cores to the urban peripheries and beyond, driven by new household formation and facilitated by the development of rail and road transport for commuting. This process of suburbanisation continues in most countries, although in some cities, central re-urbanisation is occurring. In some advanced economies, suburbanisation has spilled over into counter-urbanisation (Champion, 1989), triggered in the 1970s by retirement migrants seeking coastal and countryside locations away from urban congestion but in the 1980s expanding to the working and family ages. Fielding (1989) described the transition to counter-urbanisation in Western Europe and identified a systematic shift in the 1970s. Net migration gains changed from a positive to a negative association with settlement size, reversing a longstanding pattern. Courgeau (1992) showed the trend was sustained into the 1980s using data at the *département* level in France. Rees and Kupiszewski (1999) distinguished the contributions of internal migration, international migration, and natural change to population redistribution in 12 European countries, in the 1980s and 1990s. They found that counter-urbanisation featured only in Western Europe (UK, the Netherlands, and France) and that urbanisation remained dominant elsewhere. In Eastern Europe, rural depopulation and migration to capital cities and other countries continued in the 1990s after the transition from Communism. In Western Europe, the hollowing out of cities through outward migration created new opportunities for city centre revival, led by the service, knowledge, and cultural industries. This growth was driven primarily by international immigration and was counter-balanced by net internal losses (Rees *et al.*, 2010).

Geyer (1996) described the changing relationships between internal migration and population re-distribution across national settlement systems in graphical form as the theory of differential urbanisation. This built on earlier contributions by Berry (1978, 1988); Richardson (1980); Klassen and Scimeni (1981); Long (1985); Champion (1989, 1992); and Geyer and Kontuly (1993). Geyer and colleagues conceived urbanisation as a process occurring in seven stages, each of which exhibited distinctive flows between layers of the settlement system. The schema starts with a primate city stage where lower settlement layers send migrants to the largest city. Growth then spreads down the settlement system, and smaller cities attract migrants. At this stage, the smallest settlements lose internal migrants and the largest settlements gain. When advanced urbanisation has been achieved, a reversal occurs as migration cascades down the urban hierarchy leading in some countries to counter-urbanisation. Smaller places experience positive net migration, while larger places experience negative net migration. This relationship, however, may end and be replaced by renewed gains from migration in primate cities, losses in intermediate (de-industrialising) cities, and continued gains in accessible rural places.

Geyer (1996) reviews the explanations put forward for the migration patterns of each stage and the factors responsible for transition to new stages. The urbanisation and counter-

DOI: 10.1002/psp

urbanisation processes are driven by multiple factors linked to broad economic trends, to waves of technical innovation in production and consumption, and to individual, family, and household preferences and circumstances, related strongly to the life course. Geyer and colleagues tested their theory through a set of empirical case studies that ranged from high-income (Britain and Western Germany) to low-income countries (India and South Africa) (Kontuly & Geyer, 2003a, 2003b). Their theoretical predictions fitted reality in eight of nine cases.

Global forces may impact on internal migration in other ways. As manufacturing in many industrial economies becomes more labour-efficient or less competitive compared with emerging economies, then smaller or more peripheral cities may undergo population decline. Oswalt and Rieniets (2006) report that between 1990 and 2000, a quarter of cities in the world were losing population, mainly through internal migration outflows driven by economic, political, and environmental forces. Internal migration is also motivated by other forces including the desire to settle new lands for farming, as occurred in North America (Zelinsky, 1971), and is still important for resource frontier exploitation in regions as diverse as north-western Australia (iron ore mining) and Kalimantan (oil palm plantations). In parts of East and Southeast Asia, resource exploitation combines with political and defence motives to encourage migration to settlement frontiers.

Despite these complexities, most countries of the world have experienced long running urbanisation through rural to urban migration, and this process continues at a rapid pace in the developing world, especially where high rural fertility generates labour supply in excess of economic opportunities. But, in a small number of countries, this process is being superseded by more subtle migration streams, driving cycles, or sequences of suburbanisation, counter-urbanisation, or re-urbanisation. Interregional population flows underpin a shifting mosaic of growth and decline as individual regions compete in the national, and increasingly in the international, space economy. While these forces inevitably play out in complex ways in individual countries depending on their history and context, internal migration invariably plays a pivotal role. In the final part of our paper, we build on the work outlined here in offering a schematic framework of change in the relationship between net migration and population density over the development transition in countries across the world. If common patterns in regard to the role of internal migration are to be identified, however, what is first required is the application of rigorous measures across a large sample of countries spanning the entire development spectrum.

DATA ON INTERNAL MIGRATION

Cross-national comparisons of internal migration face impediments in regard to the types of data collected, the intervals over which migration is measured, and the spatial frameworks employed (Bell *et al.*, 2002). An allied problem is the limited availability of migration data, as data collection does not guarantee dissemination (Bell *et al.*, 2014). These issues have been explored in detail elsewhere (Bell *et al.*, 2002, 2015a), so this section confines attention to the way measurement differences bear on cross-national comparisons of migration impact. It then describes the migration data assembled for analysis in the present paper.

Migration data are collected in several ways. The main distinction is between data capturing migration events, associated with population registers, and data on migration transitions, derived by comparing place of residence at two points in time, which are generated from population censuses. Events count migrations, while transitions count migrants. Over short intervals, the number of migrants closely matches the number of migrations, but as the observation interval lengthens, transitions increase more slowly because a rising proportion of migrations are made by return or repeat movers. While this difference is important for computation of migration intensities, its effects cancel out when calculating area-specific net migration (Rees, 1985) and are negligible when migration is measured over a single year (Long & Boertlein, 1990). As a result, event and transition data reveal the same spatial pattern of net population redistribution, provided there are no differences in population coverage and reporting. Because population registers are common in Europe and Asia but rare in Latin America and Oceania (Bell *et al.*, 2014), we draw migration data from both

DOI: 10.1002/psp

population registers and censuses in order to maximise geographic coverage.

Migration events are usually measured over a single year, while migration transitions can be measured over any time interval, although the most common are 1 and 5 years (Bell *et al.*, 2014, 2015a). The longer the transition interval, the greater the potential effect of repeat and return migration, so care is needed in comparing migration intensities measured over intervals of different length. While migration flows covering different measurement intervals cannot be compared reliably, the effects cancel out for net migration so that measures can be converted to common intervals (Long & Boertlein, 1990). In practice, size and composition of the population at risk alter over time and the contextual forces driving migration also change, so that migration over any single-year interval is unlikely to be representative of the longer interval. It can be argued, therefore, that 5-year transition data provide a more realistic picture of the underlying flows and net redistribution of population. However, the 5-year data are collected and made available by only a minority of statistical agencies. We therefore compare countries separately in groups with the same measurement interval. Many censuses around the world also collect data on duration of residence, usually in association with a question on previous place of residence (Bell *et al.*, 2015a). By filtering migration data for a given duration of residence, it is possible to derive migration flows broadly comparable with conventional migration transitions. To maximise the number of case study countries, we also draw on last residence data, coupled with residence duration. Censuses also commonly collect data on lifetime migration by comparing region of current residence against region of birth (Bell *et al.*, 2015a). Lifetime migration, however, inherits the cumulative impact of moves aggregated over a miscellany of ages and time intervals, which prejudices comparability and offers a poor picture of contemporary patterns and trends. We therefore restrict attention to migration over 1-year and 5-year intervals.

Even where countries collect the same type of data over equivalent observation intervals, comparisons are made difficult by differences in the number and pattern of spatial units into which countries are divided (the MAUP). Comparing migration intensities among 96 countries, Bell *et al.* (2015b) explored and addressed the effects of the MAUP by harnessing the IMAGE Studio, a software algorithm designed to generate multiple random aggregations of geographic units at a range of spatial scales (Stillwell *et al.*, 2014). Issues of scale and zonation loom equally large in comparison of countries with respect to the spatial impact of internal migration. In Nepal, for example, the census collects data on migration between 74 districts, whereas in the UK, census data are available for movements between more than 10,000 wards. In this paper, we take as our starting point the migration data for basic spatial units that are available and manageable in each country. We examine the effect of the MAUP by generating system-wide measures of migration impact at a range of spatial scales using the IMAGE Studio. We focus in particular on the aggregate net migration rate, migration effectiveness index, and crude migration intensity, which are defined in the following section.

Although these system-wide measures provide summary indices of migration impact, they contain no information on its spatial form, so we then consider spatial patterns of net internal migration. Particular interest attaches to the role of migration in the process of urbanisation, so we examine the scale and intensity of rural–urban migration in countries around the world. Such comparisons are seriously prejudiced by cross-national differences in the definition of urban and rural areas, but an equally intractable problem is that few countries classify both the origin and destination of migrants by rural/urban status. Urban and rural areas are, in any event, coarse spatial categories so, following Rees and Kupiszewski (1999), we also utilise the more detailed geographies of migration available in each country to examine the relationship between net migration and population density.

Differences in data collection practice are complicated by issues of data availability, as countries rarely make migration statistics readily available. To address this deficit, the IMAGE project has assembled a global repository of internal migration data (Bell *et al.*, 2014, 2015a). The IMAGE Repository houses internal migration data for 135 countries and includes a

DOI: 10.1002/psp

variety of data types (event, transition, and duration), measured over intervals of different lengths (1 year, 5 years, and duration of residence) and held in varied formats (counts of migrants by type of flow, aggregate inflows and outflows, and origin–destination flow matrices), with the precise nature of the holdings determined by the nature of the data collected and made available in each country. The Repository also incorporates data for each country on populations at risk and digital boundaries of the spatial units. For many countries, flow matrices are available at multiple spatial scales corresponding to particular levels of administrative or statistical geography. For the purposes of this paper, we not only draw on the most finely grained geography available in each country but we also utilise information on flows between rural and urban areas where these are available (Table 1). The principal dataset takes the form of migration flow data for 88 countries of which 37 measure migration over a 1-year interval and 57 over a 5-year interval. Six countries, Australia, Canada, Japan, Portugal, Spain, and the US, collect data for both intervals so we have 94 flow matrices. Together, these countries account for almost half of all UN member states and nearly 80% of the world's population. Our sample covers more than two-thirds of countries in Europe, Latin America, and North America, but only one-quarter of countries in Africa and Oceania and two-fifths of those in Asia. Bell *et al.* (2014) set out in detail the data available in each country, indicating the collection year, number of spatial units, data type, interval of observation, and data format. The data used in this paper derive primarily from the 2000 round of censuses (UN, 2015), which vary in timing from 1995 to 2004, with a concentration in 2000 and 2001. The 5-year data and the 1-year census data refer to 5 and 1 years prior to the census. The 1-year register data are the most recent available data from the period 2001–2013. So the exact time footprints differ across countries, but we can say that in general, the migration data refer to the period immediately before or shortly after the start of the new millennium.

SYSTEM-WIDE INDICATORS OF MIGRATION IMPACT

Across any system of sub-national regions, the overall impact of net migration on the pattern of settlement is most effectively captured in the aggregate net migration rate (ANMR), defined as half the sum of the absolute net changes aggregated across all regions, divided by the population at risk (Bell *et al.*, 2002):

$$\text{ANMR} = 100 \times 0.5\sum_i |D_i - O_i| / P \qquad (1)$$

The variables D_i and O_i are inflows to and outflows from region i, and P is the population summed across all regions. The ANMR thus measures the impact of migration on population redistribution: it identifies the net shift of population between regions per hundred persons resident in the country. The ANMR, in turn, is a product of the crude migration intensity (CMI) and the migration effectiveness index (MEI) such that

$$\text{ANMR} = \text{CMI} \times \text{MEI}/100 \qquad (2)$$

Table 1. Number of countries by data types and region.

Region	Urban-rural migration	Regional OD matrices or aggregate inflows and outflows: 1-year interval	Regional OD matrices or aggregate inflows and outflows: 5-year interval	Coverage (countries with one or more datasets)	Coverage of UN countries (%)
Africa	3	3	11	15	28
Asia	11	3	13	18	43
Europe	9	28	5	30	67
Latin America	1	0	21	21	69
North America	0	2	3	3	100
Oceania	1	1	4	4	29
Total	25	37	57	91	48

Source: IMAGE Repository (Bell *et al.*, 2014, 2015a)

DOI: 10.1002/psp

where

$$\text{CMI} = 100 \times M/P \tag{3}$$

$$\text{MEI} = 100 \times 0.5\sum_i |D_i - O_i|/M \tag{4}$$

and

$$M = \sum_i (D_i) = \sum_i (O_i) \tag{5}$$

The CMI represents the overall incidence, or level of internal migration within a country, indicating the propensity to move. The MEI indicates the effectiveness (or efficiency) of migration as a mechanism for population redistribution by comparing net migration with migration turnover; it quantifies the spatial imbalance between migration flows and counter-flows. Low values of MEI are found when migration streams and counter-streams are closely balanced, while high values indicate asymmetry across the system, with some regions gaining population at the expense of others (Shryock *et al.*, 1976).

It follows from equation 2 that the same impact of migration on population redistribution, as measured by the ANMR, may be achieved either through high MEI combined with low CMI or vice versa. Data for Canada and Australia provide a case in point. Based on 5-year migration data, Canada (2006, 288 regions) and Australia (2011, 333 regions) both returned ANMRs of 1.8%, but the MEI for Canada (15.0) was almost twice that of Australia (8.6), while for CMI, values for the two countries were 11.8 for Canada and 21.2 for Australia.

Observed CMI is dependent on spatial scale: the larger the number of zones over which migration is measured, the higher the apparent intensity. Courgeau (1973a) demonstrated that the CMI is a log-linear function of the number of regions into which a territory is divided, and Courgeau *et al.* (2012) show it is also a log-linear function of the average number of households per region. Bell *et al.* (2015b) used the latter relationship to generate estimates of the aggregate CMI, representing all changes of address, for 96 UN member states which collectively house 80% of the world's population. The authors utilised the IMAGE Studio (Stillwell *et al.*, 2014) to generate CMIs for a cascading sequence of zonal aggregations, beginning with the finest level of geography, termed basic spatial units (BSUs), available in the country-specific origin–destination flow matrix and progressively aggregating upwards in user-defined increments. At each spatial level, the algorithm creates a series of spatial configurations by stepwise aggregation of BSUs into aggregate spatial regions (ASRs) of varying shapes and sizes. Multiple iterations at each spatial level provide a range of random spatial configurations. A suite of migration indicators proposed by Bell *et al.* (2002) are then computed for each configuration at a given level, and the results are averaged before repeating the process at the next level of aggregation. The result is a sequence of migration indicators estimated for the selected levels of spatial aggregation – for example, from 200 to 20 ASRS, using intervals of 10. The change in the mean value of the indicator indicates the scale effect of the MAUP, while the variation around the mean reveals the zonation effect. Bell *et al.* (2015b) used the IMAGE Studio to examine the effects of the MAUP on the CMI, and Stillwell *et al.* (2016) explore its impacts on the frictional effects of distance. Here, we utilise the IMAGE Studio to examine the relationship between the CMI, MEI, and ANMR in different countries at various levels of scale.

In Figure 1, values are plotted for the three indicators at various spatial scales for selected countries, which measure migration over 5-year intervals, plotting the number of regions on the horizontal axis in the graphs on the left and the common logarithms of the number of regions on the graphs on the right. Moving from right to left along each graph reveals the effect on the indicator of progressive aggregation into fewer, larger spatial units. The different starting points on the right of the graph reflect variations between countries in the finest level of geography, for which migration data were available, but have been truncated to facilitate readability for countries with a very large matrix such as Ecuador. The points at the left end of each graph indicate the final level of aggregation in the IMAGE Studio computation for each country.

The most striking feature of the graphs is the small degree of variation in the MEI with changes of geographic scale. The level of the MEI differs markedly between countries, but for most, it is largely invariant with spatial scale when computed for 20 regions or more. This result has two important implications. First, it suggests that, for a given volume of migration, the extent of

DOI: 10.1002/psp

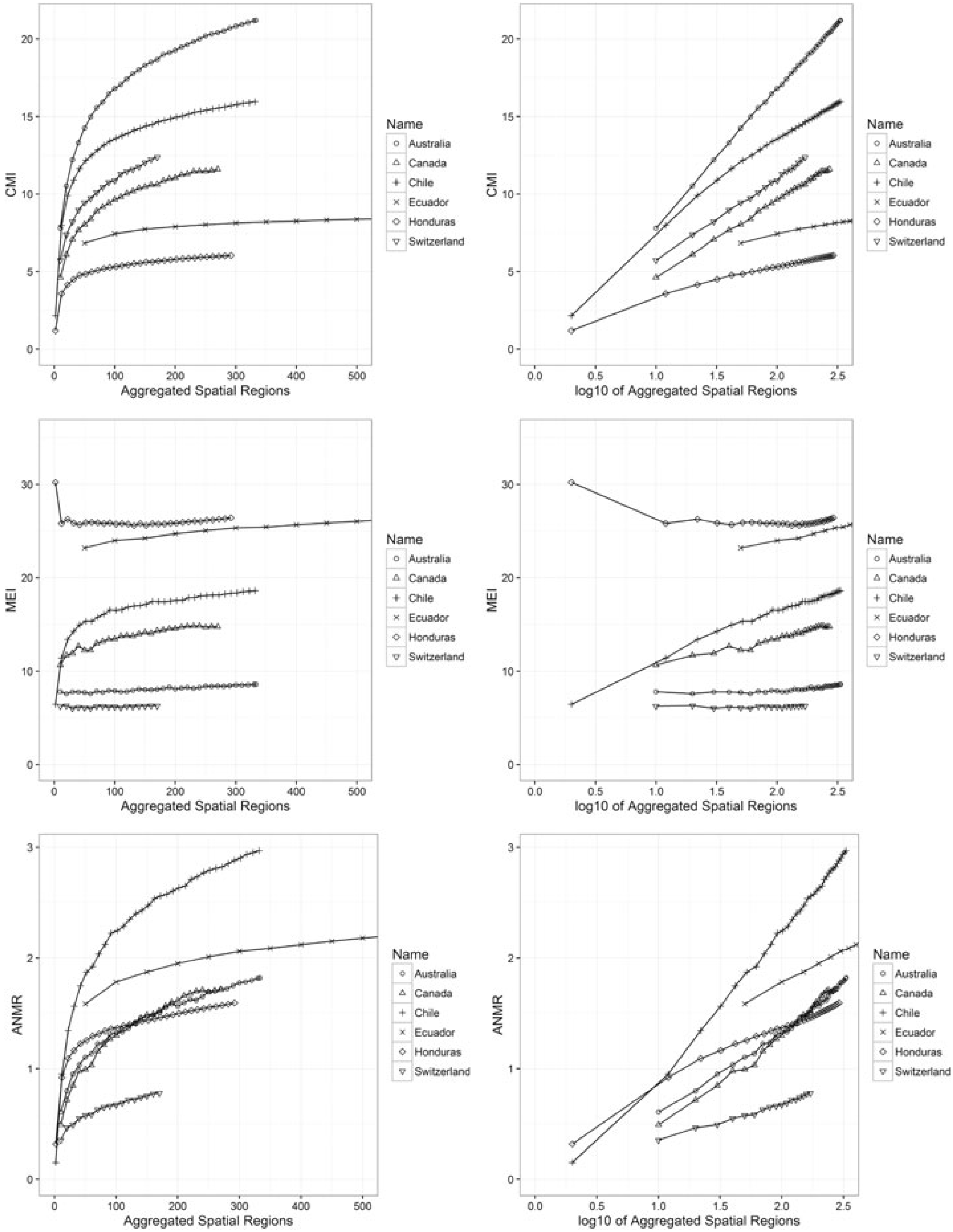


Figure 1. Migration intensity, migration effectiveness and the aggregate net migration rate, as a function of the number of spatial units, selected countries that measure migration over a 5-year interval.

DOI: 10.1002/psp

population redistribution within a country tends to be similar at a range of geographic scales: countries in which significant redistribution is occurring between regions tend also to record high levels of population redistribution at the sub-regional and local level. Only at the level of less than 20 ASRs, such as states and provinces, does this relationship falter. Processes of population redistribution within countries therefore tend to be echoed across the geographic spectrum. A second consequence of this stability in the MEI is that reliable comparisons can be made between countries even when migration data are recorded at different levels of spatial scale. In this respect, findings for the MEI match those reported by Stillwell *et al.* (2016) for distance decay, which also appears largely invariant with spatial scale, and contrast sharply with those for the CMI, which varies systematically with scale, as Figure 1 clearly shows.

Figure 2 ranks countries on the median *MEI,* computed for an incremental sequence of scale steps, starting from a minimum of 20 ASRs. Disregarding those countries, for which data are available only for fewer than 20 regions, leaves 47 countries that collect data over a 5-year interval and 24 that collect 1-year data. The boxplots reveal the remarkable degree of consistency in the MEI across spatial scale in the majority of countries. Only a small number have extensive whiskers (indicating a wide spread of possible values). Even countries such as El Salvador, Mexico, and Burkina Faso, which display a relatively large interquartile range, can be reliably positioned in the international league table with respect to migration effectiveness. For

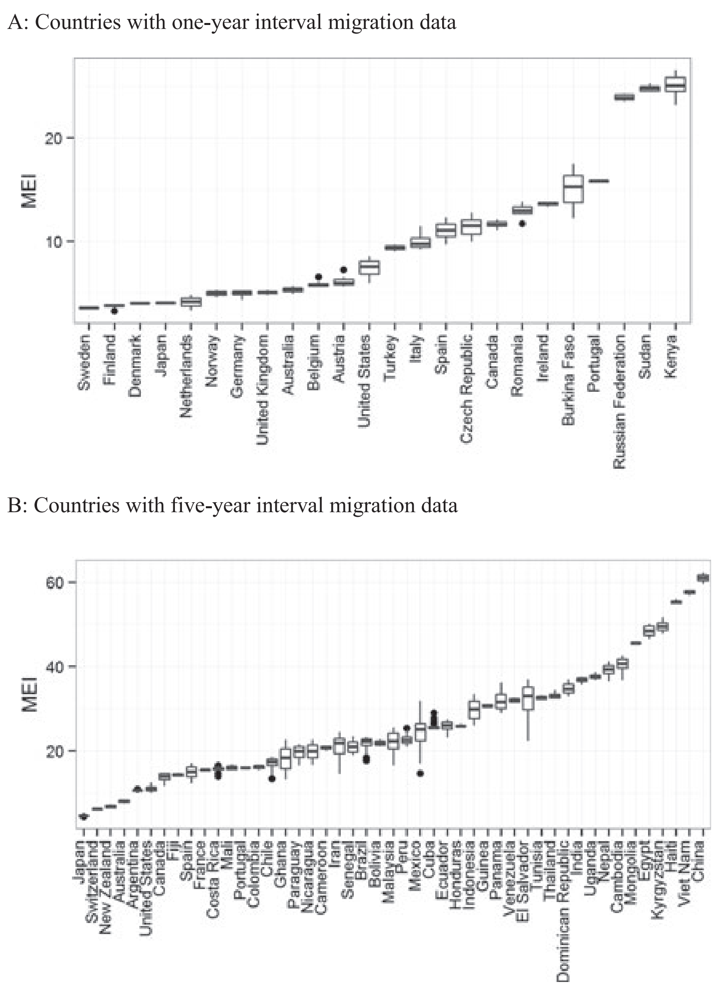


Figure 2. Boxplots of migration effectiveness.

DOI: 10.1002/psp

1-year intervals, the MEI varies from 3.5 in Sweden to 33.7 in Kenya. For 5-year transitions, the range is even larger: from 4.6 in Japan to 61.0 in China. The results show a distinctive geographic distribution with low values of MEI in North America, Australasia, northern and western Europe; grading to moderate values in eastern Europe, southwest Asia, and the Russian Federation; and rising to a peak in South and East Asia. Africa displays a patchwork of moderate to high values, whereas in Latin America, there is a clear upwards gradient moving northwards from Chile and Argentina to Central America.

The MEI itself provides useful insights into the role of migration in population redistribution because it measures the extent to which inter-regional flows are balanced by counter-flows, but it is the ANMR that captures the overall impact of migration on the settlement system. The ANMR cannot be used to make cross-national comparisons directly because it is affected by the CMI, which varies with spatial scale. As the number of spatial units increases, there is a parallel rise in migration intensity and hence in the ANMR, because the division into finer spatial frameworks progressively captures more short distance moves. However, by capturing the functional forms depicted in Figure 1, it is possible to develop a generalised version of equation 2 to deliver a composite index that enables systematic comparisons of overall migration impact to be made.

Following Courgeau, we know that logarithmic transformation of the *x* axis delivers a linear relationship with the CMI, and this holds whether spatial scale is expressed in terms of number of units (Courgeau, 1973a) or mean household density (Courgeau *et al.*, 2012). The Figure 1 analysis has also established that the MEI is broadly constant as BSUs are aggregated into ASRs with higher numbers of regions. We can fit the following regression models to the indicators, dropping the 100 constant used earlier for clarity:

$$\text{CMI} = a_1 + b_1 log_{10} n \tag{6}$$

$$\text{MEI} = a_2 + b_2 log_{10} n \tag{7}$$

$$\text{ANMR} = a_3 + b_3 log_{10} n \tag{8}$$

where n is the number of spatial units. The task is to establish the relationship between the parameters of these three models. Substituting into equation 2, we obtain

$$a_3 + b_3 log_{10} n = \left(a_1 + b_1 log_{10} n\right) \times \left(a_2 + b_2 log_{10} n\right) \tag{9}$$

Because internal migration is zero when only one spatial unit is used, the intercepts for equations 6 and 8 by definition are zero; that is, $a_1 = 0$ and $a_3 = 0$. Accepting that the MEI is largely invariant with scale, above a threshold of *circa* 20 regions, allows us to adopt the approximation that $b_2 =$ zero, so that

$$b_3 log_{10} \text{n} = \left(b_1 log_{10} n\right) \times (a_2) \tag{10}$$

and dividing through by $log_{10} n$ on both sides, this simplifies to

$$b_3 = a_2 b_1 \tag{11}$$

Thus, the slope of the ANMR (b_3) against $log_{10} n$ is a product of the average MEI (a_2) and the slope of the CMI (b_1). We cross-checked results for the value of b_3 calculated as a product of $a_2 b_1$ against the measured slope of b_3 and found a correlation coefficient (Pearson r) of 0.99986 across 70 countries. Cross-national comparisons of migration impact that incorporate the effects of both migration intensity and effectiveness can therefore be made using the slope of the ANMR, and this in turn can be estimated directly from the slope of the CMI and from the MEI computed for any number of regions. As with Courgeau's (1973a) contribution to comparisons of migration intensity, the resulting measure b_3 (the modelled slope of the ANMR) is directly scalable and decomposable into contributions from CMI and MEI. This is therefore eminently suited to comparisons of migration impact between countries or over time.

To facilitate comparisons, it is useful to adopt a benchmark to serve as a point of reference. While any single country might serve this purpose, we adopt the mean across our sample of countries as the point of reference, computed separately for 1-year and 5-year data. We calculate the ratio of CMI slope for a country to the average slope for all countries, where number of areas used, n, is equal to or greater than 20. We compute the ratio of mean MEI for a country to the average of mean MEIs over all countries in the sample. We then multiply these two ratios to generate an INMI. This is defined formally as

DOI: 10.1002/psp

$$\text{INMI} = \left[\frac{\text{CMI slope for a country}}{\text{Average CMI slope for all countries}}\right] \times \left[\frac{\text{Mean MEI for a country}}{\text{Average MEI for all countries}}\right] \quad (12)$$

Index of net migration impact is computed for all countries where ASRs are >20. Values for countries with 1-year and 5-year data are plotted in Figure 3.

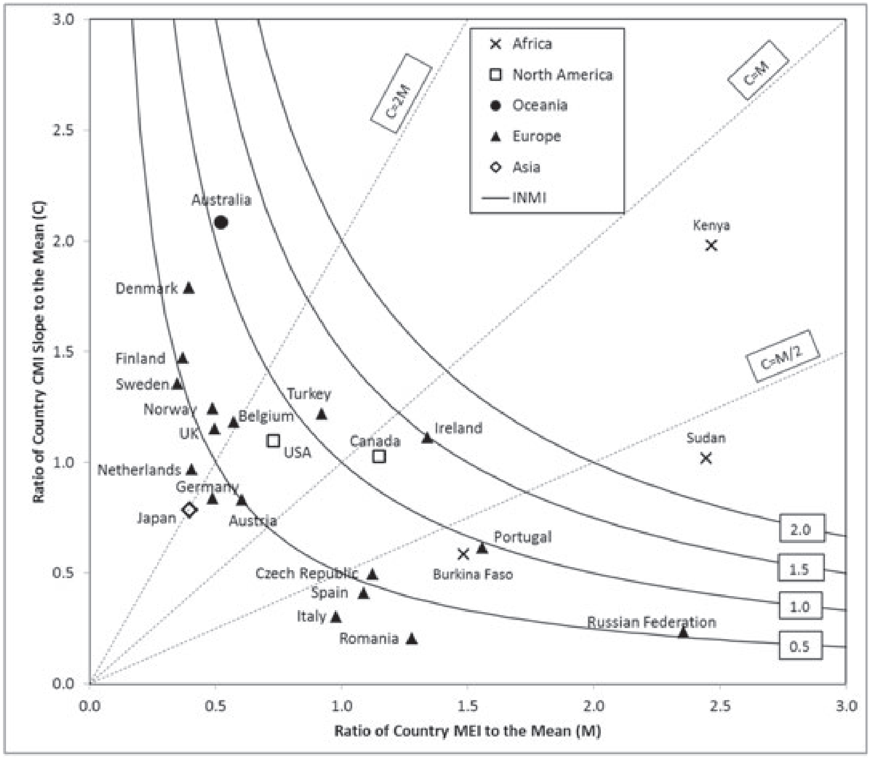
Because the INMI is the product of two ratios (as was the modelled ANMR), we are able to make robust comparisons between countries in regard to aggregate population redistribution, distinguishing the relative contributions of migration intensity and migration effectiveness. Figure 3(A and B) displays the results in a simple scatterplot, setting the ratio of the MEI against the ratio of the CMI slope. The surface of the plot therefore represents the INMI for each country, and the contour lines (0.5, 1.0, 1.5, and 2.0) link points of equal migration impact. Values of INMI above one indicate that the effect of migration in redistributing population is above the average, while values below unity denote an effect below the average. The radial lines emanating from the origin help to divide the plot and signify the relative contributions of the MEI and the CMI, with the principal diagonal dividing the plot at a point where the two factors exert an equal effect on population redistribution. Thus, in the graph of 5-year migration countries (Fig. 3B), it can be seen that Mongolia records the highest migration impact, driven equally by above average MEI and CMI. For both Cameroon and Viet Nam, the impact is somewhat lower, at a little under 1.5 times the sample mean, but the sources are quite different. For Cameroon, population redistribution is due to high intensity, whereas in Viet Nam, lower intensity is compensated by high migration effectiveness. We note that the Figure 3 plots are based on overall modelled empirical relationships for all countries in the sample rather than precise accounting relationships for a particular country.

In countries that record migration over a single-year interval, Kenya and Sudan stand out with the highest levels of population redistribution, followed by Ireland, Canada, Turkey, and Australia, while Japan, Italy, and Romania have the lowest. The remaining countries are less strongly differentiated in terms of the INMI, but the plot reveals that this masks two distinctive clusters with quite different drivers. On the one hand, there is a cluster of southern and eastern European countries, together with Burkina Faso, where migration effectiveness is above the mean but the impact on population redistribution is offset by comparatively low levels of migration intensity. In these countries, the radial grid indicates that intensity contributed less than one quarter of the aggregate INMI. On the other hand, there is an extended cluster of countries from northern and western Europe, together with Japan and the US, in which relatively high levels of migration intensity are absorbed in reciprocal exchanges, resulting in low migration effectiveness, which constrains the extent of population redistribution.

The 5-year data encompass a broader geographic spectrum of countries, but some spatial patterns are still clearly apparent. Most distinctive here is that the low levels of migration intensity that are found across much of Asia (see Bell *et al.*, 2015b) are generally compensated by high levels of migration effectiveness (China, Viet Nam, Nepal, and India). Thus, although the propensity to migrate is low, the movements that do take place are more likely to result in a net shift of population between areas within the country. Latin America displays greater diversity, with low effectiveness offsetting high intensity in Chile, Costa Rica, Bolivia, and Paraguay; a cluster of countries a little below the mean on both drivers (Peru, Ecuador, Columbia, and Brazil) generating below average INMI; and a group in Central America (El Salvador, Dominican Republic, Cuba, Honduras, and Mexico) where it is low intensities that constrain redistribution. Data for Africa are sparse but reveal relatively low levels of migration impact in Egypt, Mali, and Ghana, but more substantial redistribution in Guinea, Senegal, Tunisia, Uganda, and Cameroon. What is common to both the 1-year and 5-year datasets is a general tendency for high migration effectiveness to be offset by low migration intensity (the Russian Federation, 1-year; China, 5-year) or vice versa (Australia, 1-year; New Zealand, 5-year). It is only a minority of countries in which both drivers are either well below (Argentina, 5-year; Mali, 5-year) or well above (Kenya, 1-year; Mongolia, 5-year) the mean.

DOI: 10.1002/psp

A: Countries with one-year interval migration data



B: Countries with five-year interval migration data

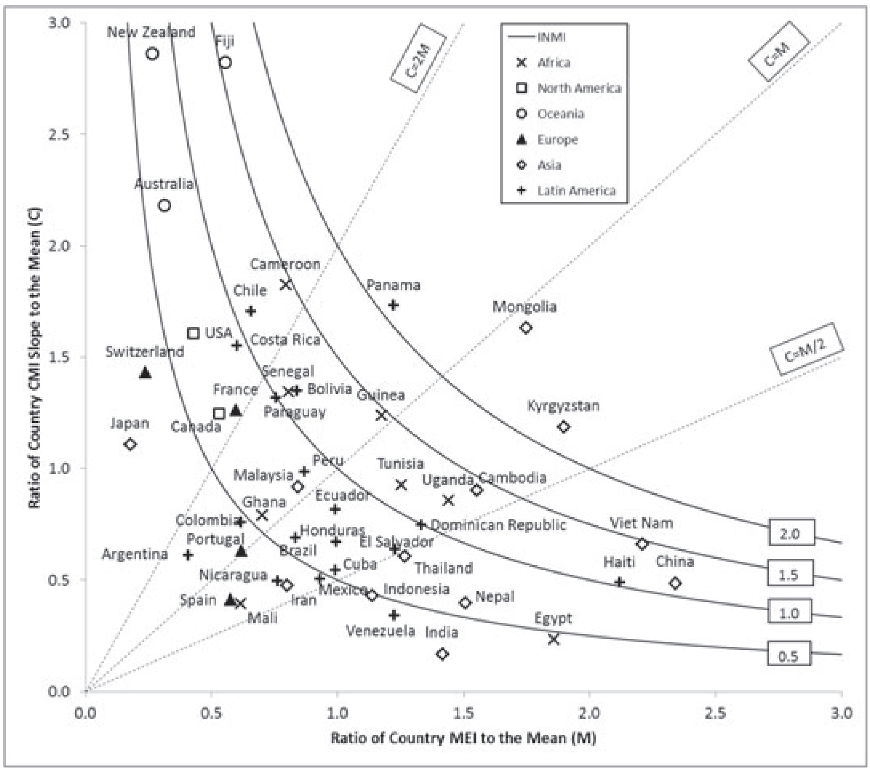


Figure 3. Index of net migration impact.

DOI: 10.1002/psp

As noted earlier, we have both 1-year and 5-year census-based migration data for just six countries (Australia, Canada, Japan, Portugal, Spain, and the US). CMIs for these six are significantly higher using the 5-year data because migration flows over 5 years are larger, although the ratio of 1-year to 5-year intensities is not identical because period effects alter migration propensities. Values of the MEI, on the other hand, are broadly comparable (Fig. 2), being just slightly higher over a 5-year period because of the cumulative effect of regionally selective migration. As a result, the six countries occupy broadly similar positions on both the 1-year and 5-year charts (Fig. 3).

Bell *et al.* (2015b) reported a moderate association between migration intensity and a range of development indicators across a large sample of countries. Table 2 reveals more modest correlations for the countries examined here, especially for countries that collect data over a single year. However, both datasets deliver strong correlations with the two measures of migration impact: the mean MEI and INMI. Computed across the 24 countries that collect 1-year migration data and the 47 countries for which we have 5-year data, there is a significant inverse association with the level of urbanisation, the Human Development Index (HDI), and GDP per capita. The associations are consistently stronger across the 1-year sample and stronger with the MEI than with the INMI. The 5-year sample also shows a modest, significant negative correlation with the international migration rate, suggesting that international migration tends to substitute for internal migration and therefore reduces the impact of internal migration within this group of countries.

In practice, there are theoretical reasons to doubt that the relationship between migration impact and development is linear, and Figure 4 confirms that many functions might fit equally well. Following the ideas outlined by Geyer (1996) and Geyer and Kontuly (1993), one possibility is an inverted U-shaped curve, reflecting a relationship similar to that identified by Kuznets (1955) where income inequality rises and then falls with development. In the case of migration, it is likely that population movement responds to regional economic differentials, triggering a rise in migration intensity and a growing imbalance in inter-regional flows as economic development proceeds at an uneven pace, followed eventually by a return to more symmetrical flows as the urban transition comes to a close and regional disparities erode. The third-order polynomial fitted to data for the 47 countries that collect 5-year migration statistics (Fig. 4) traces the theoretical relationship between the MEI and the HDI.

RURAL–URBAN MIGRATION

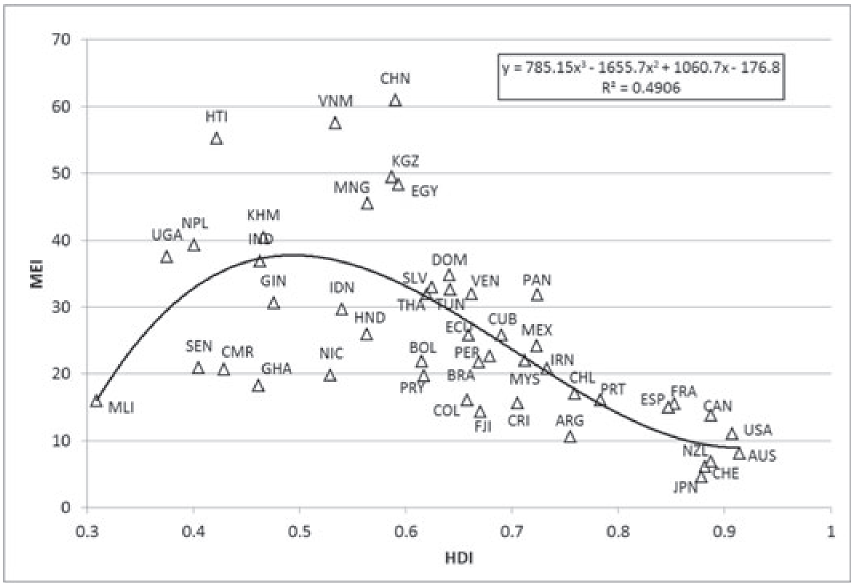
The aggregate measures discussed in the previous section provide summary indicators of the strength of migration impact on overall population redistribution but provide no information as to their spatial manifestation. In this section, we focus on the role of migration in urbanisation, arguably the most visible,

Table 2. Correlation (Pearson r) between measures of migration impact and selected development indicators.

	One-year data			Five-year data		
Development indicator	CMI slope (b_1)	MEI mean (a_2)	INMI (b_3)	CMI slope (b_1)	MEI mean (a_2)	INMI (b_3)
Urbanisation	0.133	−0.773***	−0.648***	0.273*	−0.609***	−0.290**
HDI	0.087	−0.738***	−0.577***	0.370**	−0.570***	−0.243*
International migration rate	−0.061	−0.217	−0.214	−0.054	−0.358**	−0.322**
GDP per capita	0.282	−0.743***	−0.461**	0.328**	−0.595***	−0.365**

Source: Authors' computations using the IMAGE database (Bell *et al.*, 2014)
Notes:
CMI, crude migration intensity; MEI, migration effectiveness index; INMI, index of net migration impact; HDI, human development index; GDP, gross domestic product.
1-year data, $n = 24$ countries; 5-year data, $n = 47$ countries.
Significance
***$p < 0.001$,**$p < 0.05$,*$p < 0.1$

DOI: 10.1002/psp



Key to the countries

ARG	Argentina	CUB	Cuba	HTI	Haiti	MYS	Malaysia	THA	Thailand
AUS	Australia	DOM	Dominican Rep.	IDN	Indonesia	NIC	Nicaragua	TUN	Tunisia
BOL	Bolivia	ECU	Ecuador	IND	India	NPL	Nepal	UGA	Uganda
BRA	Brazil	EGY	Egypt	IRN	Iran	NZL	New Zealand	URY	Uruguay
CAN	Canada	ESP	Spain	JPN	Japan	PAN	Panama	USA	United States of America
CHL	Chile	FJI	Fiji	KGZ	Kyrgyzstan	PER	Peru	VEN	Venezuela
CHN	China	FRA	France	KHM	Cambodia	PRT	Portugal	VNM	Viet Nam
CMR	Cameroon	GHA	Ghana	MEX	Mexico	PRY	Paraguay		
COL	Colombia	GIN	Guinea	MLI	Mali	SEN	Senegal		
CRI	Costa Rica	HND	Honduras	MNG	Mongolia	SLV	El Salvador		

Figure 4. Migration effectiveness index (MEI) and the human development index (HDI), countries with 5-year interval migration data.

widespread, and significant form of population redistribution within countries. Despite its widely recognised significance, the IMAGE Inventory revealed that few countries measure urban–rural migration directly (Bell *et al.*, 2015a). Few censuses ask respondents to indicate whether their place of previous residence was rural or urban, and *post hoc* classifications are unreliable because the geographic zones used by statistical agencies seldom provide a clear distinction between rural and urban areas. Rural–urban migration is also commonly collected in national sample surveys, such as USAID's Demographic and Health Survey and the World Bank's Living Standards Measurement Study, but cross-national comparisons are prejudiced by sample sizes, definitional differences, and population coverage. The Demographic and Health Survey, for example, is confined to women aged 15–49 years. The analysis here is based on data for 25 countries that provide complete two-by-two matrices of flows between urban and rural areas, delimited according to official national definitions.

The direction and magnitude of the flow between rural and urban areas are most readily captured by the migration effectiveness ratio (MER_{RU}), computed as

$$MER_{RU} = 100 \times (M_{RU} - M_{UR})/(M_{RU} + M_{UR}) \quad (12)$$

where M_{RU} denotes the migration flow from rural to urban areas and M_{UR} is the migration flow in the reverse direction. MER_{RU} represents the net shift of migrants towards or away from urban areas per hundred migrants crossing the urban/rural boundary and is positive when urban areas gain and negative otherwise. The ratio has limits of plus and minus 100, with

DOI: 10.1002/psp

smaller absolute values indicating that flows to and from urban areas are closely balanced. Countries with high positive values of MER_{RU}, signifying ongoing urbanisation, are located principally in South and Southeast Asia. Counter-urbanisation processes, signified by negative values of MER_{RU} are most prominent in European post-Soviet countries.

Figure 5 presents the shares of each of the four flows: urban–urban, rural–urban, urban–rural, and rural–rural, sorted by the direction and magnitude of the net flow from rural to urban areas, as measured by the rural–urban MER_{RU}. Countries differ widely in the mix of flows. Overall, urban to urban flows are the most important set, which is not surprising given that urban dwellers now represent a majority of the world population. In New Zealand, 80% of migration is within the urban subsystem, whereas rural–rural migration dominates in Timor, India, Cambodia, and Swaziland. In 15 of the 25 countries, migration results in the net transfer of population from rural to urban areas, but in the remaining ten, the rural areas gain.

There is a moderate negative correlation ($r = -0.66$) between MER_{RU} and the level of urbanisation across the 25 countries, suggesting that rural to urban migration is closely linked to the urban transition. Countries at an earlier stage in the transition, such as India and Indonesia, are undergoing rapid urbanisation through rural to urban migration, while those with high proportions resident in urban areas, such as Estonia and Poland, are registering net losses, indicating a predominance of counter-urban migration.

Urbanisation, growth in the size and share of the population living in urban places, results from the interplay of natural increase, domestic and international migration and is also affected by changes in definition and reclassification as expanding cities absorb rural settlements. The strength of these processes varies widely between

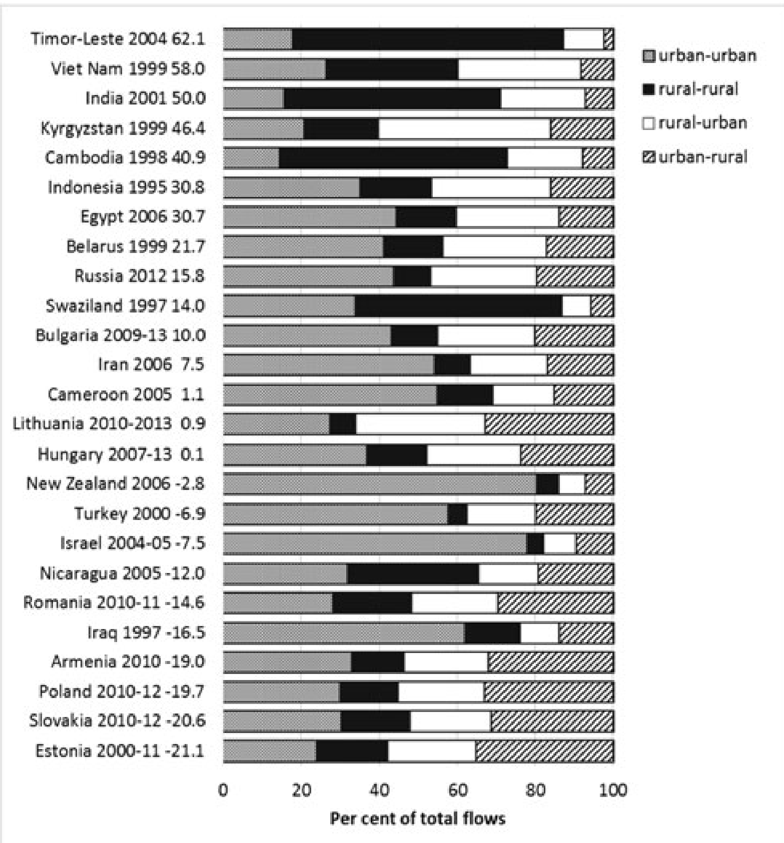


Figure 5. Shares of migration between rural and urban areas for selected countries ranked by migration effectiveness.

DOI: 10.1002/psp

countries, and few maintain the detailed population accounts that are needed to distinguish their relative contributions to changes in settlement geography. Cross-national comparisons are further impeded by differences in the way that 'rural' and 'urban' areas are defined and the criteria that are used, which variously include population thresholds, administrative status, morphology, accessibility, and functionality. As a result, rural–urban migration in Mali has a meaning quite different from that in China. The urban-rural dichotomy is too simplistic as a framework for comparing the spatial impacts of internal migration in different countries. While attempts have been made to define settlement hierarchies and classifications that have universal application (Champion *et al.,* 2003), none has been adopted by countries worldwide.

NET INTERNAL MIGRATION AND POPULATION DENSITY

One solution is to use population density as a proxy for urban/rural classification and to analyse cross-national differences in the impact of internal migration on sub-national zones according to their various levels of density. Rees and Kupiszewski (1999) applied this approach to 12 European countries using data for various administrative zones classified into density bands. Courgeau (1992) adopted a similar approach but calibrated the relationship between the net migration rate (NMR) and the logarithm of population density for individual zones by fitting a linear regression model. This was implemented using observations for 190 zones of metropolitan France (95 *départements* split into rural and urban components) for four inter-census periods. Figure 6A reproduces Courgeau's results and Figure 6B adds results for subsequent inter-census intervals for 95 *départements*, maintaining the same vertical scale to facilitate comparison. The regression line for the period 1975–1982 appears in both graphs, and the similarity of the slopes gives confidence to estimate regression in countries where the spatial units are not classified into rural and urban parts.

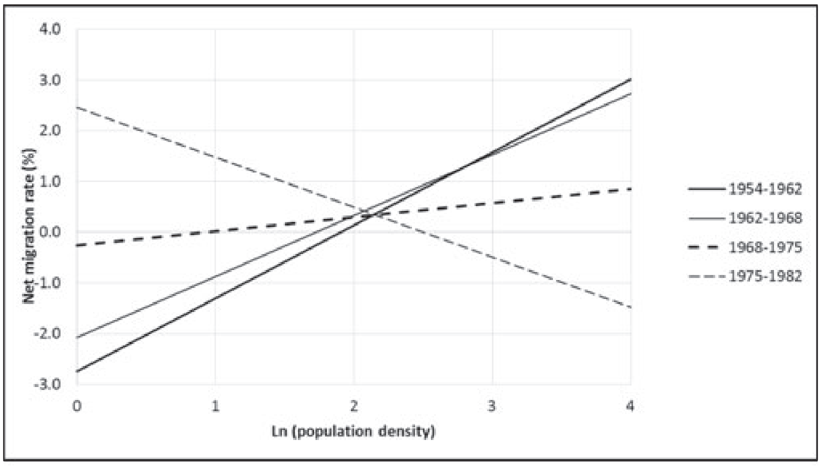
A clear progression is apparent in the slope of the regression lines over the sequence of inter-census periods. For 1954–1962, the slope is strongly positive, denoting losses from sparsely populated areas and corresponding gains in the more densely populated parts of the country. For 1962–1968 and 1968–1975, the slope moderates as the strength of this rural to urban movement weakens, and by the second half of the 1970s, the relationship has reversed, with a negative slope denoting a shift to counter-urbanisation. Net movements to less populated areas continued at a diminished rate in the 1980s, but strengthened marginally in the 1990s and early 2000s. Of course, individual *départements* at various levels of density may have continued to variously register gains or losses, in each period, but the overall shift in the settlement pattern was clear.

We can apply this approach to countries in the IMAGE database for which NMRs and population densities for individual zones are available, but first we need to check that the regression slopes are not unduly affected by the number of zones used. We used the aggregation routines in the IMAGE Studio to compute NMRs and population densities across 95 countries. Population-weighted regressions were computed using bespoke routines in R, setting NMRs against the log of population density for each scale (number of zones). In general, we found the scale effect to be small above a minimum threshold of around 30 zones. Figure 7 illustrates this finding for migration over a 1-year period measured at the Australian 2011 census. Median slope values are relatively stable at successive levels of aggregation above 30 zones, interquartile ranges are compact, and outliers are rare, but this pattern breaks down as the number of regions falls below 30. Underpinning the slope–scale relationship is a combination of different redistribution processes, with a varying mix by scale. When only a few regions are used, economic factors drive migration and the regression slopes are sensitive to the spatial configuration of zones. When many regions are used, housing markets, residential mobility, and other local factors come to the fore, which tend to reduce biasing effects.

Excluding countries for which the IMAGE database contains less than 30 regions leaves a sample of 67 countries for which we computed the slopes of population-weighted NMR regressed against the logarithm of population density at BSU level. These density slopes were plotted against the HDI in graphs (not shown). The relationships were weak: a quadratic

DOI: 10.1002/psp

A: 95 *départements* split into rural and urban areas



B: 95 *départements*

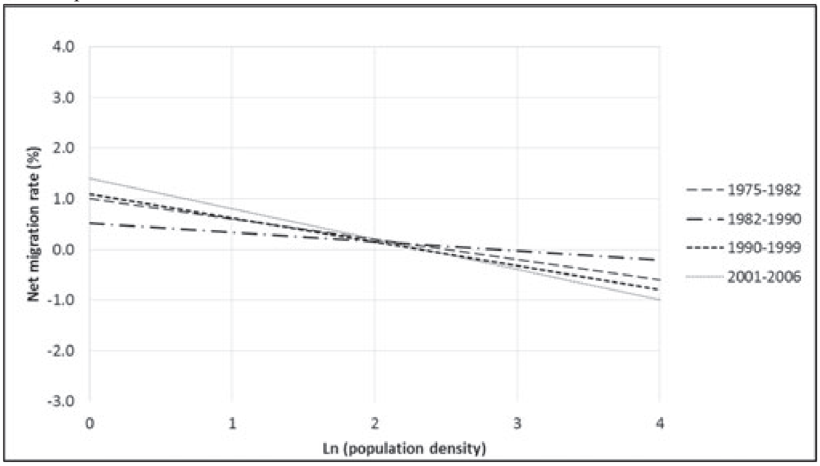


Figure 6. The relationships between annual rates of net internal migration and the logarithm of population density for the *départements* of France.

function fitted best, but the R^2 for the countries with 5-year data was only 0.28. High HDI countries (e.g. US and Canada) generally have negative or small positive slopes (e.g. Japan). Countries with low HDI scores (e.g. Guinea and Uganda) displayed strong positive slopes. Slopes for middle HDI countries range from moderately positive (e.g. China and Vietnam) to slightly negative (Indonesia).

How do we synthesise these diverse levels, causes, and patterns of spatial redistribution through internal migration? Figure 8 is a theoretical schematic framework that attempts to do this by tracing the relationship between net internal migration and population density as a country undergoes development (vertical axis) through a series of five phases (the horizontal axis). As the country urbanises, as both a cause and consequence of development, the first phase involves net internal migration from low density areas (rural settlements) to high density areas (urban settlements), and in the second phase, the process of urbanisation accelerates. In the third phase, it slows and may reverse into counter-urbanisation, with a negative slope in the net internal migration–density relationship in phase 4. The final phase recognises three alternative outcomes: (a) re-urbanisation, (b) counter-urbanisation, or (c) dynamic equilibrium. In a few countries (Australia and US) where there is a strong preference for low density living, counter-urbanisation may continue or be associated with shrinking

DOI: 10.1002/psp

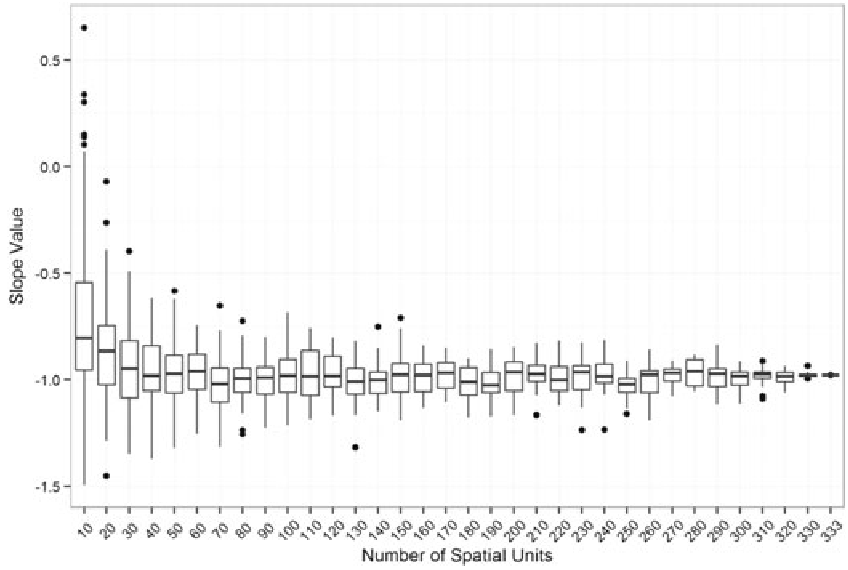


Figure 7. Slope of internal net migration rates as a function of log population density plotted against the number of zones at selected scales, 5-year migration data, 2011 census, Australia.

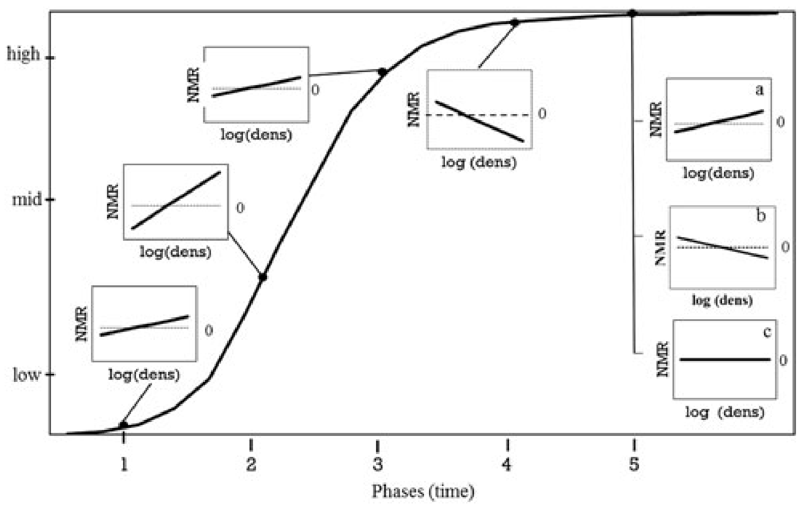


Figure 8. A theoretical framework linking development to population redistribution through net internal migration.

cities. Re-urbanisation may occur as the centres of cities are redeveloped after being emptied through de-industrialisation. Or migration flows between urban, suburban, and rural may be balanced with little population redistribution, a state of dynamic equilibrium. Turok and Mykhnenko (2007) provide evidence for population change from 1960 to 2005 for 310 European cities, defined using consistent built-up area criteria, with populations above 200,000. They find a long-term trend of decline in growth rates, particularly in Eastern Europe from rapid growth in the 1960s to a nadir of slow growth in the 1990s. The new century shows some upturns in growth. However, population change is not decomposed into migration (internal and international) and natural (fertility and mortality) components, so it is not possible to indicate which of the phase 5 relationships between net internal migration and density will be more likely, assuming countries outside Europe end up with demographic regimes in the future similar to those in 21st-century Europe.

Underpinning these shifts in spatial patterns, the overall impact of internal migration in terms

DOI: 10.1002/psp

of system-wide distribution first rises and then falls as the settlement system shifts from predominantly rural to urban, finally settling into dynamic equilibrium. Migration effectiveness declines as most migration flows are balanced by counter-flows. The evidence suggests that migration intensities, too, tend to fall after peaking at high levels of development (Bell *et al.*, 2012). Thus, countries may experience migration flows between urban areas that involve high mobility but low effectiveness, leading to minimal population redistribution. What complicates interpretation is the wide national variation in levels of migration intensity and efficiency and their complex interplay (as in Fig. 3). This variability, in turn, is a product of cross-national differences in the nature of housing markets, economic structures, policy frameworks and cultural forces, and the way these interact with the existing geographies of human settlement.

CONCLUSION

With the progressive convergence of birth and death rates between countries and regions, internal migration, together with international migration, now represents the principal source of change in the pattern of human settlement within countries. Despite its acknowledged significance, remarkably little progress has been made in understanding the spatiotemporal dynamics of internal migration and in measuring its impacts on population redistribution. We have sought to address the issue by harnessing a unique international dataset of country-specific internal migration flow matrices, assembled as part of the IMAGE Project, to bespoke software designed to compute a suite of migration indicators and simultaneously explore the effects of the MAUP on cross-national comparisons of migration. We examined migration flows at various levels of spatial scale drawn from population censuses, registers and administrative sources covering 91 countries, and explored the redistributive effects of internal migration in terms of both system wide indicators and spatial patterns.

Using the random agglomeration facilities of the IMAGE Studio, we demonstrated that two key measures of population redistribution, the MEI and the slope of the NMR/population density gradient, are stable and largely independent of scale and zonation effects above a threshold of around 20 zones. That is, very similar results are obtained irrespective of the number of zones into which a country is divided to make the calculations, or their spatial configuration. The consequence is that reliable comparisons can be made between countries on these two measures, even though they are calculated using differing numbers of spatial units. We also demonstrated that there are marked variations between countries on both these measures.

We have proposed a new system-wide measure, the INMI, which is a generalised form of the aggregate net migration rate (Bell *et al.*, 2002), and have shown how this can be decomposed into its constituent elements, the mean MEI and the slope of the CMI (the latter as proposed by Courgeau, 1973a). Like its constituents, the INMI is independent of spatial scale and can therefore be used to compute the overall redistributive effects of internal migration and make comparisons between any countries for which suitable flow matrices are available. Because the INMI is a product of the mean MEI and the CMI slope, it is also possible to determine the relative influence of migration intensity (the CMI slope) and migration effectiveness (the mean MEI) on the resulting INMI. We identified marked variations between countries in the extent of population redistribution, as measured by the INMI, and showed how the role of intensity and effectiveness varied around the globe. In Asia, we found that low levels of migration intensity were largely offset by moderate to high effectiveness, whereas most Latin American countries displayed a more balanced profile with low scores on each component. Africa showed greater diversity with some of the highest and lowest levels of redistribution. Europe, on the other hand, was characterised by relatively low levels of redistribution but with two distinctive clusters, marked by low intensity and high effectiveness in the south and east, reversing to higher intensities but lower effectiveness in countries to the north and west. Moderate linear correlations were identified with selected development indicators, but we suggested a third-order polynomial offered a more theoretically justifiable fit between population redistribution and national development.

Few countries collect data on rural–urban migration directly so we compared the spatial patterns of redistribution between countries

DOI: 10.1002/psp

using the slopes from regression equations computed by setting the NMR against the log of population density for basic spatial units in each country. Countries with lower HDI generally delivered steep, positive slopes, indicating that internal migration was serving to increase levels of population concentration, whereas slopes were shallow or negative for higher HDI countries, pointing to weak concentration or counter-urbanisation. Combining this space-rich but time-poor empirical evidence with earlier time-rich but space-poor analyses by Courgeau (1992) and by Kontuly and Geyer (2003b), we outlined a general conceptual model suggesting how internal migration redistributes population across settlement systems during stylised phases of development.

In this paper, we have expanded the study of the impact of internal migration on population redistribution in new directions. We have moved from the safe haven of advanced countries (in Europe, North America, and Oceania) to encompass a wide range of less developed countries, with a total country count that houses four-fifths of the world's population. This revealed that much stronger redistribution is under way outside the developed world. We linked our results to a model of the relationship between internal migration and the growth and decline of populated settlements. With the data available, we only considered patterns at the start of the 21st century, but further development of comparable internal migration series for past (and future) decades is a clear research priority that will add temporal depth to our spatial breadth. Underpinning our results is a set of methodological innovations that aimed to overcome the MAUP problem, which impacts internal migration acutely. Future work will also need to address another methodological challenge: the modifiable temporal unit problem, identified and researched by Courgeau (1973b).

ACKNOWLEDGEMENTS

This research was supported through funding from Australian Research Council Discovery Project DP11010136, Comparing Internal Migration around the World (2011–2015). The authors thank the IMAGE Project collaborators and national statistical agencies who contributed to the IMAGE data repository, details of which are provided in Bell *et al.* (2014). The views expressed in this paper are those of the authors and not those of the United Nations.

REFERENCES

Abel G, Sander N. 2014. Quantifying global international migration flows. *Science* **343**(6178): 1520–1522.

Bell M, Blake M, Boyle P, Duke-Williams O, Rees P, Stillwell J, Hugo G. 2002. Cross-national comparison of internal migration: Issues and measures. *Journal of the Royal Statistical Society* **165**(3): 435–464.

Bell M, Muhidin S, Zhu Y, Charles-Edwards E, Ueffing P. 2012. *Internal migration in the countries of Asia: A comparative analysis.* Paper presented to the 2nd Asian Population Association Conference, Bangkok, Thailand. Online version: http://www.gpem.uq.edu.au/qcpr-docs/Internal_Migration_in_the_Countries_of_Asia.pdf

Bell M, Charles-Edwards E, Stillwell J, Daras K, Kupiszewski M, Kupiszewska D, Zhu Y. 2013a. *Comparing internal migration around the globe (IMAGE): The effects of scale and pattern*. Keynote presentation to the International Conference on Population Geographies, Groningen, The Netherlands, 25–28 June, 2013. Online version: http://www.gpem.uq.edu.au/qcpr-docs/Comparing_Internal_Migration_Around_the_Globe.pdf

Bell M, Charles-Edwards E, Ueffing P, Stillwell J, Kupiszewski M, Kupiszewska D, Zhu Y. 2013b. *Comparing internal migration intensities around the globe*. Paper presented to XXVII IUSSP International Population Conference, Busan, Korea, 26–31 August 2013. Online version: http://www.gpem.uq.edu.au/qcpr-docs/IMAGE_IUSSP_Busan_2013.pdf

Bell M, Bernard A, Ueffing P, Charles-Edwards E. 2014. *The IMAGE repository: A user guide*. QCPR Working Paper No 2014/01. University of Queensland, Brisbane. Online version: http://www.gpem.uq.edu.au/qcpr-docs/ImageRepositoryUserGuide.pdf

Bell M, Charles-Edwards E, Kupiszewska D, Kupiszewski M, Stillwell J, Zhu Y. 2015a. Internal migration data around the world: Assessing contemporary practice. *Population, Space and Place* **21**(1): 1–17.

Bell M, Charles-Edwards E, Kupiszewska D, Kupiszewski M, Stillwell J, Zhu Y. 2015b. Internal migration and development: Comparing migration intensities around the world. *Population and Development Review* **41**(1): 33–58.

Bernard A, Bell M, Charles-Edwards E. 2014a. Improved measures for the cross-national comparison of age profiles of internal migration. *Population Studies: A Journal of Demography* **68**(2): 179–195.

Bernard A, Bell M, Charles-Edwards E. 2014b. Life-course transitions and the age profile of internal migration. *Population and Development Review* **40**: 213–239.

Bernard A, Bell M. 2015. Smoothing internal migration age profiles for comparative research. *Demographic Research* **32**(33): 915–948.

Berry B. 1978. The counterurbanization process: how general? In *Human Settlement Systems: International Perspectives on Structure, Change and Public Policy*, Hansen N (ed). Ballinger: Cambridge; 25–47.

Berry B. 1988. Migration reversals in perspective: the long-wave evidence. *International Regional Science Review* **11**: 245–251.

Champion A (ed.). 1989. *Counterurbanization: The Changing Pace and Nature of Population Deconcentration*. Edward Arnold: London.

Champion A. 1992. Urban and regional demographic trends in the developed world. *Urban Studies* **29**: 461–482.

Champion A, Hugo G, Lattes A. 2003. Beyond the rural/urban dichotomy. *Population and Development Review* **29**(2): 277–298.

Charles-Edwards E, Muhidin S, Bell M, Zhu Y. 2016. Migration in Asia. Chapter 13. In *International Handbook of Migration*, White M (ed). Springer: Dordrecht; 269–284.

Courgeau D. 1973a. Migrations et découpages du territoire. *Population* **28**: 511–536.

Courgeau D. 1973b. Migrants et migrations. *Population* **28**: 95–128.

Courgeau D. 1992. Migration nette et densité: la France de 1954 à 1990. *Population-F* **47**(2): 462–467.

Courgeau D, Muhidin S, Bell M. 2012. Estimating changes of residence for cross-national comparison. *Population-E* **67**(4): 631–652.

Daras K. 2014. *Image Studio 1.4.2 User Manual*, Online version: http://www.gpem.uq.edu.au/docs/qcpr/IMAGE_studio.pdf

De Beer J, Van der Gaag N, Van der Erf R, Bauer R, Fassmann H, Kupiszewska D, Kupiszewski M, Rees P, Boden P, Dennett A, Jasińska M, Stillwell J, Wohland P, De Jong A, Ter Veer M, Roto J, Van Well L, Heins F, Bonifazi C, Gesano G. 2010. *DEMIFER: Demographic and migratory flows affecting european regions and cities*, Final Report, Online version: http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/demifer.html

Dyson T. (ed.). 2010. *Population and Development: The Demographic Transition*. Zed Books: New York, London.

Fielding A. 1989. Migration and urbanisation in Western Europe since 1950. *The Geographical Journal* **155**(1): 60–69.

Frey W. 1979. Central city white flight: racial and nonracial causes. *American Sociological Review* **44**(3): 425–448.

Frey W. 2015. *Diversity Explosion: How New Racial Demographics are Remaking America*. Brookings Institution Press: Washington DC.

Geyer H. 1996. Expanding the theoretical foundations of differential urbanization. *Tijdschrift voor Economische en Sociale Geografie* **87**(1): 44–59.

Geyer H, Kontuly T. 1993. A theoretical foundation for the concept of differential urbanization. *International Regional Science Review* **15**(2): 157–177.

Keyfitz N. 1980. Do cities grow by natural increase or by migration? *Geographical Analysis* **12**(2): 142–156.

Klassen L, Scimeni G. 1981. Theoretical issues in urban dynamics. In *Dynamics of Urban Development*, Klassen L, Molle W, Paelinck J (eds.); St. Martin's Press: New York; 8–28.

Kontuly T, Geyer H. 2003a. Introduction to the special issue: testing the differential urbanization model in developed and less developed countries. *Tijdschrift voor Economische en Sociale Geografie* **94**(1): 5–10.

Kontuly T, Geyer H. 2003b. Lessons learned from testing the differential urbanization model. *Tijdschrift voor Economische en Sociale Geografie* **94**(1): 124–128.

Kuznets S. 1955. Economic growth and income inequality. *American Economic Review* **45**(March): 1–28.

Long J. 1985. Migration and the phases of population redistribution. *Journal of Development Economics* **17**: 29–42.

Long J, Boertlein C. 1990. *Comparing migration measures having different intervals. Current population reports*, Series P-23: 1-11; US Bureau of the Census: Washington DC.

Openshaw S. 1984. *The Modifiable Areal Unit Problem*. Geo Books: Norwich.

Oswalt P, Rieniets T (eds.). 2006. *Atlas of Shrinking Cities*. Hatje Cantz Publishers: Berlin.

Poulain M, Perrin N, Singleton S (eds.). 2006. *THESIM: Towards Harmonised European Statistics on International Migration*. Presses Universitaires de Louvain: Louvain.

Ravenstein E. 1885. The laws of migration. *Journal of the Statistical Society of London* **48**(2): 167–235.

Raymer J, Willekens F (eds.). 2008. *International Migration in Europe: Data, Models and Estimates*. John Wiley and Sons: Chichester.

Rees P. 1985. Does it really matter which migration data you use in a population model? In *Contemporary Studies of Migration*. White P, Van der Knaap B. (eds.); Geobooks: Norwich; 55–77. Online version: http://www.geog.leeds.ac.uk/fileadmin/documents/research/csap/working_papers_new/1984-383.pdf

Rees P, Kupiszewski M. 1999. *Internal migration and regional population dynamics in Europe: a synthesis*. Population Studies No.32; Council of Europe: Strasbourg.

DOI: 10.1002/psp

Rees P, Stillwell J, Boden P, Dennett A. 2010. London: DEMIFER Case Studies. *Deliverable 12/12, Demographic and migratory flows affecting European regions and cities*. Online version: http://www.espon.eu/main/Menu_Projects/Menu_AppliedResearch/demifer.html

Richardson H. 1980. Polarization reversal in developing countries. *Papers of the Regional Science Association* **45**: 67–85.

Sassen-Koob S. 1984. The new labour demand in global cities. In *Cities in Transformation*, Smith M (ed.); Sage: Beverly Hills; 139–171.

Shen J, Spence N. 1996. Modelling urban-rural population growth in China. *Environment and Planning A* **28**: 1417–1444.

Shryock H, Siegel J 1976. *The Methods and Materials of Demography*. Condensed Edition Stockwell E (ed.); Academic Press: New York.

Stillwell J, Daras K, Bell M, Lomax N. 2014. The IMAGE Studio: a tool for internal migration analysis and modelling. *Applied Spatial Analysis and Policy* **7**(1): 5–23.

Stillwell J, Bell M, Ueffing P, Daras K, Charles-Edwards E, Kupiszewski M, Kupiszewska D. 2016. Internal migration around the world: comparing distance travelled and its frictional effect. *Environment and Planning A*. DOI: 10.1177/0308518X16643963.

Turok I, Mykhnenko V. 2007. The trajectories of European cities, 1960–2005. *Cities* **24**: 165–182.

UN. 1998. *Recommendations on Statistics of International Migration, Revision*. Statistical Papers, No. 58, Rev. 1; United Nations: New York.

UN. 2014a. *World Population Prospects: The 2012 Revision*. United Nations: New York.

UN. 2014b. *World Urbanization Prospects: The 2014 Revision, Highlights*. United Nations: New York.

UN. 2015. *2010 World Population and Housing Census Programme*. United Nations Statistics Division, New York. Online version: http://unstats.un.org/unsd/demographic/sources/census/censusdates.htm.

Zelinsky W. 1971. The hypothesis of the mobility transition. *Geographical Review* **61**: 219–249.

DOI: 10.1002/psp