The potential of internal migration to shape rural and urban populations across Africa, Asia and Latin America

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Abstract

Sub-national divergence in the age and sex structures of populations can have far-stretching consequences for development: from marriage markets, to the potential for violence, to economic growth. With urbanisation and the demographic transition still underway, rural and urban populations continue to differ across low- and middle-income countries. We examine the extent by which internal migration contributes to these differences between 1970 to 2014, using estimates of migration between rural and urban sectors based on census data from 45 countries. We found that despite heavily delineated migration profiles by age and sex, internal migration does not alter sex and age structures of rural and urban populations. All the same, internal migration does increase urban growth in Asia and Latin America and the Caribbean. In contrast, in Africa, internal migration has little leverage with the urban transition. Across the continents there is potential for de-urbanisation, driven by a rural/urban gap in fertility. As such, the rural population may continue to constitute a significant proportion of national populations, necessitating critical investments to ensure they are not left behind.

Keywords

internal migration, population structure, urbanisation, rural, urban

Introduction

The population structure of a country, captured by the age and sex composition of a population, can have far-reaching effects for development. At the national level, population age structure can influence social concerns, economic growth, and public transfer systems towards health and education. Young populations require investments in schools for example, while older populations require retirement funds. These needs may change as populations shift. For instance, in high income countries with rapid population aging, public pension arrangements are unsustainable and require major reform (Bongaarts 2004). Both young and old populations necessitate investments in health systems, with returns differing substantially; health investments in children can translate into a stronger workforce in later periods. Populations with large proportions of working-aged adults, due to declining fertility, have an opportunity for economic growth under the right socio-political and financial conditions (Bloom, Canning, and Sevilla 2003; Mason, Lee, and Lee 2017; Lee and Mason 2006). Such a demographic dividend is intertwined with improved education, particularly of women (Lutz et al. 2019; Backhaus and Loichinger 2022), which increases formal labour market participation, earnings and productivity (Peet, Fink, and Fawzi 2015). Countries in eastern Asia are considered the forerunners of a demographic dividend, successful in taking advantage of rapid fertility decline (Lee and Mason 2012; Bloom and Williamson 1998). China, where fertility was strictly limited, has exhausted its demographic dividend (Zhong et al. 2013), while India has been reaping gains in economic growth, despite inequalities in opportunities and slow shifts from agriculture to manufacturing (Joe, Kumar, and Rajpal 2018). Increases in female labour force participation, and revising wage discrimination in India would be needed to achieve a robust dividend (Desai 2010).

Population sex structure also shapes society, albeit in more subtle ways, or in interaction with other factors. Imbalanced sex ratios (the proportion of men to women) can lead to a shortage of potential marriage partners (a marriage market squeeze), and can drive changes in the age range of marriage partners, and in the proportion of people marrying, and can increase ethnic intermarriage (Weiss and Stecklov 2020). In 20th century India, declining mortality and insufficient single men at older ages, rather than increased female education or legislative measures against child marriage, led to a rise in age at first marriage of women (Bhat and Halli 1999). Additionally, skewed sex ratios at birth due to strong son preference in India are expected to drive a marriage squeeze well into the 21st century (Guilmoto 2012). High sex ratios associated with increased marriage opportunities for women, can also reduce the extent of female labour force participation (Angrist 2002). Skewed sex ratios amongst young adults has further been associated with the occurrence and severity of conflicts (Mesquida and Wiener 1999). In Mexico, where young male migration to the United States has led to an abundance of women, higher risks of violent victimization are common in municipalities with especially imbalanced sex ratios (South, Han, and Trent 2021).

These social and economic consequences of age and sex composition of national populations are similarly important to consider sub-nationally. For instance, delayed demographic transition in the rural sector as seen in many African countries, primarily due to lagged and stalled fertility decline (White et al. 2005; Shapiro and Tambashe 1999; Murthi 2002; Schoumaker and Sánchez-Páez 2020), could increase wage inequalities between the rural and urban sectors (Williamson 2013), and reduce overall economic growth. Sub-national understanding of population structure is therefore essential. Governments and policy-makers need to know for example whether building more schools in the urban sector is necessary if there are more children in the rural sector, or whether investing in a new mine (attracting male migrants) could lead to higher levels of violence in an already unstable region. Overall, sub-national analysis of population structures is essential for highlighting inequalities, and guiding targeted development policies. We focus on rural/urban population structures considering that across low- and middle-income countries, roughly half the population live in urban areas (United Nations 2018), and the urban transition is not complete. Moreover, urbanisation is inherently intertwined with both development (Fox 2012), and the demographic transition (Dyson 2011), so that differential rural/urban dynamics in fertility and mortality can lead to divergent rural/urban populations and disparate consequences.

We aim to explore the compositional effects of internal migration on sub-national populations in low- and middle-income countries over the last 50 years. We examine the differences (and similarities) across Africa, Asia and Latin America and the Caribbean in internal migration patterns, and whether the role of migration in shaping these structures has changed over time and over the urban transition. We consider the effect of migration on the tension between current and stable state rural/urban populations. We employ a continental approach in order to identify macro trends integral to the theory of urban transition, rather than context-specific patterns of transition.

Internal migration as a determinant of population age and sex structure

Population structure is determined by births, deaths and migration. Over the demographic transition, as mortality declines, the increased survival of children leads to a younger population, till fertility falls and populations start to age (Chesnais 1990). Since both mortality and fertility first decline in the urban sector (Dyson 2011; de Vries 1990), divergences in rural and urban age and sex structures are expected. International migration, typically concentrated in young working ages can also alter population structure, often contributing to urban growth (Lerch 2020). However, the impact of international migration on population distribution globally has generally declined since the 1990s (Charles-Edwards et al. 2023).

Sub-nationally, internal migration is also a determining factor. Internal migration has the potential to underpin changes in population structure since it is much more common than international migration (Bell and Muhidin 2009; United Nations 2009; Bell and Charles-Edwards 2013). Indeed, migration is able to alter populations relatively quickly, without waiting for the slower generational churns associated with fertility and mortality (Billari 2022). Moreover, internal migration simultaneously shapes both origin and destination populations. This spatial redistribution of the population is considered the most significant aspect of internal migration (Rees et al. 2017). Although aggregated net migration rates may conceal considerable churning of the populations (Rogers 1990), differences in the composition of in- and out-migration flows could still shape the age and sex structure of the rural and urban populations. For example, rural-to-urban flows concentrated among 15-24 year olds reduces the working population of reproductive ages in the rural population while at the same time boosts them in the urban sector. If urban-to-rural migration flows were at an equivalent level (net migration of zero), but concentrated among 50-64 year olds, the age structure in rural and urban sectors would diverge considerably. Such compositional changes in population structure due to internal migration flows have been noted across sub-Saharan Africa (Menashe-Oren and Stecklov 2018), and in large cities in Latin America (Rodríguez-Vignoli and Rowe 2018).

The demographic consequences of internal migration are far-stretching. Migrants tend to be a select group with lower fertility (Chattopadhyay, White, and Debpuur 2006; Choi 2014), and return migrants often spread reproductive norms acquired at destination (Bertoli and Marchetta 2015). At the same time, migrants of reproductive ages shift "future births" from one region to another. Internal migrants are also selected on health, often healthier than non-migrants at origin (Lu 2008; Nauman et al. 2015), while they tend to have lower survival odds at place of destination (Ginsburg et al. 2021). Because migration flows shift over the urban and demographic transitions, from limited circular movement in pre-transition societies, to predominantly rural-to-urban migration, and then to intense intra-urban movement when fertility and mortality levels are low (Zelinsky 1971; Dyson 2011), the consequences of migration will also shift over the course of urbanisation. In the past, migration was the only way cities could grow since death rates were high in urban areas (Woods 2003; Bocquier and Costa 2015). In the future, in countries where fertility is still high, internal migrants are likely to sustain fertility decline.

Data and methods

Stable populations to assess the compositional effects of internal migration on rural and urban populations

Our goal is to examine whether internal migration has the potential to change rural and urban population age and sex structures. To do so, we use the "cohort component projection" method to examine *theoretical* populations,[i] aggregated to the continent-level, and to assess their composition by age and sex, assuming migration, fertility and mortality of the populations at the time of the census will remain unchanged, and that the national populations are closed to international migration. When fertility, mortality and migration are constant, and therefore the age structure unchanging, populations are considered stable. We run parallel analyses with either constant internal migration rates or with zero net migration, allowing us to compare the effect of migration on intrinsic growth rates (Coale 1957), and on age and sex structure, in each urban and rural sector. We use this technique as a means of determining the relative effect of migration on population growth in the rural and urban sectors, and not as projections. In contrast to decomposition analysis that is used for projections, we use stable populations to assess the role of internal migration *independently* of the current population structure. The stable populations essentially eliminate the impact of the past fertility, mortality and migration rates on the age and sex structures.

For the cohort component method, we rely on Leslie matrices which include fertility rates, survival rates, and net internal migration rates (Preston, Heuveline, and Guillot 2001; Leslie 1945). This matrix is used on our initial populations, the rural/urban population of each continent. Each matrix leads to a different stable state and corresponding constant (intrinsic) growth rate and age structure. A larger discrepancy between the observed situation and the stable state indicates greater tension between the current state (which is the result of past history) and the intrinsic state associated with current population movements (mortality, fertility, and migration).

We use a macro approach to evaluate the role of internal migration, by focusing on three continents where most low- and middle-income countries are found: Africa, Asia, Latin America. While this continental approach flattens the variation between countries, it allows us to unpack the role of migration at key stages of the urban transition. To populate the matrices for each continent and each time period (1970-1984, 1985-1999, 2000-2014),[ii] by sex, we use continent-level aggregates of fertility and mortality. For mortality and fertility rates, life table survival ratios (located in the cells below the diagonal in the matrix), and age specific fertility rates (located in the top row of the matrix for women aged 15-49, as fertility contributes to the births in the population i.e. 0-4 year olds) are respectively required. Standardised fertility and mortality data (by age and sex), and by rural/urban sector for each country-year do not exist. We instead rely on estimates of fertility and mortality at the continent level, available from the World Population Prospects (WPP) (Gaigbe-Togbe et al. 2022) and then adjust them to rural/urban-specific rates based on factors relying on empirically measured rural/urban differences, using Demographic and Health Surveys (DHS) and previous research (ICF International 2018; Menashe-Oren and Masquelier 2022; Menashe-Oren and Stecklov 2023). We include net migration in the matrices based on age-specific migration estimates from census data, as detailed below. For net migration of 0-4 year olds we indirectly estimate migration based on mothers, assuming that children mostly move together with their mothers in these young ages[iii] (see Appendix for technicalities). Further details on the fertility and mortality data used to inform the Leslie matrices, and on the methods are available in the Appendix (including Figures A1-A3 and Tables A1-A4), while we focus here on the estimation of internal migration since it is our key component of interest, and age- and sex- specific internal migration estimates are not commonly available across countries and over time.

The overall output of the cohort component analysis are 72 populations at stable state. We compare the populations using the mean absolute deviation (MAD) between population age and sex structures which allows us to check whether migration contributes to diverging or converging rural/urban population structures, and whether this changes over time. We distinguish stable state populations at a given precision level, when the MAD is less than 1/1000. Since we have stable populations based on fertility, mortality and internal migration rates from three periods, we are able to assess whether the changes in migration over the years differentially shape population structure. In other words, had the rates remained as they were in each period, would they have had the potential to alter the rural and urban populations more, or less than what they are today.[iv]

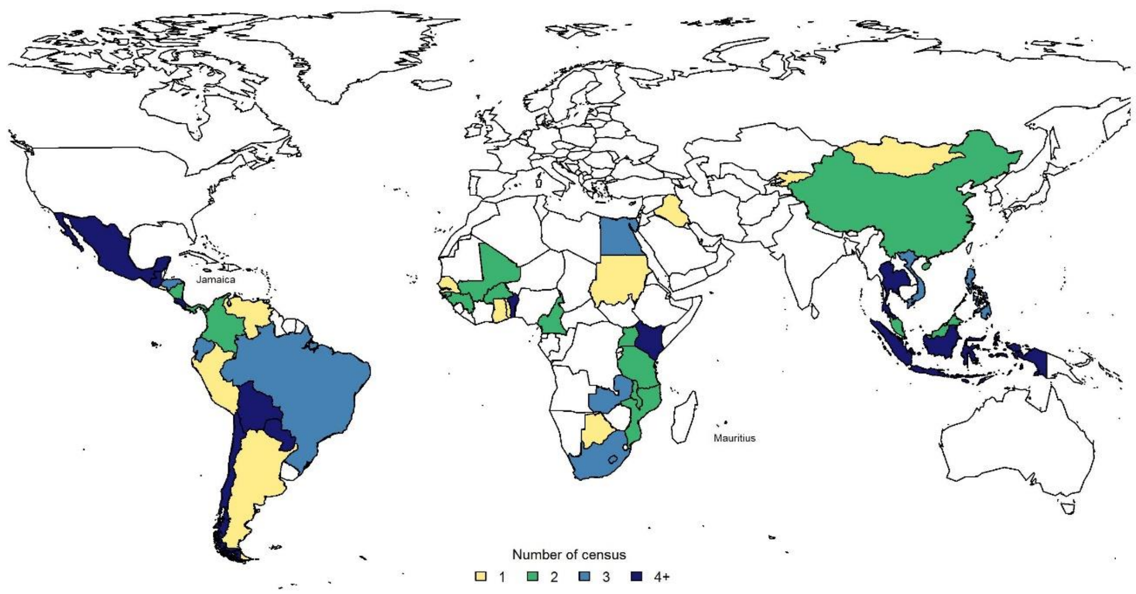
In addition to intrinsic growth, we employ two indicators to summarise the rural and urban population structures –dependency ratios and sex ratios. Total dependency ratios of migration are estimated as the number of child migrants under age 15 and adult migrants above age 65, as a proportion of working-aged migrants (aged 15-64). We do not interpret the dependency ratio as an economic measure, but purely as a demographic measure summarising the age pattern of migration. Sex ratios of migration are examined as the proportion of male to female migrants, for each age group.

Estimating internal migration

a. Data source for direct estimation of internal migration: census samples

We use IPUMS-International census samples (Minnesota Population Center 2020) to estimate migration flows between the rural and urban sectors in low- and middle-income countries. Censuses were excluded from the analysis when the proportions urban were especially high (as more recently in Latin American countries) and no rural regions were identified, or alternatively where only rural regions were identified (most frequently in Africa). Censuses were also excluded where we found a high proportion of unknowns, or when regional boundaries at the time of migration were not the same as boundaries at the time of census, or where some critical information (like place of origin residence, or time since migration) was missing. We ended up with 26 censuses from Asian countries (covering 9 countries between 1970 to 2010), 41 censuses from African countries (covering 19 countries between 1979 to 2014), and 46 censuses from Latin America and the Caribbean (covering 17 countries between 1960 to 2012).[v] As seen in Figure 1, most of the countries in Latin America and the Caribbean[vi] are covered by the census (though many island states are missing), and a reasonable proportion of South-East Asian countries are represented in the census. However, substantial sub-regions of Africa are not well represented in the data, namely central and northern Africa.

FIGURE 1 Census data used across low- and middle-income countries



Although the census data only represents a sample of countries, a comparison of the average internal migration rates at the continent level suggests that the sample of countries is in line with continental averages from other sources (Bocquier, Menashe Oren, and Nie 2023), and can be used to generalise about internal migration within each continent. To confirm this, in Table 1, we compare our sample of countries (for which we have migration data) to the continent average for all low- and middle-income countries, across a number of other indicators, based on data from 2015.[vii] Although our sample includes only 35% of all countries in Africa, 23% of countries in Asia and 52% of all countries in Latin America and the

Caribbean, it does include particularly large countries in all continents (China, Brazil, South Africa), meaning that large populations are accounted for. At the same time, the average population size of countries in our sample is higher since many very small countries are not included, including those with populations less than one million residents in the Caribbean. This is similarly reflected in the mean size of countries in terms of land coverage. Considering the proportion urban, the countries in our sample are slightly more urban on average in Asia. In Latin America many less-urban countries are not included, and these are mostly islands in the Caribbean. Across continents our sample is quite representative of total fertility rates. Under-five mortality rates tend to be lower when only considering the sample countries – and this is likely a reflection of countries in the sample being more stable – countries that are able and interested in having censuses (at specific times). Economically, our sample is more homogenous in terms of GDP per capita, representing countries that are of lower income (than middle). Based on a broader indicator of development rather than just economic (the Human Development Index (HDI)), we find that in fact the countries for which we can estimate migration are very much representative of Africa and Latin America and the Caribbean. In Asia the mean HDI is slightly higher (indicating a higher level of development) amongst countries for which we have data, but still within reasonable range of the continent average. Overall, we find that the countries with IPUMS census samples are relatively representative of a large proportion of the populations in each continent, but not of the small or very unstable countries. Thus, when we refer to the continents broadly, we are referring to the majority of countries in the continent.

TABLE 1 Characteristics of continents on average: comparison of countries in our sample (for which we have migration data) to all low- and middle-income countries in continent

		Africa		Asia		Latin America & Caribbean	
		Countries with data	***All countries on sub-continent***	***Countries with data***	***All countries on sub-continent***	***Countries with data***	***All countries on sub-continent***
Number of countries		19	54	9	39	17	33
Mean population (in millions)	Mean	27.65	22.21	220.25	107.76	33.95	18.71
	SD	23.3	32.12	441.74	298.54	52.5	40.51
Land area (sq. km, in 1000s)	Mean	564.4	549.1	1655.5	781.4	1134.1	606.9
	SD	500.0	598.4	2962.3	1601.8	2014.0	1528.1
Proportion urban (%)	Mean	40.24	44.49	53.86	51.1	71.34	62.18
	SD	13.4	18.4	14.6	20.6	13.1	20.9
GDP per capita (US$ current)	Mean	2168.36	2481.47	4641.59	5433.36	7245.62	9516.67
	SD	2428.46	2899.83	2733.71	6213.23	4131.27	6233.35
Total fertility rate	Mean	4.42	4.42	2.53	2.67	2.26	2.14
	SD	1.20	1.29	0.85	0.86	0.42	0.46
Under-five mortality rate (per 1000)	Mean	65.95	68.29	20.07	27.83	17.42	19.49
	SD	28.38	33.66	8.45	18.53	5.98	11.62
Human development index (HDI)	Mean	0.55	0.55	0.72	0.69	0.74	0.74
	SD	0.11	0.11	0.04	0.10	0.07	0.07

Source: World Bank data, and UNDP (for HDI)

Note: "Countries with data" refers to the countries in our sample, with migration questions in IPUMS census samples; All countries excludes high-income countries in these regions such as Japan and Bahrain; Comparisons are for 2015; The HDI is a composite measure of life expectancy, education and gross national income.

b. Definition of urban

Each census records current (destination) residence as rural or urban according to the national definition of urban. This can differ dramatically between countries. For instance, in Zambia an urban area is considered a locality of 5,000 or more inhabitants where the majority of whom depend on non-agricultural activities, while in Ecuador urban areas are the capitals of provinces and cantons, and in Indonesia a vague definition of satisfying certain criteria (population density, urban facilities, etc.) is given to urban. Although this cross-country heterogeneity in what is considered urban make comparisons somewhat precarious, there is no alternative.[viii] Moreover, and importantly, country-specific definitions of urban are more meaningful as they account for the context of each country. For example, an urban definition based on a low population density of 200 per square kilometre would make sense in Mongolia where land area is large and the population is small, but the same definition in Vietnam would define all of the country as urban (though it is currently less than 50% urban to date according to their own definition). Actually, many countries use compound definitions of urban, so that using a single uniform and harmonized definition, such as remote sensoring of night lights, would obscure country-specific conditions. Night lights are used to measure population density, though there is no strict correlation between density and urban living. In some northern parts of India for example, the population can be quite dense, but mostly agricultural and lacking basic services. In short, we posit that aggregating and averaging out the different country-specific urban definitions ultimately captures the macro trends in urbanisation, including the changes in definitions and context.

The census data rarely record whether origin place of residence was rural or urban. Therefore, we identify rural/urban origin residence by region, using the rural/urban classification of the region of residence at the time of the census, and assuming that the region has not shifted from rural to urban (or vice versa) over this period. Regions are determined as urban based on an intuitive 50% threshold, a commonly used threshold (Balk et al. 2018; Eurostat 2021; Hugo 2020). Sensitivity of this threshold has previously been tested, and it was found that increasing the threshold by 10% would only slightly reduce the number of regions considered urban, while lowering the threshold by 10% would lead to over-estimation of rural-to-urban migration flows (Bocquier, Menashe Oren, and Nie 2023). Inevitably a 50% threshold means that regions with large cities are considered urban, while those with a small number of secondary cities are considered rural. As such, the urban continuum is used to its extreme, as dichotomous. This method of approximating regions as urban has been found to be reasonably consistent at the continental level with the UN World Urbanisation Prospects' (WUP) proportion of people living in large cities (Bocquier, Menashe Oren, and Nie 2023). However, by classifying regions as rural or urban, internal migration is somewhat under-estimated (though a lot of migration is across neighbouring provinces albeit over short distances (Hoffmann et al. 2023)), with possible rural-urban movements within regions not included in our migration rates.

c. Computing migration rates and standardising estimates

We estimate migration based on questions of residence one-year or five-years ago, or previous residence (for which we use the most reliable period, the last 2.5 years). The five-year migration questions are most commonly asked in Latin America and the Caribbean censuses, and about half of the censuses in Asia also rely on a five-year threshold. One-year migration questions are only found in censuses in Africa, although generally one-year estimates are more accurate since within a single year return migration is negligible and resulting under-estimation less likely. We do not use questions on residence 10-years ago since there is a greater likelihood of multiple moves and return migration. Migration rates based on the five-year migration questions will also necessarily be an underestimation of migration, since return migration can be missed (when current residence and residence five years ago are the same). However, when considering net migration rates, return migration will only alter the rates by marginally overestimating the population at risk at the time of the census.

To compute migration rates, we use an event history analysis approach, estimating the number of person-years at risk. In this way, we avoid the need to identify individuals at the beginning or end of the observation interval. The migration event is assumed to happen mid-interval. We treat international migration by including the person-years lived in the destination country (moving mid-period), but not the person-years lived in the country before emigrating abroad (since this information is lacking). Migration rates are calculated as the ratio between the number of migrations and person-years at risk for each migration flow (that is, rural-to-urban or urban-to-rural). In- and out-migration rates are produced for each sex and five-year age-group using survival-time analysis. We use sample weights provided by IPUMS-International to ensure representativeness, since the census samples are mostly 10% of the national population.

We standardize the migration rates to five-year migration rates assuming that one-year rates are roughly five times the five-year rates, and 2.5-year rates are double the five-year rates (hereon we refer to this as "flat" standardization). Naturally, this assumption appears to oversimplify the variation in what the migration rates capture: for instance, return migration is more likely the longer the reference period, as is the risk of death. As such, migration rates do not change linearly with duration of the retrospective period (Rees 1977). Nevertheless, our flat assumption is based on a series of simple Poisson models empirically evaluating the relationship between the estimates. Globally the ratios hold quite well, with five-year rates being 1.7 and 5.2 times the 2.5-year and one-year rates respectively. In modelling Africa alone, we find that five-year rates are 1.6 and 3.0 times the 2.5-year and one-year rates respectively; and in Asia, the five-year rates are 1.9 times the 2.5-year rates. In modelling rates in Latin America and the Caribbean in contrast, we find that five-year rates are actually higher than the 2.5-year rates by 10%.[ix] While these models suggest differences between the continents, it is only at very low proportions urban (20-30%) that we see divergent net migration rates using such a continent-specific standardisation as opposed to our flat assumption (see Figure A4a). This is notable in Latin America in particular, though the censuses in this region do not cover this low range of proportions urban. All the same, we acknowledge that using the flat-standardised rates slightly biases migration rates at very low levels of urbanisation.

If we were to use only censuses that include five-year migration rates, the number of censuses would be reduced to 6 in Africa, to 13 in Asia, and to 32 in Latin America (only 15% of censuses in Africa, half in Asia, but including the majority, 70%, of censuses in Latin America). Despite a reduced sample, using only censuses where migration estimates are based on five-year residence we find that the net migration rates in Asia are quite similar to those obtained using flat standardization (see Figure A4b). In Latin America, at very low proportions urban, we would under-estimate migration if we only relied on censuses with five-year migration rates. We refrain from reading into the comparison of net migration rates in Africa since three of the six censuses with five-year rates are from Mauritius. We conclude that relying on five-year migration rates would mean lower net migration at lower proportions urban, and not being able to include Africa in our analysis.

These robustness checks, comparing different approaches to standardizing the migration rates, lead us to conclude that while the in and out rates shift in level depending on method of standardisation – the net does not change as much since it balances between the two. Moreover, the shape of the age and sex profiles of the migration flows do not differ, meaning that our analysis of population structure (sex ratios and dependency ratios) would also not differ using different standardization methods.

d. Smoothing migration estimates

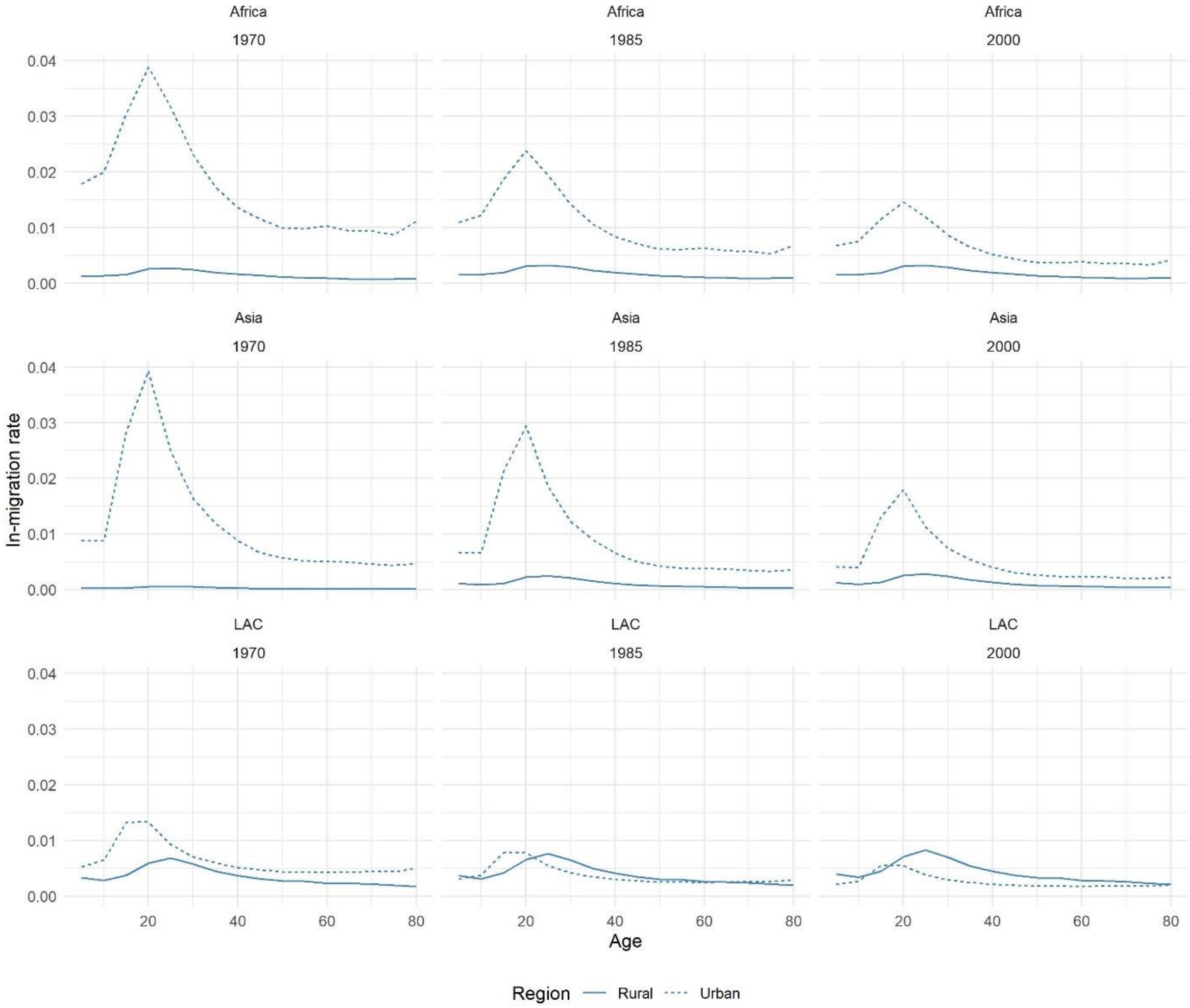
We use Poisson models to smooth the migration estimates by continent, accounting for the differential timing of the censuses and stages of the urban transition, and correcting for biases in measurement of migration associated with the different census questions. The dependent variable is a count of migrants (standardized to five-year estimates), and covariates include sex, five-year age groups (from 0 to 80+), period (in four categories: pre-1970, 1970-1984, 1985-1999 and 2000-2014), proportion urban (taken from the WUP (United Nations 2018), a correction factor for under-five year old migration (possible only in the African model where we have one-year migration estimates),[x] in- or out-migration flow, and rural/urban origin and destination. The covariates of age and sex are interacted in the model with in/out and rural/urban origin-destination factors so that each migration flow follows its own age and sex pattern. Since both in- and out-migration are included in the same model, it is possible to estimate net migration based on the marginal effects of the in- minus the out-migration rates.[xi] Predicted estimates of migration based on the model provide average net migration rates for each continent. We use these estimates to inform the Leslie matrices.

Results

Internal migration patterns across continents

We initially examine the migration patterns based on the modelled census estimates to both validate the use of these migration estimates, and to emphasis why internal migration appears to have the potential to shape rural and urban population structure, with dramatic sex- and age-specific profiles. Across Africa and Asia, we note higher urban in-migration rates than rural in-migration rates on average over the three periods (1970-1984, 1985-1999 and 2000-2014), while in Latin America the rural and urban in-migration rates are more comparable (Figure 2). A central message from the in-migration profiles in Figure 2 is the decline in urban in-migration rates over time, across all continents, though more evident in Africa and Asia where the peak rates are dramatically reduced between each period.[xii]

FIGURE 2 Model-smoothed age profile of in-migration flows in the rural and urban sectors, on average for both sexes, and across continents and periods, based on IPUMS census data (45countries, 1960-2014)



Notes: LAC is short for Latin America and the Caribbean.
The years refer to the start of the 15-year period, i.e. 1970 refers to 1970-1984, 1985 refers to 1985-1999, and 2000 refers to 2000-2014.
The four censuses from the 1960s in Latin America are included in the first period.
Under-five year old migration is under-estimated in the census so we refrain from presenting these estimates. We use an alternative indirect method to estimate net migration for these ages to inform the matrices.

Although harder to observe in Figure 2 due to the generally lower rates of rural in-migration (due to larger rural populations, used in the denominator), there is evidence of some increase in rural in-migration rates over time. This is confirmed when looking at the logged in-migration rates (Figure A5). In Latin America, rural in-migration rates are higher than urban in-migration rates during the 2000-2014 period. Moreover, the continent stands out with a higher proportion of in-migrants in older adult ages than in Africa and Asia, with 17.7% of urban in-migrants being over 65 years old.

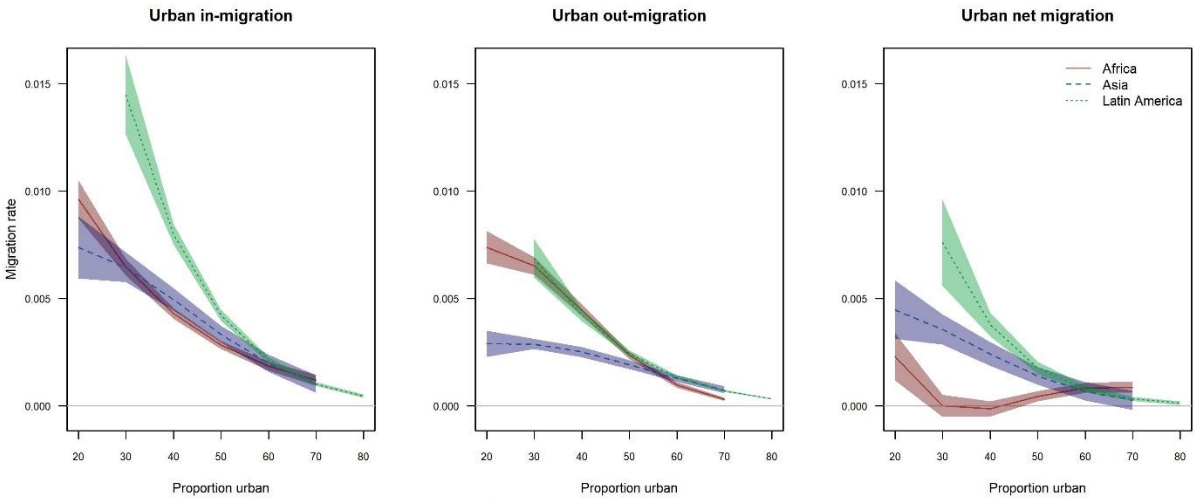
The age profile of urban in-migration across continents and periods is typical, following model age patterns (Rogers, Raquillet, and Castro 1978). We do not include under-five year old migration estimates in Figure 2 due to under-estimation of migration in the censuses (whether with one-year, 2.5-year or five-year estimates), which typically show a secondary peak. The rural in-migration rates also follow this age pattern, though this is not evident in Figure 2 due to the scale of rates in comparison to urban in-migration rates. When logged, we note very parallel age-specific migration flows, except for an older peak age of rural in-migration than urban in-migration, especially evident in Latin America (Figure A5). Overall, Figure 2 demonstrates that in-migration is mostly composed of working-aged adults. Emphasizing this, the dependency ratios of in-migration flows in Asia are considerably low (below equity), for both sexes, indicating that very few children or old-aged adults migrate (Figure A6).[xiii] In Africa and Latin America dependency ratios of in-migration are relatively balanced. The dependency ratios of out-migration flows from the rural sector are also low and indicate the dominance of working aged migration. Urban out-migration flows are more balanced in Asia and Latin America, contrasting a high proportion of dependents in Africa (Figure A6).

In addition to age patterns of migration differing dramatically between continents, there is some variation by sex too. The sex ratios of in-migrants in Africa appear more extreme than in the other continents: more girls migrate below age 20 while more men migrate in and out of the rural sector during working ages than women, and women dominate rural-to-urban migration flows from age 50 on (Figure A7). In Latin America however, the sex ratios of urban out-migrants over age 50 are above one, indicating higher proportions of men moving even at these older ages. Sex differences are also notable in the balance of the in- and out-flows (see Figure A1), with higher net rates for females in Latin America, an earlier and wider peak in net rates for females in Asia, and in Africa both an earlier peak in net rates amongst young adult females and higher male net migration between ages 40-59.

Internal migration over the urban transition

We now consider whether migration patterns shift over the urban transition differentially by continent, rather than changes in migration over time, since previous research has shown that net migration is flat over time (Menashe-Oren and Bocquier 2021; Bocquier, Menashe Oren, and Nie 2023). We consider both in- and out-migration patterns in the urban sector, and broadly find that migration rates decline as the proportion urban increases (Figure 3). In-migration rates are mostly higher than out-migration rates (leading to positive net migration), though in Africa net migration is close to zero between 30 to 40% urban, then becomes only slightly positive at higher proportions urban. Indeed, many countries in Africa remain at urbanisation levels below 50% (Figure A8), and the contribution of migration to urbanisation has been found to be negligible (Chen, Valente, and Zlotnik 1998; Menashe-Oren and Bocquier 2021; Bocquier, Menashe Oren, and Nie 2023; Stecklov 2008). In contrast, Figure 3 indicates that Latin America, with particularly high urban in-migration levels, has higher net migration than seen in other continents. The large gap between in- and out-migration rates in Latin America diminishes over the urban transition, and from around 60% urban net migration is quite flat and only slightly positive.

FIGURE 3 Shifting in-, out- and net migration rates over the urban transition, with 95% confidence intervals, modelled IPUMS census samples

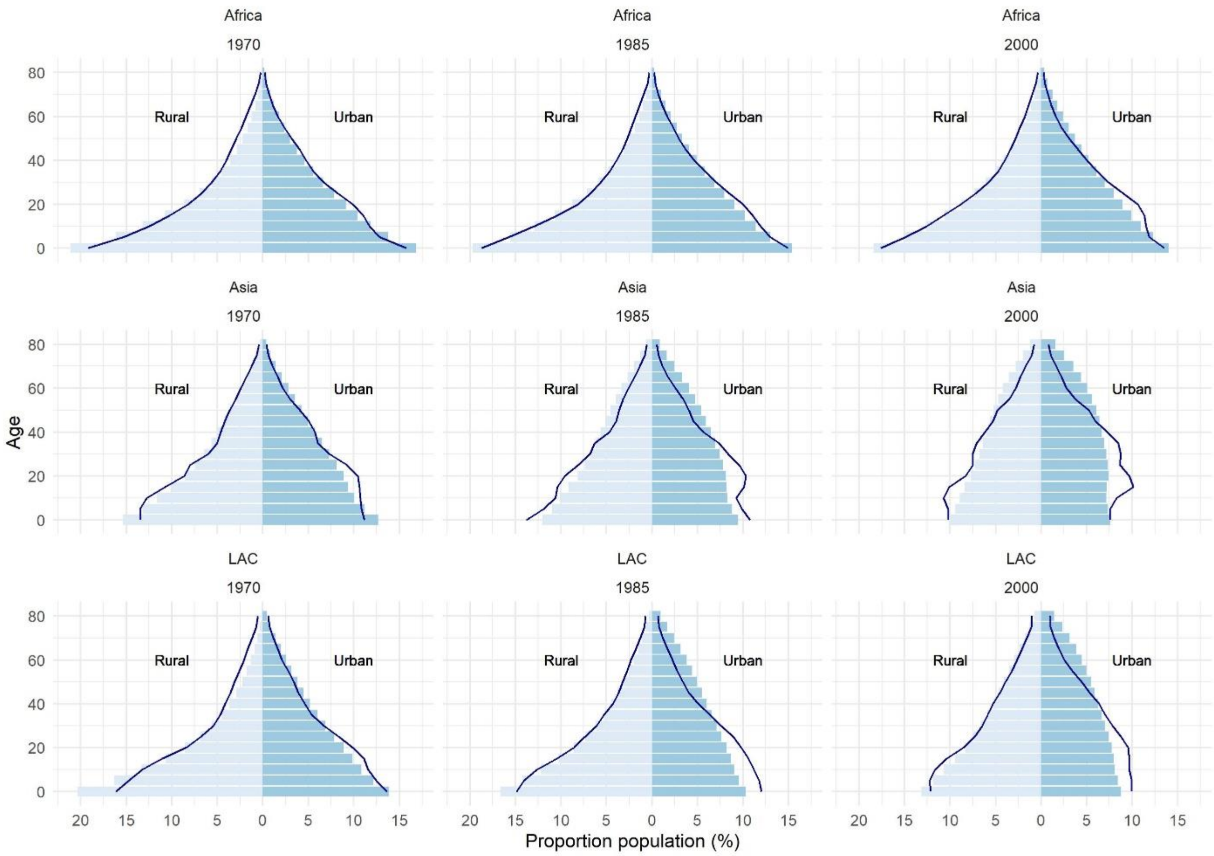


Notes: The trends for Asia and Africa end at 70% urban since we do not have any countries in the census data who have reached this stage of urbanisation, and similarly the trend for Latin America is only plotted from 30% urban since there are no countries in our data with less than this proportion urban.

The contribution of internal migration using stable population comparisons

The overall declining migration rates over the urban transition suggests that the role of internal migration in shaping rural and urban populations will depend on the stage of the urban transition. More so, it will also depend on the stage of the demographic transition. Over the period we examine, rural and urban population structures will in particular reflect declining fertility. We now turn to comparisons of stable populations to quantify the role of internal migration in shaping sub-national populations at different points of the demographic transition (using three broad time periods). In Africa, regardless of period, fertility shapes the age structure (with wide based population pyramids), while in Asia it is clear that fertility decline has narrowed the base of the age pyramid over time in both sectors (Figure 4 for men, Appendix Figure A9 for women). In Latin America, as in Asia, the urban population has seen greater fertility decline. In rural Latin America only in 2000-2014 do we start to see a decline in the proportion of children in the rural population.

FIGURE 4 Male age structures comparing estimated mid-period population and age structure at stable state, including internal migration

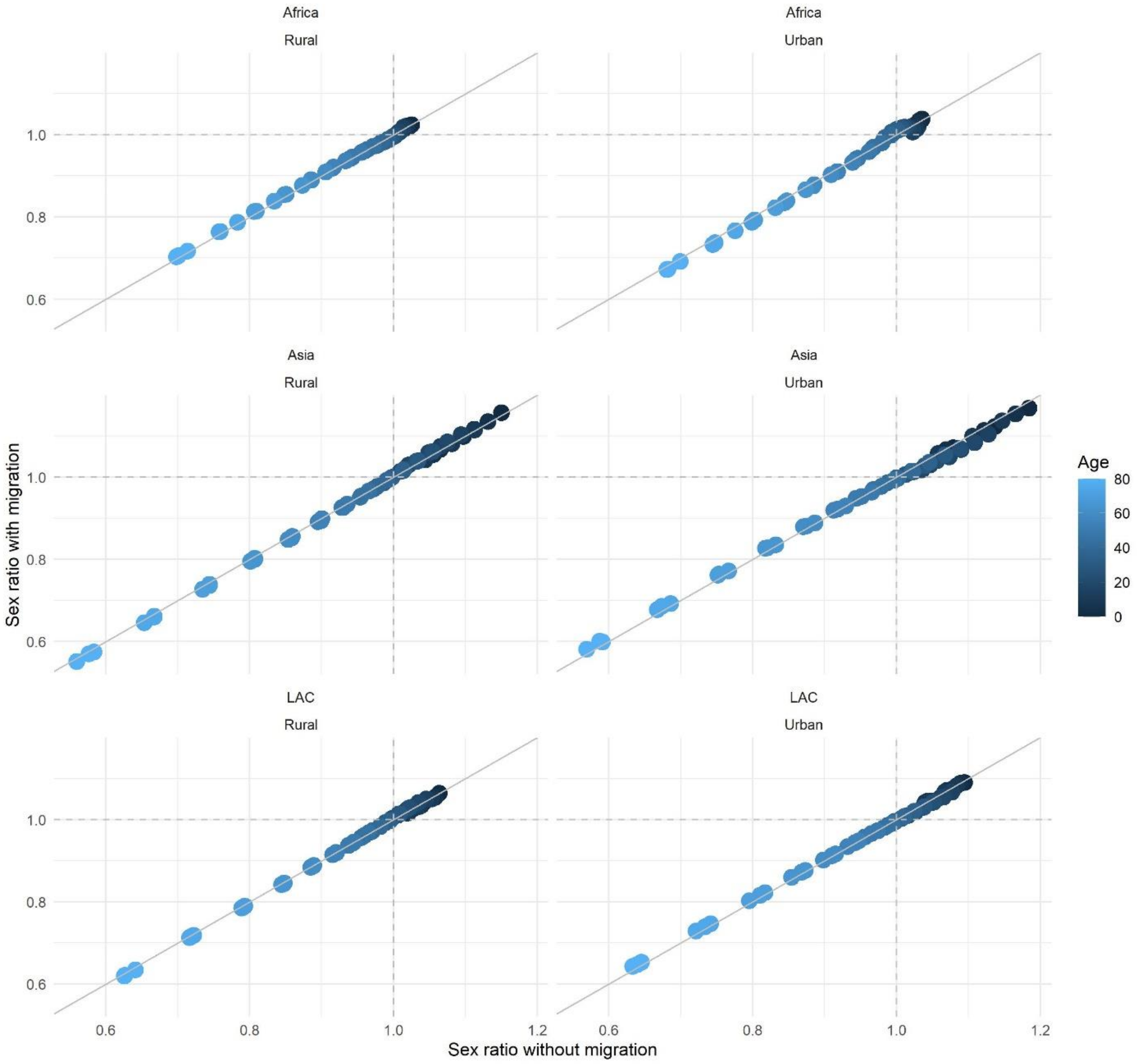


Notes: The lines represent the mid-period initial population (based on URPAS data), and the bars depict the population at stable state.
LAC is short for Latin America and the Caribbean.
The years refer to the start of the 15-year period, i.e. 1970 refers to 1970-1984, 1985 refers to 1985-1999, and 2000 refers to 2000-2014.

Overall from Figures 4 and A9 it is clear that the urban population would have faced greater changes in its population structure if mortality, fertility and migration rates were to have continued as they were in each period. When considering the age and sex structure of the rural and urban populations at stable state, we revert to sex ratios and dependency ratios of the population (Figures 5 & 6), and basically find that internal migration does not contribute to rural/urban divergence in population structure. This emerges as quite contrasting to expectations, in light of the strong age and sex patterns of migration. Part of this can be explained by net migration, and the balancing out of flows, so that even in the case of high in- and out-migration flows, migrants are replacing each other in each sector. Yet part of this is also related to the stronger forces of the demographic transition.

In Figure 5 it is clear that sex ratios of stable rural and urban populations are remarkably similar whether we account for migration or whether we assume no migration between sectors. The only deviation from the equity line is amongst children in Asia, and in Africa to a lesser extent. Migration in these young ages appears to slightly lower the sex ratios in urban areas. In Asia, this is probably since urban sex ratios tend to be higher than rural sex ratios, reflecting stronger urban son preference, while in Africa, lower urban sex ratios when accounting for migration are likely due to higher rates of girls migrating to the urban sector than boys (Menashe-Oren and Stecklov 2023).

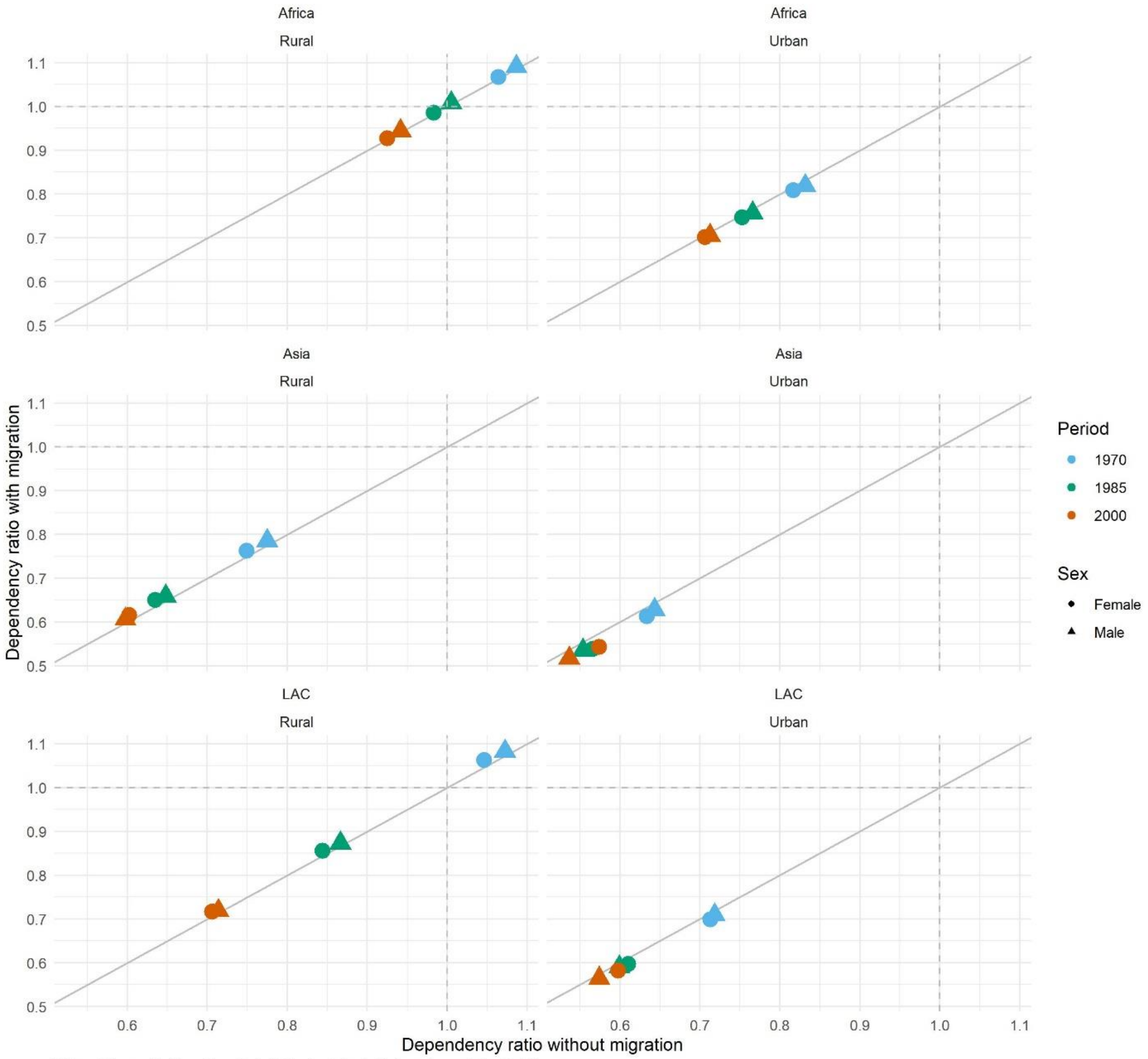
FIGURE 5 Sex ratios at stable state, accounting for migration or assuming no movement between rural and urban sectors, over all periods



Notes: Diagonal is line of equity. LAC is short for Latin America and the Caribbean.

Dependency ratios are also strikingly similar in the stable rural and urban populations, though again in the urban sector in Asia migration seems to marginally lower the dependency ratios (Figure 6). Across continents and sectors dependency ratios have declined over the period examined, or more accurately, based on more recent population dynamics, dependency ratios of stable populations are lower than those based on mortality, fertility and migration rates in earlier periods. All the same, the rural population in Africa will remain considerably young if fertility rates continue as they were between 2000-2014.

FIGURE 6 Dependency ratios at stable state, accounting for migration or assuming no movement between rural and urban sectors

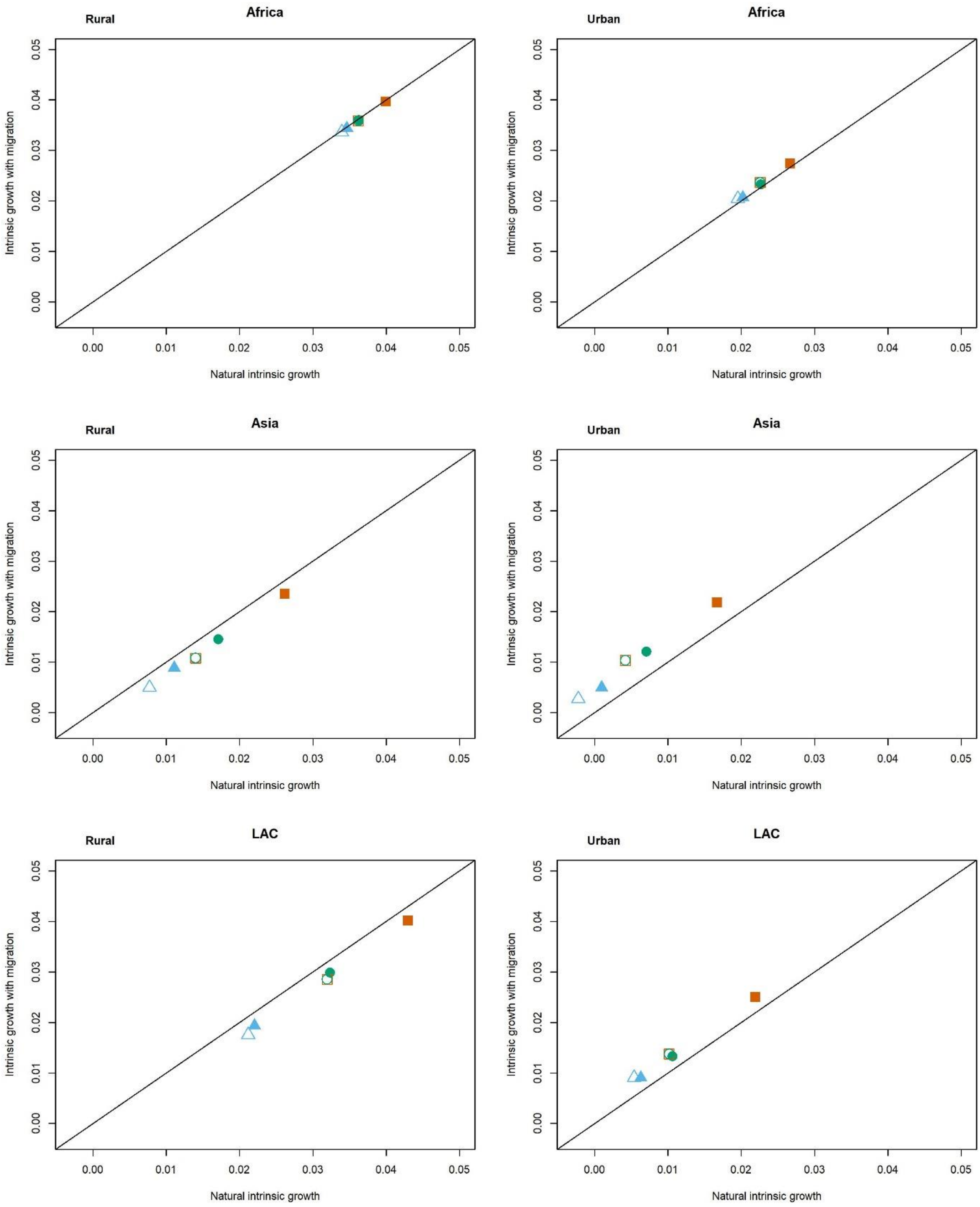


Notes: Diagonal is line of equity. LAC is short for Latin America and the Caribbean.
The years refer to the start of the 15-year period, i.e. 1970 refers to 1970-1984, 1985 refers to 1985-1999, and 2000 refers to 2000-2014.

Using the stable state analysis, we find compelling evidence that internal net migration plays a negligible role in shaping age and sex structures, despite migration flows being concentrated in young adult ages, and differential male and female flows. This does not necessarily mean that internal migration is nonconsequential. It could contribute to population growth, or, it could be that the migration flows we capture through estimates from the censuses are not quite representative of the continent. In particular, unstable countries with high numbers of internally displaced populations, or islands where international migration is more prevalent than internal, net migration rates may be quite different. All the same, these are generally atypical migration flows, and the age and sex patterns of our migration rates are in line with model migration patterns (Rogers, Raquillet, and Castro 1978), though the intensity may be different. It is also possible that our inter-regional rural-urban migration estimates do not follow the same age and sex patterns of intra-regional migration which are excluded from our estimates.

When we consider whether internal migration flows contribute to growth, in Figure 7, we see that in Asia and Latin America intrinsic growth rates are higher in the urban sector when we account for migration, than they would be without migration. In parallel, growth in the rural sector is lower when migration is accounted for. In both continents growth rates for women are lower than for men between 1970-1984. Growth rates in both rural and urban sectors in Africa, during all periods, are not influenced by migration flows. This makes sense considering that net migration rates in Africa are close to zero (see Figure 3).

FIGURE 7 Comparison of intrinsic growth rates when accounting for migration or assuming no movement between rural and urban sectors

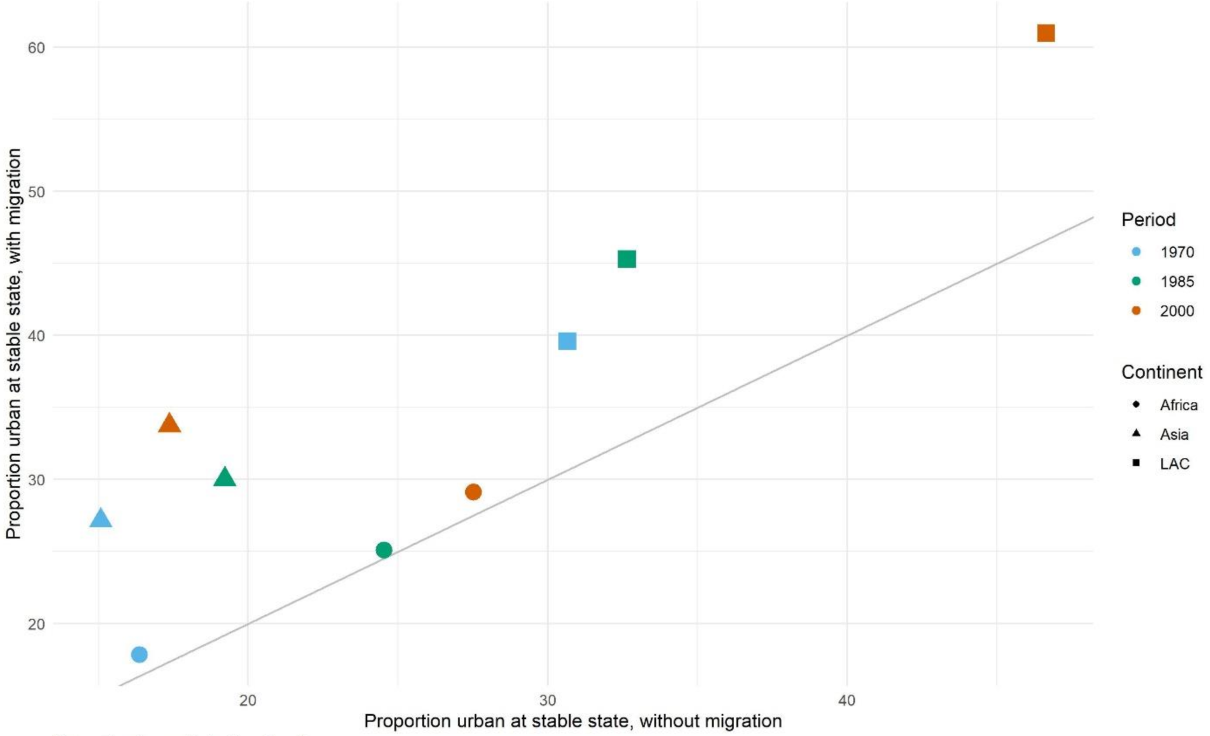


Notes: Female markers are open, male markers are full.
LAC is short for Latin America and the Caribbean.

In Africa and Latin America over all periods, we see higher intrinsic growth rates in the rural sector than in the urban (Figure 7). In other words, the urban population grows at a slower pace (the gap between births and deaths is smaller than in the rural sector), and this causes the urban age and sex structure to shift from its original population structure (which captures previous grow rates), as depicted in Figure 4. Across the three continents intrinsic growth rates (whether with or without migration) have also declined over time, from 0.029 on average in 1970-1984 to 0.015 in 2000-2014, though with much smaller declines seen in Africa.

In addition to population growth, we further examine to what extent internal migration contributes to urbanisation. In Figures 3, we noted that the contribution of net migration to urbanisation was previously found to be negligible, particularly in Africa (Chen, Valente, and Zlotnik 1998; Menashe-Oren and Bocquier 2021; Bocquier, Menashe Oren, and Nie 2023; Stecklov 2008). In Figure 8, where we compare the proportions urban at stable state, with migration or assuming no movement between the sectors, we confirm this: indeed, in Africa, internal migration appears to have no role in the urban transition.

FIGURE 8 Proportion urban at stable state, accounting for migration or assuming no movement between rural and urban sectors



Notes: The diagonal is the line of equity.
LAC is short for Latin America and the Caribbean.
The years refer to the start of the 15-year period, i.e. 1970 refers to 1970-1984, 1985 refers to 1985-1999, and 2000 refers to 2000-2014.

Figure 8 also presents lower levels of proportions urban than we see today across the continents. Essentially, since the rates feeding the cohort component analysis are assumed to be constant – unlike in projections – the proportions urban at stable state only tell us what would have happened had there been no changes. Although the populations at stable state do not account for any changes, these outcomes are useful for comparing the stable populations with no movement between the rural and urban sectors to those with internal migration. Clearly, in Asia, and even more so in Latin America, internal net migration contributes to the urban transition. In Latin America there is also a big difference in proportions urban at stable state between the latest period and the earlier two periods. In the 1970-1984 and 1985-1999 periods, the rural population was growing faster than the urban Latin American populations, likely because urban fertility had declined earlier than rural fertility (see Appendix Figure A3). This is also evident from the population pyramids in Figure 4, where the proportion of children in the rural sector was high (wide based) in Latin America, but in 2000-2014 we note a reduction in this proportion.

Discussion

Internal migration flows are effectually different in age and sex distribution to both origin and destination populations, with urban in-migration being most different to the urban population, and young adults migrating at high rates. Although we see this across continents, urban in-migration rates in Asia are highly concentrated between ages 15-29, suggesting that migration is primarily for marriage or employment. This however does not mean that older adults or children do not migrate. In Latin America, we find a relatively higher proportion of migrants over age 65 (nearly 20%) than in other continents. In Africa, migration in younger ages, amongst children aged 10-14, is higher, confirming previous findings (Beauchemin 2011; Bernard, Bell, and Charles-Edwards 2014). This is likely a reflection of child migration related to common fostering practices (Cotton 2021), schooling, and adolescent employment such as the employment of young maids (Lesclingand and Hertrich 2017). Moreover, migration in these young ages is pronounced amongst girls, with roughly 80 boys migrating for every 100 girls, before the age of 20. The dominance of female migration amongst children and adolescents in Africa can partially be explained by girls finishing school earlier, and entering the labour force (Hertrich and Lesclingand 2012; Psaki, McCarthy, and Mensch 2018), often as a means for them to secure capital and improve their social standing (Lesclingand and Hertrich 2017).[xiv] From age 60 too, women also tend to migrate more than men from the rural to the urban sector, contributing to the feminisation of mature adults in urban populations (combined with women surviving till older ages than men across the rural and urban sectors).

In addition to the continental differences in age and sex patterns, internal migration in Africa is also unique in having relatively balanced in- and out-migration flows, so that net migration is negligible, and does not contribute to the urban transition from around 30% urban. That said, it is worth noting that we underestimate migration by only considering inter-regional migration. Migration within regions, often of shorter distances, is common (Hoffmann et al. 2023) and could also contribute to urbanisation, as people shift from periphery to urban centres within the same region. Moreover, it is possible that negative growth from migration is counter-balanced by the expansion of cities through natural growth, enabling "urbanisation from within" (Randolph 2023).

In contrast to Africa, in Latin America particularly high urban in-migration levels at lower proportions urban has driven the continent to be much more urbanised to date than Asia and Africa. Our analysis of rural/urban populations at stable state (assuming constant fertility, mortality and migration rates) identifies net migration as a significant contributing factor during the 1970s through to the 2000s in Latin America. Despite this, the proportion urban at stable state, based on the demographic rates of the period 1970-1999 in Latin America are very low (around half of the estimated proportions urban in 1990 (UN 2018)), not as a result of migration, but of the large gap between rural and urban fertility driving fast rural growth (see Figure A3). In stark contrast, proportions urban in Africa at stable state are practically the same whether we account for migration or not. In Africa, where in- and out-migration flows are more balanced, and net migration close to zero, fertility plays an important role. Over the decades examined, not only has fertility remained relatively high, as the fertility transition in Africa has stalled (Shapiro and Gebreselassie 2008; Bongaarts 2016), but the gap between the rural and urban sectors remains wide. In fact, while declining fertility rates (even if they were to remain as they were between 1985-2014) clearly age the urban populations in Asia and Latin America, in Africa, only during the period of 2000-2014 does the stable state of the urban population indicate lower proportions of youth.

Overall, we find that the age and sex structure of rural and urban populations are barely affected by migration at the continental level, at least based on inter-regional migration estimates from the majority of countries in each region. However, internal migration does influence rural/urban growth rates. Notably, we find that intrinsic growth rates in Asia and Latin America are higher in the urban sector when we account for migration than they would be if there was zero migration. This is captured by the higher proportions urban anticipated in stable populations with migration than without. All the same, our analysis points to particularly low proportions urban whether internal migration contributes or not to urbanisation (notwithstanding intra-regional migration). Excluding Latin America in the 2000-2014 period, were the historical values of the fertility, mortality and migration rates to remain constant, they could have slowed down the urban transition, and even reversed urbanisation in Asia.

Our analysis focused on the broad role of internal migration in shaping rural and urban populations, a necessary perspective for reaching global conclusions on the urban transition. While the role of internal migration at the continent level appears marginal, this does not imply that there are no exceptions, or deviations from these findings at a national level. In particular, our migration estimates were based on larger and relatively stable countries, and migration patterns in unstable or smaller countries may differ. It may be possible that specific migration flows may alter rural and urban populations to some extent. For instance, women and children might leave rural areas while men remain behind to protect their land in a conflict region. Or, with the introduction of high incentives to work in agriculture, young adults may leave urban areas in larger numbers than previously seen. Such particular migration flows, and their potentially large role on shaping sub-national populations, are obscured when we average out internal migration at the continent-level.

Implications of our findings for development

Our results point to a remarkably insignificant role of internal migration in driving age and sex structures of rural/urban populations. This is likely because the in- and out-migration flows balance each other out. At the same time, we did find that internal migration has the potential to speed up the urban transition in Asia and Latin America. Since the proportions urban in Asian countries are still low (averaging around 50% (UN 2018)), migration can be expected to contribute to urbanisation in Asia. Certainly, over-confidence in the strength of migration flows is not encouraged: as was seen in China, this lead to “ghost cities” (Sorace and Hurst 2016). However, in Latin America, proportions urban are already very high (averaging over 80% (UN 2018)) and the likelihood of further urbanisation is low. In contrast, internal migration has no leverage in driving urbanisation in Africa. Indeed, over all the periods we examine (from

1970 to 2014), the role of migration is inconsequential, and we therefore cannot expect there to be a change in this in the future. While this negligible role of rural-urban migration in Africa has been known for some time (see Chen et al. 1998 and Preston 1979 for instance), scholars continue to maintain that migration contributes to urbanisation in Africa, and that rapid urbanisation is expected in the future, accompanied with poverty and poor infrastructure (see for example Collier 2017 and Parienté 2017). Urbanisation is actually considered with concern by some governments, fearing the consequences of large young populations, as in the Arab Spring (Hvistendahl 2011), despite evidence that neither urban growth nor migrants contribute to social unrest and conflict (Urdal and Hoelscher 2009; Buhaug and Urdal 2013; Menashe-Oren 2020).

The relationship between urbanisation and economic development in Africa has been debated considerably (Kessides 2007; Rogers and Williamson 1982), where on the one hand the relationship is considered decoupled (Fay and Opal 2000; Gollin, Jedwab, and Vollrath 2016), and on the other hand critically integrated (Dyson 2001). If we advocate for the later, urbanisation can be used as a proxy for economic growth. Thus, a delay in the urban transition in Africa could suggest stagnation of the economy, maintaining global inequalities and an economic hierarchy of countries. Although a reduction of economic growth may be considered disadvantageous, a slowdown in urbanisation and in economic growth could provide the opportunity to rethink the sustainability of urbanisation. As we find in Africa, people choose to live in the rural sector – migration from the urban to rural sector is as high as in the reverse direction. This suggests opportunities in the rural sector exist too, and that other aspects rather than economic perspectives are valued too, including individual well-being, resilience to climate change and social ties. Moreover, even without urbanisation, economic growth from changing age structure, a demographic dividend, is feasible in rural Africa. Assuming fertility continues to decline and educational opportunities improve in the rural sector, the possibility of leveraging economic growth in the rural sector will increase. Internal migration will not threaten such growth since rural-to-urban and urban-to-rural flows balance out, and do not affect age structures.

Our analysis of stable populations indicates a strong potential for de-urbanisation. Simply put, urbanisation is not inevitable. This is not because of changes in internal migration patterns such as increased migration to the rural sector, but because of the differential pace of fertility decline across the rural and urban sectors. Continued investment and creation of opportunities in the rural sector is therefore necessary: not to keep the rural population from migrating, but because the rural population will continue to constitute an important sector, and because people choose to migrate to the rural sector. Even if net migration is minimal, we noted a high turnover of populations. Considering the *possibility* of migration is also imperative. For example, in providing health services that require regular follow-up or adherence to treatment, the possibility of migration should be aforethought. This has been noted in relation to antiretroviral treatment of HIV/AIDS (Murnane et al. 2022; Bernardo et al. 2021). Overall, the potential of mobility should be acknowledged, at the same time that the potential for de-urbanisation recognised.

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Notes

[i] Although the method is based on projections, we do not actually project future populations, but use this method as a tool to assess the role of internal migration at different times.

[ii] For this part of our analysis we exclude censuses from before 1970 since we only have four and they are all in Latin America.

[iii] In places where fostering practices are common (e.g. Namibia), or where mothers migrate independently for work (e.g. Philippines), this assumption is weaker. All the same, this method of estimating under-five migration developed by the UN (United Nations 1980) is ordinarily used, and provides a more robust estimate of migration for these young ages than estimates based on census and survey questions used to date.

[iv] We are interested in the intrinsic growth of the populations, and we do not consider what proportion of the rural and urban populations are migrants.

[v] A full list of all census used is available in Appendix Table A1.

[vi] For simplicity, below we refer to Latin America and Caribbean simply as Latin America, and in figures as LAC.

[vii] It is possible that the comparisons done in Table 1 may deviate somewhat if we were to focus on a different year, as countries may be more similar to each other, or more diverse, at different points in time.

[viii] Standardised definitions of urban have been attempted, particularly using satellite imaging (see for example (Balk et al. 2018; Dorélien, Balk, and Todd 2013), but such definitions have not been globally adopted, or are not applicable to historical data.

[ix] This somewhat unexpected relationship in Latin America can possibly be explained by the interaction between two factors: firstly, intra-urban migration is more common in the continent than movement between the sectors, especially at the higher levels of urbanisation, and secondly, the countries for which we have migration data are quite large, and the regions within countries accordingly are also big – and since we only capture inter-regional migration (between rural and urban regions), we may be missing consequential moves within-regions.

[x] This correction factor is insufficient to capture migration in this age group. We therefore chose to population the matrices with indirectly computed net migration rates for this age group based on the migration of women aged 15-49, the age-specific fertility rates (distribution of births amongst women by age, assuming national fertility levels), and the sex ratio at birth instead. We describe this computation in detail in the Appendix.

[xi] This is done in Stata using the *dxdy()* option in Stata® *margins* commands.

[xii] Only two censuses are represented in Africa in the earliest period, from Benin and Kenya, and therefore the in-migration rates are more influenced by what is seen in these countries. Likewise, between 1970-1984 Asia is only represented by two countries, Indonesia and Thailand (though with more censuses). While we modelled the migration estimates and "borrowed" information from other censuses, smoothing the rates, we still caution against over-interpretation of these particularly high rates.

[xiii] It is important however to note here that these dependency ratios are based on direct census estimates of migration which under-estimate under-five migration flows (or do not capture them when questions on residence five years ago are posed).

[xiv] It is possible that in the past some of this migration was for marriage, but considering that the median age at first marriage has increased for women (with improvements in female education) (Hertrich 2017; Garenne 2004; Amoo 2017), and that the young female dominant sex ratios persist, other reasons are more likely.

Appendix

Data to inform the Leslie matrices

Initial Populations

Population size for rural and urban sectors by age and sex are taken from United Nations (UN) Urban and Rural Populations by Age and Sex (URPAS) data (United Nations 2014b). The UN generated these estimates based on censuses and population registers, imputed them where missing based on linear interpolation, and ensured they are consistent with the UN WUP (United Nations 2014a). As noted with the census samples, here too the definition of urban is country-specific. Since the URPAS data is in five-year intervals, we use the population size closest date to mid-period available for each region (for which the data is provided at aggregated continental level). For 1970-1984 we use the 1980 population (the earliest period available in URPAS), for 1985-1999 we use 1990 and for 2000-2014 we use 2005 data.

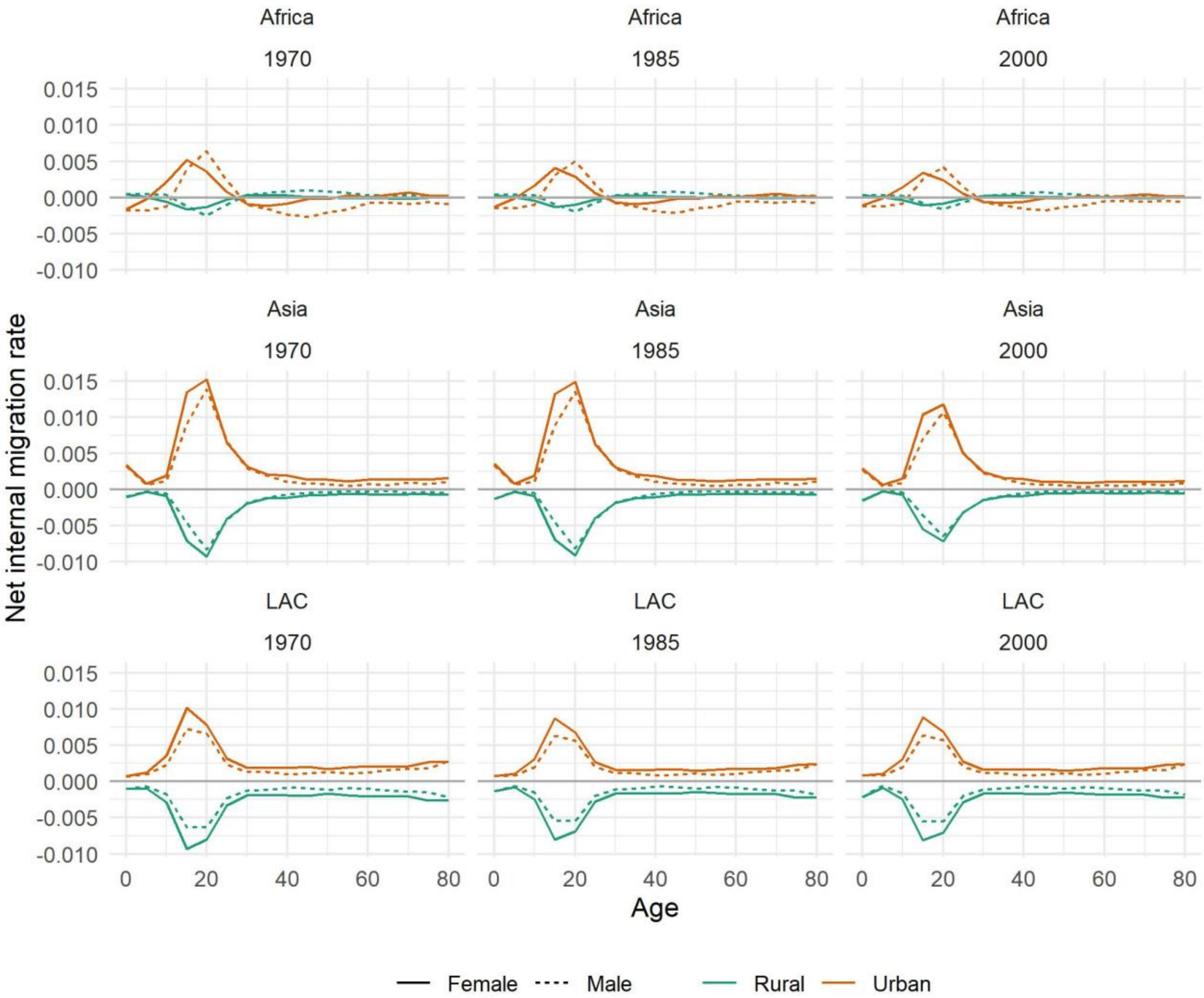
Migration

We rely on the continent-specific modelled net migration rates using direct measures of in- and out-migration from IPUMS census samples by age and sex, as described in the main text. The models are weighted by national population size. Following the model, margins where covariates are held at the mean, for each specified period (1970-1984, 1985-1999 and 2000-2009), age (17 five-year age groups) and sex, provide net internal migration rates using the *dydx()* option in Stata which provides the difference between the in- and out-flows for the rural and urban sectors. For simplicity, migration for the last age group (80+) is assumed to be zero. Note that under-five year old migration estimates are biased and cannot be corrected for in the Asian and Latin American models since we do not have one-year estimates from these censuses. Rather than rely on the under-estimated rates, for the matrices we chose to indirectly estimate the migration rates for under-five year olds ($M_{0\text{-}4}$) as follows for all continents and periods (here shown for urban sector):

Eq. 1 $$M_{0-4} = SRB_T * \frac{\sum_{x=15-49} B * P_{T,f}}{2 * P_{U,f,0-4} * 5}$$

Where *B* is the proportion of births by age group (distributed according to national-level age-specific fertility rates), *SRB* is the sex ratio at birth, and *P* represents the population size. Although these under-five migration estimates are quite rough, since they assume the children migrate with their mother, we prefer this approach developed by the UN (United Nations 1980), using a standardised method across the continents. The marginal annualised net migration rates (Figure A1) are multiplied by five to inform the diagonal of our matrices.

FIGURE A1 Rural and urban net five-year migration rates by sex, used to inform the Leslie matrix



Source: IPUMS census samples, model-smoothed to account for measurement biases and country-period effects.

Notes: LAC is short for Latin America and the Caribbean. The years refer to the start of the 15-year period, i.e. 1970 refers to 1970-1984, 1985 refers to 1985-1999, and 2000 refers to 2000-2014.

We assume that migrants do not contribute to births, and do not die during the five-year period of migration. More precisely, since migrants are assumed to move at mid-period, for 2.5 years “net migrants” do not die and do not have children. By considering that this is the case for net migrants only (the diagonal of the matrices are of net migration), we do not expect this assumption to be significant. Once incorporated in the population (after 2.5 years), migrants are assumed to adapt instantly to the population at destination, exposed to the same fertility and mortality rates. Of course, it is possible for migrants to have lower or higher fertility and survival for an extended period after migration, but results on this are mixed (see for example on mortality Ginsburg (2016) and on fertility Chattopadhyay et al. (2006)), and incorporating this in the cohort component analysis would require more complex analysis.

Mortality

Survival ratios (S_x) are needed for each age group and sex to capture mortality. We use the survival ratios from life tables available from the UN World Population Prospects (WPP) 2022 for each continent for the mid-periods of our 15-year periods: 1977, 1992, and 2007 (Gaigbe-Togbe et al. 2022). Since we require separate matrices by rural/urban sector, we adjust the S_x using a factor based on rural and urban survival rates taken from Menashe-Oren & Masquelier (2022). The ${}_{15}q_0$ and ${}_{45}q_{15}$ are averaged across the Demographic and Health Surveys (DHS) by continent (see Table A2). The rural/urban gap is slightly larger in the later period for countries in Africa, however we chose to use a stable factor over time since the DHS are not representative of all countries for all periods (notably Northern African countries are lacking), and we do not have enough surveys to conclude on trends in Asia and Latin America. Though for these two continents it appears there is a constant gap in rural/urban adult mortality over time, and in Latin America the gap for children becomes smaller in the later period, in general, there is a larger gap between the sectors amongst children than amongst adults. The adjustment factor (*Adj*) is estimated for two age groups (0-14 and 15-59) as:

Eq. 2 $$Adj = \frac{(q_{x,R} - q_{x,U})}{\frac{q_{x,R} + q_{x,U}}{2}}$$

Since the national level S_x will reflect more of the urban sector as the proportion urban increases, in adjusting the S_x we also need to account for the population in each sector. We use the UN URPAS data for population counts by continent (and by age, sex and sector). Sex- and age-specific mortality rates for the urban sector are estimated as:

Eq. 3 $$S_{x,U} = \frac{(S_{x,T} * P_{x,T}) + (Adj * P_{x-5,T}) - (Adj * P_{x,U})}{((1 + Adj) * P_{x,T}) - (Adj * P_{x,U})}$$

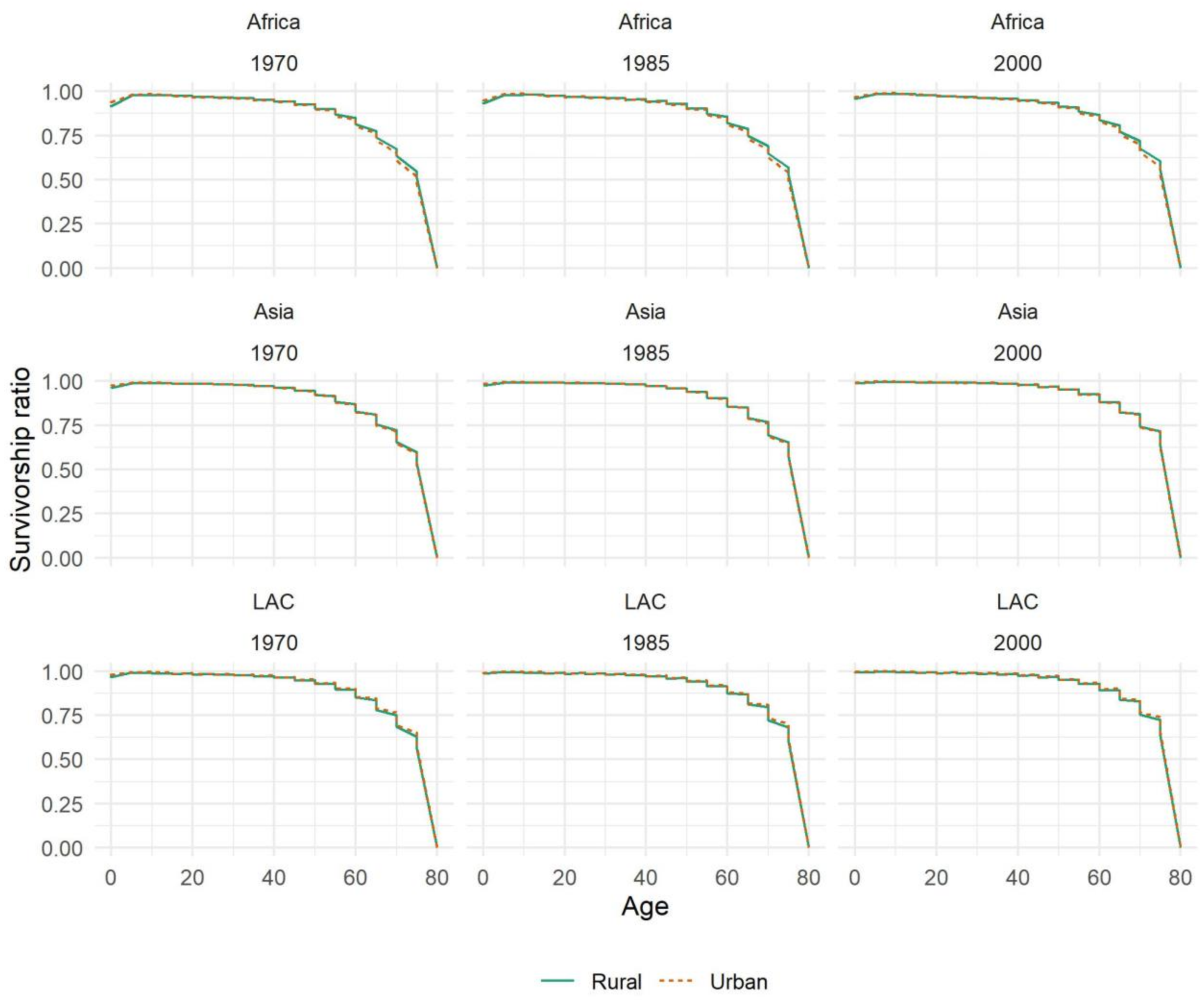
Figure A2 provides the final survival ratios by rural/urban sector used to inform the Leslie matrices.

TABLE A2 Rural and urban mean fertility rates and mortality rates used to adjust national estimates (across all periods)

		TFR	${}_{15}q_0$	${}_{45}q_{15}$
Africa	Rural	5.82	157.13	309.56
	Urban	3.92	116.69	329.96
Asia	Rural	3.65	86.79	176.68
	Urban	2.74	55.05	179.63
LAC	Rural	4.47	101.47	181.40
	Urban	2.78	65.00	169.93

Source: DHS surveys

FIGURE A2 Rural and urban survival ratios used to inform the Leslie matrix



Source: WPP, rural urban adjustment factors based on DHS

Notes: LAC is short for Latin America and the Caribbean. The years refer to the start of the 15-year period, i.e. 1970 refers to 1970-1984, 1985 refers to 1985-1999, and 2000 refers to 2000-2014.

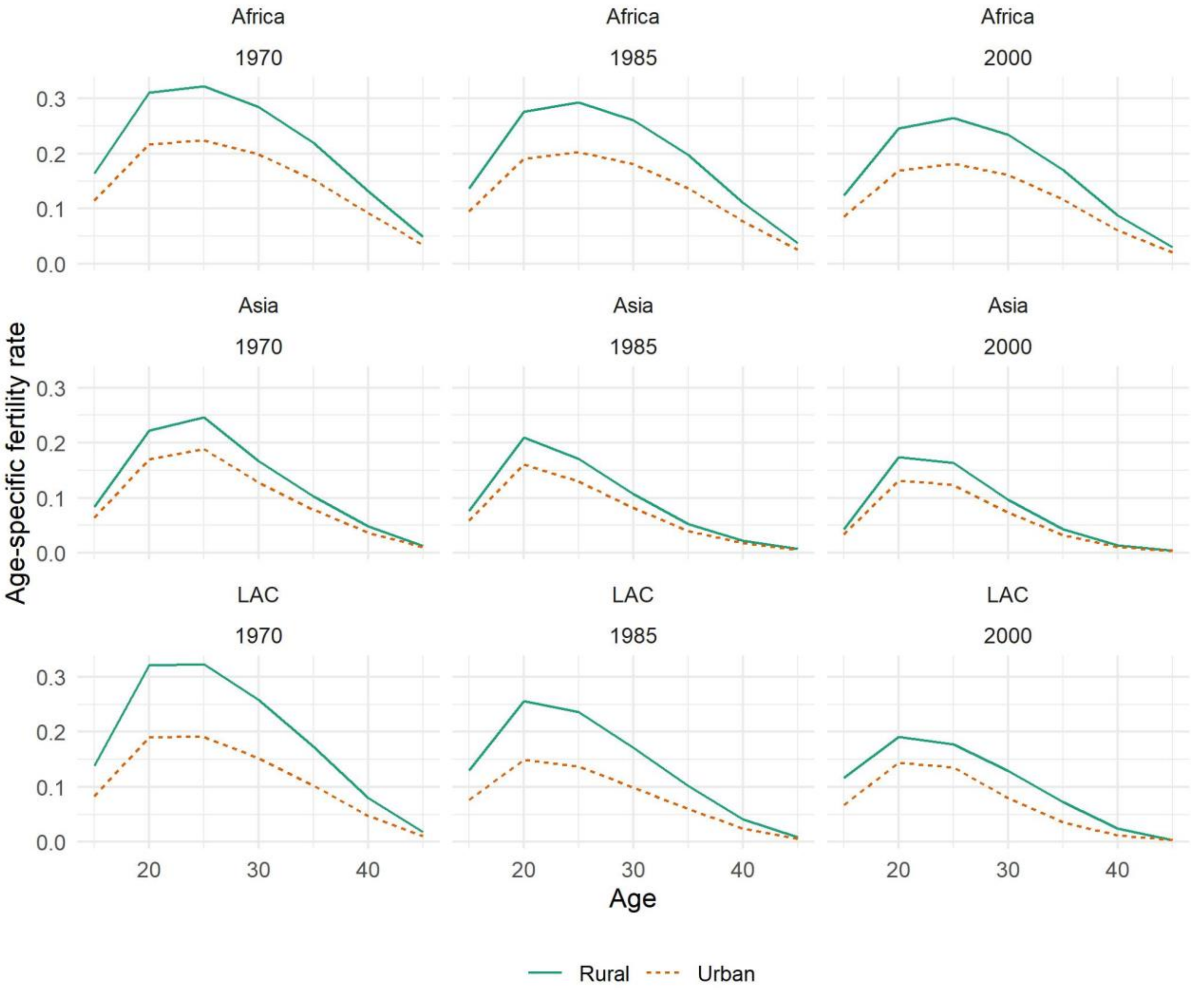
Fertility

To capture entry into the populations through birth we rely on age-specific fertility rates (ASFR) for every five-year age group between ages 15-49, from the World Population Prospects (WPP) 2022 for each continent, using the mid-period value of ASFR for each 15-year period. As with mortality, we adjust the national ASFR to get them for each rural/urban sector. For this we rely on the average rural/urban total fertility rates (TFR) obtained from all DHS available in each continent (regardless of period), downloaded from STATcompiler.com (see average adjustment factors in Table A2).[xiv] In building the matrices, the ASFR are used to estimate the number of children aged 0-4 by sex, and therefore sex ratios at birth (SRB) and survival rates S_0 are required. We proxy SRB using sex ratios for 0-1 year olds from the WPP 2022, and convert these to the proportion of births that are male.[xiv] Sex ratios of 0-4 year olds do not differ by rural/urban sector (Menashe-Oren and Stecklov 2023), so we do not adjust them to be sector-specfic. Age, and sex-specific fertility rates for the urban sector are estimated as:

Eq. 4 $$ASFR_U = \frac{(ASFR_T * P_{T,f}) * (Adj * P_{T,f}) - (Adj * P_{U,f})}{((1+Adj) * P_{T,f}) - (Adj * P_{U,f})} * \frac{SRB_T}{1 + SRB_T}$$

With the sector adjustment factor (*Adj*) is as in Eq. 2 but based on TFR rather than q_x. The age-specific fertility rates for the rural/urban sectors are presented in Figure A3.

FIGURE A3 Rural and urban age-specific fertility rates used to inform the Leslie matrix



Source: WPP, rural urban adjustment factors based on DHS

Notes: LAC is short for Latin America and the Caribbean. The years refer to the start of the 15-year period, i.e. 1970 refers to 1970-1984, 1985 refers to 1985-1999, and 2000 refers to 2000-2014.

An example Leslie matrix

To start, for each continent, period, sector and sex, we have a simple dataset, with the initial population in each age group, the fertility, survival ratios and net migration rates. For instance, in Table A3, we present this data for Asia, 1970-1984, for women in the rural sector.

TABLE A3 Example data informing the Leslie matrix for rural women in Asia, 1970-1984

Age	Population	Survival ratio	Fertility rate	Net migration rate
0	125370	0.959504	0	-0.0010302
5	125563	0.988043	0	-0.0003489
10	117202	0.988859	0	-0.0008895
15	98686	0.987074	83.97827	-0.0070858
20	79214	0.985339	222.5235	-0.0092611
25	72749	0.983869	246.6929	-0.0040135
30	56367	0.981526	167.0663	-0.0019156
35	46896	0.977183	102.7605	-0.0012439
40	43361	0.971324	47.86817	-0.0010974
45	39518	0.960772	12.97516	-0.0007638
50	34131	0.94422	0	-0.0007122
55	28685	0.915923	0	-0.0005665
60	23956	0.870458	0	-0.0006559
65	18794	0.810102	0	-0.0006941
70	13686	0.721769	0	-0.0006496
75	8514	0.599777	0	-0.0006658
80	6223	0	0	-0.0007426

This information populates the Leslie matrix, so that we get the following matrix (Table A4), which can be used to obtain the intrinsic growth rate and age-distribution of the stable population.

TABLE A4 The resulting Leslie matrix composed based on the rates in Table A3

	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
0	-0.0010	0	0	83.978	222.52	246.69	167.07	102.76	47.868	12.975	0	0	0	0	0	0	0
5	0.9595	-0.0003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0.988	-0.0009	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0.9889	-0.0071	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0.9871	-0.0093	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0.9853	-0.0040	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0.9839	-0.0019	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0.9815	-0.0012	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0.9772	-0.0011	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0.9713	-0.0008	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0.9608	-0.0007	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0.9442	-0.0006	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0.9159	-0.0007	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0.8705	-0.0007	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8101	-0.0006	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7218	-0.0007	0
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5998	-0.0007

STATA code to build a Leslie matrix and estimate intrinsic growth rates

The programme used to convert the dataset into a matrix and then estimate the population at stable state, as well as the intrinsic growth rate is provided on Github. It calls on csv files named according to continent, period, sector and sex.

Supplementary figures and tables

FIGURE A4a Robustness check comparing methods of standardization to five-year net migration rates (from one-year, five-year and previous residence (2.5-year) rates), over levels of proportion urban: Flat standardization vs. Continent specific standardization

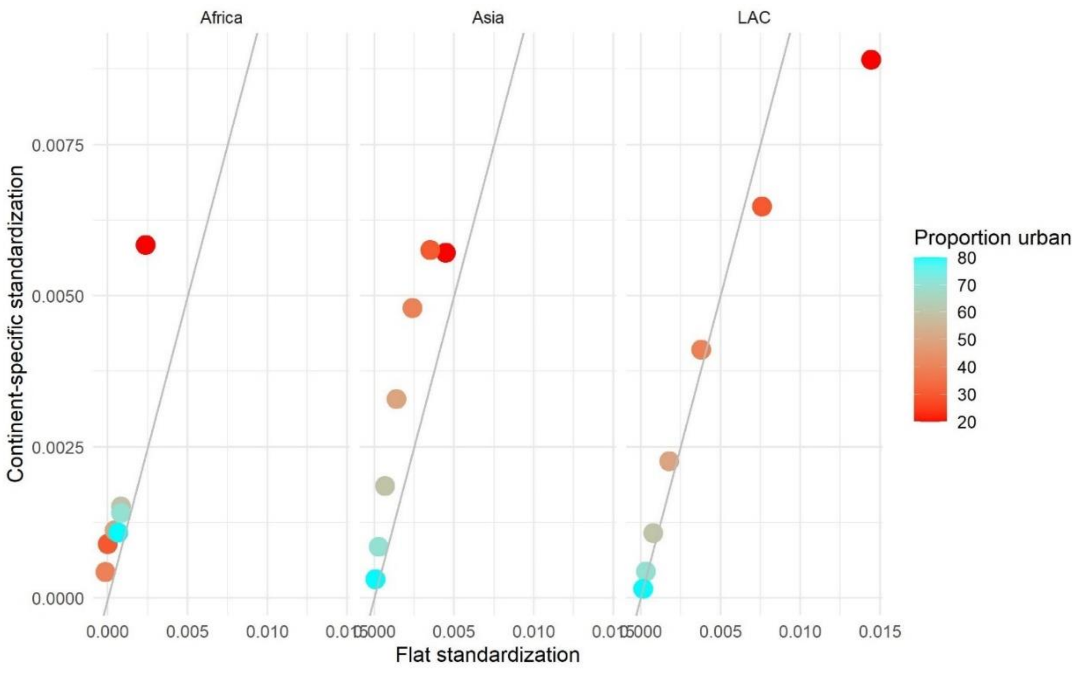
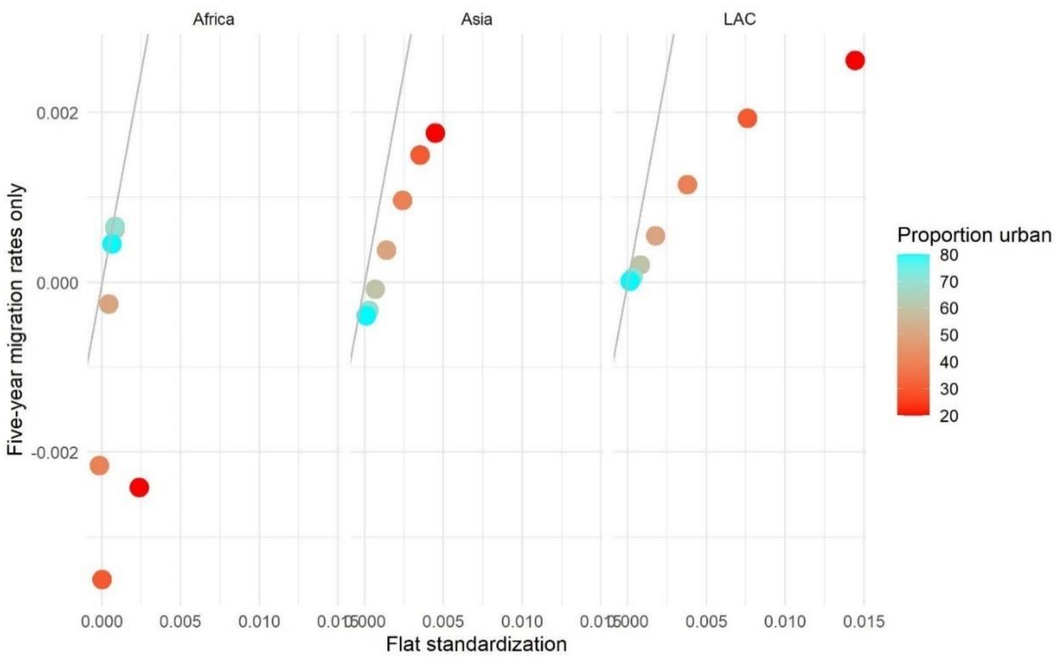
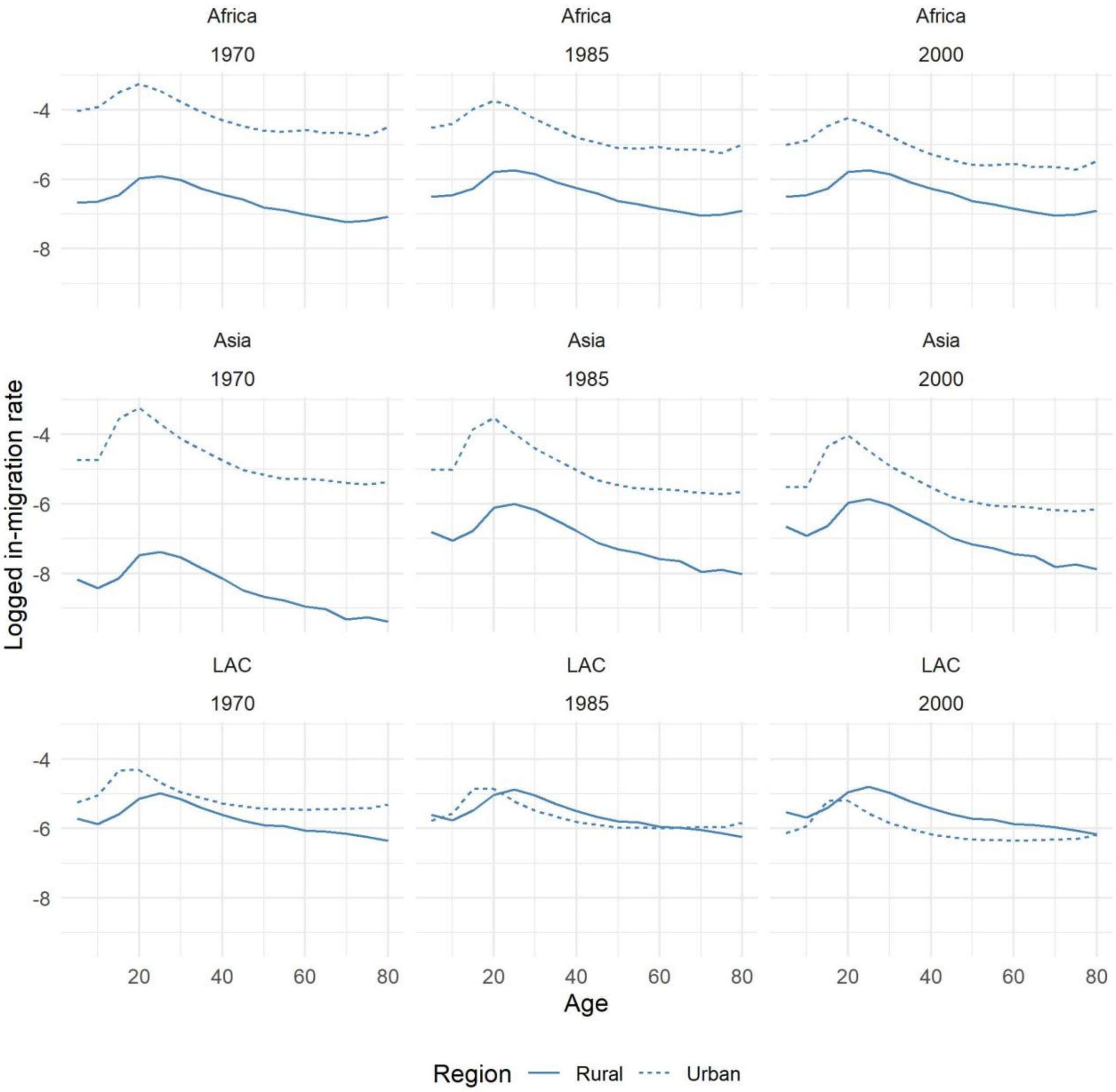


FIGURE A4b Robustness check comparing methods of standardization to five-year net migration rates (from one-year, five-year and previous residence (2.5-year) rates), over levels of proportion urban: Flat standardization vs. Only censuses with a five-year retrospection period



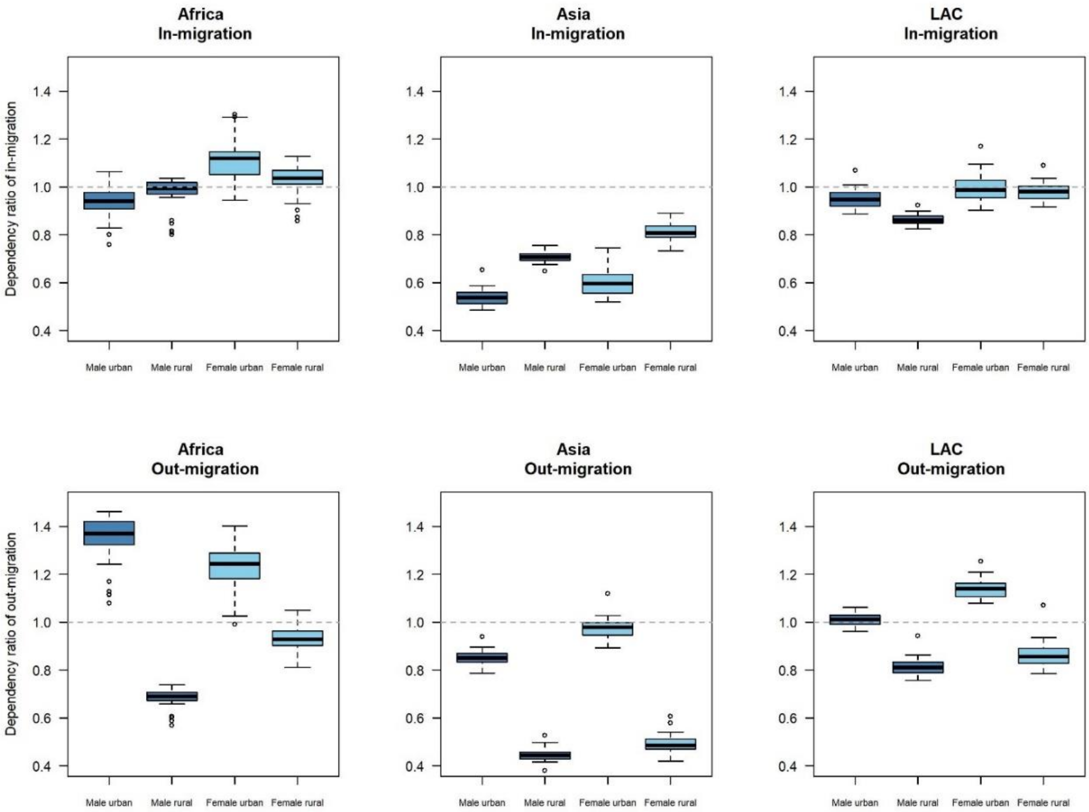
Note: LAC is short for Latin America and the Caribbean.

FIGURE A5 Model-smoothed age profile of (logged) in-migration flows in the rural and urban sectors, on average for both sexes, and across continents and periods, based on IPUMS census data (45countries, 1960-2014)



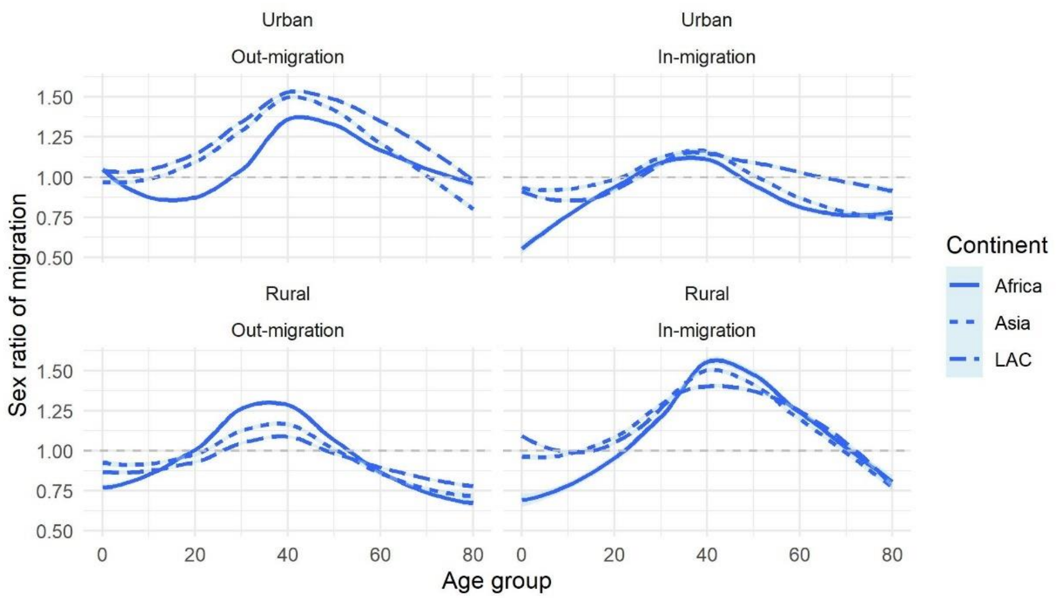
Notes: LAC is short for Latin America and the Caribbean. The years refer to the start of the 15-year period, ie. 1970 refers to 1970-1984, 1985 refers to 1985-1999, and 2000 refers to 2000-2014.

FIGURE A6 Dependency ratios of in-migrants to rural and urban sectors, by sex, based on IPUMS census data (all periods)



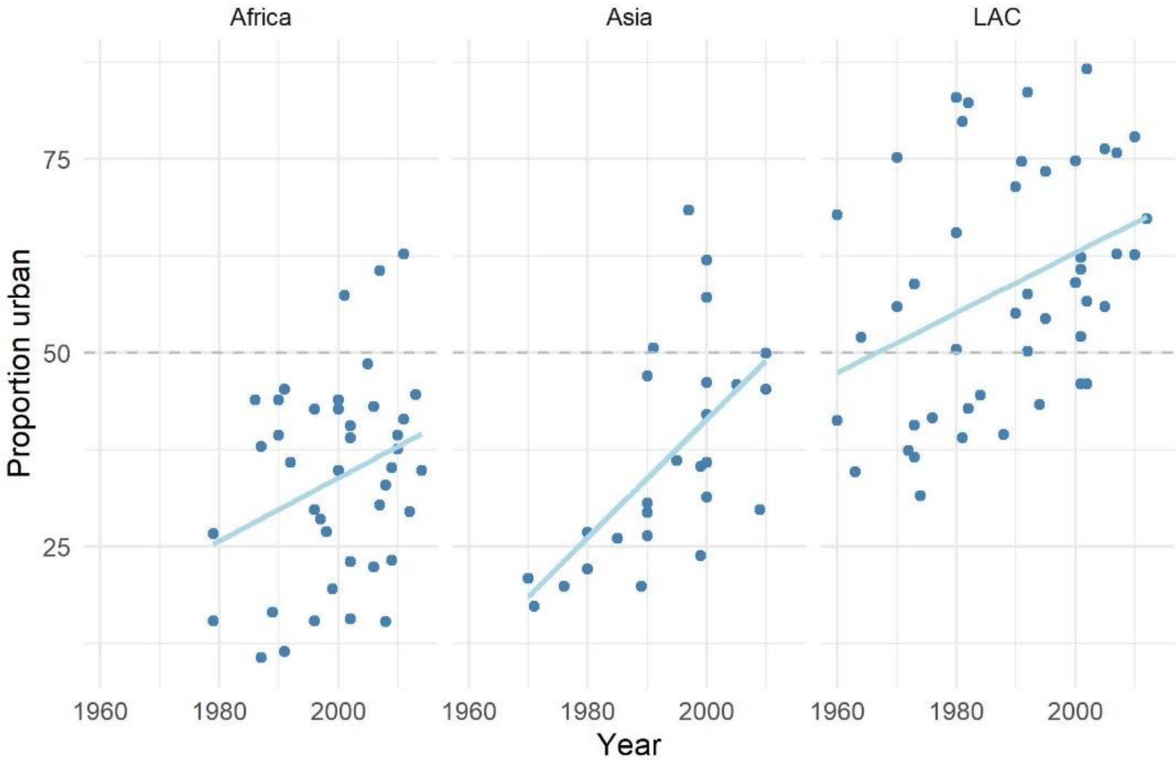
Notes: LAC is short for Latin America and the Caribbean. Asia and LAC dependency ratios do not include under-five year old migrants

FIGURE A7 Sex ratios of standardised five-year in-migrants to rural and urban sectors, by age, based on IPUMS census data (all periods)



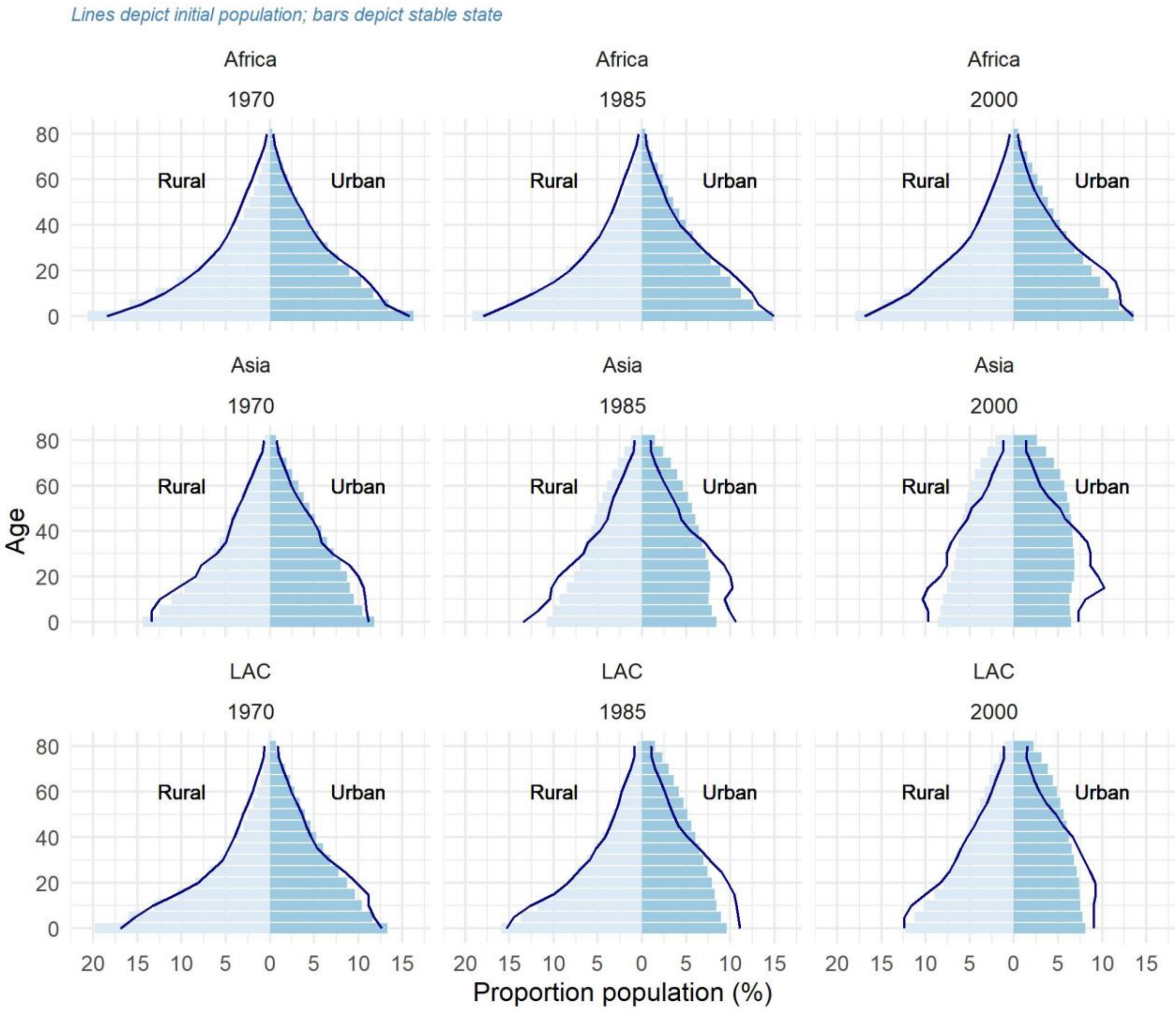
Notes: A sex ratio above one indicates higher male migration rates than female. Smoothed using Loess, with 95% confidence band. LAC is short for Latin America and the Caribbean.

FIGURE A8 IPUMS census samples distribution over time and proportion urban



Notes: Linear fitted line with 95% confidence intervals. LAC is short for Latin America and the Caribbean.

FIGURE A9 Female age structures comparing estimated mid-period population (based on URPAS data) and age structure at stable state, including internal migration



Notes: The lines represent the mid-period initial population (based on URPAS data), and the bars the population at stable state. LAC is short for Latin America and the Caribbean. The years refer to the start of the 15-year period, i.e. 1970 refers to 1970-1984, 1985 refers to 1985-1999, and 2000 refers to 2000-2014.

TABLE A1 Complete list of IPUMS census samples used

Africa		**Asia**		**Latin America & Caribbean**	
Country	**Year(s) of census**	**Country**	**Year(s) of census**	**Country**	**Year(s) of census**
Benin	1979, 1992, 2002,2013	China	1990, 2000	Argentina	1980
Botswana	1991	Indonesia	1971, 1976, 1980, 1985, 1990, 1995, 2000, 2005, 2010	Bolivia	1976, 1992, 2001, 2012
Burkina Faso	1996, 2006	Iraq	1997	Brazil	1970, 1980, 1991
Cameroon	1987, 2005	Kyrgyzstan	1999	Chile	1960, 1970, 1982, 1992, 2002
Egypt	1986, 1996, 2006	Malaysia	1991, 2000	Colombia	1964, 1973
Ghana	2000	Mongolia	2000	Costa Rica	1963, 1973, 1984, 2000
Guinea	1996, 2014	Philippines	1990, 2000, 2010	Ecuador	1990, 2001, 2010
Kenya	1979, 1989, 1999, 2009	Thailand	1970, 1980, 1990, 2000	El Salvador	2007
Malawi	1987, 2008	Vietnam	1989, 1999, 2009	Guatemala	1973, 1981, 1994, 2002
Mali	1998, 2009			Honduras	1974, 1988, 2001
Mauritius	1990, 2000, 2011			Jamaica	2001
Mozambique	1997, 2007			Mexico	1990, 1995, 2000, 2005, 2010
Senegal	2002			Nicaragua	1995, 2005
South Africa	2001, 2007, 2011			Panama	1960, 1980
Sudan	2008			Paraguay	1972, 1982, 1992, 2002
Togo	2010			Peru	2007
Uganda	1991, 2002			Venezuela	1981
Tanzania	2002, 2012				
Zambia	1990, 2000, 2010				