The Sources and Diversity of Immigrant Population Change in Australia, 1981–2011

James Raymer1 · Yanlin Shi2 · Qing Guan1 · Bernard Baffour1 · Tom Wilson3

Abstract Australia has one of the largest percentages of immigrant populations in the developed world with a highly regulated system of immigration control and regular censuses to track their changes over time. However, the ability to explain the population change through the demographic components of immigration, emigration, and death by age and sex is complicated because of differences in measurement and sources of information. In this article, we explore three methods for reconciling the demographic accounts from 1981 to 2011 for the Australia-born and 18 foreign-born population groups. We then describe how the immigrant populations have changed and what has contributed most to that change. We find that the sources of immigrant population change have varied considerably by age, sex, country of birth, and period of immigration. Immigrants from Europe are currently the oldest and slowest-growing populations, whereas those from elsewhere are growing rapidly and exhibit relatively young population age structures. Studying these patterns over time helps us to understand the nature of international migration and its long-term contributions to population change and composition.

Keywords International migration · Immigrant populations · Demographic accounting · Aging populations · Australia

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Introduction

In this article, we seek to understand the effects that different streams of immigration have had on the demographic evolution of Australia, a country which has received a large amount of overseas migration since the 1950s and continues to do so. We are mainly interested in how immigrant populations differ in terms of their demographic characteristics and sources of demographic change. This is relevant because international migration is, and always has been, an important component of population change in Australia (Borrie 1994; chapter 10; Hugo 2014; Khoo 2002). It also underpins many of the major challenges facing contemporary Australia, including economic growth, labor force needs, housing supply, infrastructure requirements, spatial population development, immigrant integration and well-being, and the environment (Hugo 2009; Jupp et al. 2007; Markus et al. 2009). More than 10 years ago, Khoo (2003:159) stated that “the growth in ethnic diversity must be considered one of the most important transformations of Australian society during the past 30 years.” Since then, immigrant populations have further grown and diversified.

The overall aim of this article is to show how building data and analytical strategies that connect international migration flows and immigrant populations help us to better understand the processes and impacts of migration and therefore Australia’s changing demography. Our argument is that treating flows separate from the populations results in both partial understanding and inconsistent data. The solution, therefore, is to create integrated data systems and analytical strategies. Fundamental to this are demographic accounting systems—for example, when a population at time $t + n$ is equal to a population at time $t$ plus births and immigration minus deaths and emigration, where $n$ is the width of the time interval. The ability to track populations and their entries or exits over time enables a better understanding of the effects on demographic change. This information can also be used to provide evidence for assessing the effectiveness or long-term implications of migration policies. Moreover, it moves the analysis of migration from simplistic thinking to dynamic thinking: international migration flows create immigrant populations, which further perpetuate or alter international migration flows, and so on. Thus, processes and effects are linked in relation to migration study.

Following this line of thinking, we analyze three main aspects of international migration in this study. The first concerns the diversity of immigrant populations in terms of their population size and age structures. Because Australia receives a large number of immigrants every year from a wide array of origins, it is important to assess not only the relative sizes of different immigrant groups but also their age and sex compositions so that their effect on society and demand for particular services (e.g., education, healthcare, employment support) can be better understood.

Second, we explore how these immigrant populations have changed since 1981 as a result of immigration, emigration, and death. Births by immigrants are not included because they represent an important source of demographic growth for the Australian-born population. Since the elimination of the discriminatory White Australia policy in the 1960s and 1970s, Australia has received immigrants from a much more diverse set of countries than was permitted under the policy, which restricted entry to predominately white European-origin immigrants (Wilson and Raymer 2017). Immigrants from the United Kingdom are still the largest foreign-born population in Australia, but other populations have been growing rapidly in recent years.
Third, we assess the contributions of various immigration cohorts over the 30-year period to the age-sex compositions of the 2011 populations. Immigrants come to Australia for a variety of reasons, and some groups are more likely than others to bring their families and stay permanently. By including immigration in a demographic accounting framework, we can assess not only how many immigrants have come over the past year for each immigrant group but also how many remained in the country after, say, 10 or 20 years.

The first challenge for our analyses is to harmonize the data so that the demographic events of immigration, emigration, and death match up with the changing immigrant stocks as measured by the quinquennial censuses from 1981 to 2011. Thus, we first explore different methods for reconciling the reported population data with the reported demographic event data. Although these exercises are normally carried out at the national level, they are rarely conducted for subpopulations. By doing so, this research provides some insights into the quality of the data being reported by the Australian Bureau of Statistics (ABS) at a subpopulation level.

Background

This study focuses on the period 1981 to 2011. According to the ABS, the population of Australia increased by 50% from 15.0 million people in 1981 to 22.3 million people in 2011 (ABS 2013, 2014). The foreign-born represented 27% of the total population in 2011, up from 23% just 10 years earlier. According to the United Nations Population Division’s International Migrant Stock data set, this places Australia in the top 20 countries in the world with high percentages of international migrants and in the top 5 of more-developed countries. Australia also has one of the most ethnically diverse populations in the world (Jupp 2001). With the country’s increased life expectancy and below-replacement fertility over the past 30 years, international migration has clearly played an important role in determining Australia’s population size and composition (Khoo 2002; Richards 2008). It has not, however, contributed much to the reduction of Australia’s population aging, given that the immigrants have also aged over time (McDonald and Kippen 1999; United Nations 2001; Young 1988).

Migration has always been an integral part of Australian society, and immigration policy has long sought to control the types and characteristics of people coming to Australia (Markus et al. 2009; Richards 2008). However, a major gap in our knowledge of international migration concerns the long-term demographic consequences of these policies. In this study, the demographic consequences include those that are direct, such as changing the population size and age composition of specific populations, and those that are indirect, such as those involving subsequent generations (Edmonston 2010; Scott and Stanfors 2010) and other demographic processes (see, e.g., Kohls 2010; Kulu 2005, 2006; Milewski and Kulu 2014). Immigrants from poorer areas of the world tend to bring with them their higher (or lower) levels of fertility, and because migration involves a selection process, they also tend to bring with them their youth and ambition. Not all immigrants remain to retire in the host country, but many do, and this has implications for both the immigrant and the health sector in the long run (Nauman et al. 2016).

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1 The data set is available online (http://www.un.org/en/development/desa/population/migration/index.shtml).
Many studies have examined the diversity of international migration in Australia (e.g., Bell and Hugo 2000; Hugo 1986, 2010; Jupp 1995; Khoo 2002, 2003; Khoo et al. 2011; Markus et al. 2009; Price 1998; Stillwell et al. 2001), including the underlying reasons of immigration (Hugo 2004), resulting social change (Markus et al. 2009) and subsequent internal movements (Burnley 1996). However, relatively little work has been undertaken in the last few years, and very little attention has been paid to the important issue of inconsistent immigrant population stocks and demographic components of change. The need to update and build on this earlier work is all the more important given the large increases in net overseas migration gains reported in Australia since the mid-2000s (ABS 2015).

The demographic study of immigrant populations provides researchers and policymakers with information about the fundamental sources of change and subsequent impacts on the age and sex compositions. Further, as Finney and Simpson (2008) noted, we have a lot to learn about the population dynamics of different immigrant groups. In Australia, very few detailed studies have examined the demographic mechanisms of change for immigrant groups during the past two decades. Hugo (2009), for example, examined the changing flows of immigration and emigration between 1993 and 2008 but did not link these to immigrant population change. Our work thus complements and extends previous research and provides a basis for understanding the underlying factors of change to studies of individual immigrant groups (e.g., Coughlan and McNamara 1997; Jupp 2001).

Data and Demographic Accounts

Sources of foreign-born population change are measured by three demographic components: deaths, immigration, and emigration:

\[
\Delta P_{t+5} = I_{t+5} - E_{t+5} - D_{t+5} + \text{error},
\]

where \(\Delta P_{t+5}\) is the intercensal population change between year \(t\) and year \(t+5\), \(I_{t+5}\) is the number of intercensal immigrants, \(E_{t+5}\) is the number of intercensal emigrants, and \(D_{t+5}\) is the number of intercensal deaths. The error term accounts for the unexplained difference between the actual population change and the reported data (i.e., provides a measure of the uncounted population change). For the Australia-born population, a birth component is added to the previous equation:

\[
\Delta P_{t+5} = I_{t+5} - E_{t+5} + B_{t+5} - D_{t+5} + \text{error},
\]

where \(B_{t+5}\) denotes the number of intercensal births and may be contributed by the Australia-born or foreign-born populations. In this case, \(I\) denotes returning Australians who have previously emigrated (\(E\)) abroad.

Data were gathered to study the demographic accounts of 19 birthplace-specific populations by age and sex from 1981 to 2011. These data were commissioned by the ABS and consisted of the following: (1) census population stocks every five years (1981, 1986, . . . , 2011), estimated resident population stocks every five years (1981, 1986, . . . , 2011), annual death registrations (1993–2011), annual birth registrations (1981–2011), annual net overseas migration (1981–2003 without birthplace; 2004–2011 with birthplace), and annual overseas arrivals and departures (1981–2011). The estimated resident population
stocks were adjusted for both undercount and overcount by the ABS and, as such, may be considered true estimates of the Australian population (ABS 2017). Net overseas immigration and emigration totals refer to permanent migration or change in usual residence, which are estimated by using a 12 of 16 month residence rule: individuals are counted as immigrants (emigrants) if they are present in (absent from) Australia for a total of 12 months of a 16-month period (ABS 2015). Deaths were backcasted to 1981. Finally, the age-specific census populations are adjusted to match the estimated resident population totals and form the basis for calculating the overall population change between censuses. All data sets are grouped into five-year age groups by sex and country or region of birth.

The birthplaces of foreign-born immigrants were grouped into 18 categories based on their population sizes in the 2011 census. The birthplaces were based on the continent and subcontinent birthplace grouping used by the ABS (2008). The most populous birthplace country of each region according to the 2011 census was selected, and the remaining countries were aggregated into “rest of region” categories. These categories and population sizes are presented in Table 1. Each of the 18 birthplaces accounts for a relative large proportion of all foreign-born population in Australia, ranging from 1% (Indonesia-born) to 21% (United Kingdom-born). The population size of the foreign-born was 5.8 million in 2011 compared with 16.5 million for the Australia-born.

The sources of population change vary considerably across the 19 birthplaces presented in Fig. 1 for the 2006–2011 period. For the foreign-born groups, the European population exhibited considerably more deaths than did the other immigrant populations. The rapidly aging South-East Europe-born population actually...

### Table 1 Estimated resident populations in Australia by country or region of birth, 2011

| Number | Birthplace                          | % of Foreign-born | Population     |
|--------|-------------------------------------|-------------------|----------------|
| 1      | Australia                           | —                 | 16,527,260     |
| 2      | New Zealand                         | 9.2               | 531,836        |
| 3      | Other Oceania and Antarctica        | 2.4               | 138,364        |
| 4      | United Kingdom                      | 20.9              | 1,211,430      |
| 5      | Other North-West Europe             | 6.5               | 374,952        |
| 6      | South-East Europe                   | 13.1              | 758,255        |
| 7      | North Africa and the Middle East    | 5.8               | 336,525        |
| 8      | Vietnam                             | 3.5               | 203,584        |
| 9      | Philippines                         | 3.2               | 188,395        |
| 10     | Malaysia                            | 2.2               | 127,833        |
| 11     | Indonesia                           | 1.2               | 69,489         |
| 12     | Other South-East Asia               | 3.1               | 182,899        |
| 13     | China (excludes SARs, Taiwan)       | 6.0               | 350,933        |
| 14     | Other North-East Asia               | 4.1               | 238,213        |
| 15     | India                               | 5.6               | 324,968        |
| 16     | Other Southern and Central Asia     | 3.9               | 225,955        |
| 17     | North America                       | 2.6               | 149,708        |
| 18     | South America                       | 1.7               | 96,465         |
| 19     | Sub-Saharan Africa                  | 5.2               | 299,828        |
Fig. 1 Sources of population change by country or region of birth, 2006–2011
experienced negative population change because of a large number of deaths. In terms of growth, the largest changes (at least 50,000 persons) occurred for immigrant populations born in New Zealand, the United Kingdom, North Africa and the Middle East, the Philippines, China, India, and sub-Saharan Africa.

Consider, for example, population change for those born in the United Kingdom, China, and India. Each population received 200,000–250,000 immigrants, yet their overall growth levels were very different. The United Kingdom–born population gained 63,000 persons, whereas the China-born and India-born populations grew much more with 122,000 persons and 162,000 persons, respectively. The sources of change presented in Fig. 1 explain why this occurs. The growth of the United Kingdom–born population was lower because of its relatively higher levels of emigration and death. Moreover, the India-born population experienced higher levels of growth than the China-born population because it had relatively lower levels of emigration. For the much larger Australia-born population, births are the dominant contributor to population change.

Interestingly, the immigration of returning Australia-born persons of 267,000 was more than the immigration reported by the four largest immigrant groups: the United Kingdom (246,000 persons), New Zealand (197,000 persons), China (229,000 persons), and India (209,000 persons). This higher level of immigration for the Australia-born, however, was lower than the level of emigration, which amounted to 326,000 persons. In terms of net gain or losses due to international migration (excluding deaths), the Australia-born population experienced a net loss of 59,000, whereas considerable net gains were observed for the populations born in the United Kingdom (143,000 persons), New Zealand (121,000 persons), China (145,000 persons), and India (153,000 persons). That said, the ratio of return migration for the Australia-born was very high relative to the top four immigrant groups. For every 100 Australia-born persons that left Australia, 81 returned (i.e., 267,000 immigration / 326,000 emigration = 0.81). Although not directly comparable, the corresponding ratios for persons born in the United Kingdom, New Zealand, China, and India were 42, 36, 37, and 27, respectively. In other words, the Australia-born population did not lose much of its population to international migration, despite having high levels of emigration. The top four countries of origin, on the other hand, lost considerably in their migration exchange with Australia.

Finally, differences exist between the population change measured by the estimated resident populations and the sum of demographic components in all of the 19 birthplace population accounts. The largest errors are for those born in China, other North-East Asia, and India.

In Fig. 2, the presentation of sources of change for all 19 birthplace populations is extended back to the 1981–1986 period. Between 1981 and 2011, most of the 19 populations experienced positive change. The exceptions are those born in the United Kingdom in 1991–2001, other North-West Europe in 1991–2006, and South-East Europe in 1981–1986 and 1991–2011. Immigrant populations born in North Africa and the Middle East, China, India, and sub-Saharan Africa exhibited particularly rapid growth in the most recent periods. The other population groups exhibited varied or steady population change over time. The issue of unexplained population change (error) occurred for most populations and periods, including the Australia-born.
Fig. 2  Sources of population change by country or region of birth, 1981–1986 to 2006–2011. The six bars represent data for 1981–1986, 1986–1991, 1991–1996, 1996–2001, 2001–2006, and 2006–2011, respectively.
Fig. 3  Sources of demographic change by age for populations born in the United Kingdom, China, and Australia: 1981–1986 to 2006–2011. The six bars represent data for 1981–1986, 1986–1991, 1991–1996, 1996–2001, 2001–2006, and 2006–2011, respectively.
Fig. 3 (continued)
Fig. 3 (continued)
Consider next the sources of population change by age. As illustrated in Fig. 1, the overall immigration levels for the United Kingdom, China, and India were similar between 2006 and 2011, but the United Kingdom experienced many more deaths. As shown in Fig. 3a, these deaths are mainly found in older age groups (i.e., 50+ years). For most age groups, immigrants born in the United Kingdom exhibited substantial amounts of migration to and from Australia, with increasingly large numbers of deaths in the oldest age groups. Immigrant populations from China (Fig. 3b) and India (not shown), on the other hand, are much younger and experienced most demographic events in the 15- to 45-year-old age groups, and were therefore subject to very small numbers of deaths. Finally, in Fig. 3c, the sources of age-specific change for the Australia-born population are presented for the six periods. Here, the main contributors to population change (overall) were births for 0- to 4-year-olds, immigration for 5- to 14-year-olds, emigration for 15- to 29-year-olds, immigration for 30- to 39-year-olds, and deaths for those aged 50+. The main contributors of population change were less clear for 40- to 49-year olds.

For the three selected birthplaces presented in Fig. 3, we found considerable data errors across the age profiles. For the United Kingdom–born population (Fig. 3a), we found substantial errors in the older and younger age groups. For the China-born population (Fig. 3b), errors are mainly in young adult age groups. The Australia-born population (Fig. 3c), aside from births, shared similar sources of change patterns with the United Kingdom population (Fig. 3a) in the old age groups. However, the errors are largely concentrated in the 5- to 34-year-old age groups.

Lastly, the male-to-female sex ratios of international arrivals and departures are presented in Fig. 4 to illustrate the differences found in the migration sources of population change by sex. Although these ratios vary greatly among the 19 birthplaces, the patterns of the sex ratios over time are roughly parallel between arrivals and departures. The values range from approximately 4 males for every 10 females (0.4) for Philippines-born immigrants in 1981–1986 to around 24 males for every 10 females (2.4) for India-born emigrants in 1996–2001 and 2006–2011.

Other interesting patterns in these ratios are of note. For example, the sex ratios of China-born arrivals are consistently below 1 (except for 1986–1991), whereas the departures are all above 1, implying not only that more females were migrating to Australia but also that they were more likely to stay in comparison with their male counterparts. Patterns for immigrants born in Vietnam and the Philippines are similar. Although we do not know what is causing these patterns, it would be useful to know what they are and whether these patterns are consistent with other destinations. Most birthplaces, however, exhibited relatively low (but above 1) sex ratios for arrivals and higher sex ratios for departures. Immigrants born in South-East Europe and India particularly follow this trend, even though their age compositions and sources of population change are quite different (see Fig. 2). Overall, there were 96 males per 100 females in 2011 in the foreign-born population.
Fig. 4 Sex ratios of international arrivals and departures by birthplace, 1981–1986 to 2006–2011. The six markers on the data lines represent the periods 1981–1986, 1986–1991, 1991–1996, 1996–2001, 2001–2006, and 2006–2011, respectively.
Reconciling the Sources of Immigrant Change With Estimated Resident Populations

Methods for Reconciling the Data

In this study, we measure errors as the difference between population change and the sum of the demographic events (see Eqs. (1) and (2)). To reconcile the mismatch between population stock data and demographic event data, we consider three approaches for distributing the observed errors: simple adjustment (Model 1), optimization (Model 2), and a hybrid of Models 1 and 2 (Model 3). In brief, Model 1 adjusts one demographic event (immigration for the foreign-born populations or emigration for the Australia-born population) to ensure the total counts by sex are consistent with the change in populations. Model 2 allows both immigration and emigration to vary by age and sex and achieves consistency with changes in the populations through numerical optimization. Model 3 uses numerical optimization to ensure consistency with the total counts by sex but retains the age profiles of the reported demographic events. In all three approaches, the quinquennial estimated resident population data, aggregated across age groups, were assumed true and without error.

In Model 1, the total error for each foreign-born population by sex, equal to \[ \sum_{0-4}^{85+} \left[ \Delta P_{t,t+5} - (I_{t,t+5} + E_{t,t+5} + D_{t,t+5} + S) \right] \], was added to the total immigration to produce a new total \( \hat{I}_{t,t+5} \). This new total was then proportionally distributed across age groups according to the reported age pattern of immigration. The justification for adjusting only immigration for the foreign-born populations is that all residual net migration totals, measured by subtracting deaths from total population change, are positive. We used the same method for the Australia-born population, but we added the error to emigration totals rather than immigration totals because, similar to the foreign-born populations, the residual net migration totals are negative for the Australia-born population.

The advantage of Model 1 is its simplicity: only one aggregate demographic component requires adjustment to meet the rules of the demographic accounting model. The main disadvantages are that errors are not reconciled across age groups and that the source(s) of the error may come from other demographic components.

To reconcile the demographic accounting model errors at the age-specific level, optimization techniques may be used (see, e.g., Luther et al. 1987). For Model 2, we assume that errors can exist in both the immigration and emigration data. We also assume that reported deaths at the oldest ages are underreported, especially for the foreign-born population groups. This assumption is based on analyses of the sources of population change, attributing immigration (emigration) to the error resulted in unrealistically high numbers in these ages. To address this issue, we assume that deaths over 60 years of age are underreported and that the contributions of age-specific deaths to the errors increase linearly with weights of 1/6, 2/6, 3/6, 4/6, and 5/6 attributed to the reported deaths for ages 60–64, 65–69, 70–74, 75–79, 80–84, and 85+ years, respectively. This apportioning of error to deaths is used to account for the increasing importance of this component of demographic change in age groups where migration levels tend to be near 0 (see Fig. 3a).
The errors for the remaining age groups 0–4 years to 55–59 years are distributed to immigration and emigration using optimization. For age group \( x \), \( p_x \) is the proportion of \( e_x \) (error) distributed to immigration \( \hat{I}_x \), and \( 1 - p_x \) is the proportion distributed to emigration \( \hat{E}_x \). To obtain \( p_x \), we minimize the quantity of \( \sum_{0-4}^{85+} \left\{ (\hat{I}_x - I_x)^2 + (\hat{E}_x - E_x)^2 \right\} \). This ensures the age profiles of the adjusted immigration and emigration flows resemble those of their unadjusted counterparts as best as possible by using the reported age profiles from the populations at times \( t \) and \( t + 5 \) as constraints. To perform the minimization, we use the global optimization algorithm of differential evolution (Storn and Price 1997) to generate the initial estimates of \( p_x \). We then obtain the final estimates by using the general simulated annealing algorithm (Kirkpatrick et al. 1983) to find optimal estimates of emigration and immigration flows that maintain the reported age profiles while simultaneously minimizing the errors.

The main advantage of Model 2 is that errors at the age-specific level are reconciled. The main disadvantage is that the adjusted immigration and emigration flows may exhibit a very different age profile compared with the raw data in order to meet the age-specific population constraints.

Finally, Model 3 combines aspects from the first and second models. In this model, optimization is used to adjust immigration and emigration totals to match the corresponding population totals. The age patterns of these demographic events are then redistributed using the reported age patterns as proposed in Model 1. Constraining the estimates to match the reported age distributions ensures that the differences between the reported and estimated results are minimized while still maintaining realistic age profiles of immigration and emigration.

Finally, we obtain the estimated age-specific population change for all three models by using the following formula:

\[
\Delta \hat{P}_x = B_x + \hat{I}_x - \hat{E}_x - \hat{D}_x,
\]

where the birth component applies only to the Australia-born population aged 0–4. All three approaches reconcile the errors for the age-aggregated data. Model 2 also reconciles the error at the age group level. Hence, an implicit assumption of Models 1 and 3 is that age-specific errors are also affected by inaccurate age distributions in the estimated resident population counts.

Reconciled Demographic Components of Change

As described in the previous section, we propose three data-reconciliation approaches for the Australia-born and the 18 foreign-born population groups. To illustrate their differences, we plot the estimated (reconciled) 1981–1986 age-specific immigration and emigration flows for the populations born in the United Kingdom, China, and Australia in Fig. 5. For Model 1, the estimated immigration flows are the same as the reported flows for the populations born in the United Kingdom and China. The estimated immigration flows have been adjusted but have the same age-specific profiles as the reported data. For the Australia-born population, the same is applied but in the opposite direction: immigration remains the same, and emigration totals are adjusted. For Models 2 and 3, the estimated
Fig. 5  Reported and reconciled flows of immigration (top row) and emigration (bottom row) by age for populations born in the United Kingdom, China, and Australia, 1981–1986
immigration and emigration totals are equal to each other. Hence, despite the different age-specific patterns, the values of the reconciled migration flows are also close to each other. In general, the adjusted flows tend to be greater than the corresponding reported data for all three approaches.

In examining the estimated age-specific immigration and emigration flows presented in Fig. 5, we find considerable differences. Similar to Model 1, Model 3 assumes the same age patterns as the reported data. However, Model 2 forces reconciliation at each age group. As a consequence, the resulting age patterns can differ substantially from the reported data. This is apparent in the Model 2 estimates for 1981–1986 Australia-born immigration and emigration and the United Kingdom–born immigration presented in Fig. 5. Not much difference, however, is evident between the three approaches for the China-born migration flows.

The Model 2 estimates for the Australia-born immigration and emigration flows result in large increases at the age group 5–9 years. The large increases are due to the large positive errors for this age group (see Fig. 3c). Because these increases are unusual and lack any demographic evidence or support, the estimated age patterns produced by the Model 2 are not considered realistic despite the model’s effectiveness in completely redistributing age-specific errors. Further, Model 1 is considered arbitrary because it simply assigns all errors to immigration (emigration), which is unlikely to be the only source of error. Therefore, Model 3 is considered the most pragmatic of the three approaches. As described earlier, Model 3 uses optimization to reconcile the age-aggregated errors but retains the age patterns of the reported immigration and emigration data.

The reconciled sources of change components (aggregated by age and sex) obtained using Model 3 is presented for the Australia-born and the 18 foreign-born populations in Fig. 6 for the six periods between 1981 and 2011. These values may be compared with those in Fig. 2. Most of the errors in the observed data are distributed to immigration and emigration with the result of increased levels for both. The most noticeable difference is found in the reconciled immigration and emigration flows for the Australia-born, which are nearly double the values of the reported figures in the last three periods. In some cases, the reconciled data result in slightly different trends. For example, the reported figures of China-born immigration show exponential increases over time, whereas the reconciled data show a sharp increase between the first (1981–1986) and second (1986–1991) periods and between the fourth (1996–2001) and fifth (2001–2006) periods.

The reconciled data is further compared by age for the populations born in Australia and China in Fig. 7, panels a and b, respectively, for the 2006–2011 period (see the figures in the online appendix for other examples). Because Model 3 does not correct age-specific errors, the estimated overall change by age differs from the reported data. Consider, for example, the Australia-born in Fig. 7, panel a. Here, we see that the reconciled data estimates results in very different change patterns for the following age groups: 5–9 years (negative instead of positive), 15–19 years (zero instead of negative), 20–24 years (lower negative), and 30–34 years (lower positive). Few differences between reconciled and reported data are found in the older age groups, where mortality is a more important factor in population change.
Fig. 6 Model 3 reconciled sources of population change by country or region of birth, 1981–1986 to 2006–2011. The six stack bars of each birthplace are data for 1981–1986, 1986–1991, 1991–1996, 1996–2001, 2001–2006, and 2006–2011, respectively.
Fig. 7 Comparison of three models sources of change by age with reported data for populations born in Australia and China, 2006–2011. First bar = reported, second bar = Model 1, third bar = Model 2, fourth bar = Model 3
Fig. 7 (continued)
Contributions of Immigration to the Size and Age-Sex Composition of Immigrant Groups

After identifying the contributions of population change for the different ages and immigrant groups, we investigated the importance of different immigration cohorts to the age compositions of the 2011 immigrant populations. This was accomplished through cohort component population projections using the reconciled data from Model 3 with immigration set to zero after certain periods. We applied observed fertility, mortality, and emigration rates. We then used comparisons of the counterfactual projections with the reconciled data to identify the contributions of immigration to the 19 birthplace population groups. Our analyses focused on the immigration cohorts who arrived (1) pre-1991, (2) between 1991 and 2001, and (3) after 2001.

Without immigration, the sizes and age-sex compositions of immigrant populations can change only through emigration and mortality. The difference between the survived population and the actual population informs us about the impact of specific immigration cohorts on the age-sex structure at a particular time (i.e., 2011). This analytical technique is based on the one developed by Edmonston and Passell (1992) and later applied to study the contributions to population change attributable to immigration in Canada (Edmonston 2010) and regional foreign-born population change in the United States (Rogers and Raymer 2001; Rogers et al. 1999).

In Fig. 8, the age and sex compositions by immigration cohort are presented for eight selected immigrant populations in 2011. The eight populations were chosen to highlight some key differences found between the foreign-born groups and include persons born in the United Kingdom, South-East Europe, Vietnam, China, India, North America, sub-Saharan Africa, and North Africa and the Middle East. The plots are based on the counterfactual projections described earlier. For each 2011 immigrant population by sex and age group, these plots show when the migrants arrived: prior to 1991 (black bars), between 1991 and 2000 (gray bars), or after 2001 (white bars).

The age-sex compositions presented in Fig. 8 highlight a selection of the different shapes found among immigrant groups in Australia. Some are relatively old (e.g., the United Kingdom and South-East Europe), while others consist almost entirely of young adults (e.g., China and India). In between these two extremes are a variety of patterns. Another important aspect to consider is the balance between sexes in the populations. For immigrants born in Vietnam, China, and North America, females are noticeably more prevalent, which is opposite that found for immigrants born in North Africa and the Middle East, and India.

When the age-sex compositions are disaggregated according to the three historical periods, the majority of immigrants are found to be recent immigrants who arrived after 2001. This is most clearly demonstrated by the North American immigrant population, which almost exclusively comprises post-2001 arrivals. There are two major exceptions to this pattern: the immigrant populations born in the United Kingdom and South-East Europe. These populations are dominated by those who arrived prior to 1991, largely as a result of the large recruitment of Europeans before the White Australia policy was dismantled in the 1960s and 1970s (Richards 2008). Another interesting exception to highlight is the Vietnam-born population. Many of the older immigrants came as refugees in the 1970s, followed by subsequent waves of immigrants who arrived...
through the family reunion schemes (Thomas 1997) and, more recently, student
and skilled migration schemes (Baldassar et al. 2017). Similar to the United
Kingdom–born population, the 2011 North Africa– and Middle East–born population
received very few immigrants between 1991 and 2001.

Fig. 8 Age-sex compositions of immigrants born in selected countries or regions by period of
entry, 2011. For each age-sex composition, males are on the left, and females are on the right.
In summary, age-sex compositions by period of immigrant arrival provide additional insights into the complexity and dynamics of international migration that are not possible when population stock data are analyzed separately from demographic event data. The selected patterns show the diversity of not only periods of arrival but also the age and sex characteristics of the immigrants by place of birth.

Conclusion

In this study, the differences that occur between census counts of birthplace-specific populations and the resulting counts obtained using demographic accounting of the underlying sources of change have been explored. Substantial gaps were found between the two sets of reports, which was expected because the data came from very different sources with different measurement criteria applied. It also focused on immigrant populations, a group known to be difficult to count (e.g., Kaneshiro 2013; Van Hook et al. 2014). Our analysis of the sources of population change found unevenly distributed errors across age, sex, birthplace, and period.

To overcome the data inconsistencies, we proposed three models to reconcile the demographic event data with the census population stock data. We found Model 3, a model that combined optimization with fixed age profiles, to be the most pragmatic. One of the reasons underlying this choice is that although we assume that the estimated resident populations are accurate and true, in all likelihood, they are also a source of error. For the analyst, however, this creates a dilemma. Demographic estimation requires reliable benchmarks. Future work should address this issue by identifying and incorporating uncertainty in all sources of data and using this information to infer consistencies in the demographic accounts (Bryant and Graham 2013).

Our analysis of the reconciled data provides a complete and consistent understanding of how 18 immigrant populations have evolved in Australia since 1981 in terms of their population size and age-sex distributions. In some cases, the patterns differed substantially from the reported data, implying that more effort is needed to improve both the estimated resident population data and the demographic change components of immigration, emigration, and immigrant death registration. The research also shows how immigrant populations evolve over time in terms of their age-sex structures. We found that more recent immigrant populations have young age structures with some notable differences in male-to-female sex ratios, whereas older immigrant populations (especially those born in Europe) have aged considerably despite continued immigration. Furthermore, by bringing together international migration flows and immigrant populations in a demographic accounting framework, we see that cohort changes are not uniform across the populations, and this has important implications for family formation and social care for each of the immigrant populations residing in Australia. The more common practice of examining international migration flows in isolation of immigrant populations is unable to provide these insights.

The counterfactual analysis showed the value of harmonized demographic event data and could lead to further analyses of the contributions of past immigration to current population age and sex compositions. One obvious way forward would be to consider subnational populations along with the inclusion of internal migration as a source of population change (see, e.g., Rogers et al. 1999). We plan to do this in future
work for the 19 birthplace-specific populations presented in this article. Aside from Hugo and Harris (2011), very little research has been accomplished in this area, and none of it has gathered all the demographic sources of change together in a consistent and harmonized framework.

One of the main contributions of this research is the provision of a complete and consistent set of demographic information that can be used to study the evolution of 19 different subpopulations in Australia by birthplace. This information not only provides reliable details on the sources of change but also can be used to study the long-term effects of international migration. For example, by including consistent demographic components of change in a cohort component projection framework and conducting counterfactual analysis, we assessed how many of the immigrants in each age group from a particular country or region of birth who arrived before 1991 are still in Australia. This allowed us to identify the relative retention of immigrant groups and the subsequent effects on population sizes and age compositions.

In conclusion, this work provides a framework for improving our understanding of migration processes and its effects. For the past 40 years, Australia has exhibited relatively stable total fertility rates, mostly in the range of 1.8 to 2.0, and steady increases in male and female life expectancy. International migration has been a major and increasing driver of population growth since the 1950s. Both immigrant and host populations age over time. What makes the study of immigrant population change difficult is the constantly changing sources of international migration. We found that most immigrant population groups in Australia are growing but at very different rates, by age and sex, depending on the country or region of birth. The more established European population groups, aside from those born in the United Kingdom, are rapidly aging and declining as a result of deaths. The same can be expected to happen with the other immigrant populations as they age in Australia over the next several decades.

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