Chapter 4
The Demography of Migration

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4.1 Introduction

In this chapter, we focus on the study of migration from the perspective of demography. Demography is the study of population dynamics with a strong emphasis on compositions, e.g. by age and sex, and the underlying mechanisms of change, i.e. fertility, mortality and migration. What makes the demographic study of migration different from other migration studies is the importance placed on population change and measurement, especially in relation to the demographic accounting equation (Raymer et al. 2019; Rees and Willekens 1986).

Migration complicates demographic study because of the ambiguity of the population 'at risk' of experiencing an event which is a fundamental aspect of demographic thinking (Rogers 1990). While the population of any given country or region is at risk of producing babies (fertility), dying (mortality), out-migration (domestic) and emigration, the study of in-migration (domestic) and immigration is more problematic because the population at risk is outside the population of interest. Indeed, an out-migrant (emigrant) from one population must be an in-migrant (immigrant) to another. Therefore, in order to study the demographic effects of migration, one needs to consider at least two populations: the sending population and the receiving population.

How migration affects both origins and destinations simultaneously is the main focus of this chapter. In addition to the direct effects on both population age compositions, we also describe how migration can have other demographic consequences through their subsequent births, deaths and further migration. The basic model for studying the demography of migration is the multiregional demographic model

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pioneered by Andrei Rogers and colleagues starting in the 1960s (Rogers 1966, 1968, 1975, 1995; Rogers and Willekens 1976; Willekens and Rogers 1978). We use this model as a basis for understanding the role of migration in population change.

Understanding the demography of migration is important in today's world, where migration increasingly affects all spheres of life, from economic to social to political. The demographic distinctions between 'developed' and 'less developed' parts of the world are diminishing. Just about everywhere, populations are living longer and having fewer children, and they are increasingly being altered by both internal and international migration (White 2016, p. 1). Moreover, cross-border moves represent major political and security concerns for many countries throughout the world (Castles et al. 2014, pp. 312–314). Having a sense for the numbers, and their effects on population change, is needed to inform policies, and to eventually create better systems of migration management.

Migration has always been an important factor in society, and immigration policies have long sought to control the types and characteristics of people coming to their countries. However, a major gap in our knowledge of migration concerns the long-term demographic consequences of these policies and the subsequent implications for population distribution and composition. Moreover, we also know little about the consequences of domestic migration, which tend to involve larger numbers of people than international migration. Demographic consequences include, for example, those that are direct, such as changing the population size and composition of specific populations, and indirect, such as those involving subsequent generations (Edmonston 2010, 2016; Scott and Stanfors 2010) and other demographic processes, such as fertility or mortality (see, e.g. Kohls 2010; Kulu 2005, 2006; Milewski and Kulu 2014). Migrants from poorer areas of the world tend to bring with them their higher levels of fertility, and because migration involves a selection process, they also tend to bring with them their youth and ambition. Not all migrants remain to retire in the host country but many do, and this has implications for the health sector in an ageing society.

One major and long-standing issue concerning the demographic study of migration is data and its measurement on both migration flows and migrant population stocks. For example, the United Nations (1998) provides recommendations on how international migration flows should be measured but most countries in the world do not provide any data at all. For those (mostly developed) countries that do, they tend to collect data for their own needs and purposes. Rarely are considerations given for international comparability. So, we do not actually know how many people are crossing borders and contributing to population change. Some methods for indirectly estimating this information are available (see, e.g. Abel 2013, 2018; Raymer et al. 2013; Rogers et al. 2010), and they will likely continue to provide the necessary basis for augmenting the missing and inadequate data in the future so that we may better identify the role of migration in population change.

A demographic perspective on migration provides a unique line of enquiry. For example, a demographer might be interested in whether migrants from rural areas living in cities have higher or lower fertility? How many of the people who arrived in the past 15 years are still living in the area? And how many of them can be expected to remain until they retire? What is the probability of return migration? Are migrants who cross international borders healthier than those who decide to remain in their country of origin? These are just a few examples that link the process of migration with demographic change.

4.2 Background

In order to study the role of migration in demographic change, we need to have a basic understanding of concepts, data, processing and estimation and outputs (Raymer et al. 2015). Here, concepts refer to particular types of population or migration statistics, such as usual residents and people present in countries with foreign citizenship. Data are any information gathered about the population of interest and its movements, usually obtained from censuses, surveys or administrative registers. Processing and estimation refer to data cleaning, imputation, combining two or more information sources through matching or proportioning and statistical modelling. Outputs are the published statistics.

The concepts of population may vary depending on the needs of the user. However, all types of population can be related to the actual population at time t in location i. Likewise, concepts of migration can be related to the movement of all people in and out of location i between two-time points. To estimate particular populations, therefore, one must consider the types of entries and exits (including births and deaths, respectively) between time points $t - n$ and t, where n refers to the width of the time interval (e.g. days, months or years). There are various data sources that can be relied on to capture particular populations present in location i at time t in statistical form. The geographies are obtained from the location attributes linked to these data sources. From the data sources, attributes of the population and migrants also can be obtained, where the main attributes are often age and sex. Processing is required to match the concepts to the data. In some cases, estimation is required to combine data or to include auxiliary information. The result of the data processing and estimation is the outputs. Due to time, budget and available data constraints, the outputs rarely consider all the different types of population present in location i and at time t. More often, they include just one type of population, such as those considered to be usual residents.

The conceptual framework described above, based on Raymer et al. (2015), is useful for reconstructing population change using data obtained from multiple sources. In Australia, for example, fertility and mortality are obtained from administrative registers, internal migration flows are obtained from censuses and Medicare, and immigration and emigration flows are obtained from processing arrival and departure cards. Population stocks are available from censuses as enumerations and the Australian Bureau of Statistics as official estimates. This information can be brought together using the demographic accounting equation. This relates population stocks at any given point in time to the components of population change as follows:

$$P_i(t+1) = P_i(t) + B_i - D_i + M_i - O_i + I_i - E_i$$

In words, the population of region i at time $t + 1$, $P_i(t + 1)$ is equal to the population at time t, $P_i(t)$, plus the number of births in the intervening period B_i, minus deaths D_i, plus in-migrants arriving from within the country, M_i, minus out-migrants, O_i, plus immigrants, I_i, minus emigrants, E_i. At the national level, in- and out-migrants within the country are equal by definition and cancel each other out.

The demographic accounting equation thus situates the role of migration in the process of population change. Migration represents one of the three components of demographic change alongside births and deaths and is made up of at least two separate flows—arrivals (in-migration and immigration) and departures (out-migration and emigration). As stated in the Introduction to this chapter, distinguishing between these types of flows is important because they originate in two mutually exclusive populations at risk, in addition to having potential counteracting effects on population change. In constructing the demographic accounting equation, it is important to align the measurement of the demographic components to fit the population statistic or measurement of interest. Most countries use a 'usual residence' (de jure) definition of population, however, from the accounting perspective, any population could be used, such as the actual population present (de facto) or a temporary population of interest. Whichever definition is chosen, measurement of the components of change, including migration, must be drawn from and be consistent with this population.

The demographic accounting equation is the basis for understanding the demographic drivers of population change and for projecting the population forwards and backwards through time. These are typically achieved by calculating and projecting age- and sex-specific rates of fertility, mortality and migration, defined as the number of people experiencing these events divided by the populations at risk. Through multiregional life tables (described below), projected rates of mortality and internal migration transition probabilities are converted into survivorship ratios which, alongside projected values (rates) of fertility and international migration, are used to create population projections. Projections can identify and quantify the direct and indirect effects—in terms of the size and composition of migrant flows and the subsequent fertility, mortality and onward migration, respectively—on the size and composition of sending and receiving areas. In this respect, migration is not only an interesting phenomenon and area of research in its own right but also a critical input for understanding and estimating broader population dynamics.

Migration is a difficult and hard to measure statistic. Part of the problem is related to the difference between a concept of migration and the practical implementation of that concept. Moreover, migration data are hardly ever collected for the study of migration or demographic change. Rather, they are obtained as an offshoot of an administrative procedure or legal basis. Consequently, the measurement of migration is typically based on the number of people who change their residential address or who report different addresses at two separate points in time. Further, this may refer to any change in address or only changes across a geographic border such as a national, state, city or neighbourhood border. By contrast, migration may be thought to have a deeper conceptual meaning. For example, Raymer and Smith (2010, p. 173) provide the following definition:

> Migration is a loosely defined process that represents the relocation of people during a period of time that causes them to relinquish the ties with their previous locality. The key factors that separate migration from general mobility are distance travelled and length of time spent in the destination; together they work to alter the economic and social networks of the migrant. Migration can involve people moving within a country, as well as across international borders.

In this light, migration extends beyond an administrative by-product or accounting input, concerned as it is with the loss and formation of economic and social networks. However, few data sources appropriate for migration analyses capture such information. From a pure demographic perspective, arguably, the most important aspect of any definition is that it fulfils the requirements of the demographic accounting equation (Rees and Willekens 1986). In practice, this invariably means a permanent or semi-permanent change in residential address across a geographic border.

Migration data are typically collected from census and administrative sources. Most censuses ask respondents where they were living one year ago, five years ago, where they born and/or the year they arrived in the country if applicable. Cross-tabulating these past locations by locations at the time of the census produce matrices of migration transitions between origin and destination locations. These can be converted into migration transition probabilities using the methods described by Rogers (1995) and in the case study below. Population and health registers provide information on migration flows where individuals and families register a change of address or enrol with municipal authorities or health providers. Census and register data are particularly useful for measuring internal migration while also providing information on international migrant arrivals. Measuring emigration is complicated by the fact emigrants do not appear in national censuses (as they have left the country) and may not register a departure with authorities. Emigration (and immigration) may instead be measured from data on international air, land and seaports, including in the form of arrival and departure cards and international passenger surveys.

Detailed demographic and socio-economic data on migrants and sending and receiving areas are usually obtained from censuses. General-purpose surveys often collect migration data but, because of relatively small sample sizes, they are usually inadequate below the national or broad regional levels. Population or health registers may be used to track migration flows, however, these sources are often not accessible and do not contain much demographic or socio-economic detail. Also, because migration data tend to be collected from sources that have other purposes, the questions underlying the patterns may not fit a particular research question of interest, e.g. measuring migrant status tells us little about migration frequency. There may also be situations in which the required data are available but cannot be considered reliable due to, for example, statistical disclosure control. Missing data is usually caused by suppression of data or by non-response by migrants. Substantial time lags often exist between the time individuals move and the time their new address or emigration is registered in administrative data.

4.3 Theories

In thinking about the demography of migration, we review two theories that emphasise the fundamental relationship between population change and migration processes. The first is the mobility transition theory by Zelinsky (1971; see also recent review by Skeldon 2018). The second is the life course theory (Kulu and Milewski 2007; Willekens 1999). We provide brief overviews of both theories and their importance in understanding migration patterns. There are a host of other migration theories originating in other disciplines that are not treated here. These include, for example, neoclassical economic ("push-pull") theories, dual labour market theory, migration network theory and cumulative causation (see Massey et al. 1993). While these theories are important for understanding the processes and motivations of migration, they do not emphasise the demographic aspects that are central to this chapter's purpose.

Zelinsky's (1971) mobility transition theory is tied with the demographic (vital) transition theory in that mobility and migration patterns are affected by changes in the economic development or modernisation process of a country. Five phases of the mobility transition linked to demographic and economic development are included:

1. *Pre-modern traditional society* which exhibits low migration or mobility;
2. *Early transitional society* which experiences large scale rural to urban migration, emigration to other countries, immigration of skilled workers, and increased mobility in general;
3. *Late transitional society* which experiences a slowing down of rural to urban migration and emigration but continues to experience increases in mobility and internal migration;
4. *Advanced society* which experiences stable and high levels of mobility and internal migration and net immigration of unskilled workers and
5. *Future super-advanced society*, which exhibits lower levels of mobility and internal migration with some control of its internal and international movements.

While some countries may not fit neatly into the five stages above, Zelinsky's mobility transition theory provides explanations for why some countries are primarily senders of emigrants and others are receivers of large amounts of immigration. It also helps us to think about the likely changes countries will face as their economies develop. For example, consider Asia, a region currently experiencing rapid demographic and economic change (Castles et al. 2014, p. 151; see also Liu-Farrer and Yeoh 2017). Here, we find that rapidly developing countries, such as China and India, are major senders of migrants and recently developed countries, such as Singapore and South Korea, have become major receivers of immigrants.

The second demographic theory important for the study of migration is the life course. In this theory, an individual's life is composed of a series of transitions or life events, which are embedded in trajectories (or status passages) that give them a distinct form and meaning (Kulu and Milewski 2007). This approach examines these trajectories with the aim of explaining movements between various statuses for the purpose of understanding social change and social phenomena. Here, an individual's life course is embedded in social institutions and is subject to historical forces and cohort pressures, among other factors. This approach has developed since the 1960s and has become a research paradigm in many areas of social sciences. The four key factors that shape an individual's life course are human agency, linked lives, historical and geographical context and timing of life events.

In studying migration, we are interested in the relationship between important life transitions and migration. These include those associated with early childhood, middle to late childhood, leaving the parental home, marriage and divorce, childbirth, retirement and loss of spouse or sickness in later stages in life. As a result, migration patterns often exhibit regularities in their age patterns.

> The most prominent regularity in age-specific profiles of migration is the high concentration of migration among young adults; rates of migration also are high among children, starting with a peak during the first year of life, dropping to a low point at about age 16, turning sharply upward to a peak near 20 to 22, and declining regularly thereafter, except for a possible slight hump at the onset of retirement and possibly an upward slope after that hump. (Raymer and Rogers 2008, p. 177)

These age regularities or model migration schedules (Rogers and Castro 1981) have direct implications for the age-sex compositions of the origin and destination populations. Moreover, the shapes of the migration age schedules are reflective of the life course transitions that populations experience, and the patterns may vary depending on the characteristics of the origin and destination locations (Bernard et al. 2014).

The life course theory also corresponds with multistate demography or the modelling of subpopulations (Willekens 2014). Here, populations are stratified by age, sex and one or several attributes. This can include, for example, region of residence, marital status, education, number of children, household type, occupation, employment status and health status. A population that is stratified is a multistate population, and people who occupy the same state constitute a subpopulation. The evolution of multistate populations over time is governed by state-specific fertility and mortality rates, and transfers between subpopulations. When geographic units represent the subpopulations and migration is the mechanism of transfer between them, then it becomes multiregional demography.

4.4 Methods and Modelling

In order to fully understand the consequences of internal and international population movements, researchers and policymakers need to overcome the limitations of the currently available data sources on population stocks and demographic components of change, including inconsistencies in data availability, definitions and quality. This topic of research is important for most countries in the world. For example, in Australia, the main source of numbers on immigration and emigration comes from arrival and departure cards collected at major entry points with uncertainty about the destinations and origins within the country. For internal migration, the public have access to census place of current residence by place of residence one year or five years ago, however, the Australian Bureau of Statistics relies on the Medicare health registration data for its population estimates, which are not publically available in detailed form.

Demographic estimation techniques and statistical modelling may be used to reconcile the measurement differences between the conceptual framework and the data, and to overcome other limitations, such as inadequate demographic or geographic detail and irregularities in the observed data caused by random or sample-based variation. Rogers et al. (2010) provide a useful strategy for estimation based on smoothing, imposing and inferring migration patterns. *Smoothing* limits the effect of randomness on the age, spatial or temporal patterns of migration caused by natural variation or variation due to insufficient sample size. For a contingency table of migration events, this may involve (i) fitting a line or curve to a particular pattern or (ii) removing higher order interaction effects in a log-linear model. *Imposing* refers to the borrowing of age, spatial or birthplace patterns from other areas or higher order patterns, e.g. when a national level age profile of immigration is used to represent the age profile of immigration of a particular geographic area not captured adequately in the reported data. *Inferring* refers to the borrowing of age, spatial or birthplace patterns from auxiliary sources that serve as useful proxies for the particular demographic pattern that requires estimation.

Lastly, multiregional (or multistate) population models provide a general and flexible platform for modelling and analysing population change over time and across space (Raymer et al. 2019). These models may be considered extensions of the life table and the cohort-component projection model. They allow the combination of all the main components of population change by age and sex with various transitions that population groups may experience throughout their life course. The developments of these models can be found in Rogers (1975, 1995), Rees and Wilson (1977), Willekens and Rogers (1978), Land and Rogers (1982) and Schoen (1988, 2006). Most standard cohort-component population models operate independently of other populations and ignore migration transitions. Instead, they rely on net migration or (slightly better) out-migration and in-migration rates to account for the change due to migration. Although more cumbersome, including the transition information maintains consistency and improves accuracy across demographic accounts, particularly in highly mobile societies (Wilson and Bell 2004).

Multiregional demography treats geographic areas, whether countries, states, cities or neighbourhoods, as interconnected units within a system. A demographic accounting equation applies to each in which area-level population change is governed by births, deaths and migration. Migration connects each unit in the system as shown in Fig. 4.1. Central to the estimation of the multiregional model, therefore, is the measurement of migration flows or transitions between origin and destination areas. This is achieved from two main types of data. The first and most common is aggregated cross-tabulations of the number of people living in each area at two points in time (usually one or five years apart). This information is most often collected in national censuses and converted into age- and sex-specific migration transition probabilities. These probabilities are applied to multiregional life tables which are

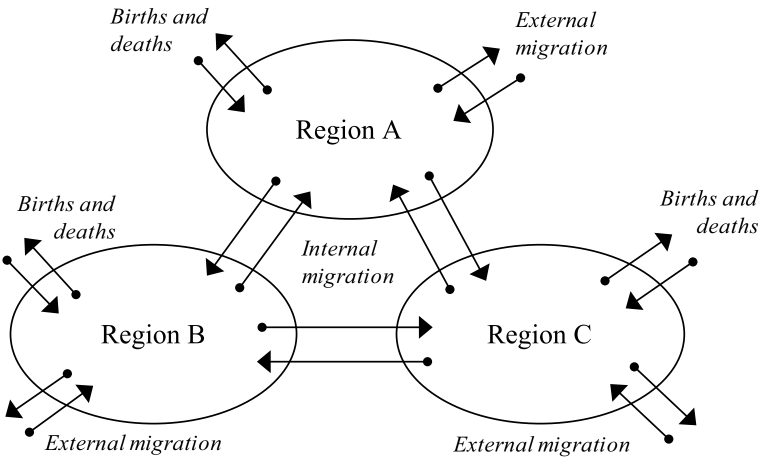

Fig. 4.1 Example of a three region multiregional system

used as the basis for population projections and location-specific life expectancies. This approach is also useful for analysing macro-level effects of migration such as the demographic and socio-economic consequences for origin and destination areas and for understanding migration processes and dynamics in the context of Zelinsky's theory.

The second type of data is an individual unit record microdata. These are typically collected from administrative data, panel surveys and Census sample files that track migration flows or transitions for an individual sample or population. As above, migration probabilities can be calculated and applied to multiregional life tables with the advantage that other information in the dataset can be used to analyse the individual-level drivers and consequences of migration. Multivariate regression models can be specified, for example, to predict the effect on migration of (i) commencing or completing university education, (ii) obtaining, losing or retiring from a job or (iii) getting married or divorced for the entire population or by some social strata such as sex, ethnicity, birthplace, family type or economic class. Migration probabilities and life tables can be constructed that are specific to these sub-groups and events to estimate and project their effects on local level population change. To preserve some of the complexity and interactions between variables, microsimulation can be used to generate life histories for synthetic populations (Willekens 2014). This offers a promising approach for considering migration within life course theory, as well as considerable flexibility in analysing migration and other social phenomena. As previously noted, a key disadvantage is that census and survey samples are typically not large enough to model a large number of origin- and destination-specific migration probabilities, often necessitating relatively simple or stylised multiregional systems.

4.5 Case Study: Migration in New South Wales and the Australian Capital Territory

To illustrate the relevance of migration in demographic change, we present in this section an application of multiregional demography to analyse change in the population size, composition and distribution. This application is used to study the demographic effects of internal migration within the Australian state of New South Wales (NSW) and the Australian Capital Territory (ACT) over the period 1981–2011. NSW is the most populous state of Australia, containing the city of Sydney, as well as a relatively diverse mix of urban, rural and remote areas. The ACT contains the city of Canberra, the capital of Australia and a city of approximately 400 thousand people. The ACT is entirely contained within NSW. The multiregional demographic approach can be applied to any migration system, including a multi-country or global system. However, as described above, the required data are often readily available for internal migration and lacking for international migration.

In recent decades, internal and international mobility characteristics have placed Australia in the *Advanced Society* stage of Zelinsky's theory. After World War II and particularly since the mid-1970s, Australia has had a large immigration programme, progressively drawing migrants from Anglo, western, eastern European and increasingly south and east Asian countries and the Middle East (Jupp 2002). Tighter regulation in the last 20 years has focused the immigration programme on bringing in skilled migrants to fill identified shortages in the domestic labour market (Hugo 2014). Domestically, rates of internal migration are among the highest in the world and strongly linked to life course events (Bell et al. 2015; Bernard et al. 2016). The city of Sydney has played an important role in these internal and international dynamics, providing the largest point of arrival for immigrants, an important destination for internal migrants, particularly young adults from the rest of the state and a sending area, particularly for young families and retirees.

A map of NSW and the ACT is presented in Fig. 4.2. For the illustration, we focus on ten areas based on the old Statistical Division geography developed by the Australian Bureau of Statistics (ABS 2010). Aside from Sydney and the ACT, Illawarra takes in the city of Wollongong and parts of the south coast. Hunter includes the city of Newcastle, as well as towns of the Upper Hunter and parts of the coast north of Newcastle. North Coast stretches from Hunter up to the state border with Queensland. Murray, Murrumbidgee and South East, Central West and Northern are all predominately rural and regional areas, while Far West is largely remote.

In Fig. 4.3, population age-sex compositions are presented for six of the ten areas over time for the Australian-born population. These age-sex compositions show the population structure in 1981 in the salmon colour, 1996 in grey and 2011 in blue. In 1981, all regions had a relatively young Australian-born population. As throughout Australia, populations have become older over time, however, it is particularly evident in Hunter and the North Coast. Sydney, on the other hand, has remained relatively unchanged. Part of this is driven by foreign-born parents having children in Australia

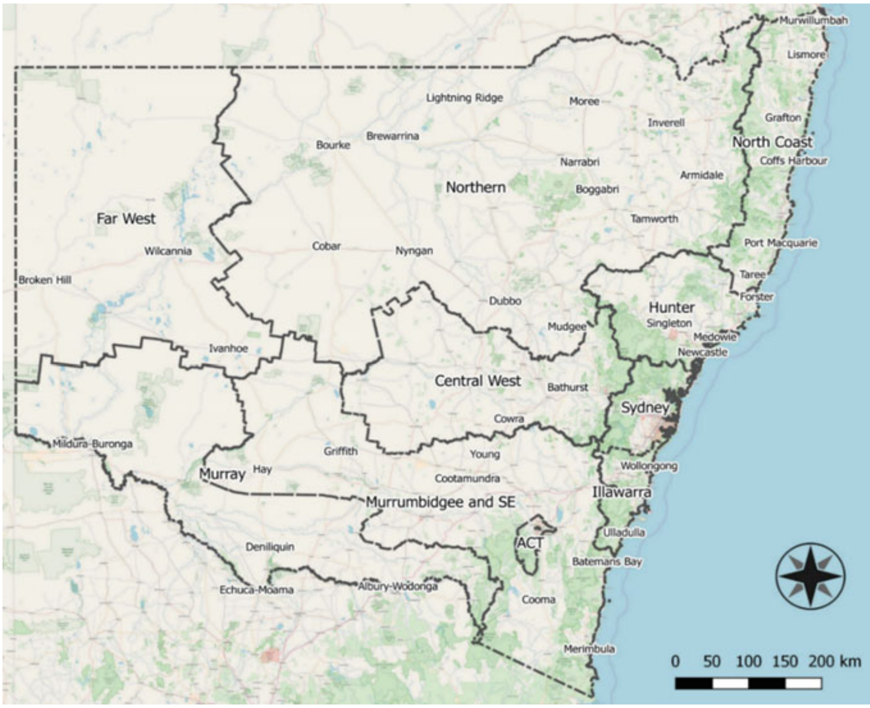

Fig. 4.2 Map of New South Wales and the Australian Capital Territory. *Source* Created by authors based on ABS (2010) geographies

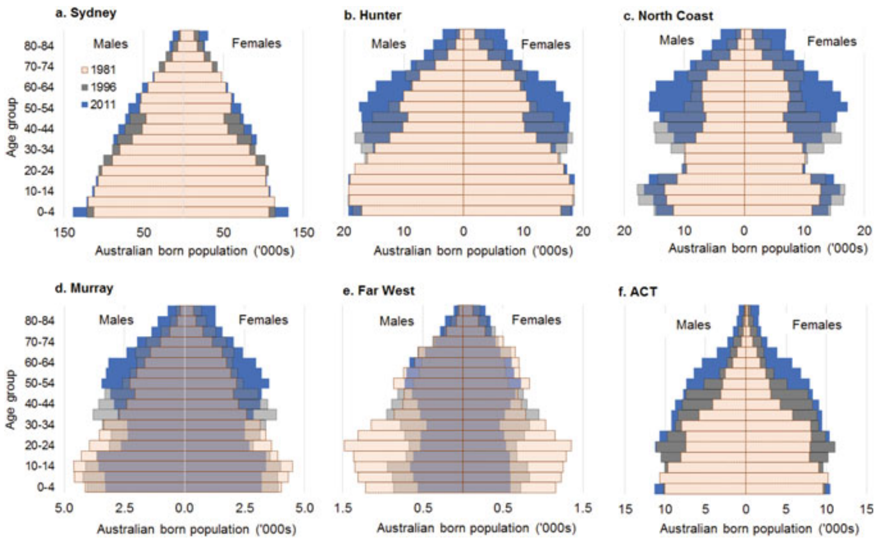

Fig. 4.3 Population pyramids for selected regions, 1981–2011

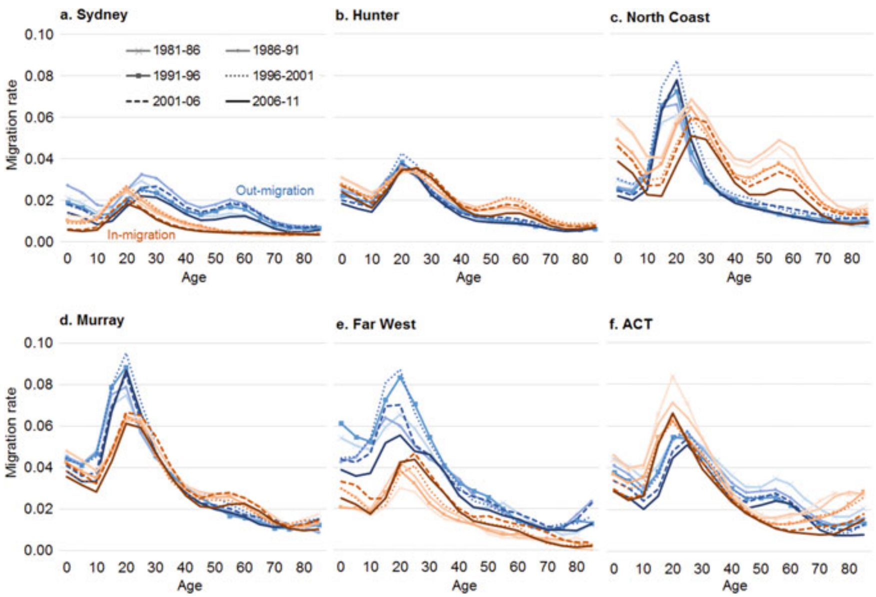

Fig. 4.4 Internal migration for selected regions, 1981–2011

and by sustained out-migration. The population decline experienced by young adult cohorts in the regional and remote areas during this 30-year period is striking.

For the purposes of our illustration, we are interested in the extent that internal migration contributed towards the changes in the age compositions over time. One important indicator is provided in Fig. 4.4, which presents the in-migration ratios (brown lines) and out-migration rates (blue lines) for the same six regions above and over time. Note that in-migration ratios are calculated by dividing the number of in-migrants to region i by the population of region i, which as we argued above is separate from the population 'at risk' of migrating. Here, and for the remainder of this section, we combine males and females together.

These patterns are strongly suggestive of both the effects of life course events on migration and the enduring influence of rural–urban migration. Out-migration of young adults has been very high in the North Coast, Murray, Far West and the other regional areas not shown. For example, during the 1996–2001 period, around nine per cent of 20–24 year olds left these areas. The slightly delayed peaks of in-migration most likely include some return migration of previous young adult out-migrants from these areas, bringing with them young families as evidenced by higher rates among 0–4 year olds. There are also clear retirement-aged bulges present in the age profiles of migration from Sydney and ACT. However, these bulges have been declining over time. Indeed, out-migration rates have declined across most age groups in Sydney, Hunter, Far West and ACT between the 1981–1986 and 2006–2011 periods. These declines have been observed across Australia (Bell et al. 2018), as well as in other developed countries (Champion et al. 2018; Cooke 2013). The underlying causes are thought to be population ageing and changing economic structures (i.e. manufacturing to service-based). Interestingly, such evidence is line with Zelinsky's *Future Super-advanced* stage of the mobility transition theory.

The evidence also poses a series of other questions. For example, what happened to the young adult population in the North Coast, Murray and Far West areas? And, what were the implications for other areas in NSW and ACT? To answer these, we construct multiregional life tables, which combines age- and origin–destination-specific migration with age-specific rates of mortality to estimate the duration of life years spent in the areas of interest. Below, we provide a brief introduction to the calculations and key aspects of these tables. For a full description and set of equations on multiregional life tables, refer to Rogers (1995; see also Willekens and Rogers 1978).

Consider Table 4.1, which includes some of the multiregional life table inputs for the area of Sydney. A life table is constructed for each area that is joined together by origin–destination-specific migration probabilities as shown in the third to seventh columns. A person born in Sydney is estimated to have a half of 0.5% chance of dying before age five, an almost 93% chance of still being in Sydney at age five and a seven per cent chance of living elsewhere in Australia. (Note, emigration is also a possibility but is not included in this illustration.) From these probabilities, we can calculate life table survivorship by age (Columns 8 to 12 in Table 4.1). These represent the proportion of a synthetic population expected to be living in each location at each age, given where they were born and assuming age- and sex-specific migration and mortality rates remain constant. And, from these numbers, we can estimate the number of person-years spent in each location given their birthplace and location-specific life expectancies (Columns 13 to 17 in Table 4.1).

Estimating the migration transition probabilities usually starts with calculating survivorship ratios:

$$S_{ij}(x) = \frac{K_{ij}(x+5)}{K_{i+}(x+5)}.$$

These ratios are based on Census data calculated from the number of people K living in area j, who said they were living in area i five years ago and by dividing this by everyone who said they were living in area i five years ago. The multiregional survivorship ratios are then converted into conditional transition probabilities. These are the probabilities of a person exact age x living in region j in five years given they are currently living in region i conditional of their survival to the end of the five years:

$$p_{ij}(x) = \frac{1}{2}\big(S_{ij}(x-5) + S_{ij}(x)\big) \times (1 - q_i(x)),$$

where q is probability of dying between age x and $x + 5$. The number of persons surviving to each exact age, l, are calculated in matrix form to incorporate each of the different possible migration transitions:

Table 4.1 Multiregional life table example for Sydney

		Probability of transitioning to					Survivorship in region					Person years lived in				
Age	Death	Sydney	Hunter	Illawarra		Rest of Aus.	Sydney	Hunter	Illawarra		Rest of Aus.	Sydney	Hunter	Illawarra		Rest of Aus.
x	q	P_{11}	P_{12}	P_{13}	…	P_{111}	l_{11}	l_{12}	l_{13}	…	l_{111}	L_{11}	L_{12}	L_{13}	…	L_{111}
0	0.005	0.927	0.007	0.007	…	0.034	1.00	0.000	0.000	…	0.000	4.8	0.05	0.07	…	0.04
5	0.000	0.943	0.006	0.006	…	0.028	0.93	0.020	0.029	…	0.016	4.5	0.14	0.20	…	0.11
10	0.000	0.959	0.004	0.004	…	0.019	0.88	0.036	0.051	…	0.029	4.3	0.23	0.31	…	0.17
15	0.001	0.948	0.006	0.005	…	0.024	0.84	0.054	0.073	…	0.039	4.1	0.36	0.49	…	0.24
20	0.002	0.913	0.010	0.008	…	0.042	0.80	0.091	0.123	…	0.057	3.9	0.58	0.78	…	0.36
25	0.003	0.890	0.013	0.011	…	0.055	0.74	0.140	0.189	…	0.086	3.5	0.76	1.03	…	0.48
30	0.004	0.893	0.012	0.011	…	0.053	0.67	0.166	0.223	…	0.107	3.2	0.85	1.13	…	0.55
35	0.005	0.910	0.009	0.009	…	0.043	0.61	0.173	0.229	…	0.115	2.9	0.86	1.14	…	0.58
40	0.007	0.929	0.007	0.007	…	0.031	0.56	0.173	0.227	…	0.117	2.7	0.86	1.13	…	0.58
45	0.011	0.938	0.006	0.006	…	0.023	0.53	0.171	0.224	…	0.116	2.6	0.85	1.11	…	0.58
50	0.016	0.932	0.007	0.007	…	0.020	0.50	0.169	0.220	…	0.115	2.4	0.84	1.09	…	0.57
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
85+	1	0	0	0	…	0	0.188	0.082	0.103	…	0.054	1.2	0.53	0.66	…	0.35

$$\begin{bmatrix} l_{11}(x) \ l_{21}(x) \\ l_{12}(x) \ l_{22}(x) \end{bmatrix} = \begin{bmatrix} p_{11}(x-5) \ p_{21}(x-5) \\ p_{12}(x-5) \ p_{22}(x-5) \end{bmatrix} \times \begin{bmatrix} l_{11}(x-5) \ l_{21}(x-5) \\ l_{12}(x-5) \ l_{22}(x-5) \end{bmatrix}$$

This is a simple two region example with four possible transitions. A 10 region system would have a 100 different transitions and a 10 by 10 matrix for each age group and so on. So while the formulas are the same between a single and multiregional life table, the more regions we have, the larger the matrices become. The L s are calculated in the same way as the traditional life table—in this case with a linear estimation:

$$\begin{bmatrix} L_{11}(x) \ L_{21}(x) \\ L_{12}(x) \ L_{22}(x) \end{bmatrix} = \frac{5}{2} \times \left(\begin{bmatrix} l_{11}(x) \ l_{21}(x) \\ l_{12}(x) \ l_{22}(x) \end{bmatrix} + \begin{bmatrix} l_{11}(x+5) \ l_{21}(x+5) \\ l_{12}(x+5) \ l_{22}(x+5) \end{bmatrix} \right)$$

Finally, the multiregional life expectancies are calculated by summing person-years lived in location j over all ages and dividing by the starting population:

$$e_{ij}(0) = \frac{\sum_{x=0}^{85+} L_{ij}(x)}{l_i(0)}$$

The multiregional survivorship curves for the 2006–2011 data are plotted in Fig. 4.5. These results show that 50% of people born in Sydney will have died

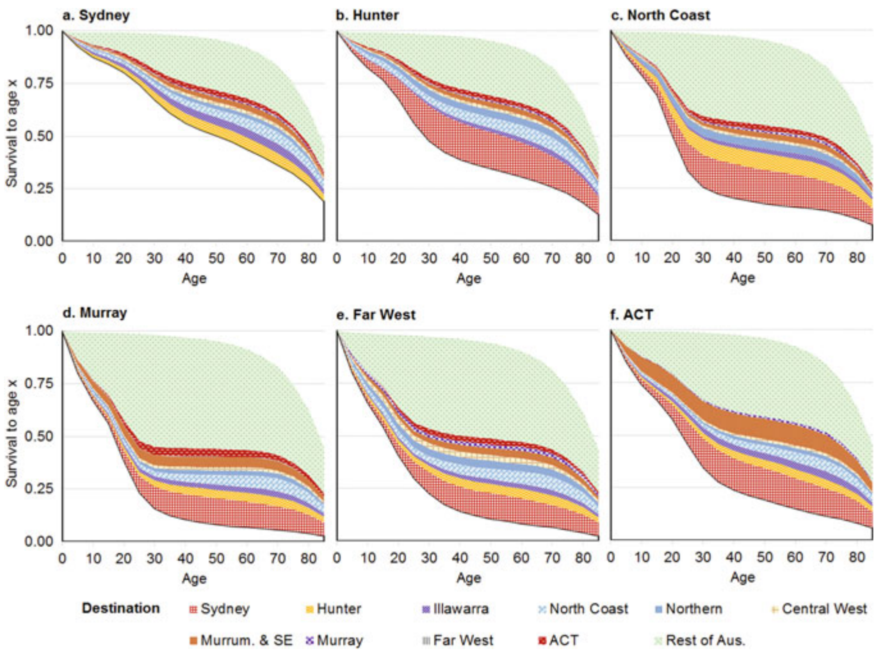

Fig. 4.5 Multiregional survival for selected regions, 2006–2011

or lived elsewhere by age 50. Given the low probabilities of dying at ages below 70 years, most of these persons end up living outside of NSW. In Hunter, fifty per cent of the population have left by age 30. In North Coast, Murray and Far West, the numbers leaving are even more extreme with 50% leaving before age 20. The sharpest declines in survivorship occur before age 30. In terms of destinations, Sydney is the most common in NSW, followed by Hunter and the North Coast. Murrumbidgee and South East is a relatively important destination for areas that share its border, particularly the ACT, which is close to the towns of Queanbeyan, Bungendore, Yass and Goulburn.

The multiregional life expectancies are shown in Fig. 4.6. Here, we find that a person born in Sydney can expect to live for 80.5 years based on the 2006–2011 mortality and migration rates. Of that, 50.9 years are spent in Sydney and 15 years outside the state of NSW. People born in other areas spend less time in their places of birth. Those born in Murray are expected to spend only a quarter of their lives living there. People in all areas are predicted to spend longer in their origin areas than they did in the past—particularly ACT. People living outside their origin areas spend longest in Sydney—though time spent in Sydney seems to have declined over the years. Based on 1981–1986 rates, for example, people born in the North Coast were expected to spend 16.3 years in Sydney. By 2006–2011, this had declined to 10.4 years.

Multiregional life expectancies assume that when people migrate to a different area they become exposed to the mortality rates of their new area. This assumption

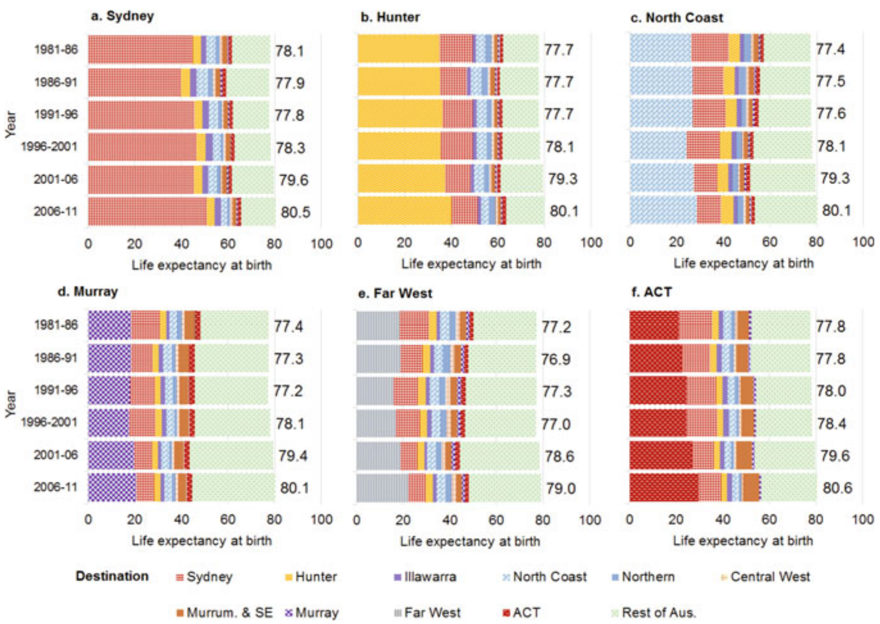

Fig. 4.6 Multistate life expectancy for selected regions, 1981–2011

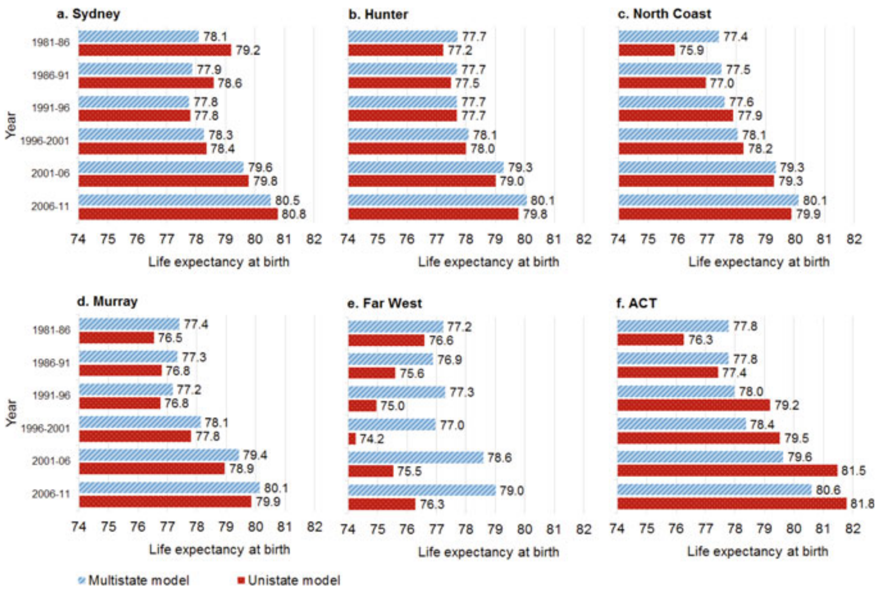

Fig. 4.7 Multiregional and single region life expectancies for selected regions

is standard practice in life table calculations and is a consequence of the underlying Markov process, i.e. the probability of transitioning from one state (location) to another depends on the state (location) at the start of the transition period (Keyfitz 1980, p. 197). Since the calculation of single state life expectancies does not include migration transition probabilities, the population is only exposed to mortality rates in one area.

The inclusion of migration transition probabilities may result in multiregional life expectancies that are different from the single state life expectancies, as shown in Fig. 4.7. Here, the differences in overall life expectancy are particularly important in relatively high mortality (and migration) areas such as Far West. Under the multiregional model, a person born in Far West is expected to live for 79.0 years, compared with 76.3 years in the single state model. The reason for this is that people born in Far West move in large numbers to areas with lower mortality rates—which the multiregional model accounts for. This may be more accurate for a number reasons. A person moving from Far West to Sydney faces a different climate, lifestyle, types of employment, income, health and aged care services. However, the multiregional life expectancy may also disguise part of the mortality disadvantage experienced in a region.

The multiregional life table can be put to all sorts of interesting purposes. Area-specific life expectancies and durations being one. Another is the net migraproduction rate. This is analogous to the total fertility rate in that it estimates the total number of migrations an individual will make over their lifetime given their place of birth. Briefly, the rate is calculated by summing the product of the person-years spent in each area given their birthplace by the out-migration rate for that area. And that is summed across ages to give a lifetime estimate.

$$NMR_1 = \sum_x L_{11}(x) \times o_1(x) + L_{12}(x) \times o_2(x).$$

In Fig. 4.8, we find that migraproduction rates have been slowly declining over time. Note that these rates capture migrations across division borders. Obviously, there is a lot of movements within borders, particularly in places like Sydney. So thinking about cross-border migration, the rates are relatively low in Sydney and Hunter. They both peaked at about 1.6 in 1986–1991 and have since fallen to 1.1 in Sydney and 1.3 in Hunter. In the regional and remote areas, historically the rates have been closer to two migrations per person. Though since the early 2000s, these have been falling too. Thus, the migraproduction rate provides a useful summary measure, indicative in this case of declining rates of internal migration and perhaps a transition towards a *Future Super-advanced Society*.

The above analysis can be extended in various ways. Probabilities of emigration and assumptions about return immigration could be added to the analyses. The above analyses could be used to inform regional population projections. We could combine the results with employment data to look at the economic drivers of population change. Ethnicity and foreign-born populations could be introduced to analyse the changing face of regional NSW. Finally, although the data are not available for Australia, it would be particularly insightful to distinguish the migration patterns of

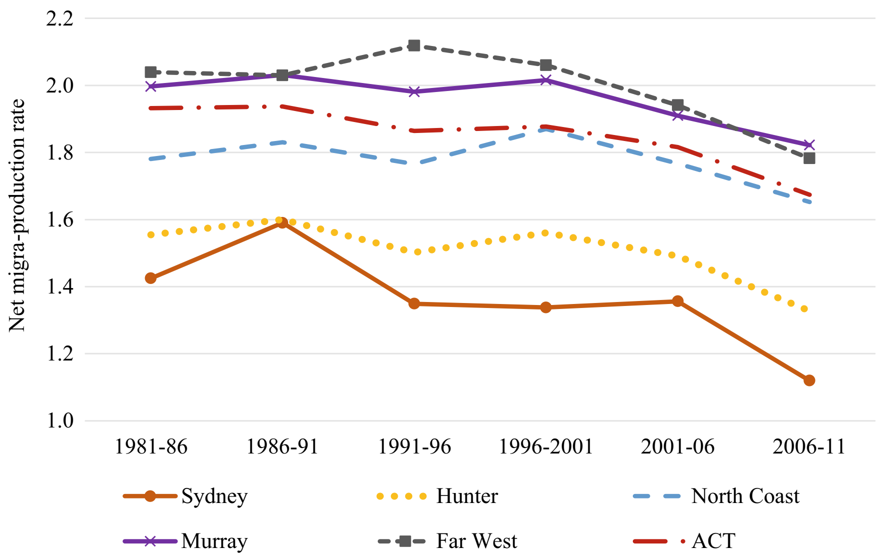

Fig. 4.8 Net migraproduction rates for selected regions

those born in the regions with those born elsewhere, that is, to introduce birthplace-specific information into the analyses (Ledent 1980; Rogers 1995, Chap. 6).

4.6 Policy Framing and Lessons

The study of migration and its impacts on demographic change provides researchers and policymakers with information about the fundamental sources of population change and subsequent impacts on the age and sex composition of the population. It also provides information on how the population is redistributing itself across the country, allowing one to assess where the areas of growth or decline are (or will be) and whether this growth or decline is affecting particular population groups. Furthermore, detailed accounts of population change over time allow a better understanding of how migrant groups are integrating and evolving within society, which can then be used to communicate areas of success or neglect with areas or countries of origin. For example, some migrant groups may exhibit very different demographic patterns or may be relatively isolated geographically. Having such information may be useful for designing social policies directed at migrants or at facilitating information to origin communities.

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