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Measures of Population Ageing in Australia from 1950 to 2050

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Abstract This study utilises annual historic and forecasted population figures from the UN World Population Prospects (2015 Revision) to describe Australia's population changes for the period 1950–2050. A number of population indices have been employed to describe these changes. Specifically, we constructed population pyramids and computed measures including economic dependency ratios, support ratios, ageing/Billeter indices and coefficients of inflow, outflow and exchange of productive populations. Our results suggest that a combination of factors including declining fertility and mortality have contributed to Australia's ageing population. The implications of these changes are broad and raise major challenges for Australia's economy and infrastructure. To tackle both the drivers and impacts of population ageing, multi-faceted approaches are needed together with prompt evaluation to ensure that current and future challenges posed by population changes in Australia are fully contained.

Keywords Population dynamics · Dependency ratios · Demographic transition · Australia

Background

Many societies around the world are experiencing dramatic population changes that have been described by the United Nations as "unparalleled" and "unprecedented" (Department of Economic and Social Affairs Population Division 2001). In most

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developed countries, these changes are largely manifested as an accelerated expansion of older populations[1]; a phenomenon often termed "population ageing" (Christensen et al. 2009; Zaidi 2008). Population ageing is usually said to be occurring when a nation's population structure is evolving such that a higher proportion of the future population will be in older-age groups (Gavrilov and Heuveline 2003; Turner 2009). Nonetheless, population ageing is not limited to an increasing number of people in the older-age group, but also includes a decline in the proportion of younger individuals (bottom-up ageing) (Kalache 1999; Zaidi 2008).

Population age-structures have become an essential tool for understanding changes within populations. However, the processes underlying population age-structures can be highly complex (Káčerová and Mládek 2012). This complexity stems from multi-causal demographic and socioeconomic trends. The age-structure of a population at any period is the end-product of many years of interaction between demographic processes including mortality, natality and migration (Sander et al. 2015), and changes occurring in a population's age-structure are important from both a demographic and social point of view (Bloom et al. 2007; Turner 2009).

Population ageing may present economic challenges as it relates to the balance of economically active and inactive individuals (Bloom et al. 2015; Bloom, Canning and Sevilla 2003;Weber 2010). With growing numbers of older persons (along with declines in number of younger people), population productivity is expected to be affected and pension schemes stretched, bringing their sustainability into question (Bloom et al. 2011; Lee et al. 2010). Additionally, population ageing necessitates specialised health, nutrition, housing, transport, cultural and sport services, all of which are costly (Beard et al. 2012; Fried and Paccaud 2010), although factors such as declining tax revenue could impact on availability of resources to provide these services (National Research Council 2012). As a result, population ageing is considered one of the most pressing issues in many developed countries (Lanzieri 2011).

Within Australia, population ageing is emerging as a key demographic issue for government and policy makers and is often at the centre of public debate (O'Brien, 2016; Productivity Commission 2013; Piggott 2016). Studies on population ageing in Australia have been published, although the emphasis has been on a few indicators such as numbers and proportion of older people (Deacon 2000; Hoon Han and Corcoran 2014; Jackson and Felmingham 2002; O'brien 2016; Hugo 2014a, Hugo 2014b), which are essential but do not help to convey other important aspects of the ongoing demographic transition (Johnstone and Olga 2009; Hock and Weil 2012; Káčerová and Mládek 2012). A comprehensive overview encompassing multiple indices is likely to reveal different perspectives of population changes supporting the discussion and framing of policies within a broader context (Jackson 2001).

Accordingly, we provide a general overview/description of population changes in Australia from 1950 to 2050 by performing a survey of a wide range of indices. The probable factors underlying the patterns of population changes are reviewed; the potential impacts and policy responses are briefly discussed.

[1] Changes within the population may also occur in the form of 'rejuvenation' where the population is growing younger. This is not common and less described in literature

Methods

Data Sources

Population figures for Australia from 1950 to 2050 were sourced from the United Nations (UN) World Population Prospects (2015 Revision) (Department of Economic and Social Affairs Population Division 2015). The World Population Prospects is a database that includes population estimates and projections for all countries and territories in the world. It is produced by the Population Division of the United Nations and is revised every two years (Department of Economic and Social Affairs Population Division 2007). Population estimates were stratified by gender and 5 year age groups. Demographic data including birth rate, median age and mortality rates were also retrieved. To minimize the uncertainties in the projected population estimates, only medium variant figures were utilised. The world population prospects estimates were used for this analysis as it allow us to make reasonable comparison of Australian figures with global and similar developed countries' figures also generated by the UN.

UN Population Projections: Methodology and key Assumptions

The UN employs a cohort-component projection method for estimating country-level population projections (Department of Economic and Social Affairs Population Division 2015b). This methodology incorporates 3 key dimensions; fertility, mortality and net migration and is an extension of the demographic balancing equation [Box 1] (Preston, Heuveline and 2000). This equation identifies two entry routes into any population; i.e. via birth or migration and similarly two routes of exit —by death or migration.

- *Fertility:* For countries in post demographic transition periods such as Australia, a time series model was adopted to project fertility from 2015 to 2050 with the assumption that in the long term, fertility would hover around country-specific terminal levels based on a Bayesian hierarchical model (Department of Economic and Social Affairs Population Division 2015b). This new method of country-specific projection is an update from previous methods employed which assumed a uniform pace recovery in fertility with ultimate convergence at 1.85 children per woman (United Nations 2011).
- *Mortality:* Mortality was incorporated into the projections by estimating death rates per age group and sex. Life expectancy was assumed to generally rise from 2015 to 2050 (i.e. the rate of increase was considered to be non-negative) and no limit on life

Box 1 *Population balancing equation*

$P(t_1 + n) = P(t_1) + X(t_1) - Y(t_1) + M(t_1) - R(t_1)$

where:

- $P(t_1)$ is the population at time t_1
- $X(t_1)$ and $Y(t_1)$ are number of births and deaths occurring between t_1 and $t + n$.
- $M(t_1)$ and $R(t_1)$ are the number of immigrants and of emigrants from the country during the period t_1 to $t_1 + n$.

expectancy was imposed. Unlike fertility, however, only one future mortality trend was utilized in the 2015–2050 projection. The probabilistic methods adopted for projecting life expectancy were similar to those previously employed with additional modifications and adjustments in gender (female-male) differences in life expectancy (Department of Economic and Social Affairs Population Division 2015b). That is, changes in life expectancy were separated into systematic decline and random distortion terms (Department of Economic and Social Affairs Population Division 2015b). The systematic changes in life expectancy at birth were modelled as a function of the level of life expectancy via a double-logistic improvement function with parameters estimated from a Bayesian hierarchical model.

- *Migration*: In the 2015 population prospects projection, international migration was assumed to remain fairly stable at current levels till 2050. Refugees were assumed to typically return to their home countries within 5 to 10 years. As Australia experiences both international migration and refugee movement, these were combined to estimate the overall migration.

Analysis

To assess the population changes in Australia, a number of indices were considered including general population distribution indices, reproductive indices and economic indices.

General distribution indices were drawn from population pyramids, constructed for the years 1950, 1980, 2015 and 2050,[2] using raw population figures from the most current UN population prospects (Department of Economic and Social Affairs Population Division 2015). The distribution measures assessed included the proportion of youth (<15 years), elderly (≥65 years) and older-olds (≥85 years).

Reproductive (fecundity) changes were described using the Billeter index (J), which was developed by Ernest Billeter in 1954 and represents the ratio of difference between the populations at the child – pre-reproductive age (children's generation) and post-reproductive age (grandparent's generation) and the population in the reproductive age (parents' generation) groups (Hoffmann and Menning 2004; Káčerová et al. 2012). To compute the Billeter index, the population was stratified into pre-reproductive (<15 years), reproductive (15–49 years) and post-productive (50+) groups (Fischer 2015). The Billeter index (J) attains a negative value when the population is ageing; a positive value represents a state of juvenescence (Fischer 2015; Weber 2010).

To assess the economic dynamics of population ageing, the population was stratified into "productive" and "dependent" population groups (Schatz et al. 2015), where productive groups refer to the 'working' age group (15–64 years) while the dependent population represents those that are young (0–14 year olds) and old (aged 65+ who are often considered the post-productive group in the economic literature) (Bucher 2014; Department of Economic and Social Affairs Population Division 2001). The 'working' age group was varied in sensitivity analyses to 15–69 years in line with increasing retirement age. Subsequently, we computed the ageing index (otherwise known as the elderly-child ratio) comparing the size of the post-productive population with the size of the pre-productive population. For instance, an ageing index of 2 can be interpreted

[2] We selected years that are adequately spaced to allow for meaningful changes to be observed in the pyramids

as 2 elderly individuals per 100 children, and increases with population ageing (Christensen et al. 2009). We also assessed the balance between the dependent and productive populations by computing the total dependency ratio, youth dependency ratio, old-age dependency ratio and potential support ratio (Department of Economic and Social Affairs Population Division 2001).

To explore the social dynamics of population ageing we computed the parental support ratio which represents the number of older-olds (85+) per 100 individuals aged 50–64 (Department of Economic and Social Affairs Population Division 2001). The parental support ratio is regarded as an important parameter for tracking population ageing as the older-olds may require greater family and social support (Bucher 2014; Káčerová and Mládek 2012). According to Káčerová et al. (2012, p. 28), the parental support ratio largely reflects the "relationship between the generation of parents and their children and as a potential possibility of direct inter-generation assistance". In our analysis we only report parental support ratios for the period 1990–2050. This is because 5 year age group population figures beyond age 80 are only available from the World Population Prospects database from 1990 onwards.

To quantify the speed and direction of population aging we computed the dynamic economic ageing index by comparing the size of age groups that enter and/or exit the productive age categories at any time (Káčerová and Mládek 2012; Káčerová et al. 2012). The higher the value of the dynamic index, the faster the speed of population change; a positive value indicates an ageing population while a negative value means that the population is undergoing rejuvenation (Długosz and Kurek 2009; Káčerová and Mládek 2012).

Changes in Australia's workforce were assessed by quantifying the rate of flow into and out of the productive population by youth (10–14 years) and older persons (60–64 years), respectively. These processes were described by computing the coefficients of inflow, outflow and exchange (Bucher 2016; Dufek 2006; Káčerová et al. 2012). Once the rate of exit from the productive population exceeds that of the inflow, a value of <100% is observed for the coefficient of exchange.

Descriptions of the indices calculated, and the formulae used, are provided in Table 1.

Ethics

Ethics approval was not necessary for this study as only publicly available aggregate population data were used.

Results

Changes in Australia's Population Pyramid

Population changes in Australia are characterised by a mix of an expanding older-age group and a diminishing younger-age group relative to the overall population.

The proportion of the country's population under 15 years declined from 26.6% in 1950 to 18.7% in 2015. The under-15 population is projected to reach 17.2% by 2050. In contrast, the proportion of the population aged over 65 years has increased. In 1950, 8% (~668,000) of Australia's population was aged over 65 years; this increased to

Table 1 Summary of indicators for accessing temporal changes in population age-structure (Department of Economic and Social Affairs Population Division 2001; Długosz and Kurek 2009; Káčerová and Mládek 2012; Weber 2010)

Measure	Description	Calculation steps
General distribution indices		
• Proportion of youth	Percentage of total population under 15 years.	p(0–14)/t(P)*100
• Proportion of elderly persons	Percentage of total population aged 65 and over.	p(0–14)/t(P)*100
• Proportion of older-olds	Percentage of total population aged 85 and over.	p(85+)/t(P)*100
Reproductive indices		
• Billeter index (J)	The ratio of difference between the populations at the child–pre-reproductive age (0–14) and post-reproductive age (50+) and the population in the reproductive age (15–49).	[((p(0–14)-p(50+))/p(15–49))]*100
Economic indices		
• Ageing index (A_I)	The number of persons 65 years old or over (post-productive) per hundred persons under age 15 (pre-productive)	p(65+)/p(0–14)*100
• Total dependency ratio (tD_R)	The ratio of dependents (people who are too young (0–14) or too old (65+) to work) to the number of productive (working, 15–64) population	[((p(0–14) + p(65+))]/ t(P)*100
• Youth dependency ratio (yD_R)	The number of persons 0 to 14 years per one hundred persons 15 to 64 years.	p(0–14)/p(15–64)*100
• Old-age dependency ratio (oD_R)	The old-age dependency ratio is the number of persons 65 years and over per one hundred persons aged 15 to 64 years	p(65+)/p(15–64)*100
• Potential support ratio (pS_R)	The potential support ratio is the number of persons aged 15 to 64 per every person aged 65 or older	p(15–64)/p(65+)
• Parental support ratio (paSR)	The parent support ratio is the number of persons 85 years old and over per one hundred persons 50 to 64 years	p(85+)/p(50–64)*100
• Dynamic economic ageing index (I_{ead})	Draws comparison between the population making entry into the productive population and those exiting	[p(0–14)t — p(0–14)t + n] + [p(65+)t + n — p(65+)t]
• Coefficient of inflow (K_i)	Details the rate at which 10–14 year olds are entering the productive age.	p(10–14)/p(15–64)*100
• Coefficient of outflow (K_o)	Quantifies the rate of outflow of 60–64 year olds from the productive age.	p(60–64)/p(15–64)*100
• Coefficient of exchange (K_e)	Quantifies the changes in the rates of population entry and exit from the productive group.	p(10–14)/p(60–64)*100

15.1% (~3.6 million) in 2015. By 2050, 22.5% (>7.5 million individuals) will be aged 65 years and over. The proportion of the population in the "productive" age group (15–64 years) has remained fairly stable accounting for 65.2% in 1950 and 66.2% in 2015. However, by 2050 the proportion of the population aged 15–64 will decrease to 60.3%. The older-olds (85+) are the most rapidly expanding group, with rates increasing more than two fold in size from 0.84% of the total population in 1995 to 1.94% in 2015. By 2050, almost 5% of Australians will be aged 85 or more. Even among centenarians (those living to 100 years or beyond), the numbers have increased greatly from around 1290 in 1995 to about 4600 in 2015. By 2050, the proportion of Australia's population aged 100+ will be about 2100% (21 times) higher than the proportion in 1990.

Women constitute a greater proportion of the elderly population in Australia, although the gap between males and females appears to be narrowing over time. In 1970, for every man aged over 65 years, there were 1.37 women over 65 years. This decreased to 1.26 women to every man in 2000 and 1.13 women to every man in 2015.

These population changes have increased the median Australian population age by approximately 6 years over the last three decades, from 30.8 years in 1985 to 37.5 years in 2015. By 2050 Australia's median age is projected to reach 41.4 years. These changes are clearly reflected in the country's evolving population pyramid, which has shifted from one with a broad base of young children and a narrow apex of older people in 1950, to one with a more uniform age distribution in 2015, and projected to move towards a pyramid broadened upstream in 2050 (Fig. 1).

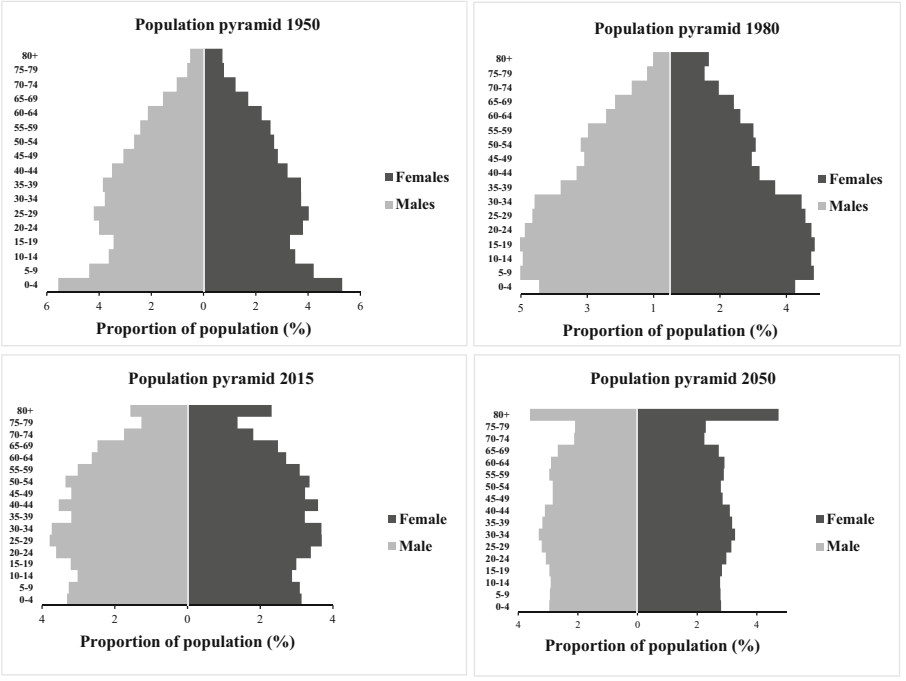

Fig. 1 Population pyramids of Australia for the years 1950, 1980, 2015 and 2050. Source: produced by authors using UN world population prospect figs. (2015 revision)

Changes in Ageing and Billeter Indices

In 1950, Australia had an ageing index of 31, thus for every 100 young people (0–14 years), there were 31 elderly (65+) persons. This ratio increased more than 250% from 31 to 80 in 2015 (Fig. 2). By 2030, the ageing index is expected to exceed 100 (104) with a further increase to 131 by 2050. Conversely, Australia's Billeter index has been declining since 1950 (Fig. 2) with a negative value first reported in 1985 (−1.2%). This reached −30.2% in 2015 and is projected to reach −52.6% by 2050.

Changes in Economic Dependency and Social Support

The total dependency ratio (tD_R) in Australia decreased slightly from 63 per 100 people in the productive population in 1960 to 51 per 100 people in the productive population in 2015. More specifically, the old-age dependency ratio has increased from 14 to 23 per 100 productive people within this time period, whilst the youth dependency ratio has decreased substantially, from 49 per 100 productive persons in 1960 to 28 per 100 productive persons in 2015, thus resulting in a reduced total dependency ratio.

Post-2015 projections predict a steep rise in total dependency ratio (expected to reach 66 per 100 productive people in 2050) due to a rapid rise in the old-age dependency ratio which is estimated to reach 37 per 100 people in the productive population by 2050. This will also impact the potential support ratio (pS_R), with an expected decline from 8 productive people per 100 people aged 65+ in 1970 to 4 in 2015 and projected to reach 3 productive people per 100 people aged 65+ years by 2050 (Fig. 3).

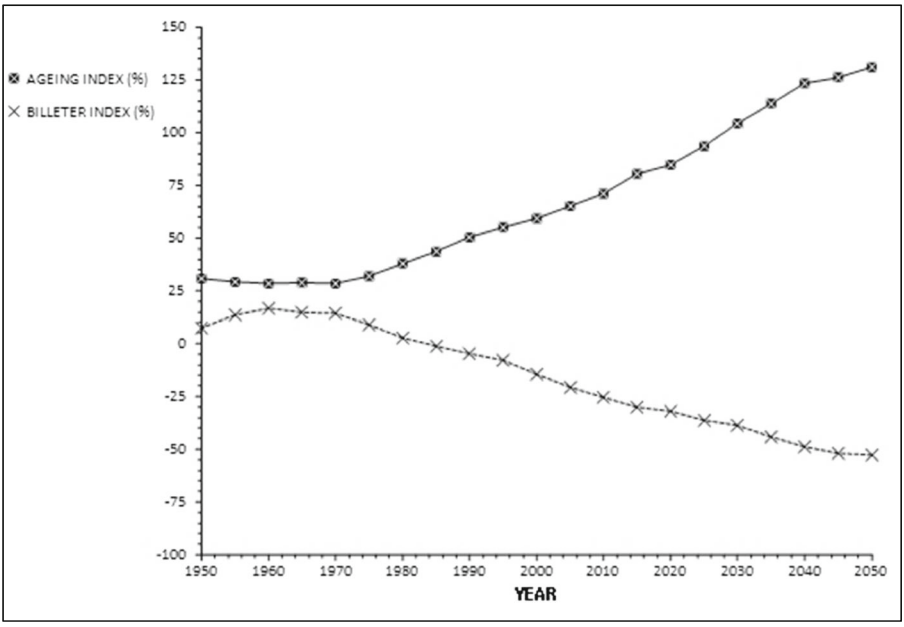

Fig. 2 Ageing and Billeter indices for Australia (1950–2050). Source: Produced by authors based on the UN world population prospects figs. (2015 revision)

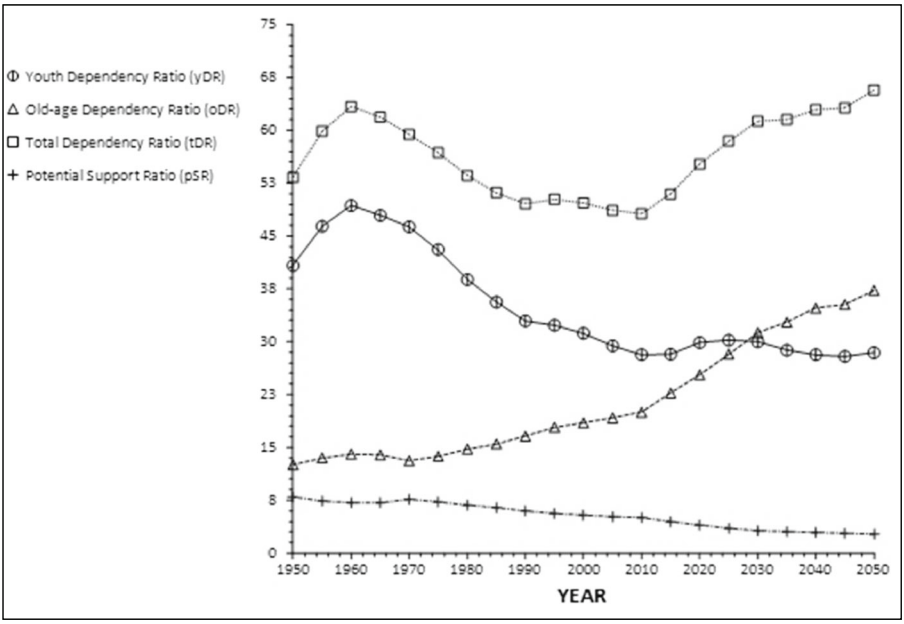

Fig. 3 Australia's **economic** dependency and support ratios (1950–2050). Source: Produced by authors based on the UN world population prospects figs. (2015 revision)

The parental support ratio has also been rising (**not shown on** Fig. 3) in Australia, increasing from 6 older-olds (85+) per 100 individuals aged 50–64 in 1990 to 11 in 2015. By 2050, the parental support ratio is projected to reach 28; representing a more than fourfold increase from the 1990 figure.

Changes in Australia's Workforce

As can be seen from Fig. 4, the rate of inflow (K_i) of youth into the productive (working age) population was highest during the period 1960–1975 when there was about 2–2.5-times more inflow into the productive population than outflow into the post-productive age group. This means for every 1 person (60–64) likely to exit the workforce, there were about 2–2.5 persons (10–14) likely to enter. *After 1975, the rate of inflow began to decline while the outflow remained relatively stable.* Since 2000, however, the rate of outflow (K_o) has accelerated rapidly bringing the coefficient of exchange (K_e) down to 110% in 2015 (i.e. 1.1 people entering the productive population for every 1 person exiting). It is estimated that by 2050 the rate of inflow into the country's workforce, the productive population, will be insufficient to compensate for the rate of outflow from the working population (K_e = 98%).

Speed of Population Ageing

The dynamic economic ageing index (I_{ead}) of Australia is shown in Fig. 5. Up until 1965, population rejuvenation was observed, as depicted by negative I_{ead} values. Since then, no population rejuvenation has been experienced in Australia. The fastest speed

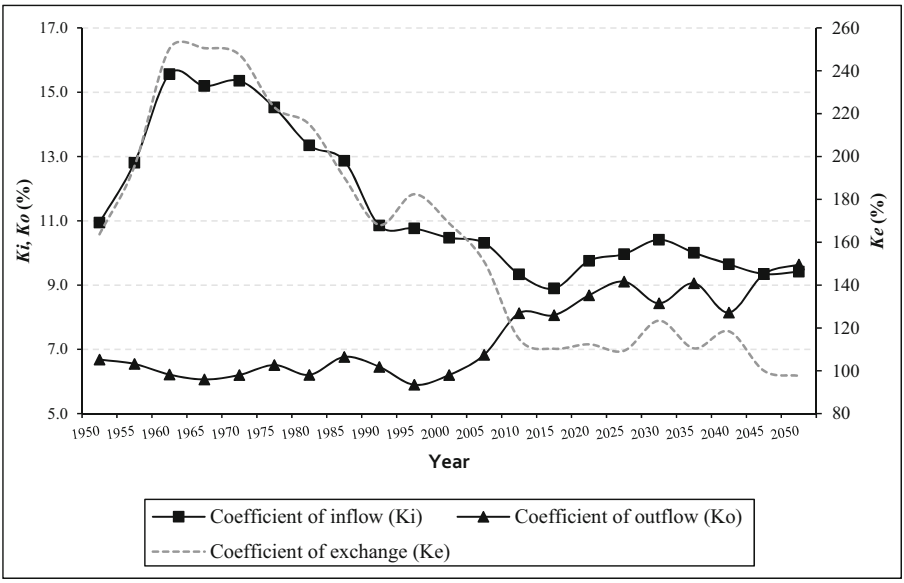

Fig. 4 Coefficients of inflow, outflow and exchange of productive population in Australia (1950–2050). Source: Produced by authors based on the UN world population prospects figs. (2015 revision)

of population ageing occurred in the period 1980–1990, with an average I_{ead} of +2.6. Between 1995 and 2015, an average I_{ead} + 1.6 was observed. As per the population projections, the speed of ageing of the Australian population is expected to fluctuate between now and 2050. However, rejuvenation, the reversal of population ageing, is not expected at any time point (as per the observed positive I_{ead}).

Sensitivity Analyses

The results reported are subject to uncertainty in the input parameters as well as assumptions made during the computation of these indices. For example, economic indices are subject to the age limits imposed on productivity. The age of retirement was assumed to be 65 years as per current guidelines. Varying this to age 70 results in a marked reduction in the old-age dependency ratio. That is, the projected old-age economic dependency ratio would decrease from 33 per 100,000 to 23 per 100,000 in 2035 when it is assumed that retirement age is increased from 65 years to 70 years, respectively. In addition, the total economic dependency ratio would decline from 62 per 100,000 to 50 per 100,000. It is also possible that if net-immigration or fertility rates were to change significantly from that projected by the UN, significant shifts in the projected population distribution may emerge, although, such assessments are beyond the scope of this paper and have not been interrogated.

Discussion

Prior studies have typically described Australia's ageing population by focusing on a few measures such as the numbers and proportion of older people. Such analyses do not

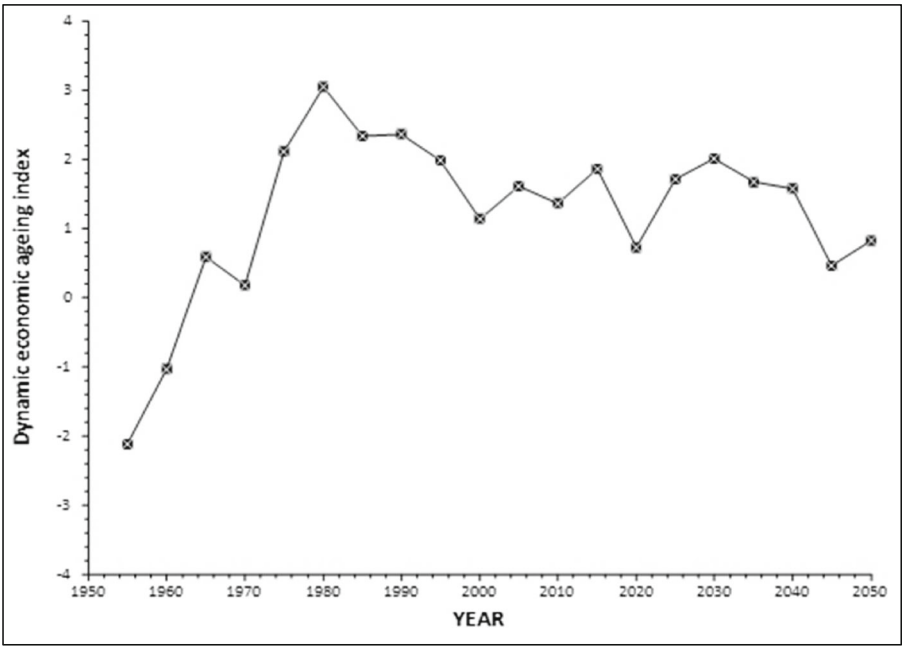

Fig. 5 Dynamic economic ageing indices for Australia (1950–2050). Source: Produced by authors based on the UN world population prospects figs. (2015 revision)

elucidate the broader perspective for understanding population changes in Australia. In the present study, we have described Australia's population changes from 1950 to 2050 through the use of multiple measures to demonstrate various aspects of population transition. The indices described offer a broader scope for understanding population ageing and probable impacts, particularly to non-demographers who may find the discussions around population ageing confusing. The measures also capture how demographic, economic and health considerations may influence policy choices. For instance, projected numerical changes in the elderly population allow governments to anticipate and plan for future demand in health and social care services but also help to anticipate likely revenue changes as a result of decreased productivity due to declining labour workforce (Department of Economic and Social Affairs Population Division 2001; Gavrilov and Heuveline 2003).

Population Ageing in Australia; Drivers and Implications

Our analysis demonstrates Australia's population is aged well above the global average. In 2015, the proportion of people that were elderly (65+) was almost twice the global average (15.1% versus 8.3%) (Department of Economic and Social Affairs Population Division 2015). The proportion of people in Australia's younger population (<15 years) was 18.8% of the total population, well below the global average of 26.1% but comparable to other developed countries such as the US (19.0%), UK (17.8%) and France (18.5%) (Department of Economic and Social Affairs Population Division 2015). The median age of Australia's population in 2015 was almost 8 years above the world's average of 29.6 years (See Supplement 1).

Changes in both productive and reproductive indices further support an ageing Australian population. For example, the ageing index is projected to exceed 100 by 2030 similar to calculations for most other developed countries, although, in 2000 only a few countries such as Germany and Japan had an ageing index greater than 100 (Gavrilov and Heuveline 2003). The reduction in the size of the reproductive population, and an ongoing expansion of post-reproductive population as observed in the Billeter index, supports the premise that no population rejuvenation will be observed in Australia between now and 2050.

Aside from decreases in the size of the reproductive population (as observed in the Billeter index), an important contributor to Australian population ageing is families having fewer children. The UN World Population Prospects figures demonstrate that in Australia, fertility rates have declined since their peak (of 3.41 children per woman) in 1955–1960 (See supplement 2). Although, there was a slight increase in fertility rates between 2005 and 2015 (from 1.77 to 1.92 children per woman), future projections indicate a decline between now and 2050 (to 1.78) (Department of Economic and Social Affairs Population Division 2015). Typically, developed countries with a fertility rate of 2.1 children per woman or less, are classified as sub-replacement fertility (Espenshade et al. 2003); that is, the number of children born is insufficient to replace the parents' generation. Currently, almost 50% of the world's population is living in below-replacement level countries (United Nations Department of Economic and Social Affairs Population Division 2015). This may produce short term benefits as the youth dependency ratio and total dependency ratio decreases, where the number of dependents (children and/or older individuals of retirement age) is less than the number of productive, working age individuals. This was seen in Australia with the generation of "baby boomers", the largest and most influential age group in the Australian workforce to date. Eventually the large mass of productive individuals begins to age and leave the workforce, and productivity declines as they become dependents. Since 2000, the rate of outflow of people leaving the Australian workforce has increased dramatically, fuelled by the baby boomers ageing and reaching the post-productive stage (Rogerson and Kim 2005). As Australia is also a sub-replacement fertility country, and has been for some time, this means that there are fewer people entering the workforce. Our projections indicate that by 2050 there will be a significantly reduced workforce due to the increased number of people in the post-productive population and reduced number of people entering the productive age group (Coefficient of exchange, K_e = 98% in 2050). This will result in a higher number of older-age dependents to care for, and thus, a higher dependency ratio.

The contribution of population ageing towards declining workforce in Australia is significant, resulting in reduced productivity and economic output (Productivity Commission 2005; Pye 2012). In the early 1990s, Australia experienced economic growth of about 2.2% per annum. However, this has reduced to approximately 1.5% since the early 2000s. It is projected that economic growth in the next four decades will be lower than over the last 40 years (Commonwealth of Australia 2015). Economists have explained that countries typically go through different cycles/phases of economic development and progress due to multiple reasons (Bhaumik 2011; Craigwell and Maurin 2012). Nonetheless, Australia's 2015 Intergenerational Report (Commonwealth of Australia 2015, p. xii) concluded that "in reality it is almost certain that any economy will go through such cycles over a 40 year time period. However, the

outlook to 2054-55 will not be driven by these cycles, but by the underlying trends in population, participation and productivity". The effects of a reduced workforce as observed from our analysis may go far beyond changes in current productivity and economic output, but will also impact other things such as the resources available for future growth investments (Simon et al. 2012).

Another factor contributing to population ageing is the declining mortality rates with increased survival to old-age. Data from the UN world population prospects (2015 revision) suggests that the crude death rate in Australia has decreased by about 80% from 36 deaths per 1000 population in 1950–1955 to 6.7 deaths per 1000 population in 2010–2015. Between 1950 and 1992, the age-standardised death rate from all causes in Australia declined by almost 43% from 1018.7 (per 100,000 population) to 579.8 (per 100,000 population) (Australian Institute of Health and Welfare 1998). In 2014, the age-standardised mortality rate was 550 per 100,000 population. The mortality trends in Australia over the last century are largely driven by significant decreases in deaths from all major causes including reduction in mortality rates of about 96% for infectious diseases, 80% for respiratory diseases and 70% for motor vehicle accidents (Australian Institute of Health and Welfare 2005). The declines in mortality and increasing survival are also represented by an increased life expectancy in Australia which has risen by approximately 12.7 years since 1955–60 (69.43 years in 1955–60 and 82.09 years in 2010–15) (Department of Economic and Social Affairs Population Division 2015). This is consistent with trends in life expectancy in many other developed countries and indeed across the globe (Christensen et al. 2009; Department of Economic and Social Affairs Population Division 2015; World Health Organization 1998).

As a result of the long-term reduction in mortality, significant numbers of Australians are surviving to older ages (eg., the number of people aged 65+ set to exceed 7.5 million by 2050 —more than two-fold increase from 2015) where chronic ailments such as dementia, muscoloskeletal disorders, cardiovascular diseases, disability and comorbidietes are prevalent (Australian Bureau of Statistics 2013; Zhang et al. 2010). The implication is a greater demand on health services and a rising health expenditure which has grown from $50.3 billion in 1989–90 to $154.6 billion in 2013–14. Within this period, the percentage of health expenditure relative to Australia's GDP increased from 6.5% to 9.7% (Australian Institute of Health and Welfare 2016). The cost per person increases with age, with health expenditure in Australians aged 85+ years in 2008–09 almost 20 times higher than those aged 5–14 years (Australian Institute of Health and Welfare 2016). The ongoing changes are important for health policy makers to consider when planning for the needs of the older population, particularly around preventive care to reduce burden on the health system and to preserve functionality and quality of life (Mangin et al. 2007). This is necessary as the possible future declines in economic productivity could mean far less resources are available to invest and expand essential health and social services (National Research Council 2012).

Our analysis of the population distribution revealed a higher number of older women relative to men. This observation is consistent with global patterns, a trend often termed the feminization of ageing (Davidson et al. 2011; Gavrilov and Heuveline 2003). However, historically the pattern has not always been like this. Before 1950, there were more men than women aged 65 years or older globally, a result of very high maternal mortality. Reduced maternal mortality, due to advancements in knowledge and technology, as well as proportionally higher mortality in men due to biological and

or behavioural mechanisms, including working patterns and lifestyle choices such as smoking (Gjonça et al. 1999; Rogers et al. 2010), has reversed this. However, our analysis suggests that some sort of convergence is being observed which may due to a range of factors including the limited potential for further reductions in maternal mortality with a plateau having been reached.

As stated previously, there has been a decline in the number of children born, subsequently affecting the parental support ratio. This is likely to impact the social support that elderly people may receive. Research has shown that most elderly individuals would like to remain in a domestic environment such as living with their children or relatives (Department of Economic and Social Affairs Population Division 2005; Tinker 2002), especially when they can no longer care for themselves. For some elderly, this aspiration is unlikely to be possible and a sizeable proportion may need institutional care. The provision, location and regulation of these services will become extremely important. In Australia, the remaining lifetime risk of requiring residential care at age 75 has been estimated as 72% and 53% for women and men, respectively, at a current annual cost of AUD $7 billion Australian dollars (Productivity Commission 2011). A significant proportion of this cost is for nursing home care in a residential facility which is estimated to cost almost AUD $65,000 per person per year (Australian Institute of Health and Welfare 2012). The probable implications of population ageing on other social services and infrastructure such as transportation systems and the design of the built environments has been widely acknowledged (Clarke and Nieuwenhuijsen 2009; Raeside et al. 2012; World Health Organization 2015).

Policy Responses to Population Ageing

A number of proposals have been made towards addressing/minimizing the effects of population ageing. Such proposals include increasing the levels of immigration (Denny 2015; Muysken 2008; Simon et al. 2012) as immigrants tend to be younger and therefore can contribute to economic productivity (Dumont et al. 2010) and also often have higher fertility rates which may help to sustain population growth (Kinnear 2001). Unsurprisingly, the proportion of young skilled immigrants accepted in the Australian government's migration program increased by more than 200% between 1995 and 2003 (The Treasury 2004). However, aside from the difficulty in attracting a sustained high numbers of skilled migrants due to competition from other countries (Schachar 2006), in the long term these immigrants will also age (thereby contributing to higher old-age dependency ratio) requiring a progressively higher number of immigrants to maintain the population structure. Therefore, immigration has been shown to be a poor mechanism for tackling population ageing; increasing the annual net overseas immigration in Australia by 100,000 would only lead to a 2.6 year change in the median age of the Australian population by 2051 (Australian Bureau of Statistics 2000).

Due to declines in the number of children born, strategies to boost birth rates have also been proposed including offering better employment conditions for working parents (Grant et al. 2004). An analysis by Kippen (1999) showed that if birth rates in Australia in 1999 were maintained over the next century, the proportion of Australia's population aged 65 years and over could be contained at 27% while maintaining the total population at 27 million by 2098. This is equivalent to doubling immigration intake along with a decline in total fertility rate from 1.76 to 1.65— the

latter option however would result in a total population of 35 million (Kippen 1999). Over the last two decades improved access to part-time jobs and increases in social family benefits (e.g. including family tax breaks) have been credited for the increased fertility rate observed in the period 2005–2010 (Lattimore and Pobke 2008). There is, however, concern that recent adverse changes in family benefits (Pederson-Mckinnon 2016) could potentially erode some of the modest gains made regarding raising families. Policy changes to support fertility are complex and as explained by Kinnear (2001, p.36) must also broadly consider "easing the tension between women's participation in the paid work force and their caring roles" by focusing on the provision of child care, maternity leave provisions and the introduction of 'family friendly policies' in the workplace to ensure that women can choose motherhood without suffering significant economic disadvantage.

There is also increasing discussion around raising the retirement age to sustain the number of people in the workforce (Grant et al. 2004; Turner 2016) with the argument that most individuals aged 65+ years may be in better physical health state than generations before (Kinnear 2001). With such changes already implemented in some countries (Grant et al. 2004; Teitelbaum 2000), steps are underway in Australia to increase pension qualifying age be increased from 65 years to 67 years by 2023 and 70 years by 2035 (Department of Human services 2016). To aid in receiving the benefits of increasing retirement age, perceptions regarding old-age, working lifestyle as well as preferences to employ younger people who may accept a lesser pay will need to change (von Schrader and Nazarov 2016).

Strengths and Limitations

In this comprehensive review, we have examined population changes in Australia through analysis of multiple indices to provide an understanding of various components of the ongoing changes. There are, however, some limitations. Firstly, assessment of the level of economic dependency within the Australian population was based on age (biological) cut-offs (where dependants were those aged <15 years or 65+ years, and non-dependants were those of working age (aged 15 to 64 years). By using age cut-offs alone, we cannot account for those who retire before age 65 or those aged over 65 years who continue to work and/or care for themselves as well as those who are unable to work due to issues such as disability. Additionally, working age is assumed to begin at age 15 when in reality many individuals continue their education beyond this age and remain financially dependent (Gavrilov and Heuveline 2003). Ultimately, the projected economic dependency levels are liable to future policy changes such as increases in pension and/or retirement age. Another limitation pertains to the reproductive classification adopted, which assumes that procreation only occurs in those aged 15 to 49 years. In many developed countries, there has been a gradual shift in reproduction with parenthood delayed towards later stages in life as a result of multiple factors including the increased availability of modern contraception, the legalization of abortion and prolonged education (Mills et al. 2011; Neels et al. 2013; Sobotka 2010). This emerging phenomenon is often termed "postponement transition" (Kohler and Billari 2002). It is possible that with increasing technological advancement many individuals may give birth well beyond the limits of the boundaries set. In our analysis, the various indices were calculated using the medium variant population projection figures from

the UN database. It is worth noting however that population figures can be inconsistent, difficult to explain and hard to predict (Mc Morrow and Roeger 1999), and the fact that previous global population forecasts underestimated the level of population ageing currently being experienced, the validity of population estimates and projections including those reported by the United Nations have been the subject of debate (Keilman 1998, 2001; Khan and Lutz 2007). Additionally, the UN population projections assume a near stable trend in net-immigration towards 2050 and this assumption has been questioned.

Conclusions

In this comprehensive review, we have applied a range of indices to describe population changes in Australia. The analysis suggests that a combination of factors including declining fertility and mortality have contributed to significant ageing of Australia's population. The implications of these changes are broad and could be felt in areas such as economic productivity and demand for age-related essential health and social care services. The ongoing changes raises major challenges for Australia's economy and infrastructure as institutions and policies that have been successful thus far, were developed in an era when the demographic landscape was different. A broader perspective encompassing multiple approaches is needed to tackle both the drivers and adverse effects of population ageing.

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