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**THE FUTURE AGED: NEW PROJECTIONS OF
AUSTRALIA'S ELDERLY POPULATION**

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Abstract

Objectives: To use new methodology to forecast mortality for use in projections of the elderly population of Australia and to compare them with official projections.

Method: The Lee-Carter method is applied to data for Australian females and males for 1968–2000 to forecast mortality to 2031. These forecasts are used with standard population projection methods to produce projections of the elderly population.

Results: By 2027, forecast life expectancy is 88.1 and 82.9 years for females and males, compared with official projections of 85.4 and 81.4 years. Over the period to 2031, the populations aged 65+ and 85+ are forecast to increase by factors of 2.3 and 3.4 respectively. Compared with official projections, the forecast elderly population is substantially larger and has higher old-age dependency ratios, higher proportions aged 85+ and lower sex ratios.

Conclusion: Official projections underestimate the size of the future elderly population especially the female and oldest-old populations.

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THE FUTURE AGED: NEW PROJECTIONS OF AUSTRALIA'S ELDERLY POPULATION

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Introduction

Knowledge of the likely future size and structure of the elderly population is essential for planning and policy purposes. Health and social services agencies require age- and sex-specific population numbers for determining future service demand. Such data are also essential for estimating the cost to society of old age social security measures such as publicly-funded pensions. The potential market for consumer goods aimed at the elderly is also determined largely by population size and structure.

Population growth depends on fertility, mortality and migration. Forecasts of the size of the future Australian elderly population depend almost entirely on future mortality. Since net migration is now largely confined to ages less than 40 [1:p7], its effect on forecasts of up to 30 years will be small. Similarly, though past fertility has resulted in structural effects such as the large cohort born after World War II, known as the baby boomers, future fertility will not affect the elderly population size for at least 65 years. Accuracy in forecasting the elderly population is thus dependent on the ability of demographers to reliably forecast mortality.

Experience has shown that in developed countries including Australia official forecasts of mortality often underestimate the reductions in mortality that in fact occur: life expectancy is almost always assumed to increase at a slower rate than turns out to be the case [2, 3, 4:p132, 5]. This conservatism arises from a widespread belief that most of the possible reduction in mortality has already been achieved, often leading forecasters to assume that some upper limit to life expectancy will soon be reached [6]. The subjectivity of such assumptions has been criticised as a weakness of the methods often used [5].

A recent development in forecasting methodology is the Lee-Carter method [7]. Among its advantages are that it involves a minimum of subjective judgement since forecasts are based entirely on past trends, and that probabilistic confidence intervals are provided for its forecasts. The method has been applied to data for the US [7], giving results that were significantly better than official US forecasts [5], and the G7 countries [6], among others. A modified version of the method, designed to improve forecasting reliability, has been developed and applied to Australian data for both sexes combined [8]. This state-of-the-art method is used in this analysis.

The aims of this paper are to apply the modified Lee-Carter method to Australian data for females and males separately in order to obtain forecasts of mortality for use in projecting the elderly population, and to compare the resulting projections with the most recent official projections.

Method

The Lee-Carter method of mortality forecasting combines a demographic model of mortality with time-series methods of forecasting [7]. The demographic model expresses the logarithms of death rates at any given age and time as a function of two age-related parameters, a time-related parameter representing the general level of mortality, and a random error. The time-related parameter can be extrapolated into the future and used to derive future mortality. The Lee-Carter model of mortality is:

$$\ln m_{x,t} = a_x + b_x k_t + \varepsilon_{x,t} \quad (1)$$

where $m_{x,t}$ is the central death rate at age x in year t
 k_t is an index of the level of mortality at time t
 a_x is the general pattern of mortality by age
 b_x is the relative speed of change at each age
 $\varepsilon_{x,t}$ is the residual at age x and time t .

The a_x were calculated as the average of $\ln m_{x,t}$ over time, in which case the b_x sum to one and the k_t sum to zero. Singular value decomposition [9] was used to estimate the model parameters. In order to correct for the distorted weighting involved in estimating the logarithms of rates, each k_t was adjusted by refitting to the age distribution of observed deaths, while a_x and b_x remained unchanged [8].

For forecasting purposes, only k_t is of interest since a_x and b_x are assumed constant over time. The series of k_t obtained from the fitted Lee-Carter model is extrapolated into the future using time series methods. The time series model fitted to k_t was

$$k_t = k_{t-1} + d + e_t$$

where d is constant annual change in k_t and e_t are uncorrelated errors. This linear model was used to extrapolate k_t into the future. The combined standard error in d and e_t represents the uncertainty associated with a one-year forecast. This is used to produce probabilistic confidence intervals for the forecast values of k_t and, through substitution in equation (1), for forecast mortality rates and hence for life-table functions such as life expectancy.

The model was applied to data drawn from a set of sex- and age-specific central death rates for Australia. The age groups employed were 0, 1–4, 5–9, 75–79, 85+. The model was applied to each sex separately. In fitting the model, data for the period 1968–2000 were judged to be ‘optimal’ based on statistical goodness-of-fit criteria assuming the above linear model. Choice of fitting period is an integral part of the modified Lee-Carter method (for technical details see [8]). The forecast rates at age 85+ were extended to age 105+ using relational models [10]. Life expectancies calculated from these rates were compared with official projected life expectancies [11]. Both past and forecast life expectancies were calculated using extended rates and accepted life table methods [12].

The forecast mortality rates were used to project the 2000 female and male populations to 2031 using standard population projection methodology (the cohort-component method [13]) with linear interpolation used to find results for years corresponding to those reported by ABS. The projections assume zero net migration and use the ABS high fertility assumption of a constant total fertility rate of 1.75 births per woman [11]. Comparison was made with the corresponding ABS population projection [14]: in other words, the main difference between the two projections is in the mortality assumption. An additional minor difference is that the ABS projection uses 1999 rather than 2000 as the base year.

Results

Mortality forecasts

Past values of life expectancy at birth and forecast values with 95% confidence intervals are shown in Figures 1 and 2 for females and males respectively. Also shown are official projections to 2027. Table 1 shows these values for selected years determined by the availability of official values. By 2027, life expectancy is forecast to increase by 5.4 years for females and by 5.8 years for males. This is compared with official projected increases beyond 2000 of only 2.7 and 4.3 years respectively. For both females and males, the official projection falls increasingly below the Lee-Carter forecast, but remains within the confidence interval for the entire forecast period. The Lee-Carter forecasts indicate that the sex difference in the expectation of life will decrease from 5.6 years in 2000 to 5.2 in 2027. Over the same period, the official projections indicate a more rapid decrease to 4.0 years.

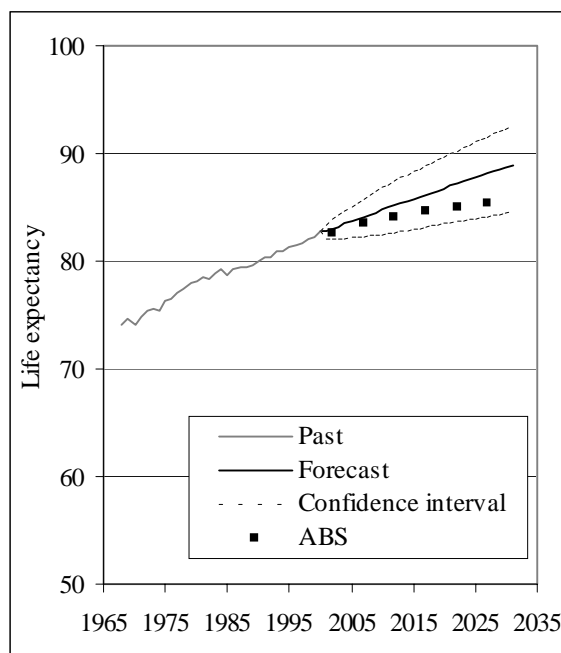
Table 1 Forecast life expectancies at birth with 95% confidence intervals and official projected life expectancies by sex, Australia, 2002 to 2027

	Female			Male		
	Lee-Carter	Confidence Interval	ABS	Lee-Carter	Confidence Interval	ABS
2000	82.7			77.1		
2002	83.0	(82.1 – 83.9)	82.6	77.6	(76.8 – 78.3)	77.4
2007	84.1	(82.3 – 85.8)	83.5	78.8	(77.2 – 80.2)	78.6
2012	85.1	(82.7 – 87.4)	84.1	79.9	(77.8 – 81.8)	79.6
2017	86.2	(83.1 – 88.9)	84.6	81.0	(78.5 – 83.2)	80.4
2022	87.1	(83.6 – 90.2)	85.0	82.0	(79.1 – 84.4)	80.9
2027	88.1	(84.1 – 91.5)	85.4	82.9	(79.8 – 85.6)	81.4

Notes: Values for 2000 are actual life expectancies. ABS values are three-year averages, centred on the year shown, and are projected from a base in 1996–98 of 81.5 for females and 75.9 for males.

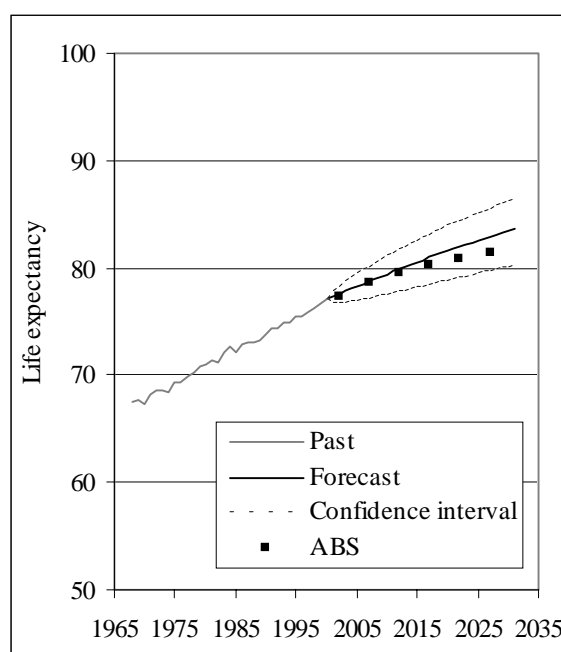
Source: ABS values from: ABS. Population Projections: Australia 1999–2101. Canberra: ABS, 2000. Catalogue No. 3222.0.

Figure 1 Past and forecast values of life expectancy with 95% confidence intervals, females, Australia, 1968 to 2031



Source: Authors' calculations. Australian Bureau of Statistics. Population Projections: Australia 1999–2101. Canberra: ABS, 2000. Catalogue No. 3222.0.

Figure 2 Past and forecast values of life expectancy with 95% confidence intervals, males, Australia, 1968 to 2031

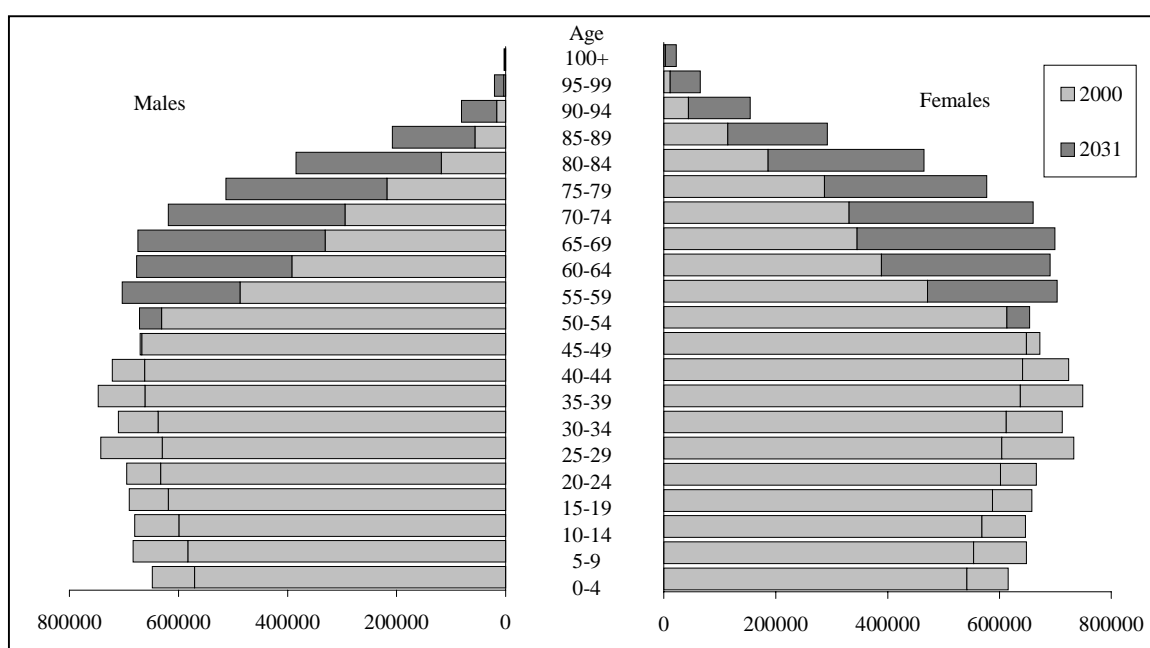


Source: Authors' calculations. Australian Bureau of Statistics. Population Projections: Australia 1999–2101. Canberra: ABS, 2000. Catalogue No. 3222.0.

Population projections

Population projections based on the Lee-Carter forecasts are compared with the 2000 base population in Figures 3 and 4. Figure 3 shows the extent of population ageing over the 31-year period in terms of both the large increase in population size at ages 50+ and the reduced population size at younger ages. By 2031, the population aged 65+ is projected to increase by a factor of 2.3 and that aged 85+ by a factor of 3.4. Relative to the total population, the population aged 65+ is projected to comprise 24.9% in 2031 compared with 12.3% in 2000. The corresponding figures for the population aged 85+ are 3.9% and 1.3%. These percentages are higher than those obtained for 2031 in the official population projections: 24.4% aged 65+ and 3.1% aged 85+ [14].

Figure 3 Age and sex structure of the population, Australia, 2000 and projection for 2031



Note: Projection assumes zero net migration.

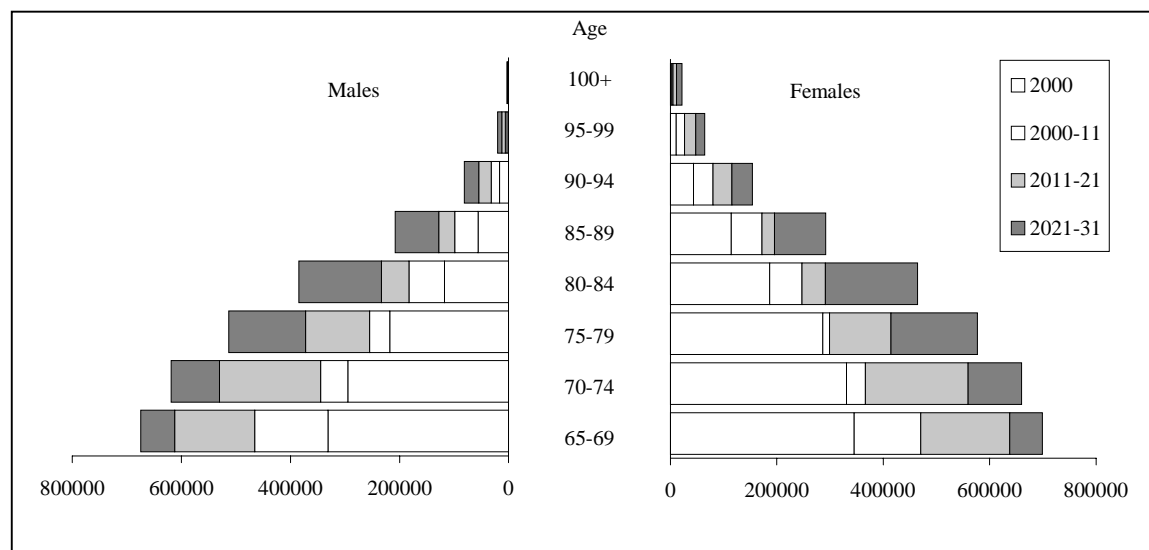
Source: Authors' calculations.

This growth in population size at older ages will not be uniform over time due to existing differences in cohort size. Figure 4 shows increments in projected population size at ages 65+ by ten-year time intervals. The baby boomers account for the large increments between 2011 and 2021 in the population aged 65–74, and between 2021 and 2031 in the population aged 75–84. Figure 4 also shows that in relative terms, the greatest increases occur at older ages. The number of females aged 95–99, for example, is projected by 2031 to increase by a factor of 5.8 compared with only 2.0 for females aged 65–69.

Projected population sizes by age and sex are compared with official projection values in Table 2. The Lee-Carter-based projections of the populations aged 65+ and 85+ exceed official projections to a greater extent for females than for males and by an increasing amount over time. By 2031, the Lee-Carter-based projected female population aged 85+ is 34% greater than the official projection. For the population aged 65–84 the differences are relatively small, amounting to only 1–2% of the official values, and the pattern is less clear: the difference is smallest in 2021 and the male difference is greater than the female

in 2031. This is due to the combined effects of the baby-boom cohort and the different rates of change in age-specific mortality rates.

Figure 4 Projected increments in the age and sex structure of the population aged 65+, Australia, 2011 to 2031



Note: Projection assumes zero net migration.
Source: Authors' calculations.

Table 2 Projected size of the elderly population by age and sex by basis of projection, Australia, 2011 to 2031

Age	Year	Female				Male			
		Lee-Carter	ABS	Difference		Lee-Carter	ABS	Difference	
				No.	%			No.	%
65+	2000	1,321,034	1,321,034			1,038,044	1,038,044		
	2011	1,668,018	1,624,449	43,569	2.7	1,385,756	1,369,416	16,340	1.2
	2021	2,274,634	2,191,761	82,873	3.8	1,945,271	1,921,101	24,170	1.3
	2031	2,934,181	2,757,431	176,750	6.4	2,502,403	2,400,744	101,659	4.2
65-84	2000	1,149,377	1,149,377			961,149	961,149		
	2011	1,383,849	1,369,227	14,622	1.1	1,247,946	1,236,646	11,300	0.9
	2021	1,904,003	1,894,590	9,413	0.5	1,748,389	1,745,456	2,933	0.2
	2031	2,401,125	2,359,707	41,418	1.8	2,190,586	2,138,713	51,873	2.4
85+	2000	171,657	171,657			76,895	76,895		
	2011	284,169	255,222	28,947	11.3	137,810	132,770	5,040	3.8
	2021	370,631	297,171	73,460	24.7	196,882	175,645	21,237	12.1
	2031	533,056	397,724	135,332	34.0	311,817	262,031	49,786	19.0

Note: All projections assume zero net migration.
Source: ABS values are from unpublished population projections.

Selected indices of the elderly population are shown in Table 3. Considerable changes will take place in these indices over the 31-year projection period. Examination of the Lee-Carter-based indices shows that the old-age dependency ratio (ages 65+/(20-64)) is projected to more than double while the oldest-old dependency ratio (ages 85+/(20-64)) is projected to more than triple. (If future migration was taken into account, increases in these indices would be somewhat reduced.) The oldest-old population is projected to

increase substantially as a proportion of the old-aged, by a factor of 1.4 for females and 1.7 for males. The sex ratio (males per 100 females) of the old-aged and oldest-old populations will also increase over time as a result of the narrowing of the sex differential in mortality. The exception to this, at ages 65+ in 2031, is due to existing age patterns in the sex ratio: the 2000 sex ratio at ages 30–49 is relatively low as a result of past migration patterns [15]. In 2031 the low sex ratio of this cohort will outweigh mortality effects.

In comparison, the official dependency and age ratios are relatively low, especially in later years, due to the lower projected life expectancies. In contrast, the official sex ratios are relatively high, particularly at age 85+. This is a direct result of the more rapid narrowing of the sex differential in life expectancy in official mortality projections.

Table 3 Current and future indices of the elderly population by basis of forecast, Australia, 2011 to 2031

Year	Basis of forecast	Dependency ratio per 20–64 (%)		85+/65+ (%)		Sex ratio (%) at age	
		65+	85+	Female	Male	65+	85+
2000	Observed	20.5	2.2	13.0	7.4	78.6	44.8
2011	Lee-Carter	24.9	3.4	17.0	9.9	83.1	48.5
2011	ABS	24.4	3.2	15.7	9.7	84.3	52.0
2021	Lee-Carter	34.6	4.7	16.3	10.1	85.5	53.1
2021	ABS	34.0	3.9	13.6	9.1	87.7	59.1
2031	Lee-Carter	46.3	7.2	18.2	12.5	85.3	58.5
2031	ABS	44.7	5.7	14.4	10.9	87.0	65.9

Note: All projections assume zero net migration.

Source: ABS values are calculated from unpublished population projections.

Discussion

The Lee-Carter forecasts of life expectancy are substantially higher than official projections, though as already acknowledged the official projections do fall within the 95% confidence intervals. There are two reasons for believing that the Lee-Carter forecasts will prove to be the more accurate of the two. First, for females the official projection of 82.6 years in 2002 had already been surpassed by 2000 (an observed value of 82.7), while for males the official projection for 2002 is only 0.3 years higher than the observed 2000 value¹. Second, experience has shown that the Lee-Carter method tends to under predict life expectancy [5]. Thus official projections of Australian mortality almost certainly underestimate future gains in life expectancy.

The Lee-Carter forecasts also differ from the official projections in the evolution of the sex differential over time. The convergence of female and male life expectancies is more

¹ Random error may have contributed to these differences. In addition, it is possible that part of the difference between the Lee-Carter-based and official life expectancies is due to slightly different life table methods and/or slightly different data. By way of comparison, using the method used in this analysis [12] average life expectancy for 1996–98 is 81.7 for females and 75.9 for males. These may be compared with ABS 1996–98 values of 81.5 for females and 75.9 for males. The differences are slight and insufficient to detract from the overall findings.

rapid in the official projections than in the Lee-Carter forecasts. As Figures 1 and 2 show, this is due to a larger difference between the two methods in future female mortality than in male. This arises in large part from the different periods on which the two methods are based.

The official projections are based on data for the ten-year period 1985–87 to 1995–97; the observed rates of increase in life expectancy during this period are assumed to continue for the next five years and thereafter to gradually decline [11]. Use of a ten-year period is standard practice in recent official projections. The use of this particular period as the basis for projection is problematic since the period is unrepresentative of general trends: female mortality was decreasing relatively slowly, not only in time but also in comparison with male rates of decline. The continuation of these declines (albeit attenuated) and in particular the relationship between female and male mortality leads to the relatively rapid convergence of female and male projected life expectancies over time.

In contrast, the Lee-Carter forecasts are based on data for a much longer period, 1968–2000, and make no subjective assumptions about shifts in rates of change. This period is ‘optimal’ in the sense that it is the maximum period for which a roughly constant rate of mortality decline holds, and its selection is an integral part of the modified Lee-Carter method [8]. In general, the use of a longer fitting period reduces the likelihood of basing forecasts on anomalous or unusual rates of change, and in this sense this 33-year period may be regarded as more reliable than the 10-year basis of official projections. A longer fitting period is also statistically desirable for reducing the standard error of the forecast so that the confidence interval for life expectancy is not unduly wide. The period was not extended further, however, because of non-linearity prior to 1968. This non-linearity was in fact caused by rapidly changing trends in cardiovascular disease, the major cause of death in the elderly [16]. Short of an unforeseen epidemic, such trends are unlikely to be repeated for any cause of death in the current low mortality environment, and are therefore not modelled in this forecast. In other words, a linear time series model is considered appropriate for the short-term future.

Thus, in terms of both the level of mortality and the sex differential, the Lee-Carter forecasts can be regarded as more reliable than official projections. That official projections are highly likely to both underestimate future life expectancy (particularly for females) and overestimate the degree of convergence between the sexes is supported by other projections of mortality. For example, the life expectancy projections of the Australian Government Actuary (in 2030, 87.5 for females and 83.0 for males [17]) are higher than those of ABS and embody a wider sex differential. Similarly, the Intergenerational Report assumes a substantially wider sex differential than ABS: citing Treasury projections, the Report assumes life expectancies in 2032 of 86.7 for females and 81.7 for males [18:p20].

A minor difference between the two population projections is the populations on which they are based. Comparison has been made between Lee-Carter-based population projections from a base of 2000 and the official projections from a base of 1999. While it would have been possible to base the Lee-Carter projection on data to 1999, this would have had the disadvantage of ignoring the most recent and most relevant data. The use of the 2000 data is justified in that the purpose of the comparison is substantive, being concerned with the provision of more accurate projections than currently available, rather than methodological in the sense of demonstrating in the Australian context the technical advantages of the Lee-Carter method of mortality forecasting over the official method.

While the population projections presented here are based on zero net migration and a given level of fertility, these assumptions have little or no relevance for the elderly population, particularly as trends are towards younger migrants as a result of proportionally increasing skilled migration [1:p16]. Thus, since all official projections are based on the same or similar mortality assumptions, the differences reported here between the Lee-Carter-based and official projections of the elderly population will generally hold true of other official projections at the national level such as those with non-zero net migration and with different fertility assumptions. Where dependency ratios are concerned, however, the reported differences may be less typical of those obtained using other migration and fertility assumptions because of their influence on the population aged 20–64.

On the basis of this assessment, it can be concluded that current official population projections substantially underestimate the future size of the elderly population and misrepresent its likely age and sex structure. In particular, the new projections suggest that while official projections underestimate the future population aged 65–84 by only 1–2%, they underestimate the oldest-old population by up to 22%. Further, the new projections indicate that females will constitute a larger proportion of the total than currently expected from official projections.

Clearly these conclusions have important implications for planning and policy development in the areas of health and welfare that concern the elderly population. First, greater resources than currently expected will be needed to provide a given level of service to greater numbers of elderly people. Second, the fact that most of the hitherto unforeseen growth will occur in the oldest-old population will have additional resource implications since per capita health and welfare costs are higher at these ages. In particular, the indication that this age group will be up to 28% larger than expected from official projections calls for a revision of health and aged care planning. Third, the uneven growth over time of the elderly population should be taken into account in service provision.

Acknowledgment

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Key Points

- The Lee-Carter method of forecasting mortality provides a superior alternative to official mortality projections.
- Official mortality projections underestimate future gains in life expectancy, especially for females.
- The future elderly population will be larger than official projections suggest, especially at ages 85+ and for females.

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