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Joelle H. Fong, John Piggott, and Michael Sherris*

*Email: h.fong@unsw.edu.au; j.piggott@unsw.edu.au; m.sherris@unsw.edu.au.
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Joelle H. Fong, John Piggott, and Michael Sherris*

ARC Centre of Excellence in Population Ageing Research
Australian School of Business
University of New South Wales
Sydney, NSW 2052, Australia

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Abstract

This paper assesses the cost and risk faced by public sector, defined benefit plan providers arising from uncertain mortality, including longevity selection, mortality improvements, and unexpected systematic shocks. Using longitudinal micro data on Australian pensioners, we quantify the extent of longevity selection at both aggregate and scheme level. We also show that as the age-membership structure in a pension scheme matures, scheme-specific longevity selection risk and systematic shocks become quantitatively more important and have larger consequences for plan liabilities than aggregate selection risk or the impact of mortality improvements.

*Email: h.fong@unsw.edu.au; j.piggott@unsw.edu.au; m.sherris@unsw.edu.au.

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1. Introduction

Public sector employees are traditionally covered by government-sponsored pension schemes exclusive to civil servants. In recent times, the funding of public sector pensions has attracted much policy attention around the world, because the unfunded liabilities associated with civil service defined benefit (DB) schemes are both substantial and uncertain.[1] A major source of uncertainty is the future life expectancy and mortality outcomes of civil servants, which may be distinguished as a group from the general population. This paper explores the exposure of unfunded pension liabilities to longevity risk in public sector DB plans, using a unique data set covering the entire population of civil service pensioners in Australia. In particular, we assess and quantify the impact of increasing longevity and differential public pensioner longevity on the legacy costs of the federal and state pensions system.

The exposure of unfunded pension liabilities to longevity risk comes into sharper focus for the public sector than the private sector for two reasons. One reason is the sheer numbers of full-time civil servants covered by DB pension plans as compared to their private sector counterparts. In U.S., for example, DB plan coverage still remains the norm in the public sector even though it has declined dramatically in the private sector over the past three decades (Brown et al. 2011). Although some other countries, including Australia, have enforced a closure of public sector DB schemes in recent years, these plans (with a frozen membership base) will continue to accrue liabilities for the next few decades. The second reason is that public plans tend to be characterized by much lower normal retirement ages and more generous pension benefits than private sector plans. This holds not only in the U.S., but also in U.K., Germany, Switzerland, Spain, and Australia (see Beshears et al. 2011; Clark 2011; Palacios and Whitehouse 2006).

This paper assesses the cost and risk faced by public sector, defined benefit plan providers arising from uncertain mortality in several forms, including longevity selection, computational omission of mortality improvements, and unexpected systematic longevity shocks. As providers of the pension promise, public sector employers – and taxpayers – are exposed to the risk that *public sector* pensioners in aggregate are a select group that is more long-lived than the general

[1] In high income OECD countries – including U.S., U.K., Australia, Switzerland, and others – it is reported that spending on civil service pensions makes up one quarter of total pension spending (Palacios and Whitehouse 2006). Specifically, unfunded liabilities (or so-called legacy costs of closed, public sector DB schemes) amount to some 15% of GDP in Australia (Bateman and Piggott 2012). Concerns in the U.S. have focused on the implications of pension liabilities on state-level budget balance requirements and local pensions (Brown et al. 2011; Clark 2011). In emerging economies such as Brazil, China, and India, civil service pensions are fast becoming a major fiscal burden given low income and limited tax bases.

population (and potentially the *average* pensioner). This is because civil servants generally have higher education levels, or because they enjoyed the benefits of a long stable career. While private-sector workers move between jobs, civil servants tend to remain in the public sector for a considerable period, if not their whole career (Palacios and Whitehouse 2006). To determine if longevity selection exists at the aggregate level, we construct the pensioner mortality experience from raw data and compare that to general population mortality. We also apply a proportional hazards framework to evaluate mortality heterogeneity by pension size and scheme.

Results demonstrate that the risk of longevity selection exists at both aggregate and scheme level. The effect of aggregate longevity selection is strongest at younger ages, for instance a 60-year-old pensioner would attract 4.6% higher pension liability than a same-aged male randomly drawn from the general population. Importantly however, we observe that this effect does not perpetuate beyond ages 85-90 since higher proportions of pensioners' deaths are concentrated at older ages compared to the population-at-large. In addition, we find longevity selection effect at scheme level to be quantitatively important. For example male pensioners in one of the occupational schemes have almost 30% lower mortality than the average public sector pensioner. This translates into at least 8.3% increase in pension obligations for the employer, or A$30,500 more per pensioner given that the government's cost of fulfilling its pension promise to a male civil servant retired in 2006 is, on average, A$0.367 million based on our present value estimates.

The level of unfunded liabilities in a pension plan is also exposed to systematic longevity risk, which arises if everybody (including pensioners) on average live longer than expected, for instance due to improvements in health technology.[2] Our results indicates that a uniform 10% increase in survival probabilities would trigger a 2.0% increase in pension liabilities owed to a 60-years old male pensioner and an even larger 5.2% increase if he is 20 years older. In contrast to this, the resultant understatement of liabilities arising from omission of future mortality improvements from liabilities valuation is inversely related to age. Consequently as the age-membership structure in a pension scheme matures, scheme-specific longevity selection risk and systematic shocks become quantitatively more important and have larger consequences for plan liabilities than aggregate selection risk or the omission of mortality improvements. The overall

[2] Idiosyncratic longevity risk (that any one particular pensioner may live longer than anticipated) is eliminated through pooling since public pension schemes at Federal and State levels typically encompass tens of thousands of employees.

magnitude of longevity risk faced by public sector, defined benefit plan providers varies significantly with membership characteristics. covered.

A few prior studies suggest that the majority of employer-provided DB private and public pension plans in the U.S. – as well as in several other OECD countries – do not fully account for future mortality improvements in liabilities valuation, leading to understatements in projected pension liabilities (Antolin 2007; Dushi et al. 2010). They also show that stochastic mortality projections, often based on some variant of the Lee-Carter model (Lee and Carter 1992), may be used in place of deterministic life tables typically relied on by plan providers so as to achieve more accurate mortality forecasts. Nevertheless, these studies rely heavily on the highly structured Lee-Carter model and use datasets with only representative funds or employees. Related research in the field of actuarial science largely focuses on the estimation and projection of mortality rates for retirement benefits valuation (e.g. Pitacco et al. 2009; Sithole et al. 2011). These studies seek primarily to understand the methodological differences in the construction of mortality estimates; for instance, Sithole et al. (2011) examine in detail the mortality assumptions used in the valuation of company-sponsored pension liabilities across 18 countries (including Australia) and find a lack of consistency in cross-country practices.

The present study extends previous analyses in two ways. First, we evaluate pension liabilities for an entire nationally representative sample of public sector DB pensioners. This is important since focusing on a mean (or median) pensioner conceals wide differences in pension sizes and age structures across the pensioner population. Our valuation of prospective pension payments takes into account pension size at the individual level and ages structures at the scheme level. Second, our approach allows for mortality to differ by occupational schemes within the pensioner population so that *scheme-specific* longevity selection effects may be assessed, in addition to the *aggregate* longevity selection effect. Given a maturing public sector workforce, the results will be of interest both to policymakers concerned with overall public debt, as well as taxpayers and fund administrators. The findings will also be germane to current and future public sector DB plan participants since longevity risk can consequently threaten their income security if the government decides to cut benefits in order to hold down increases in unfunded pension liabilities.[3]

The Australian public sector, thought of as comprising Federal (or Commonwealth) civilian employees and the employees of Australia's six state and two territory governments, is an interesting setting to examine the impact of pensioner longevity on unfunded employee liabilities for three reasons. First, unlike some countries where public employee pension system borrowing is kept "off the books", unfunded net pension liabilities in Australia are transparently calculated and acknowledged in all state and federal government budget documents. Politicians have also taken steps to close the funding gap in a systematic and gradual manner. Second, there is evidence of longevity selection among public sector pensioners in Australia (Knox and Nelson 2007; Sithole et al. 2011; Mercer 2011). These studies show that pensioner mortality is considerably lighter than the mortality of the Australian general population at ages below 85-95.[4] The fiscal impact of this selection effect is potentially exacerbated by the fact that Australian civil servants obtain more generous pension benefits than their counterparts in the private sector superannuation schemes. Palacios and Whitehouse (2006) report that a public sector worker in Australia can expect a replacement rate of around 66-88% as compared to just 52% for private sector worker. Third, pension reforms in Australia over the last 30 years have resulted in an almost complete changeover to a defined contribution system. Almost all the major public sector DB plans have thus been closed to new entrants for some time, so our study captures the current unfunded liability pertaining to existing pensioners.[5] Future pension liabilities for current contributors are not included in the analysis.

The paper proceeds as follows. Section 2 discusses the setup of defined benefit pension schemes for Australian government employees, and presents the magnitude of the associated unfunded superannuation liabilities across states. Section 3 describes the data. We implement actuarial methods to obtain smoothed, aggregate pensioner mortality rates over a seven year period, then compare this to general population mortality, so as to evaluate the extent of

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[3] For instance, it has been recently recommended in the UK that the pension increments for civil servants be pegged to the (lower) CPI index rather than the (higher) RPI index and to calculate pensions based on career average salary rather than final salary (HM Treasury 2011).

[4] Past ages 85-95, however, these studies generally find that pensioner mortality is heavier than the general population possibly because the selection effect has worn off. Another reason suggested is that the population life tables survival probabilities at these very advanced ages are likely too optimistic (Knox and Nelson 2007).

[5] The Commonwealth government left two federal DB pension schemes open, one pertains to defence personnel while the other pertains to the judiciary.

longevity selection. Section 4 presents the proportional hazards model and regression results used to derive individualized, cohort survival curves. We apply these mortality inputs to value the pension annuities for each public sector DB scheme, and assess the sensitivity of these estimates to an unexpected longevity shock. Section 5 concludes.

2. Unfunded Liabilities in State Pension Plans

Until the 1980s, it was common practice in Australia for the Commonwealth and State governments to require their employees to join a DB pension scheme (Knox and Nelson 2007). These public sector superannuation DB schemes mostly have an unfunded employer-contribution component, which is financed on a pay-as-you-go (PAYG) basis.[6] In addition, retirement benefits are paid out as a lifetime pension, with some schemes even offering inflation-indexed pensions (e.g. the Commonwealth DB schemes). Separately, some of these public sector plans may have a fully-funded accumulation component for voluntary (or mandatory) employee contributions. The net unfunded superannuation liability in a scheme, as at a given valuation date, is essentially a present value estimate of future pension payments (arising from the unfunded employer-contribution component) to be made over the next few decades.

Over the last 30 years, pension reforms in Australia have resulted in a progressive shift from defined benefit to defined contribution schemes. Consequently, all but one of the major public sector DB schemes has closed to new members as at end 2008.[7] For example, the 2011-12 NSW Budget statement reports that less than 20% of NSW public sector workers are presently members of DB schemes (NSW Government 2012). Nonetheless, the completely closed DB schemes still contractually owe pension benefits that have already been promised and accrued to past employees, and furthermore, continue to accrue pension entitlements due to present active employees. These employee superannuation entitlements sit on the Government's balance sheet as a financial liability.

To clarify the valuation of public sector employee superannuation liabilities, it is useful to begin with the information provided in the governments' annual budget documents. The reported "unfunded superannuation liabilities" in the governments' budget reflect the difference between

[6] An exception is the closed Queensland QSuper DB scheme which features fully-funded employer contribution. Also note that some smaller DB schemes under local governments are not included in this present paper.

[7] In 2007, the government decided that Military Super (a hybrid scheme for defence personnel), along with a smaller pension scheme for judges, shall be the only two PAYG DB schemes to remain open in the Commonwealth sector. See Bateman and Piggott (2012).

the estimated gross liabilities and assets of public sector DB schemes within each jurisdiction. Superannuation assets (typically made up of investment returns, and employee contributions in the case of a hybrid scheme) are valued on a market value basis.[8] Superannuation liabilities, on the other hand, are based on the present value of accrued pension entitlements, derived from forecasts of salary growth, CPI increases, retirement rates and benefit payments. In accordance with the Australian accounting standard AASB 119 (*Employee Benefits*), the liabilities are discounted using long-term government bond rates.[9] Some schemes (e.g. state of NSW) have applied a floating discount rate as at June 30 in each financial year to value the liabilities while others (including the federal schemes) have used an actuarially-determined discount rate that is relatively close to the long-term bond rate.[10] Consequently, the levels of unfunded superannuation liabilities are somewhat comparable across jurisdictions, and the aggregated liability reflects the present value of the total accrued pension entitlements due to public sector workers in DB schemes in any given year.

Table 1 displays the published estimates of the unfunded superannuation liabilities over the last five years by State. As at June 2011, the estimated net unfunded liabilities pertaining to federal and state governments' pension schemes stand at a total of A$210.0 billion.[11] Of this total, 62% (or A$129.5 billion) is attributable to three Commonwealth DB schemes, namely the Commonwealth Super Scheme, the Public Sector Super scheme, and the Defence Force Retirement and Death Benefits Scheme. The remaining 38% is split among seven State and Territory governments, with the states of New South Wales (A$32.2 billion) and Victoria (A$22.8 billion) reporting relatively larger liabilities than other states. Interestingly, the Queensland government reports zero unfunded superannuation liabilities across all years.

[8] A hybrid scheme is a public sector DB plan with both an unfunded employer-contribution component, and a fully-funded employee accumulation component. Typically, retirees may choose to draw down the employee accumulation component as a lump sum, phased withdrawal, or life annuity.

[9] 10-year Australian Government Bond rates are typically used for this purpose. Rates are converted to annual effective rates since liabilities may have a term longer than 10 years. Nominal rates are about 6.6% as at June 2008 and 5.2% as at Jun 2010. In contrast, public pension liabilities in the US are discounted at the expected rate of return on pension assets as stipulated by the Government Accounting Standards Board ruling 25 and Actuarial Standards of Practice item 27. Novy-Marx and Rauh (2011) argue that doing so underestimates the magnitude of the liabilities, and suggest alternative discount rates which better reflect the risk of the payments from a taxpayer perspective (such as using the default-free Treasury zero-coupon yield curve or using a discount rate equal to each state's own zero-coupon bond yield corrected for the tax preference on municipal debt).

[10] For example, a discount rate of 6% is used by the Commonwealth government in 2011 to estimate the present value of future unfunded superannuation benefits. This rate is actuarially-determined through an external actuarial review for the Commonwealth civilian and military DB schemes.

[11] As at end May 2012, the Australian dollar traded at almost parity with the U.S. dollar.

Queensland's public pension schemes have been fully funded for some time due to its government's long-standing policy of setting aside funds to meet future employee entitlements. For instance, the Queensland QSuper DB scheme (closed since 2008) had specified a fully-funded 12% employer contribution.

[Table 1 here]

The Table also indicates that the aggregate level of unfunded liabilities in nominal terms has increased over time. As at June 2007, the reported liability across all public sector DB schemes is A$136.4 billion. By June 2009, this amount has increased to A$186.2 billion in nominal terms, representing a 37% increase. Between 2009 and 2011, the aggregate unfunded liability increased further by another 13% to A$210.0 billion. With an ageing population likely to place significant pressure on the Australian government's finances, concrete steps have been taken through legislation in recent years to finance the liabilities. In 2006, the Commonwealth government established 'The Future Fund' as a mechanism to accumulate financial assets to provide for future unfunded superannuation liabilities associated with federal employees. As at Mar 2011, the Fund's assets are A$74.6 billion and it is expected to generate at least a benchmark return of the CPI plus 4.5-5.5% per annum over the long term (Australian Government 2012). At the State level, governments have also strived to reduce the liabilities through regular contributions from public sector budgets. For example, the New South Wales government aims to fully fund the superannuation liabilities in the state's PAYG DB schemes by 2030 under the Fiscal Responsibility Act of 2005 (NSW Government 2005). Similarly, the Victoria government aims to eliminate the superannuation liabilities by 2035.

Despite a common valuation approach in place for budget reporting purposes, unfunded liability computations remain very sensitive to several assumptions employed in assessing the future pension benefit streams, including worker turnover and mortality patterns, discount rates, salary growth rates, take-up rate of pension benefits, and investment rates of return. Most governments have engaged external actuaries to undertake a detailed actuarial review of the scheme every three years. The main objective of these actuarial investigations is to assess scheme and employer funding levels and contribution rates, and to review actuarial and economic assumptions underlying asset and liability estimates. The results of these triennial actuarial reviews have been central in ascertaining the size of the net accrued unfunded liabilities, and also in determining a long term financing strategy for these long-term costs.

Of particular interest in this study is the unfunded superannuation liability pertaining to age pensioners and its interaction with pensioner longevity. In a closed, occupational DB plan, unfunded liabilities are typically attributable to three main categories of plan participants: existing employees who are current contributors to the schemes ('contributors'), past employees who have preserved their benefits upon termination ('preserved members'), and 'pensioners'. Pensioners can be split more finely into age (or retiree) pensioners, invalidity pensioners, and reversionary pensioners.[12] To gain insights on scheme demographics and the size of liabilities pertaining to pensioners in a closed DB plan, we turn to some key statistics of the two large federal schemes that account for a substantial proportion of total liabilities – the Commonwealth Super Scheme (CSS) and the Public Sector Super scheme (PSS). The first superannuation scheme for Commonwealth government civilian employees was established in 1922. This was replaced by the CSS scheme in 1976 (closed in 1990), and then by the PSS scheme in 1990 (closed in 2005). Since 2005, all new Commonwealth government employees are covered by the defined contribution Public Sector Super accumulation plan.

Table 2 reports the number of pensioners and their associated unfunded liabilities for the closed DB Federal-CSS and PSS schemes as at June 2005 and 2008 per the actuarial review reports. A couple of observations are worth highlighting. First, in terms of membership size, the PSS manages more individual accounts than the CSS. The total number of existing members in the PSS as at 2008 is 252,354 (compared to 149,055 for CSS). Nonetheless, most of the PSS members are still current contributors; less than 7% are pensioners. In contrast, more than 70% of the members in the older CSS scheme are already pensioners. Among these CSS pensioners, three-quarters are age and invalidity pensioners who are still alive while a quarter are reversionary pensioners (e.g. spouse or child of the deceased employee). Second, despite the differences in pensioner demographics, the derived estimated unfunded liability per pensioner turns out to be rather similar in both schemes: A$0.338 million for CSS and A$0.334 million for PSS in 2008 dollars. The fact that these figures are substantial is indicative of the huge fiscal

[12] In many instances, pensions in the DB schemes are paid until the death of the individual retiree, or his or her spouse. A 'reversionary pensioner' is a dependant of the insured who is nominated to receive a reversionary pension in the event of the insured's death. Upon death of the insured, the fund will continue to pay the remaining balance of the pension account, as a pension, to the person nominated.

burden on the Australian government with respect to accrued unfunded superannuation liabilities after incorporating population-based mortality improvements.

[Table 2 here]

3. Pensioner Data & Aggregate Mortality

Data overview

The information on public sector pensioner mortality used in this study is obtained from the Mercer (Australia) Pensioner Database. The database is an ongoing effort by Mercer to collect information on pensioners in Australian occupational superannuation funds, and covers major public sector schemes from 2002 onwards. The administrative data is of high quality, and is reconciled from year to year to permit updating of older data particularly to redress late reported deaths or exits. It features a wide range of pensioner types, including retiree, spouse, child, invalidity, and early retiree pensioners. Plan-level data include name and jurisdiction of the scheme. Unit-record data on existing age pensioners includes pensioner ID, sex, annual pension received, birth date, commencement date, and cessation date as well as reason for cessation (if applicable).

Table 3 lists the individual schemes, together with the sample breakdown. We analyse a total of 13 schemes, of which 12 belong to the general government sector.[13] The exception is the NSW-EISS (Energy Industries Super Scheme) which technically belongs to the public trading enterprise sector but is included here because it still falls under the NSW government superannuation arrangements (NSW Government 2012). Notably, this sample covers *all* the closed, federal/state DB schemes in Australia that pertain to civilian public servants. The majority of the DB schemes closed in the 1990s, although a few had closed as early as the mid-1980s (e.g. the South Australian Super and Police Scheme and the NSW State Super scheme). Among the last schemes to close are the Federal-PSS scheme and the Queensland schemes. By and large, all 13 schemes had closed as at end 2008. Although DB membership is frozen, several schemes separately manage DC/accumulation accounts which are still open.

[Table 3 here]

[13] These 12 schemes are identical to those listed in Bateman and Piggott (2012), except that we exclude here the scheme for defence personnel (Defence Force Retirement and Death Benefits scheme). These are Federal/State schemes that pay benefits in the form of lifetime pensions and are closed to new members.

Normal retirement age in the Australian public sector varies from 55 to 65. Consequently, this present analysis focuses on retiree pensioners (or age pensioners) who had retired at or after age 55.[14] Our sample comprises 158,623 retiree pensioners observed over an eight-year span from 1 July 2002 to 30 June 2010 (see Table 3). About half of the pensioners belong to the federal schemes; the older Federal-CSS scheme alone accounts for 43.4% of the sample since most of its members have reached retirement age. The states of NSW and Victoria each contributes to about 19% of the sample, and four other states make up the reminder. Not surprisingly, the pensioner base in the Federal schemes is larger than that in the individual State schemes partly because the former includes government employees from the Australian Territories (the Australian Capital Territory and the Northern Territory) in addition to Commonwealth employees.[15] About 70% of the sample is male. This statistic is not surprising since it characterizes the public sector workforce composition around the 1930s-1960s. Moreover, three of the 13 occupational schemes consist predominantly of male members due to the nature of work. These are the police schemes (NSW Police Superannuation scheme and Queensland State Police Superannuation Scheme) and the NSW Energy Industries Superannuation Scheme.

Aggregate pensioner mortality & longevity selection

To determine the mortality experience of the public sector pensioners over the eight-year period, we first compute the observed age-specific mortality hazards by sex. This analysis treats the 111,257 male and 47,366 female pensioners separately since mortality is known to differ systematically by sex. Formally, assume that the underlying distribution of deaths is from a Poisson distribution with parameter $\mu_x E_x^c$. The force of mortality for each exact age x (μ_x) is estimated as follows:

$$\hat{\mu}_x = \frac{d_x}{E_x^c} \qquad (1)$$

[14] We did not include early retirees in the analysis since the mortality experience of early retirees could differ from that of normal retirees. A two-tail paired t-test confirms that the raw mortality rates of male early retirees are significantly different from that of male retirees at the 5% level. Moreover, the numbers of early retirees in the data are not especially large, comprising just about 16% of the total number of retirees.

[15] Government employees in the Northern Territory and the Australian Capital Territory were enrolled in the Federal DB pension schemes for Commonwealth government employees prior to 1988 and 2005 respectively.

where d_x is the observed number of deaths for lives aged x, E_x^c is the total time the pensioners are exposed to the risk of dying, and $\hat{\mu}_x$ is an estimate of the true mortality hazard. The in-sample tabulations of d_x and E_x^c by sex are summarized in Appendix A. Overall, 17.6% of the sample pensioners (or 27,937) died during observation. The majority of deaths occurred in the 80-84 and 85-89 age bands; about 0.7% of the deaths occur at ages of 100 and over. The maximum observed death ages are 106.5 for males and 105.4 for females, indicative of the presence of right-tail longevity risk among public sector pensioners irrespective of sex. The oldest surviving pensioner as at the 2010 cut-off is 103.8 years old. Nonetheless, the number of exposure years in the last age group (100+) is relatively small so care is taken in interpreting any results pertaining to this age group.

Unlike large mortality investigations involving a broad population base (e.g. a census used to build the population life tables), the sample of pensioners here is comparatively small. Because of the small sample size and independent sampling errors, the crude estimates $\hat{\mu}_x$ may not progress smoothly. To smooth the mortality estimates, we employ an actuarial technique known as 'graduation by reference to a standard table' which involves selecting an appropriate life table (typically the population life table) and using the shape of its mortality hazard function as the given standard for smoothing. This method of smoothing (or graduation) is appropriate here for two reasons. First, the true underlying mortality of the pensioners' lives is by and large related to that of the general Australian population, particularly in the overall progression of mortality rates from age to age. Second, the sex-specific population life tables constructed from millions of lives provide a basis to estimate increases in mortality hazard at very advanced ages where pensioner data are scarce. Graduation by reference to the published population life tables is also convenient since it enables use of the published population mortality improvement rates by extension.

The choice of the standard table is important in the graduation process. There are two Australian population life table candidates. One is the Australian Life Table (ALT) published by the Australian Government Actuary and the other is the Australian Bureau of Statistics (ABS) Life Table. The sex-specific mortality rates published in both tables are very similar up to about age 90. The ALT table, however, is more suited for our graduation purposes since it extends up to age 109. In comparison, the ABS table terminates at age 100.[16] Using the ALT table will therefore allow estimates of pensioner mortality past age 100, which is appropriate since it has been observed that the current cohort of sample pensioners are already surviving past 100. Specifically, the Year 2006 ALT tables are used here since it is the mid-point in the observation window.

We denote $\{\dot{\mu}_x\}$ as the set of graduated estimates we need to obtain, and $\{\mu_x^s\}$ as the set of hazard rates (forces of mortality) in the 2006 ALT period life tables. Given the assumed similarity in the true underlying mortality of the public sector pensioners' lives and that of the general population, it is possible to specify some simple functions to link the pensioner mortality experience to the standard table. In particular, we test a linear relationship: $\dot{\mu}_x = a + \mu_x^s$ ('Function F1'), and a multiplicative relationship: $\dot{\mu}_x = (b + cx)\mu_x^s$ ('Function F2'), where a, b, and c are suitable constants to be estimated. In order to adjust for heteroskedasticity, weighted least squares estimation is used. One standard approach is to set the weights (w_x) proportional to the reciprocal of the estimated variance of the crude rates as illustrated in Eqn. (2):[17]

$$w_x = \frac{E_x^c}{\hat{\mu}_x}. \qquad (2)$$

Table 4 shows the weighted least squares estimates of the fitted parameters and their associated standard errors for males and females. For each group of pensioners, there are two alternative specifications given by Functions F1 and F2. To choose between the specifications, several test statistics are calculated. One of the statistics reported in the Table is the root mean square error; a lower value would indicate lower error variance. In this regard, it appears that the multiplicative function F2 is superior in terms of explaining variability in the observations for both sexes. For instance the root mean square error using function F2 is 0.0014 (as compared to 0.0023 using F1) in the regression for males.

[Table 4 here]

[16] The ALT life table is constructed using deaths and estimates of population over a period of three years centred on a Census. The ABS life table is based on the deaths and population data of Australian residents who are physically present in Australia over a three-year period. Sex-specific mortality hazard rates in the 2005-07 (or Year 2006) ALT and ABS tables are very similar up to about age 90. Slight differences in rates emerge past age 90, partly because the ALT table extends up to age 109 whereas the ABS table terminates earlier.

[17] Alternatively, the exposure to risk at each age x (E_x^c) may be employed as weights in the WLS estimation.

We also evaluate two essential qualities of the graduation outputs: fit (i.e. consistency with the observed data), and of lower priority, smoothness. Fit is measured two ways – first using the Pearson correlation coefficient between the raw and graduated mortality rates, and second using the chi-square test between the observed and expected deaths. The Pearson correlations reveal that the graduated mortality rates from both functions fit the raw data well ($r > 0.90$ for all specifications). In particular for males, both goodness-of-fit measures reveal that the F2 function provides better adherence to the data. For females, however, the Pearson correlation statistic indicates that the F1 function provides better fit whereas the chi-square test specifies that F2 is better fit. The last statistic reported in the Table pertains to smoothness and is calculated by the sums of the squares of the third-order differences in the graduated values (see Bayo and Faber 1983). Results show that the F1 function generates marginally smoother graduated rates for both groups of pensioners (test statistic smaller by five decimal places), which nonetheless reflects some trade-off between fit and smoothness. Overall, we select to proceed with the F2 function in deriving the aggregate mortality rates since it results in lower error variance (for both sexes), better fit to the data (especially for males, partly for females), and a relatively smooth function.

Figure 1 illustrates the smoothed hazard rates generated from our graduation procedure, separately by sex. They are constructed based on 610,765 years of exposure in respect of male retirees and 260,233 years of exposure in respect of female retirees. In the Figure the circle markers represent the raw hazard estimates and the black line represents the smoothed hazard function. The age axis extends up to 109 to capture the right-tail longevity among pensioners. We see considerable volatility in the raw estimates at the older ages due to small number of exposure years. Specifically, at these ages, the solid line (representing the F2 function) presents a much better fit than the dotted line (representing the F1 function). This set of mortality rates would technically apply to pensions valuation as at Year 2006, which is the mid-point of our observation span (1 July 2002 – 30 June 2010). These rates may also be updated to any given valuation year using mortality improvements factors in the population tables.

[Figure 1 here]

To ascertain the credibility of our mortality estimates, we first recover the discrete one-year probabilities of death ($\dot{q}_x$) from the forces of mortality and then compare them with the corresponding mortality rates in the 'Mercer 0205' pensioner life table. Developed by Mercer (Australia), the Mercer 0205 table is based on the combined mortality experience of retiree pensioners from five major Australian public sector schemes for the period 1 Jul 2002 to 30 June 2005 (Mercer 2011).[18] It is now widely recognized as the standard pensioner life table in the Australian pensions business (Sithole et al. 2011). Table 5 shows that our mortality estimates in this study are quantitatively similar to those in the Mercer 0205 table (see columns 1 and 2). This is not surprising given that our sample includes all five schemes used in Mercer 0205. Nonetheless, differences in sample selection, observation periods, and graduation methods result in slight deviations in rates which, as illustrated in column (4), are mostly well below 10%.

[Table 5 here]

We also investigate whether there is evidence of longevity selection among public sector pensioners in relation to the general population. To do so, we compare our mortality estimates against the corresponding population mortality rates from the 2006 ALT period table at exact ages of 55, 60, 65, and so on. A ratio of the two values is reported in column (5) of Table 5. A ratio lower than unity means that pensioners have lower mortality than the population-at-large (i.e. presence of longevity selection), while a ratio greater than unity means the reverse holds. Consistent with earlier studies (e.g. Knox and Nelson 2007; Sithole et al. 2011), we find that pensioner mortality is considerably lighter than the general population mortality at ages below 85-90. For instance, the mortality rate of .0039 for a 60-year-old male pensioner is about half that of the general population (.0072). Similarly, a 60-year-old female pensioner has a 40% lower mortality rate than an average female drawn from the population. This positive longevity selection effect is possibly due to civil servants being more educated and having higher income on average than private-sector employees in Australia. Their higher socioeconomic status is further reinforced by job stability within the public sector as compared to private-sector workers who are more likely to move between jobs (Palacios and Whitehouse 2006). Less visible to us, however, is whether the sample pensioners are also positively selected in terms of health. We have no data on the pensioners' health statuses and lifestyle choices, but because our sample

[18] The five schemes are NSW State Superannuation Scheme, Victorian State Superannuation Fund, Western Australian Government Superannuation Scheme, and the Commonwealth PSS and CSS schemes. Mercer also recently released an updated 'Mercer 0509' table specifying retiree pensioner mortality experience over the period 1 July 2005 to 30 June 2009. It is not appropriate for comparison purposes here since those rates pertain to a base valuation year of 2007.

excludes early retirees (people who may have retired early due to poor health) and invalidity pensioners, it is plausible that the normal retiree pensioners observed might have retired in good health.[19]

Interestingly, the results also show that pensioner mortality is heavier than population mortality from about age 90. The ratios exceed unity. One way to rationalize this is through the distribution of deaths among retiree pensioners. Because pensioners face lower chances of death below ages 85-90, most of them survive to advanced ages. Consequently, given an age ceiling, pensioner deaths are compressed at advanced ages above 85-90 causing mortality rates at those ages to be higher than those of the general population. In comparison, the death distribution in the general population may not be as skewed. Another reason proposed by earlier studies is that the selection effect among pensioners somehow diminishes or wears off over time (Knox and Nelson 2007; Mercer 2011). In sum, we conclude that some degree of longevity selection exists among public sector pensioners but this effect does not extend to advanced ages. This implies that plan providers and taxpayers are exposed to the risk that public sector pensioners in aggregate are a select, long-lived subgroup compared to the population-at-large. Importantly, this risk is characterized by the likelihood of large numbers of pensioners living to their 85th or 90th birthday before exiting the system, rather than an extreme long-tail risk.

4. Longevity Heterogeneity & Unfunded Liabilities across Schemes

In many developed countries such as the U.S. and U.K., annuitant (and/or pensioner) life tables have been constructed from actual annuitant mortality experience, and used in place of population life tables in the valuation of retirement products such as life annuities and lifetime pensions. While it is well-established that mortality differentials exist between the pensioner subgroup and the general population, the extent to which longevity is heterogeneous among pensioners/annuitants and whether that is quantitatively important in terms of valuation of unfunded employee liabilities is largely unclear. Most famously, a long-running cohort study of mortality among British male civil servants (the Whitehall Study) finds that workers in the lower employment grades (e.g. messengers, doorkeepers, etc.) had much higher mortality than those in the higher employment grades (e.g. administrators). Similarly, one may anticipate members of a

[19] Early retiree pensioners tend to retire before the normal retirement age of 55-65. In the Mercer Pensioner database, some early retiree pensioners commence their pensions as early as age 24. Workers who retire due to invalidity also tend to commence their pensions earlier than age 55 (on average around age 49 from the data).

public sector police pension scheme or emergency services pension scheme to have higher post-retirement mortality compared to members in occupational schemes for teachers or administrative workers. If so, this would imply that some sectors of public sector employers are potentially more exposed in terms of unfunded pension liabilities than others.

This section explores how mortality differs by pension size, birth cohort, and pension scheme in the sample of 158,623 retiree pensioners. While this set of determinants is somewhat restricted, it represents all available observables in the pensioner database. More importantly, they are potentially meaningful in explaining some variation in mortality. For example, Knox and Tomlin (1997) find a strong inverse relationship between pre-retirement final salary and post-retirement mortality among male employees under the federal Commonwealth Super Scheme over 1991-1994. Pension size is also a close proxy for final employee salary, and possibly socio-economic status (SES). A recent study reports that Australians with higher SES – measured by income and education – face significantly lower mortality risk (Philip and Leigh 2011). Specifically, we also aim to leverage on the administrative data to draw out mortality differences attributable to occupational profiles (using scheme dummies) while controlling for age, pension size, and cohort effects. This is challenging given that the membership base of some schemes is smaller than others, and also because the overall observation span is fairly short (only eight years). As a result, mortality data for the small schemes is scarce at certain age ranges and often noisy.

Proportional hazards estimation

In an effort to better understand the relative effects of pension size and occupational profile on mortality, we develop and estimate a Cox proportional hazards model. As before, we sample males and females separately. Algebraically, the mortality hazard of a pensioner at a given time may be expressed as:

$$\mu(t|\boldsymbol{x}_j) = \mu_0(t) \cdot \exp(\boldsymbol{x}_j\boldsymbol{\beta}), \qquad (3)$$

where $\mu(t|\boldsymbol{x}_j)$ is the resultant hazard rate for the j^{th} subject given age t and the subject's vector of covariates $\boldsymbol{x}_j$; $\mu_0(t)$ is the baseline hazard function; and $\boldsymbol{\beta}$ is the vector of regression coefficients to be estimated. This equation states that the death hazard (or force of mortality) that pensioner j faces is multiplicatively proportional to a baseline hazard that a same-aged person would face, modified by his or her personal characteristics expressed as a vector $\boldsymbol{x}_j$. In this context, the individual attributes include the annual pension received (in real dollars) and the scheme the pensioner belongs to.

The semi-parametric Cox model is selected over a full parametric estimation because it allows for greater flexibility given no need to impose a parametric assumption on the underlying hazard function $\mu_0(t)$. We are also able to leave the baseline hazard unconstrained (and consequently un-estimated) since the aggregate, sex-specific, smoothed mortality function derived earlier in Figure 1 serves as a pseudo-baseline hazard. This works mainly because we had sufficient data to model the human (pensioner) mortality process over the desired age range of 55 – 110. We later compare the pseudo-baseline hazard to the estimated Cox baseline hazard built from estimates of baseline hazard contributions to ensure validity.

The two explanatory variables are entered collectively into the regression model. Specifically, pension size is modelled as a categorical variable to capture 'low', 'average' (ref.), and 'high' pension sizes. The distribution of annual pensions for both sexes is positively skewed, with a small number of pensioners receiving payouts much higher than the average. Consequently, we set the 50th percentile of the distribution (median value) as the midpoint of the 'average' pension category, and use the 25th percentile to determine the lower categorical marker. The male median pension is about A$27,400 (25th percentile = A$16,000). As such, the three categories of pension sizes for males are <$16,000 ('low'), $16,000-38,000 ('average'), and ≥$38,000 ('high'). The median pension for females is about A$17,900 (25th percentile = A$9,000) and so the three pension categories work out to be <$9,000 ('low'), $18,000-27,000 ('average'), and ≥$27,000 ('high').

Occupational profile is captured using dummy variables for individual schemes. The reference category is the Federal-CSS scheme dummy. Federal-CSS is by far the largest among the 13 pension schemes in our sample, accounting for 46% of male pensioners and 37% of females. Several of the individual scheme dummies, however, do not satisfy the proportional hazards assumption based on a test of Schoenfeld residuals (Cleves et al. 2010).[20]-This arises because a particular scheme is small and so the data is noisy, or because the scheme's data is

[20] Under the null hypothesis of proportional hazards, the scaled Schoenfeld residuals should have the sample path of a random walk and the slope in a regression of the scaled residuals on functions of time should be zero. A non-zero slope is an indication of a violation of the proportional hazard assumption. Graphically, the estimated survival curves for a particular scheme will be non-parallel to that of the reference Federal-CSS scheme (curves may intersect).

concentrated only around a short age span (e.g. members are all ages 80-95). Part of the underlying reason for the latter may be traced to scheme mobility whereby employees took up options to either convert their pension benefit into a lump sum benefit or switched to a defined contribution arrangement, and exited the DB scheme. Consequently, we group schemes which do not independently satisfy the proportional hazards assumption into a common category called "grouped schemes". This is done primarily to retain sample size, although it is noted upfront that the coefficient on this variable cannot be meaningfully interpreted. Members of these grouped schemes are assumed to face a scheme-specific mortality risk identical to that of the baseline scheme – the Federal-CSS scheme.

To summarize, the proportional hazards regression for males involves 111,257 subjects from 13 schemes and a total of five individual scheme dummies (the other seven schemes are categorized under "grouped schemes"). The regression for females involves 47,350 subjects from 10 schemes. Three schemes (corresponding to 16 females) are dropped from the female subsample. These schemes – NSW-EISS, NSW-PSS, Queensland-PS – are predominantly male: in the sample, the percentage of males in each of these schemes exceeds 95%. The female regression involves seven individual scheme dummies (two schemes fall into the "grouped schemes" category). *STATA 12.0* is used for estimation.

The results appear in Table 6. Reported hazard ratios and 95 percent confidence intervals show the partial effects of the explanatory variables on the odds of mortality. A hazard ratio larger than 1 indicates an increased hazard (probability of death) associated with the explanatory variable whereas a ratio less than 1 indicates a decreased hazard. Focusing first on females, we see that pension size has a statistically significant effect on mortality (p<.01). In particular, female pensioners with low pension income have about 13% higher hazards of death than those receiving average-sized pensions. Correspondingly, retirees with higher annual pensions face 23% lower mortality risks than the average pensioner (HR=0.77, CI=0.72, 0.83). This finding is consistent with prior studies (e.g. Knox and Tomlin 1997; Philip and Leigh 2011) showing that Australians with higher socio-economic status (measured here by pension sizes) tend to live longer. Scheme variables appear to have little explanatory power after controlling for pension size in the regression for females. Of the seven individual scheme dummies included, only one is statistically significant (p<.05). The hazard ratio of 1.15 (CI=1.01, 1.31) for the Western Aust-

GESB scheme suggests that female in this scheme face about 15% higher mortality than females pensioners in the reference Federal-CSS scheme.

[Table 6 here]

The relative effects of pension size are similar for the male subsample, except that the magnitudes are larger. For example, high pension income males have a 36% lower mortality hazard than those receiving average pensions, compared with 23% for females. In addition, two out of five individual scheme dummies are statistically significant. The first pertains to the Western Aust-GESB scheme where members face higher mortality risk *after* retirement than those in the reference category (HR=1.07; CI=1.01, 1.12; p <.05). The other statistically significant scheme variable pertains to the Federal-PSS (Public Sector Super) scheme. Members of this scheme face almost 29% lower mortality hazards as compared to those in Federal-CSS after controlling for pension size (p<.01).

Before turning to annuity valuation, a final exercise required here is to validate that the pseudo-baseline hazard (given by the aggregate mortality function in Figure 1) is close enough to the estimated Cox baseline hazard that is derived from estimates of baseline hazard contributions and smoothed via a kernel-smoothing function. Specifically, the Cox baseline hazard pertains to a male/female pensioner in the Federal-CSS scheme who receives an average pension income. We find the two sets of sex-specific hazard rates to be relatively close at ages of 60, 70, 80, 90, and 95.[21] This is not surprising given that pensioners from the Federal-CSS scheme comprise more than two-fifths of the overall sample which implies that their mortality experience contributes heavily to the aggregated experience. Accordingly, the regression estimates are applied to the sex-specific, aggregate mortality functions to derive individualized, cohortized survival curves for annuity valuation; an issue we will turn to next.

Present value of unfunded pension liabilities by scheme

Longevity risk affects the net unfunded liabilities of DB pension plans through the expected annuity payments owed to existing pensioners over their remaining lifetimes. This section uses a discounted annuity value approach to examine the impact of longevity risk on the net present

[21] Details are available upon request. The percentage difference between the two sets of hazard rates at these specified exact ages is less than 10% on average (ranging from 2-16%).

value of pension obligations in two steps. In the first step, we focus solely on the quantitative impact of varying mortality assumptions, holding other factors such as pension size constant. Specifically, we calculate the change in the net present value of annuity payments for a representative male pensioner at different ages so as to decompose the various aspects of longevity risk on annuity value. The second step then allows for variation in pension levels and age-membership structures and compares the levels of unfunded pension liabilities across dissimilar DB schemes in a nationally representative sample of public sector pensioners.

All calculations presented here are based on a valuation year of 2006, which is selected mainly to coincide with the mid-point of our observation span for which our pensioner experience is based. In particular, we extract a cross-sectional sample of pensioners from our data as at 30 June 2006. Formally, the actuarial present value (APV) of the annuity payments for a pensioner i can be expressed as:

$$\text{APV} = \sum_{t=0}^{\infty} \$A^{i} \cdot v^{t} \cdot {}_{t}p_{e}^{i} \,. \qquad (4)$$

In Eqn. (4), $\$A^{i}$ is the annual dollar pension (in real terms) received by the individual, v is the discount rate based on a real annual interest rate of 3.5%, e is the age as at valuation date (or so-called entry age), and ${}_{t}p_{e}^{i}$ is the set of cumulative survival probabilities differentiated by sex, pension size, birth cohort, and schemes (if applicable). A real annual interest rate of 3.5% is reflective of historical margins between nominal rates and inflation in Australia for that period. Specifically between 1995 and 2006, the average annualized nominal rate of return on Australian Government 10-year bonds is about 6.5% and average inflation (measured by the CPI index) is about 2.6%; the average margin approximates 3.8%. This discount rate is also consistent with that chosen by the fund actuary (Mercer Australia) in its actuarial valuation of pension liabilities for the closed Federal-PSS and CSS schemes (Australian Government 2006; 2009). Consistent with the ALT population tables, a terminal age of 110 is assumed. In essence, the APV is the sum of the discounted annual annuity income that a pensioner can expect to receive over his/her remaining lifetime.

The starting point for our analysis is an examination of how the net present value of annuity obligations to a public sector employer (or plan administrator) varies under different mortality assumptions. We aim to quantify the impact of three distinct aspects of longevity risk on the unfunded liabilities of a public sector DB pension plan, namely:

(1a) the longevity selection risk that *public sector* pensioners in aggregate are a select group that is more long-lived than the *general population*, and in association,

(1b) the risk that pensioners in a *specific* public sector occupational scheme are more long-lived than the average public sector pensioner due to previous occupational profile;

(2) the computational risk arising from pension valuations that fail to incorporate mortality improvements or use forecasts that do not fully account for mortality improvement; and

(3) systematic longevity risk (an unexpected longevity shock).

Prior studies have largely focused on the second aspect (i.e. computational risk) by contrasting the net present value of annuity payments when mortality improvements are taken into account versus when they are not. For example, Antolin (2007) estimates that the actuarial present value of the pension annuity increases by almost 3.3% for a 65-year old male pensioner when mortality improvements are incorporated as compared to not doing so. In addition, that study finds that this gap in APV is inversely related to age and thus concludes that pension funds with older age-membership structures will experience a smaller impact from longevity risk on their liabilities. We extend this analysis by examining the other forms of longevity risk outlined above so as to better draw conclusions on the extent of exposure of pension liabilities to each form of risk, and also how this may vary with the age-membership structure of a scheme.

Since we are only interested in the relative change in APV across different sets of mortality assumptions, we set $\$A^i = \$1$ in Eqn. (4) and vary only the ${}_tp_e^i$. The actuarial present value computations are performed for a representative male as at valuation Year 2006 for three different entry ages (e): 60, 70, and 80. For each given age, we compute separately the APV of the pension annuity using 'population' mortality, then 'pensioner' mortality as given by our aggregate mortality rates estimated for public sector pensioners in Section 3, and also using the 'pensioner (cohortized)' mortality assumption which is derived by incorporating long-term mortality improvement into 'pensioner' mortality.[22] The age-specific long-term mortality improvement factors are obtained from the 2006 ALT male population life tables and are appropriate considering that they have also been used by fund actuaries in valuing the public

[22] Cohortization is the process of incorporating future improvements in life expectancies into period mortality rates, and effectively shifts the mortality curve downwards.

sector pension liabilities. In this manner, the difference in APV between 'population' and 'pensioner' mortality would capture the estimated impact of aggregate longevity selection risk (*risk 1a* above) and that between 'pensioner' and 'pensioner (cohortized)' mortality would capture the impact of computational risk (*risk 2*).

Results on the percentage change in APV under varying mortality assumptions appear in Table 7. For a 60-year old male, we see that a pensioner will obtain 4.6% more in terms of net present value from the pension annuity relative to a male randomly drawn from the general population, ignoring any mortality improvements. This arises from his lower mortality which is consistent with our earlier observation that longevity selection exists in the sample of public sector pensioners possibly due to their higher education, stable career, or better health. If future mortality improvements are taken into account, the APV of the annuity for the 60-year old male would increase further by an estimated 2.7%. In other words, unfunded pension liabilities would be under-estimated by about 2.7% for a 60-year old male pensioner if the valuation of accrued liabilities failed to consider potential improvements in life expectancies. Though substantial, this estimated impact of computational risk on the level of unfunded liabilities is nonetheless smaller than that of aggregate longevity selection risk.

[Table 7 here]

Aside from longevity selection at the aggregate level, there is also scheme-specific selection risk in the sense that pensioners in a *specific* public sector occupational scheme could be more long-lived than the average public sector pensioner (*risk 1b* above). Thus certain sectors of employers in the civil service could be exposed to higher unfunded pension liabilities than others. This risk is quantified here by comparing the APV for a 'pensioner (cohortized)' with the APV for a pensioner in the Federal-PSS scheme, both allowing for mortality improvements. As shown earlier in proportional hazards regression, a male pensioner in the Federal-PSS scheme is associated with a 29% lower mortality compared to a same-aged male in the reference Federal-CSS scheme, controlling on pension size. Our estimate in Table 7 shows that this lower scheme-specific mortality translates into an 6.4% higher annuity APV for the 60-year old pensioner in the Federal-PSS scheme over his remaining lifetime than an average public sector pensioner. Scheme-specific mortality is a proxy for pre-retirement occupational profiles. The final aspect of longevity risk assessed here is that of an unexpected, systematic longevity shock (*risk 3*). This is implemented by decreasing the 'pensioner (cohortized)' mortality rates uniformly across all ages by 10%. Interestingly, we find that this leads to a 2.0% increase in the APV for the 60-year old male pensioner. Overall, the magnitudes of percentage changes in APV suggest that the risk from longevity selection (either in aggregate or scheme-specific) is likely to have a larger fiscal impact on the level of unfunded liabilities than the risk arising from a systematic shock or computational issues.

We also assess these findings by testing their sensitivity to alternative entry ages. Moving from left to right of Table 7, we find that the impact of aggregate longevity selection risk decreases with age and, in fact, reverses at very advanced ages. This is consistent with our earlier finding that longevity selection effect is strongest among the younger age groups immediately after retirement and that this effect does not perpetuate into advanced ages. If a pensioner survives to age 80, he receives almost the same in present value terms from the pension annuity (-0.4% difference in APV) as a member from the general population. If he survives to age 90, he will actually receive 8.9% *less* in annuity income in present value terms relative to the latter. Shifting attention to computational risk pertaining to mortality projections, we observe that the gap in APV (before and after accounting for mortality improvements) is inversely related to age. For instance, the percentage change in APV for an 90-year old male pensioner is just 0.7% as compared to 2.7% for the 60-year old. This is consistent with the finding in Antolin (2007), and credible since the exposure of pension fund to future mortality improvements should be smaller the older the pensioner is today. In contrast to this, the impact of a systematic longevity risk is larger the older the pensioner. The percentage change is more than double for an 80-year old (5.2%) as compared to the 60-year old (2.0%). A uniform 10% increase in survival probabilities causes larger absolute changes in mortality at older ages than at younger ages.[23] Consequently, because the right-tail cash flows are more heavily discounted for a 60-year old than an 80-year old, the impact of this shock on the pension obligations owed to a younger pensioner is smaller. Likewise, it is not surprising that scheme-specific longevity selection risk is positively related to age since a constant mortality adjustment factor is applied across all ages.

[23] It may be plausible that a longevity shock may not affect all ages uniformly. For example, a medical breakthrough (e.g. cure for cancer) may be most impactful in increasing survival possibilities for relatively younger than very older ages. Thus in an alternative scenario, we assume that the mortality shock is 10% up to age 90, and 0% thereafter. Results show that the APV percentages changes are 1.8% for the 60-year old and 4.2% for the 80-year old whereby the gap between these two individuals works out to be 2.4% (compared to 3.2% in the uniform shock). In such a scenario, the fiscal impact of the shock would be less sensitive to a scheme's age-membership structure.

In the second part of the analysis, we compare the levels of unfunded pension liabilities across dissimilar DB schemes in a nationally representative sample of public sector pensioners. Our cross-sectional sample as at 30 June 2006 comprises of 80,330 male pensioners from 13 schemes, and separately, 33,692 female pensioners from 10 schemes. No valuation is performed for females in the NSW-PSS, NSW-EISS, and Queensland-PS schemes since there are less than 10 female subjects in each of these schemes as at valuation date. The quantum of a scheme's unfunded liabilities depends on a combination of factors, including pension size, age-membership structure, and mortality of its members.

We report the valuation results by schemes in Table 8, sorted by per capita APV. This 'per capita APV' measure represents the present value of the lifetime pension annuity to a single pensioner in each scheme, and thus allows comparability across schemes. It ranges from A$100,855 to 586,144 for male pensioners; the dispersion for female pensioners is slightly smaller (A$100,740 – 526,928). Clearly, this measure would depend on a combination of factors, including the scheme's age-membership structure, pension levels, and mortality assumptions. Overall, our analysis shows that a male public sector pensioner in Australia – on average – can expect to receive a pension annuity of about A$0.367 million in present value terms in Year 2006 (average is weighted by schemes' membership size). Because of her lower pension income, a female pensioner can anticipate a smaller present value of pension benefit, which nonetheless still stands at a considerable A$0.309 million.[24] These weighted average estimates are credible given that actuarial estimates of the accrued unfunded liabilities per pensioner is approximately A$0.29 – 0.34 million in the federal DB schemes (per Table 2).

[Table 8 here]

One interesting observation is that per capita APV is higher for older schemes, primarily due to more generous pension benefits. The three DB schemes attracting the highest per capita APV in the male subsample (NSW-EISS, NSW-SSS, and NSW-PSS) have been in operation before 1920 and are among the earliest public sector DB schemes to close in Australia.[25] Similarly for females, the top two per capita APV values are associated with very old schemes (the NSW-SSS

[24] In the cross-sectional sample, the average median pension is approximately A$27,800 (males) and A$18,900 (females).

[25] The NSW-PSS and NSW-SSS started in 1907 and 1919 respectively. Although the NSW-EISS officially started in 1997, it consists of members who transferred over from the NSW-SSS scheme. These are employees of certain designated Energy Industries employers who were formerly under the NSW-SSS.

and South Aust-SASS). The distribution of pension sizes in the middle columns of the Table reveals that these older schemes tend to offer more generous pension benefits than the newer DB retirement plans. For example, 63-93% of male pensioners in the relatively small-scale NSW-PSS and NSW-EISS schemes receive high annual pensions in their retirement (i.e. exceeding A$38,000) as compared to only 35% in the reference Federal-CSS scheme.[26] Notably, pension levels are quite disperse across schemes even though they are all under the ambit of the public sector.

Only two individual schemes in the male sample had statistically different mortality from the Federal-CSS scheme: the Federal-PSS with lower-than-average mortality and the Western Aust-GESB with higher-than-average mortality. Yet we see from Table 8 that Federal-PSS did not rank very highly in terms of per capita APV in the table, ranking even below the Federal-CSS. This is partly rationalized by the fact that the bulk of its members receive only low to average-sized pensions. Another pertinent reason related to our earlier finding is that scheme-specific longevity selection risk is positively related to age. As at 30 June 2006, the Federal-PSS scheme had zero pensioners above age 80 which means that the impact of this selection effect on the present value of liabilities is presently much muted by the youthful age composition of the scheme. As more members of the Federal-PSS scheme start to attain advanced ages, we posit that its per capita APV may soon outrank some of the others.

There is also evidence in the Table that a more matured age-membership structure is generally associated with a lower level of unfunded pension liabilities. This is best illustrated by the females in the Victoria-ESSS scheme who have the lowest per capita APV among all public sector female pensioners. Given that the bulk of females in this scheme receive average-sized pensions, the low per capita APV is primarily attributable to its disproportionate age-membership structure (92% of the members are above age 80 compared to just 18% in the reference Federal-CSS scheme as at 30 June 2006). The last column of Table 8 illustrates the sensitivity of these actuarial present value estimates to an unexpected longevity shock whereby mortality decreases by 10% uniformly across all ages. In line with our earlier finding that systematic longevity risk is positively related to age, we observe that the shock has a greater impact on the total APV of schemes with older age-membership structures. For instance, the

[26] The pension size categories refer to those used in the Cox regression; see Section 4. For males, these are given by <$16,000 (‘low’), $16,000-38,000 (‘average’), and ≥$38,000 (‘high’). The pension categories for females are <$9,000 (‘low’), $18,000-27,000 (‘average’), and ≥$27,000 (‘high’).

NSW-PSS and Victoria-ESSS schemes (which comprise of at least 70% male pensioners above age 80) experience a 5-6% increase in pension obligations, compared to a modest 2.7% for the Federal-CSS scheme where only a quarter of the pensioners are in advanced ages. Similarly, the increase in total APV ensuing from the longevity shock is largest for the Victoria-ESSS scheme (5.5%) in the female sample since more than 90% of its members are above age 80. In contrast, the Federal-PSS scheme with an extremely youthful age composition experiences only a modest 1.7% increase in pension obligations. The Pearson correlation between the percentage of members above age 80 and the change in total APV from the longevity shock is 0.93 (males) and 0.98 (females).

5. Conclusion

We consider the exposure of unfunded pension liabilities to longevity risk in defined benefit plans using a rich new panel dataset of over 150,000 pensioners from a complete set of closed, major civil service retirement schemes in Australia. These defined benefit schemes have been closed to new members for some time (the last scheme to close is in 2008) but continue to accrue substantial amounts of unfunded financial liabilities owed to past and present public sector employees. Our assessment distinguishes between various aspects of longevity risk, including longevity selection risk (both aggregate and scheme-specific), computational risk pertaining to mortality projections, and systematic longevity risk.

We find evidence of longevity selection among public sector pensioners in relation to the general population at ages below 85-90. A 60-year old male pensioner has a mortality rate of about half that of the general population. This selection effect, however, does not extend to advanced ages due to higher proportions of pensioners dying at these very old ages compared to the population-at-large. Aggregate longevity selection risk translates into a 4.6% higher net present value from the pension annuity for a 60-year-old pensioner relative to a same-aged male randomly drawn from the general population. Nonetheless, the fiscal impact of aggregate longevity selection risk decreases with age and even reverses at very advanced ages. A pensioner who survives to age 80 will actually receive almost the same in present value terms from the pension annuity as a member from the general population.

At the same time, public sector pension plan providers are also exposed to scheme-specific longevity selection risk. Due to their pre-retirement occupational profiles, certain sectors of civil servants may live even longer than those from other sectors. We estimate that a 30% lower mortality level (higher survival chances) translates into an approximately 8.3% increase in annuity actuarial present value for the 60-year old pensioner, and correspondingly a 8.3% increase in pension obligations for the employer. In comparison to longevity selection risk, the exposure to the risk of computational errors, or an unexpected longevity shock, potentially has a smaller impact on the level of unfunded liabilities. A scheme that fails to take into account future mortality improvements will under-estimate pension liabilities by 2.7% for a 60-year old male pensioner in our sample. Nonetheless, consistent with prior studies, we find that this exposure is inversely related to age and thus smaller for schemes with an older age-membership structure. Schemes comprising mainly of older pensioners, however, suffer from a larger exposure to systematic longevity shocks. This is because a uniform 10% increase in survival probabilities causes larger absolute changes in mortality at older ages than at younger ages.

Pension obligations from defined benefit plans can be very costly to employers and plan providers. Specifically, unfunded PAYG pension schemes become unsustainable as populations age, because fewer and fewer workers finance growing numbers of retirees. In our nationally representative sample of Australian public sector pensioners, a male civil servant retired in 2006 will cost the government, on average, about A$0.367 million in present value terms. Similarly, each female civil servant will cost about A$0.309 million in remaining lifetime annuity payments. These figures are indicative of the huge fiscal burden on the Australian government with respect to accrued unfunded superannuation liabilities for the next few decades.

A sustained effort has been made by the Federal and State governments in Australia to ultimately eliminate these net superannuation liabilities from public sector balance sheets. An early measure was to initiate a nation-wide changeover from a defined benefit to a defined contribution pension system and close the DB schemes. Most prominently, the introduction of the Superannuation Guarantee mandate in 1992 required that employers (both in the public and private sectors) contribute into a pension fund nominated by the employee, with the quantum of employer-contribution determined by the central government (9% in 2002-2012 and will increase to 12% by 2019). As at end 2008, all major public sector DB schemes have closed to new members (except for specific schemes pertaining to the judiciary and defence personnel). Notably, this changeover was not accompanied by an explicit reduction in DB pension benefits although benefits have been made implicitly less generous through rises in the 'normal retirement age' over time. We find evidence of this in our broad cross-sectional analysis of unfunded liabilities levels across schemes whereby pensioners in older public sector schemes are observed to have higher per capita annuity values, stemming from their more generous pension benefits. Other government efforts to reduce the pre-existing unfunded superannuation liabilities in Australia include the establishment of specific funds to pre-finance future liabilities (such as 'The Future Fund' by the Commonwealth government), and legislating regular contributions to target a gradual fall in liabilities.

Appendix A

In this appendix, we describe the actuarial methodology used to derive the graduated mortality estimates $\{\dot{\mu}_x\}$ for the analysis. Longitudinal data on 158,623 retiree pensioners is obtained from the Mercer pensioner database for the period 1 Jul 2002 – 30 June 2010. Pensioners are aggregated across the 13 schemes (schemes listed in Table 3). Unit-level information includes pensioner ID, sex, birth date, commencement date of pension, cessation date and reason for cessation (if applicable). Of primary interest is cessation due to death.[27] Overall, 17.6% of the sample pensioners (or 27,937) died during observation, 0.5% discontinued their pensions, and 81.9% remain pensioners at the 2010 cut-off.

To determine the aggregate, raw mortality experience of pensioners retiring on or after age 55, we tabulate the observed number of deaths (d_x) for lives aged x and the total time the pensioners were exposed to the risk of dying (E_x^c). In actuarial terminology, E_x^c is known as the central exposure years to risk representing the total observed waiting time. Table A1 reports the total observed deaths and exposure years by age bands. There is a total of almost 880,000 exposure years summed over the eight-year period and 13 schemes. As expected, the number of exposure years for males is higher than that of females since males comprise 70% of the sample. Males also account for a disproportionate percentage of total deaths. Of the 27,937 deceased pensioners, 82% are males. Regardless of sex, however, the majority of deaths are observed in the 80-84 and 85-89 age bands. About 0.7% of the deaths occur at ages of 100 and over. Notably, the number of exposure years in the last age group (100+) is relatively small. Given that longevity is a right-tail risk, we decide to include these records in the analysis but care is taken in interpreting any results pertaining to this age group.

[Appendix Table A1 here]

[27] Among retiree pensioners, other reasons for cessation of pension may include commutation (i.e. convert from pensions to lump-sum option) and termination. Over the course of seven years, 17.6% of our sample pensioners died, 0.35% commutated, and 0.17% terminated their pensions.

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Table 1: Net Unfunded Superannuation Liabilities by State, 2007 – 2011 (in A$ billion)

State / Territory	2011	2010	2009	2008	2007
Federal (Commonwealth, including defence)	129.5	122.9	108.1	102.7	95.5
New South Wales	32.2	32.7	29.4	17.6	14.4
Victoria	22.8	20.3	24.4	12.9	10.1
South Australia	8.7	9.5	8.9	6.5	5.1
Western Australia	7.3	7.4	7.2	5.9	5.7
Tasmania	4.4	4.5	3.7	2.5	2.5
Queensland	0.0	0.0	0.0	0.0	0.0
Northern Territory	3.1	2.6	2.4	2.1	2.1
Australian Capital Territory	2.0	1.9	2.0	1.1	1.1
Total	**210.0**	**201.8**	**186.2**	**151.3**	**136.4**
% of GDP	**14%**	**14%**	**14%**	**12%**	**12%**

Notes: The Table shows estimates of unfunded superannuation liabilities published in the Federal and State governments' budget documents as at 30 June of each financial year. All figures are in nominal terms, and are obtained from the most recent budget release. In general, estimated actual/actual figures are reported for June 2011 and actual/revised figures are reported for June 2007 – 2010. The present values of liabilities are calculated by the governments using a discount rate based on the long-term government bond rate in accordance with the Australian Accounting Standard AASB 119.

Source: ACT Government (2011), Australian Government (2011), New South Wales Government (2011), Northern Territory Government (2012), Queensland Government (2011), South Australian Government (2011), Tasmanian Government (2011), Victorian Government (2012), and Western Australia Government (2011). Gross Domestic Product (GDP) figures at current prices are obtained from the Australian Bureau of Statistics.

Table 2: Unfunded Liabilities per Pensioner in Closed, Commonwealth DB Schemes

	Federal-CSS		**Federal-PSS**	
	2008	**2005**	**2008**	**2005**
Scheme demographics:				
Total number of members	149,055	157,821	252,354	252,025
Number of pensioners [line A]	115,432	113,588	16,452	11,419
% Age and Invalidity pensioners	*75.3%*	*74.9%*	*95.8%*	*95.6%*
% Reversionary pensioners	*24.7%*	*25.1%*	*4.2%*	*4.4%*
Accrued unfunded liability (A$m):				
Estimated total unfunded liability	$59,200	50,600	20,900	13,800
Estimated unfunded liability for pensioners [line B] (and % of total)	$39,000 (66%)	31,900 (63%)	5,500 (26%)	3,300 (24%)
Unfunded liability per pensioner ($= B/A$)	**$0.338**	**0.281**	**0.334**	**0.289**

Source: Australian Government (2006; 2009).
Notes: The Commonwealth Super Scheme (Federal-CSS) scheme was open from 1976-1990, and the Public Sector Super scheme (Federal-PSS) was open from 1990-2005. The unfunded liability represents an estimate of the accrued superannuation liabilities in respect of service up to 30 June of each valuation year for which no assets are held. The liabilities are split between contributors, preserved members, and pensioners; see text. Only the amount of liabilities pertaining to the pensioners group is reported in this Table.

Table 3: Public Sector Pension Schemes with Closed, Defined Benefit Accounts

Federal/ State	Name of Scheme	Acronym	Sample (1 Jul 2002 – 30 Jun 2010)	
			# retiree pensioners	**In %**
Federal	Commonwealth Superannuation Scheme (1976-1990)	Federal-CSS	68,200	43.4%
Federal	Public Sector Superannuation scheme (1990-2005)	Federal-PSS	9,563	5.5%
NSW	New South Wales State Superannuation scheme (1919-1985)	NSW-SSS	28,115	17.2%
NSW	New South Wales State Authorities Superannuation scheme (1988-1992)	NSW-SASS	3,594	2.2%
NSW	New South Wales Police Superannuation scheme (1907-1988)	NSW-PSS	433	0.3%
NSW	New South Wales Energy Industries Superannuation Scheme^ (Closed in 1985)	NSW-EISS	286	0.2%
Victoria	Victorian State Superannuation Fund# (Closed in 1994)	Vic-SSS	28,432	18.4%
Victoria	Victorian Emergency Services Superannuation Scheme# (Closed in 1994)	Vic-ESSS	1,039	0.7%
South Australia	South Australian Superannuation and Police Scheme (Closed in 1986)	SA-SASS	5,831	3.6%
Tasmania	Tasmanian Retirement Benefits Fund (Closed in 1999)	TAS-RBF	6,066	3.9%
Western Australia	Western Australian Government Superannuation Scheme (Closed in 1996)	WA-GESB	6,192	4.0%
Queensland	Queensland State Superannuation Scheme+ (Closed in 2008)	Queen-SS	778	0.5%
Queensland	Queensland State Police Superannuation Scheme+ (Closed in 2008)	Queen-PS	94	0.1%
			158,623	**100%**

Notes: NSW refers to New South Wales. The Table shows the defined benefit (DB) public sector schemes in the sample. This sample covers all the Federal/State DB schemes pertaining to civilian public servants and pay benefits in the form of lifetime pensions. 12 schemes belong to the general government sector while the NSW-EISS scheme technically belongs to the public trading enterprise sector. As at end 2008, the DB portions of all these schemes have closed to new members. Several schemes may separately manage DC/accumulation accounts which are still open to new members.

This scheme is part of the so-called Victoria Emergency Services and State Super.

+ This scheme is part of the so-called QSuper DB account.

^ The NSW-EISS scheme technically belongs to the public trading enterprise (PTE) sector (instead of the general government sector). PTEs are public sector entities which provide major economic infrastructure assets such as water, power and public transport, and typically finance the bulk of their operations from own sources revenues and borrowings.

Source: Authors.

Table 4: Fitted Estimates using Weighted Least Squares Methods

Sex	Functions	**F1: $\dot{\mu}_x = a + \mu_x^s$**	**F2: $\dot{\mu}_x = (b + cx)\mu_x^s$**
Males	Fitted parameters	$\hat{a}$ =-0.00299 (.00032)	$\hat{b}$ =-0.60116 (.09466) $\hat{c}$ =0.01949 (.00119)
	Root MSE	0.0023	**0.0014**
	Fit: Pearson correlation coefficient	0.914	**0.930**
	Fit: Chi-square test statistic (df)	540.2 (48)	**171.3 (47)**
	Smoothness test statistic	**1.67E-05**	3.15E-05
Females	Fitted parameters	$\hat{a}$ =-0.00146 (.00019)	$\hat{b}$ =-0.32260 (.09716) $\hat{c}$ =0.01597 (.00122)
	Root MSE	0.0013	**0.0009**
	Fit: Pearson correlation coefficient	**0.912**	0.906
	Fit: Chi-square test statistic (df)	129.1 (48)	**50.5 (47)**
	Smoothness test statistic	**4.34E-06**	8.17E-06

Note: N= 158,623 retiree pensioners (111,257 males and 47,366 females) observed over 1 Jul 2002 – 30 June 2010. The table shows the weighted least squares estimates of the fitted parameters, with standard errors in parenthesis. The test statistic which is superior in each row is shown in bold for ease of comparison between functions F1 and F2. The mean square error (MSE) is an estimate of error variance; a smaller MSE is generally interpreted as better explanation of the variability in the observations. The chi-square goodness-of-fit test is performed using expected versus observed deaths; a lower test statistic indicates better adherence to the data. For the smoothness test, a lower test statistic indicates more smoothness in the graduated rates.
Source: Authors.

Table 5: Comparison of Pensioner Mortality Rates (q_x) by Sex

A. Males

Age	(1) Mercer0205 (updated to 2006)	(2) This study: 2006 rates	(3) 2006 ALT table	(4)= $\frac{(2)-(1)}{(1)}$ Deviation from Mercer's rates	(5)= $\frac{(2)}{(3)}$ Ratio of rates
55	.0019	.0021	.0045	7%	0.45
60	.0037	.0039	.0072	6%	0.54
65	.0071	.0076	.0120	7%	0.63
70	.0137	.0140	.0192	3%	0.73
75	.0264	.0269	.0331	2%	0.81
80	.0514	.0523	.0576	2%	0.91
85	.0917	.0988	.0991	8%	1.00
90	.1630	.1775	.1629	9%	1.09
95	.2690	.2727	.2311	1%	1.18
100	.3263	.3553	.2821	9%	1.26
105	.3844	.4244	.3207	10%	1.32

B. Females

Age	(1) Mercer0205 (updated to 2006)	(2) This study: 2006 rates	(3) 2006 ALT table	(4)= $\frac{(2)-(1)}{(1)}$ Deviation from Mercer's rates	(5)= $\frac{(2)}{(3)}$ Ratio of rates
55	.0017	.0015	.0027	-14%	0.53
60	.0029	.0026	.0044	-9%	0.61
65	.0050	.0047	.0068	-6%	0.69
70	.0085	.0084	.0112	-1%	0.75
75	.0161	.0164	.0198	2%	0.83
80	.0320	.0328	.0366	2%	0.89
85	.0640	.0686	.0709	7%	0.97
90	.1277	.1368	.1309	7%	1.05
95	.2392	.2351	.2090	-2%	1.13
100	.3260	.3375	.2828	4%	1.19
105	.4015	.4216	.3369	5%	1.25

Source: Authors'.

Table 6: Effects of Selected Covariates on Mortality

	Males		Females	
	HR	**[95% CI]**	**HR**	**[95% CI]**
Pension sizes:				
Low	1.23***	[1.20,1.27]	1.13***	[1.06,1.21]
Average (ref.)	1.00	-	1.00	-
High	0.64***	[0.61,0.66]	0.77***	[0.72,0.83]
Specific schemes:				
Federal-CSS (ref.)	1.00	-	1.00	-
Federal-PSS	0.71***	[0.60,0.84]	0.84	[0.67,1.05]
NSW-SSS	NA[(b)]		1.05	[0.97,1.13]
NSW-SASS	NA[(b)]		0.90	[0.73,1.10]
NSW-PSS	NA[(b)]		NA[(a)]	
NSW-EISS	NA[(b)]		NA[(a)]	
Victoria-SSS	NA[(b)]		NA[(b)]	
Victoria-ESSS	1.01	[0.91,1.12]	0.86	[0.54,1.37]
South Aust-SASS	NA[(b)]		NA[(b)]	
Tasmania-RBF	1.00	[0.94,1.08]	1.01	[0.86,1.17]
Western Aust-GESB	1.07**	[1.01,1.12]	1.16**	[1.01,1.32]
Queensland-SS	NA[(b)]		0.97	[0.76,1.22]
Queensland-PS	1.38	[0.90,2.12]	NA[(a)]	
Grouped schemes	1.03**	[1.00,1.06]	1.13***	[1.05,1.22]
# subjects	111,257		47,350	
Chi-squared	1,162		102	
df	8		10	
Adjusted R2	3.2%		1.1%	

Source: Authors'.
*** Indicates 1% significance level; ** indicates 5% significance level; * indicates 10% significance level.
HR = hazard ratios; CI = confidence intervals. NA[(a)] = not applicable because this scheme comprises 95% or more males and is therefore excluded from the female subsample. NA[(b)] = not applicable because this individual scheme dummy does not independently satisfy the proportional hazards assumption, and so not included as a covariate. Members of this scheme are categorized under the "grouped schemes" category.
Note: The table shows the results from Cox proportional hazard regressions indicating how the selected covariates are associated with mortality for the male and female subsamples. Reported hazard ratios are the partial effects of the explanatory variables on the odds of mortality. 95% confidence intervals of the marginal effects are reported in square brackets. Retiree pensioners are observed over the period 1 Jul 2005 to 30 June 2010. The pension size categories are sex-specific since females are observed to generally receive lower pensions than males in the data. For males, these are given by <$16,000 ('low'), $16,000-38,000 ('average'), and ≥$38,000 ('high'). The pension categories for females are <$9,000 ('low'), $18,000-27,000 ('average'), and ≥$27,000 ('high').
Acronyms for schemes are used in this table; full names of schemes are given in Table 3.

Table 7: Percentage Changes in Annuity Actuarial Present Values under Varied Mortality Assumptions

Mortality assumptions	Aspects of Longevity Risk	% change in APV values for different ages			
		60	70	80	90
General population vs. Pensioner	Aggregate longevity selection risk	4.6%	3.4%	-0.4%	-8.9%
Pensioner vs. Pensioner (cohortized)	Risk of computational omission of mortality improvements	2.7%	2.3%	1.6%	0.7%
Pensioner (cohortized) vs. Pensioner (cohortized) from the Federal-PSS scheme	Scheme-specific longevity selection risk	6.4%	10.3%	16.5%	23.7%
Pensioner (cohortized) vs. Pensioner (cohortized) with 10% uniform increase in survival probabilities	Systematic longevity shock	2.0%	3.3%	5.2%	32.9%

Source: Authors'.

Notes: This table shows the relative change in actuarial present value (APV) across different sets of mortality assumptions. The APV computations are performed per Eqn. (4) assuming a $1/year pension annuity for a representative male as at valuation Year 2006 for entry ages 60, 70, and 80. For a given age, the APV of the pension annuity is separately computed using each of the mortality assumptions given in the first column of the table, and the percentage difference is derived. For example, the first row shows the percentage change in APV when 'pensioner' mortality is used in place of 'population' mortality.

Table 8: Annuity Valuation by Schemes (as at 30 June 2006)

A. Males

Schemes	# Males	Total APV (A$m)	per capita APV (A$)	% by Pension Size			% by Age (30 June 06)			Change in total APV (10% shock)
				Low	Average	High	<65	Age 65-80	>80	
NSW-EISS	160	94	586,144	11	27	63	39	57	4	2.4%
NSW-SSS	11,369	5,917	520,466	19	32	49	24	49	27	3.2%
NSW-PSS	270	133	493,132	5	2	93	7	23	70	4.8%
Federal-CSS	38,273	15,149	395,821	15	50	35	35	41	25	2.7%
Federal-PSS	2,267	835	368,155	46	31	23	56	44	0	2.0%
South Aust-SASS	2,934	985	335,738	16	47	37	10	54	36	3.7%
Tasmania-RBF	3,330	1,114	334,574	30	47	24	22	59	19	3.0%
Victoria-SSS	15,071	3,860	256,147	37	56	7	48	35	17	2.8%
Western Aust-GESB	4,130	1,025	248,065	21	48	31	5	48	47	4.3%
Queensland-PS	45	11	241,253	24	64	11	18	56	27	3.6%
Queensland-SS	294	70	239,455	37	43	19	16	48	36	3.5%
Victoria-ESSS	663	104	157,030	26	58	16	0	25	75	5.6%
NSW-SASS	1,524	154	100,855	81	17	2	8	25	67	3.8%
	Total= 80,330		**Weighted average= $366,627**							

B. Females

Schemes	# Females	Total APV (A$m)	per capita APV (A$)	% by Pension Size			% by Age (30 June 06)			Change in total APV (10% shock)
				Low	Average	High	<65	Age 65-80	>80	
NSW-SSS	7,912	4,169	526,928	9	24	66	43	41	16	2.3%
South Aust-SASS	736	214	291,163	12	44	44	10	58	32	3.1%
Federal-CSS	13,351	3,475	260,270	23	53	24	33	49	18	2.2%
Tasmania-RBF	1,198	283	236,064	29	54	16	31	54	14	2.4%
Federal-PSS	2,419	566	234,075	36	53	11	66	34	0	1.7%
Western Aust-GESB	934	211	225,497	13	41	46	3	57	40	3.8%
Queensland-SS	235	52	219,612	20	57	23	18	50	32	2.9%
Victoria-SSS	6,456	1,358	210,318	31	59	10	48	36	15	2.3%
NSW-SASS	402	64	159,568	39	57	4	21	52	27	2.4%
Victoria-ESSS	49	5	100,740	24	59	16	0	8	92	5.5%
	Total= 33,692		**Weighted average= $308,571**							

APV = actuarial present value of the pension annuity; see Eqn. (4) in text.
Note: The pension size categories shown in this table corresponds to those used in the Cox regression. For males, these are given by <$16,000 ('low'), $16,000-38,000 ('average'), and ≥$38,000 ('high'). The pension categories for females are <$9,000 ('low'), $18,000-27,000 ('average'), and ≥$27,000 ('high'). The female cross-sectional sample excludes three schemes which are predominantly male (comprises 95% or more males as at 30 June 2006), namely the Queensland-PS, NSW-PSS, and NSW-EISS schemes. No pension annuity valuation is performed for these schemes.
Source: Authors'.

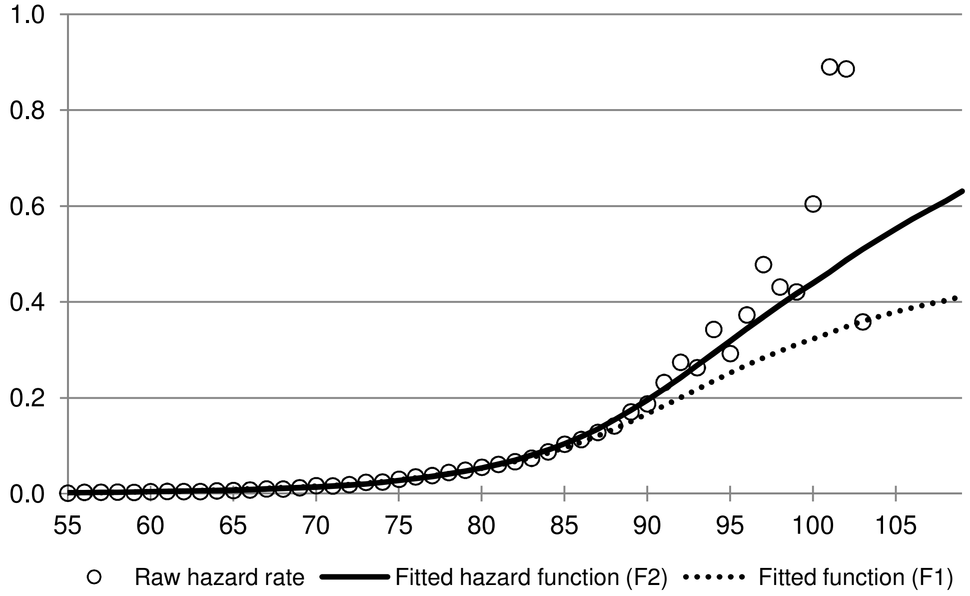
Appendix Table A1: Total Observed Deaths and Exposure Years by Sex and Age Bands

	Male		Female		Total	
Age Band	**Observed deaths**	**Exposure years**	**Observed deaths**	**Exposure years**	**Observed deaths**	**Exposure years**
55-59	256	87,722	102	49,132	358	136,854
60-64	596	121,123	212	57,641	808	178,765
65-69	836	90,084	249	44,775	1,085	134,859
70-74	1,403	69,351	353	32,437	1,756	101,787
75-79	3,602	89,976	727	32,415	4,329	122,391
80-84	6,179	90,958	1,177	26,140	7,356	117,098
85-89	5,676	45,354	1,108	12,405	6,784	57,760
90-94	3,271	13,582	757	4,187	4,028	17,769
95-99	897	2,432	342	1,010	1,239	3,442
100+	132	248	62	122	194	369
Total	**22,848**	**610,831**	**5,089**	**260,264**	**27,937**	**871,095**

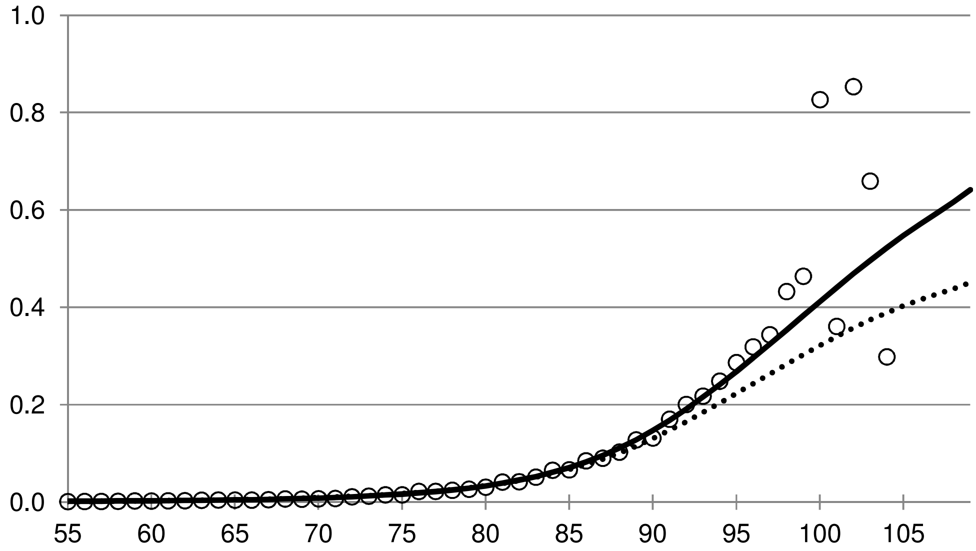
Note: N= 158,623 retiree pensioners (111,257 males and 47,366 females) observed over 1 July 2002 – 30 June 2010.
Source: Authors' computations.

Figure 1: Smoothed Hazard Rates for Retiree Pensioners by Sex

A. Males



B. Females



N= 111,257 male and 47,366 female retiree pensioners observed over 1 July 2002 – 30 June 2010.
Notes: The figure shows the sex-specific, fitted hazard functions based on weighted least squares regressions and graduation using function F2 by reference to the ALT table; see text.
Source: Authors'.