The Dialogue

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The impact of climate change on mortality and retirement incomes in Australia

Ramona Meyricke and Rafal Chomik

Actuaries Institute

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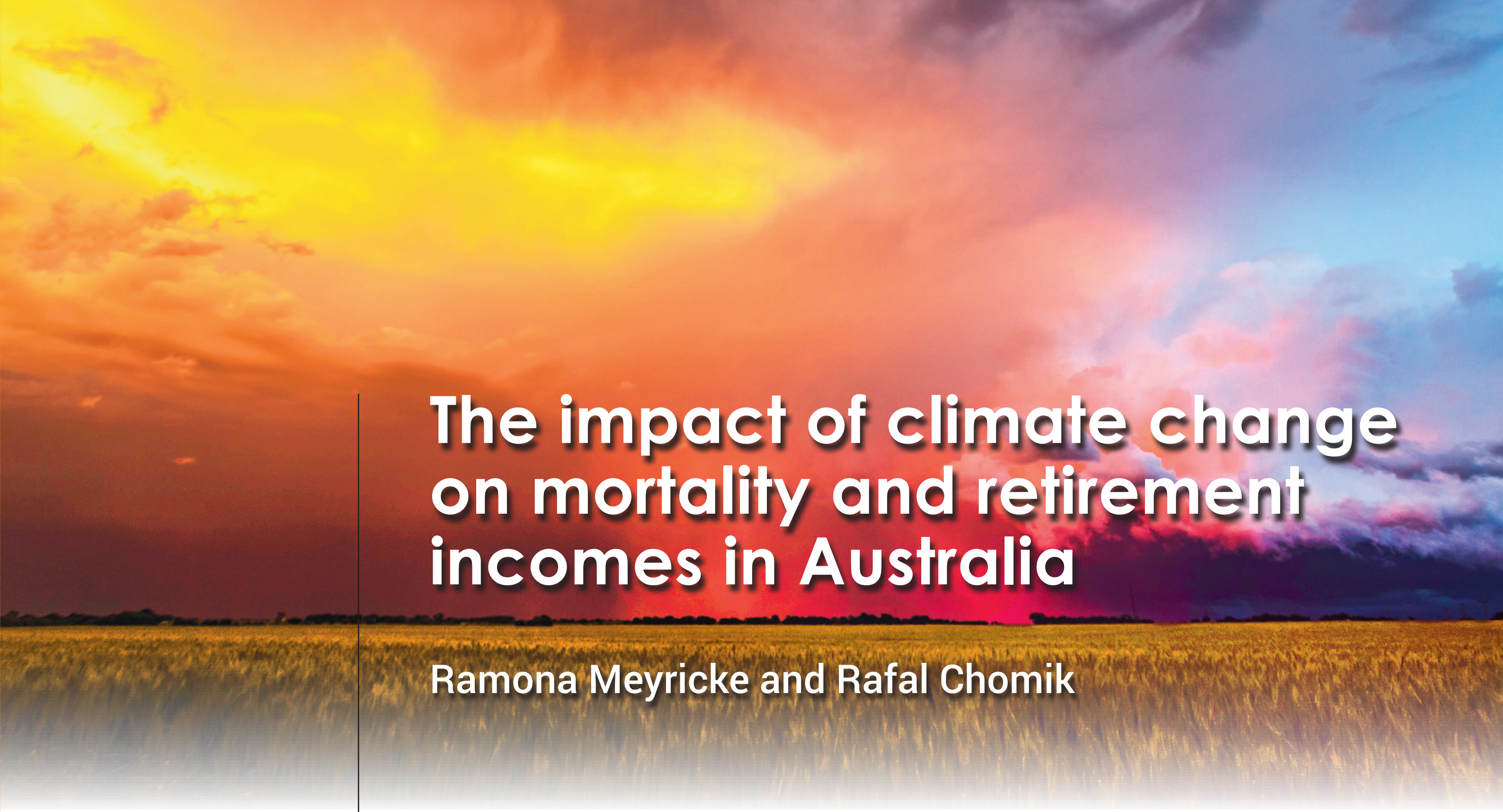

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Executive summary

Australians' health and finances are at risk in coming decades, as a result of climate change. The wide-ranging implications of climate change include higher mortality, lower superannuation balances and lower retirement incomes.

- In Australia, the main risk to human life from climate change arises from heatwaves. Historically heatwaves have killed more Australians than any other natural hazard. The January 2009 heatwave in Victoria alone is estimated to have caused 374 deaths.
- The frequency and duration of heatwaves will increase significantly over the 21st century, with greater increases in the north than south of Australia. Increases in heatwaves will drive a significant increase in the number of heat-related deaths in Australia. Many factors will affect the number of deaths from heatwaves in the future including public awareness, how we work and other factors.
- Older people are most vulnerable to heatwaves so, all else being equal, ageing of the population will amplify the absolute mortality impacts of climate change.
- Life and health insurers are increasingly focussed on customer wellbeing and on helping their customers reduce risks to their health. This could be extended to increasing customer awareness of how to avoid the risks posed by extreme heat.
- From a financial perspective:
    - **For life insurers and annuity providers,** the impact of climate change on mortality needs to be considered alongside the impact it may have on investment returns. Climate change could have negative long-term return implications for investors who are not diversified at a total portfolio level to climate change.
    - **For individuals,** exposure to the negative long-term return implications of climate change could be expected to lower the accumulated superannuation balance (at age 67) and retirement income (including Age Pension) of a worker on median earnings by 18% and 5% respectively. Reduced capacity to contribute to superannuation due to income shocks driven by the physical or transition risks (linked with climate change) could further erode balances and retirement income.
    - **For government,** while higher levels of mortality translate into lower fiscal expenditures on the Age Pension, lower investment returns on superannuation savings could translate into higher fiscal expenditures on the Age Pension. The present value of extra Age Pension expenditure on the median earner, if investment returns were 1% p.a. lower over that person's life, is estimated to be around $30,000, all else being equal.
- In terms of public policy, the wide-ranging consequences of climate change on mortality, public health and the economy mean that system-wide policy responses (across the health system, aged care services, emergency services, and other social services) are necessary to mitigate the risks posed and their interaction with population ageing.

1. Background

As global warming takes place, how might climate change affect mortality in Australia, and what are the consequences for life insurers, pension providers and public policy? Furthermore, what are the interactions with one of the other megatrends that will define the 21st century: population ageing?

The evidence base relating to climate science is strong (IPCC, 2014). But as Australia braces for higher temperatures and more extreme weather events such as fires, floods, and tropical cyclones (CSIRO and BoM, 2015), less thought has gone into interrogating the potential magnitude and distribution of effects on human health and life. Evidence suggests that the extent and timing of such effects are subject to a great deal of variability (IAA, 2017), and the impacts are likely to differ at a regional level, requiring place-specific responses.

The segment of the Australian population most vulnerable to the mortality impacts of climate change is the elderly. Older people are identified in health assessments as more vulnerable than younger people to a range of health outcomes associated with climate change, including injury and illness resulting from weather extremes such as heatwaves, storms, and floods (WHO, 2003). As such, the effects and management of the risks of climate change on mortality in Australia are related to demographic change.

In this Dialogue we first explore how climate change may affect mortality in Australia and how population trends could exacerbate the effects. We then discuss the potential impacts of climate change on economic growth and investment, life insurance and retirement incomes. We conclude by discussing several implications for policy-makers.

2. Climate change and mortality

Over recent decades, the world has grown accustomed to increases in life expectancies. In high-income countries life expectancy at birth has increased by about 15 years since 1950 to reach over 80 years of age. World-wide, life expectancy improvements have been even more dramatic, increasing over the same period by about 25 years to reach over 70 years of age (UN, 2017). But further increases are not guaranteed, with some countries witnessing a recent slow-down in mortality improvements (e.g., UK and US). To what extent could climate change affect these trends in the future?

2.1 Global overview

At the global level, there is strong evidence of several health impacts of climate change (WHO, 2015). Globally, climatic changes impact health and mortality via three main channels:

1. severe weather-related events (floods, droughts, and bushfires);
2. heat-related mortality or morbidity; and
3. infectious illness and vector-borne diseases (IPCC, 2014; WHO, 2015; Zhang and Beggs, 2018).

Severe weather-related events (floods, droughts, bushfires) induced by a changing climate, expose communities to the threat of unusually high incidence of mortality or morbidity, including both physical and mental health disorders. A warming climate can also result in heat-related mortality or morbidity and drives an increasing incidence of infectious illness and vector-borne diseases. In some parts of the world, climate change is also expected to increase the risk of under-nutrition resulting from diminished food production in poor regions and lack of drinking water (IPCC, 2014; WHO, 2015; Zhang and Beggs, 2018).

There is weaker evidence of positive effects from climate change, including modest improvements in cold-related mortality and morbidity. Expert advice is that, on balance, there is high confidence that negative health effects will outweigh positive effects at the global level (IPCC, 2014; WHO, 2015).

The relative importance of these channels is influenced by geography and the level of resilience of the human systems in a given location. For example, many Asian cities, such as Dhaka, are situated in low-lying delta areas, which puts millions of people at risk from impacts of climate change such as flooding (World Bank, 2014). Rapid urbanisation, large populations, poverty and low levels of economic development mean there are very low levels of resilience to flooding, and therefore it is a major risk to life in such cities.

2.2 Climate change and mortality in Australia

In Australia, there is strong evidence that climate change will have a wide range of negative impacts on health and mortality. For example;

- Climate change is likely to drive longer, harsher and more frequent droughts in parts of Australia (Herold et al., 2018). The negative impacts of drought on mental health of those living in remote and regional communities is widely evidenced (Austin et al., 2018).
- Climate change is likely to exacerbate the health and mortality impacts of air pollution. In Sydney, for example, the influence of climate change on ozone concentrations alone is expected to cause an additional 55-65 deaths per year in 2051-2060[1] (Physick et al.,

2014). In addition, the issue of more heavy smoke days due to more bushfires, could be expected to contribute to more deaths.

- While Australia experiences relatively low incidences of vector borne disease, it has been shown that expected cases of the Ross River virus, for example, will increase as certain regions get warmer (Herold et al., 2018).

Life insurers operating in Australia tend to have significant amounts of both morbidity and mortality risk on their books. Data on how morbidity products (Income Protection, Total Permanent Disability and Trauma insurance) could be affected by climate change, however, is virtually non-existent. For example, for a heart attack occurring during a heatwave the primary cause of claim would likely be recorded as 'heart attack' with few, if any, details of climate related drivers recorded. That is, life insurers commonly record the clinical diagnosis behind a claim, and not the climate related factors linked to an event. This makes it difficult to quantify how climate change might affect morbidity products[2]. For this reason, this paper focusses on the impact of climate change on mortality.

Heatwaves have killed more Australians than any other natural hazard and have caused more deaths since 1890 than bushfires, cyclones, earthquakes, floods and severe storms combined.

The main impact of climate change on mortality arises from heat-related mortality. Heatwaves have killed more Australians than any other natural hazard and have caused more deaths since 1890 than bushfires, cyclones, earthquakes, floods and severe storms combined (Climate Council, 2016). The Victorian 2009 heatwave is estimated to have caused 374 more deaths than what would otherwise have been expected (Victorian DHS, 2009). In comparison to heatwaves, other natural disasters are expected to result in low numbers of deaths. For example, bushfires were the most common natural disaster in NSW between 2004-2014, followed by storms and floods (Sewell et al., 2016). Due to relatively high building standards and emergency response capabilities, among other factors, these fires, storms and floods resulted in a far lower number of deaths than the Victorian 2009 heatwave (Victorian DHS, 2009).

Heatwaves are also responsible for a range of other adverse impacts such as: increased demand for social and health services, ambulance services, GP attendances, Emergency Department presentations, and additional strain on infrastructure such as electricity supply (Victorian DHS, 2009). Hotter overnight temperatures also adversely affect sleep and can lead to a range of other adverse impacts, for example workers may become fatigued which increases the risk of accidents (Safe Work Australia, 2017).

2.3 Defining a heatwave

Heatwave effects on mortality are significant, especially in the context of climate change. But there is no universally consistent definition of a heatwave, and the estimated magnitude of the effect that heatwaves have on mortality varies under different heatwave definitions. A systematic review and meta-analysis were conducted to assess the heatwave definitions used in the literature published up to 1 April 2015; it showed that mortality risk during heatwaves was 3% to 16% higher than on non-heatwaves days:

- 3% when "mean temperatures ≥95th percentile for ≥2days"
- 4% when "mean temperatures ≥ 98th percentile for ≥ 2 days"
- 7% when "mean temperatures ≥ 99th percentile for ≥ 2 days" and
- 16% when "mean temperatures ≥ 97th percentile for ≥ 5 days" (Xu et al., 2016).

Despite the absence of a universal definition of a heatwave, it is agreed that the intensity and duration of heatwaves consistently influence the mortality impact (Xu et al., 2016).

1 Estimated impact on ozone-related mortality in Sydney due to climate change, ignoring changes in population size or structure, or baseline emissions, and under an A2 emission scenario, compared to a baseline of 1996-2005.

2 The consequences of climate change on morbidity risk are potentially severe for some market segments, and insurers could improve monitoring of these risks and think about them in their product terms and conditions.

Heatwaves are responsible for a range of adverse impacts such as increased demand for social and health services, ambulance services, GP attendances, Emergency Department presentations, and additional strain on infrastructure such as electricity supply. Hotter overnight temperatures can also adversely affect sleep, leading to fatigue, which increases the risk of accidents.

2.4 Projecting excess mortality of heatwaves in Australia

Many factors will affect the number of deaths from heatwaves in Australia in the future including: changes in demographics, air pollution, adaptation to climate change including increased use of air-conditioning and better building standards, how we work, and other environmental factors. Population ageing would increase absolute excess mortality (the number of deaths above that expected in non-heatwave conditions), though factors such as acclimatisation and the increased availability of air-conditioning, for example, would likely decrease absolute excess mortality. There are, however, physiological and behavioural limits (e.g. 100% penetration of air-conditioning) to adaptation to climate change (Sherwood and Huber, 2010).

The following results (taken from Herold et al., 2018) illustrate the best estimate of the impact of future climates in Sydney and Brisbane on excess mortality, should they occur in the present demographic structure and environmental conditions. For the future periods, the simulations assume emissions follow the Special Report on Emission Scenarios (SRES) A2 scenario. Current global emissions data suggests global emissions are following a trajectory slightly higher than SRES A2 (Peters et al., 2013), thus the projections presented below, as they relate to temperature extremes, may be conservative.

Climates vary significantly across Australian capital cities, meaning that the impacts of climate change need to be investigated at a regional level, rather than at a national level. Sydney and Brisbane, however, have similar current and projected mean daily maximum temperatures. As detailed in Table 1, the studies of excess mortality were conducted at all-ages in Sydney and over 65s in Brisbane. Comparing the results between Sydney and Brisbane, therefore, illustrates the difference in the estimated impact of future climates on excess mortality across different age groups.

Table 1: Projected average summer daily maximum temperatures in Sydney and Brisbane and related excess mortality expected (all-age for Sydney, over age 65 for Brisbane)

City	Relationship	Units	Recent past	2020-2040	2060-2080
Sydney	Increase in excess mortality for **all-ages** of 0.9% per °C in monthly **mean summer daily max temp**	mean daily max temp	29°C	30°C **1% excess mortality increase for all-ages**	31°C **2% excess mortality increase for all-ages**
Brisbane	Increase in excess mortality for **for ages > 65** of 7% per °C in monthly **mean summer daily max temp**	mean daily max temp	29.3°C	29.8°C **4% excess mortality increase for over age 65**	31°C **12% excess mortality increase for over age 65**

Source: Herold et al., 2018

Table 1 shows that excess mortality in over 65s is approximately *four to six times* higher than excess all-ages mortality caused by similar heatwaves. Excess mortality expected in 2020-2040 is 1% for all ages (Sydney), but 4% in over 65s (Brisbane). Over the period 2060-2080, excess mortality from heat is projected to be 2% at all ages, but 12% in over 65s. It is likely that among the oldest in the population, the mortality rates would be higher still.

Many States and Territories have already implemented heatwave response plans, early warning systems and/or conducted awareness campaigns to educate people about the health risks of heatwaves. With ongoing improvement in public awareness and risk mitigation, the amount of excess mortality from climate change should be below the projected levels in Table 1. In addition, life and health insurers are increasingly focussed on customer wellbeing and helping their customers reduce risks to their health. This could be extended to increasing customer awareness of the risks posed by extreme heat in order to reduce the mortality impacts of climate change.

Notwithstanding this, the results suggest that ageing of the population will amplify the mortality impacts of climate change. This is critical because the population over age 65 is projected to increase significantly. Australian Bureau of Statistics (2018) projections suggest that by 2050, the populations aged 65+ and 85+ are expected to nearly double and triple, respectively.

2.5 Vulnerability of older people

Older Australians are especially vulnerable to the health risks posed by climate change due to factors such as the physiological changes of old age, impaired functional responses to heat stress and the higher prevalence of chronic diseases.

Older Australians are especially vulnerable to the health risks posed by climate change (Horton et al., 2010; Tong et al., 2014; Victorian DHS, 2009). Understanding the reasons why the elderly are at risk is essential to inform policy that could reduce the mortality impact of future heatwaves. The primary driver of this relates to the physiological changes in the human body from ageing, which are particularly acute for older women. The increased vulnerability relates to a combination of an impaired physiological response to heat (reduced thirst response and diminished ability to sweat) and the higher prevalence of chronic diseases among the elderly (Kovats and Hajat, 2008).

Older people also tend to have lower cardiovascular fitness, which is essential for thermoregulation. Chronic under-hydration may also be observed among the frail and elderly, increasing their vulnerability to environmental and physiological stressors. Finally, common characteristics among older people, such as impaired mobility, cognitive decline, and waning social connectedness and support, all further reduce the capacity of the elderly to adequately protect themselves from the effects of extreme heat (Victorian DHS, 2009).

The vulnerability of older disadvantaged people may be even greater. For example, Toloo et al. (2014), studied heat-related emergency department visits in Brisbane between 2000-2008, breaking down the data by age and area-based measures of disadvantage. They found that for younger people, the increase in visits during heat waves was similar whether they lived in a poor or an affluent area. But among those aged 65-74, those from poor areas had a substantially elevated level of visits.

2.6 Indirect impacts of climate change

Additional indirect impacts on mortality and morbidity related to climate change include impacts caused by a sustained surge in demand beyond the capacity of a healthcare system to cope effectively (IAA, 2017). For example, in 2005 when Hurricane Katrina hit the United States, it caused massive displacement of people and an overload of healthcare services, which did not have enough spare capacity to cope (IAA, 2017). In the 2009 Victorian heatwave, emergency services, ambulances, hospitals and morgues were overwhelmed by a surge in demand (Victorian DHS, 2009). While these indirect effects and impacts are important, we do not explore them further in this paper.

In summary, as global warming raises the frequency, severity and duration of heatwaves in Australia, the population is expected to experience greater excess mortality, particularly among people aged over 65. Population ageing will amplify the burden of heat-related mortality and health risks in a warming climate; an interaction that policymakers and insurers have not yet fully taken into account.

3. Impact on life insurance and retirement incomes

Two material cost drivers for life insurance and pensions (annuities) are mortality and investment returns. Climate change is expected to impact on both, driving changes in the cost of these products.

3.1 Impact on life insurance

Two material cost drivers for life insurance and pensions (annuities) are mortality and investment returns. Climate change is expected to impact on both.

The CRO Forum (2019) reviewed the exposure of life insurers to climate change and concluded that climate change has the potential to lead to: adverse claims experience, deterioration of macroeconomic conditions and lower new business sales of life insurance. An additional risk is that customers lapse their cover following a natural disaster due to financial difficulties. Some Australian life insurers have recognised and responded to this risk. For example, TAL waived premium payments for up to two months to help customers affected by the 2019 Queensland floods and Tasmania bushfires (Insurance News, 2019).

Section 2 showed that climate change is expected to increase mortality in Australia, particularly among the older population, because of more frequent and intense heatwaves. The projected mortality impacts have the potential to impact the cost of life insurance and annuities. Higher levels of mortality, in isolation, would increase the cost of life insurance, and reduce the cost of annuities. The impact on life insurers of increased mortality should be kerbed by their lower exposure beyond age 65, however, as the impact of climate change on mortality under age 65 is expected to be limited.

It is misleading to look at the impacts of heatwaves in isolation because climate change will have wide-ranging direct and indirect physical impacts, as well as socio-economic implications, that will affect life insurers. This range of impacts on life insurance is illustrated in Figure 1. The risk that climate change presents to investment returns is discussed further in the next section.

Figure 1: How life insurers are exposed to climate change

Physical impacts		Socio-economic impacts		Impacts on life insurance
Direct	**Indirect**	**Social**	**Economic**	
• Heatwaves • Storms • Floods • Bushfires • Droughts	• Air pollution • Water and food supply • Diseases	• Health infrastructure • Emergency services • Social services	• GDP growth • Investment returns • Employment • Tax increases (e.g. infrastructure repair)	• Claims experience • Premiums • Lapse rates / Retention • Investment returns • Insurability • New business

Source: Authors' compilation

3.2 Impact on economic growth and investment returns

Climate-change poses a risk to economic growth and investment returns. Economic impacts occur through two main channels: physical damage arising from more frequent and intense natural disasters and higher temperatures ('physical risk'), and the risks associated with transition of the economy from dependence on fossil fuels to a low-carbon economy ('transition risk').

3.2.1 Physical risk

The extent to which natural disasters have an adverse effect on the economy has been subject to debate. The empirical literature shows mixed results, but recent meta-analyses suggest that the effect of natural disasters on GDP has been negative and increasing (Klomp and Valckx, 2014). On the one hand, natural disasters can destroy productive capital, causing a negative deviation from the economy's long-term growth path. On the other hand, such shocks can stimulate the economy and lead to higher long-term growth if the event accelerates capital stock upgrades. Past events show that in the short term, disasters have a negative impact on output, income, and employment, but subsequent recovery spending may lead to higher output and employment (Bally, 2011). While the 'recovery spending' effect means that moderate disasters can have a growth effect in some sectors, research shows that severe disasters do not lead to higher long-term growth (Loayza et al., 2012). As natural disasters become more frequent and more intense some economies may struggle to rebound.

Deloitte Access Economics (2013) estimated the tangible cost of natural disasters in Australia was $9 billion in 2015 (or 0.6% of GDP) and expected to rise to $23 billion a year by 2050, in 2011 prices, even without factoring in any increase in frequency or intensity of natural disaster events from climate change. The increase is driven by continued population growth, concentrated infrastructure density, and migration to particularly vulnerable regions. Any increase in frequency or intensity of natural disaster events from climate change would increase this cost. Wade and Jennings (2016), from Schroders, suggest that the impact of climate change on global economies could be a 1 percentage point reduction in GDP growth per year. They argue that lower growth will be caused by the combination of greater damage to property and infrastructure, lost productivity, mass migration and security threats.

Studies looking at the effect of historic temperature variations also suggest that a warming climate could negatively affect GDP growth (IMF, 2017; Carleton & Hsiang, 2016; Dell et al., 2014). Temperature shocks appear to affect growth via various channels, including lower agricultural and industrial output, higher energy demand and lower labour productivity. However, the relationships are complex, and most studies emphasise the greater impact on developing countries.

3.2.2 Transition risk

Results of investment modelling by Mercer (2015, 2019) demonstrate climate change will inevitably have an impact on investment returns under scenarios of global temperature rises this century of 2°C, 3°C and 4°C above pre-industrial levels. Mercer (2015, 2019) identify four channels by which climate change will impact investment returns:

1. **Progress and investment in technology to support a low-carbon economy**
2. **Physical impacts on investments of natural disasters**
3. **Resource availability**
4. **Policy**

In a 2°C scenario, average sector-level return impacts to 2050 are all negative except for renewables, infrastructure, and minor positives for materials, telecoms and consumer staples (Mercer 2019). In 3°C and 4°C scenarios, all sectors, apart from renewables, have negative return impacts to 2030, 2050 and 2100, with return impacts varying between -0.1% p.a. and -7.7% p.a. (Mercer 2019). Across all scenarios the sectors expected to be most negatively impacted by climate change are: Coal, Oil and Gas (Mercer, 2019). Weighting the sector-level returns to 2050 under a 2°C scenario (Mercer, 2019 p.47-48) by the ASX 200 market capitalisation by sector at 1 July 2019 gives a weighted average expected reduction in annual returns of around 0.7% p.a.

It is important to note that these results are only expected average sector-level returns. Individual stocks within a sector will move differently. In addition, variations in results between asset classes and across regions, as well as sustainable opportunities such as renewables, mean that climate change may have positive impacts for some investors.

Under almost all future scenarios, climate change has negative long-term return implications for investors who are not diversified at a total portfolio level to climate change.

The report also highlights that sovereigns such as Australia and New Zealand are expected to be more sensitive to the impact of physical damages and resource scarcity (Mercer, 2019); an added dimension that investors in Australian government debt should note.

Under almost all future scenarios, climate change has negative long-term return implications for investors who are not diversified at a total portfolio level to climate change (Mercer 2015, 2019). The fact that many institutional investors are rebalancing their portfolios to address climate change risk lends support to this finding.

3.3 Impact on retirement incomes

There are several consequences of climate change that may impact on individuals' accumulated superannuation balances at retirement:

- **Income risks:** The economic transition required to combat climate change is likely to lead to the loss of jobs in carbon-intensive industries. The transition is also forecast to create millions of new job opportunities that will offset losses in traditional industries (ILO, 2018). In cases where individuals lose a job and need to retrain, however, this may mean a period of lost income and superannuation contributions.

  In addition, natural disasters can result in financial losses for individuals. Insurance can ease the financial burden, but there are challenges involved in ensuring both the affordability and sufficient coverage against disaster risks in a changing climate (OECD, 2015). Under-insurance may lead to the erosion of savings and/or gaps in superannuation contributions following a natural disaster if either (a) households' savings are diverted into repairing personal property or (b) business disruption leads to a drop in employment income[3].

- **Return risks:** The negative long-term return implications of climate change for investment returns, outlined in the previous section, have the potential to negatively impact retirement incomes. A greater number or severity of such shocks can compound and reduce individuals' accumulated superannuation savings.

Post-retirement, in Australia, a typical individual's total retirement income is the sum of any Age Pension income they receive plus the draw-down of their accumulated superannuation balance. The Age Pension is means tested, so any losses that push an individual's accumulated superannuation balance or superannuation income in retirement below certain asset or income test thresholds[4] will increase an individual's entitlement to the Age Pension (Age Pension income).

3 Following the Brisbane floods in 2011 there was a fall in the labour force participation rate equivalent to an extra 18,000 people out of work each month (Queensland Treasury, 2011). Many of those that continued to work saw reduced hours. In one survey, 17% of adults in Queensland reported experiencing lower income in the aftermath of the flooding (Clemens et al., 2013). Reduced employment income or draw-down of savings impacts retirement funding.

4 For example, based on thresholds in place in March 2019, a single non-homeowner, could receive a full Age Pension if their assessable assets were below $465,500; a part Age Pension, which reduces as assets increase between $465,500 and $771,000; and no pension if they had assets beyond $771,000. Similarly, a single person could receive a full pension with an annualised assessable income below about $4,500; a part pension, which gradually reduces as income increases to about $52,000; and no pension with income beyond. The actual level of pension received depends on the lower of the asset and income tests.

To gain an insight about the potential impact of climate change on individuals' retirement incomes we estimate a baseline scenario of superannuation and Age Pension income, for each percentile of the full-time earnings distribution, and compare this with two 'what if' scenarios designed to illustrate the potential impacts of climate change on retirement incomes:

- **Scenario 1** is designed to illustrate the income risks of climate change (economic transition risks and natural disaster risks). It models the effect of a periodic loss of employer contributions into an individual's superannuation account one year in every 10 (Figure 2), equivalent to approximately a 10% reduction in lifetime employer super contributions[5].
- **Scenario 2** models the effect of lower investment returns on superannuation, which are assumed to decline by 1 percentage point[6] from a nominal return of 4.8% p.a. (ASIC's default return assumption for a Balanced portfolio) to 3.8% p.a. (Figure 3).

The results of Scenario 1 show that with a loss of employer contributions once every 10 years, accumulated superannuation balances and average retirement income are expected to drop by about 11% (Table 2) and 2% (Figure 2) respectively, though this varies across the earnings distribution. Retirement income would decline by just over $900 per year for a median earner, in today's wage terms. The lower reduction in retirement income compared to accumulated superannuation savings (2% vs 11%) occurs because the government funded Age Pension hedges an individual's retirement income against lower investment returns.

The impact of Scenario 2, 1 percentage point lower investment returns, is greater than Scenario 1. That is, a 1 percentage point drop in investment returns could be expected to lower accumulated superannuation balances and retirement income of a worker on median earnings by 18% (Table 2) and 5% (Figure 3) respectively. In dollar terms, this equates to a decrease in retirement income of about $2,000 per year for the median earner. The decrease in retirement income is lower than the decrease in superannuation balances and superannuation income (as shown in Figure 3) because, again, the Age Pension offsets superannuation losses, providing a safety net for individuals.

Table 2: Effect on accumulated superannuation savings of climate-risk related scenarios at the median of the full-time earnings distribution

	Annual income	Investment return	Superannuation accumulation at age 67 (% change from base)
Baseline	$75,000	4.80% p.a.	$382,000
Scenario 1	$75,000 but $0 p.a. once every ten years	4.80% p.a.	$341,000 (-11%)
Scenario 2	$75,000	3.80% p.a.	$313,000 (-18%)

Note: Table 2 shows expected accumulated superannuation balances in current wage terms (rounded) for an individual who starts working at age 20 in 2018, works full-time at a given point in the earnings distribution until age 67, and accumulates mandated superannuation. The median full-time worker is assumed to earn $75,000 p.a. Assumptions of real wage inflation (1.2% p.a.), price inflation (2%p.a.), fees ($50 p.a. + 1.1%p.a.), tax on investment earnings (6.5% p.a.) and returns (4.8% p.a.) are based on those provided by the Australian Securities and Investments Commission. Income is based on the median weekly earnings of all Australians as at August 2018 (ABS, 6333.0 - Characteristics of Employment, Australia, August 2018).

5 The choice of 1 in 10 years is illustrative, it is not based on climate forecasts and damage functions because these are not available at present. The last ten years of Australian economic transition and natural disaster experience broadly support the feasibility of this scenario. Within the last ten years: (a) there have been widespread job losses in South Australia and Victoria linked to closure of car manufacturers and coal-fired power stations (b) Queensland has experienced two large scale flooding events, the 2011 Brisbane floods and the 2019 Townsville floods, damages from Cyclone Debbie in 2017, and flash flooding in 2013. Looking to the future, extreme rainfall events are projected, with high confidence, to increase in intensity (CSIRO and BoM, 2015; Rafter and Abbs, 2009) and other natural disasters such as bushfires, tropical cyclones and storms are projected to increase in frequency and/or intensity (Reisinger et al., 2014).

6 The choice of a 1% reduction in investment returns is illustrative but plausible based on the projections in Mercer (2019) and Wade and Jennings (2016). Actual investment returns could be higher or lower and highly sensitive to portfolio construction.

Figure 2: Effect on average retirement income of climate-related losses of employment income – Scenario 1, across the full-time earnings distribution

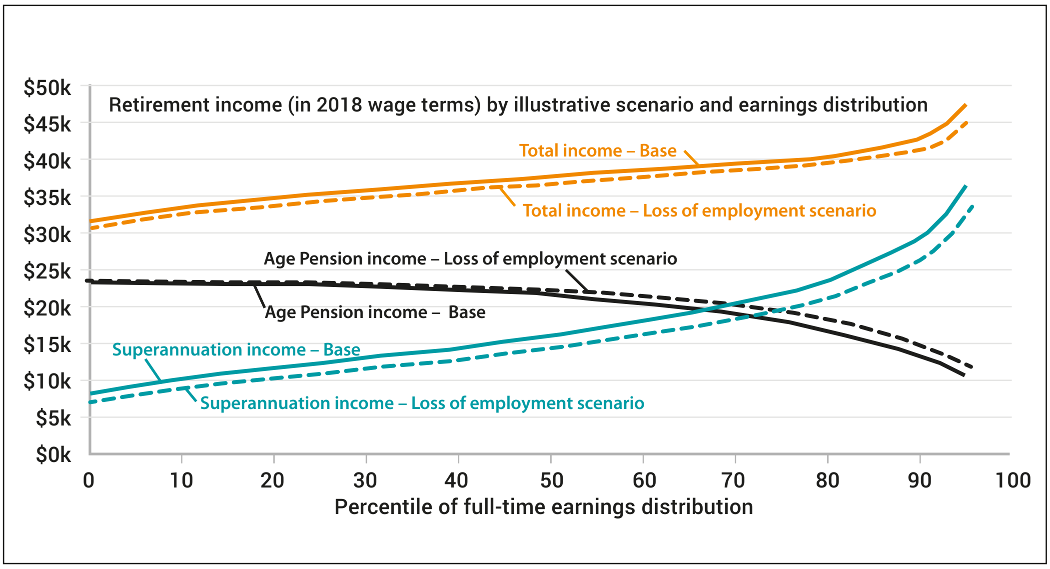
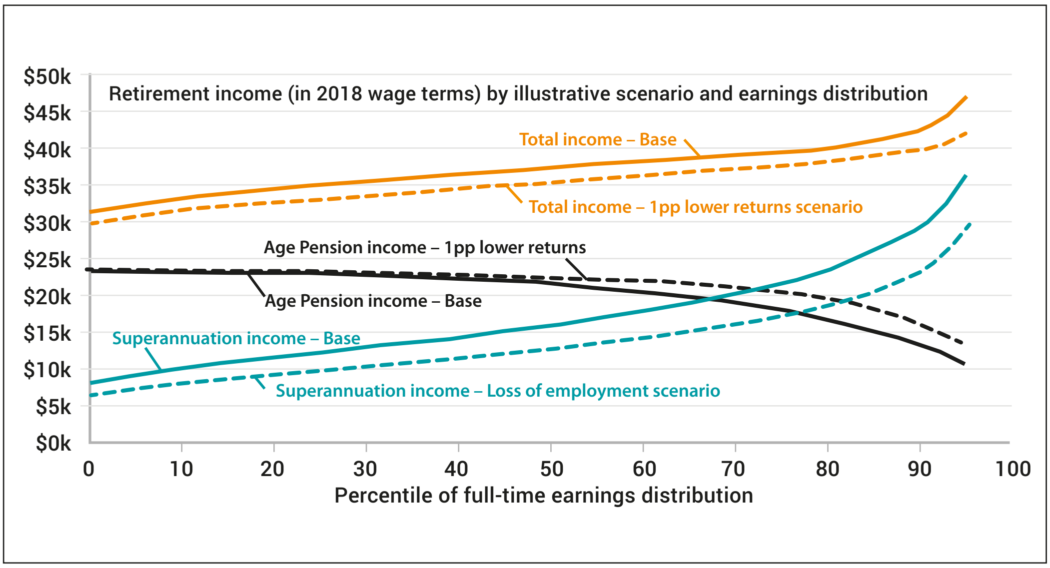


Figure 3: Effect on average retirement income of climate-related losses of investment returns – Scenario 2, across the full-time earnings distribution



Note: Figures 2 and 3 show average retirement income in current wage terms for an individual who starts working at age 20 in 2018, works full-time at a given point in the earnings distribution until age 67, accumulates mandated superannuation, runs this down by age 92 and then receives the Age Pension (as a homeowner) according to a wage-indexed, future means test in line with 2018 parameters. Assumptions of real wage inflation (1.2% p.a.), price inflation (2% p.a.), fees (1.1% p.a.), and returns (4.8% p.a. before fees) are based on those provided by the Australian Securities and Investments Commission. Post-retirement, the assumed nominal return after retirement is 2.9% p.a. after fees. See Chomik and Piggott (2016) for further details.

The declines in an individual's total income vary across the earnings distribution because of the Age Pension means testing rules. The Age Pension hedges those at the bottom of the earnings distribution against shocks to superannuation savings but provides no protection for individuals with assets and income above the means test limit. At the bottom of the earnings distribution, those who already receive the maximum Age Pension are not compensated for lower superannuation income, those in the middle see a greater amount of Age Pension replacing superannuation losses, while self-funded retirees will not receive any Age Pension until their assessable assets fall below the assets test limit. (The average Age Pension income in Figures 2 and 3 is above zero for the highest earners because it is assumed that individuals spend down their superannuation over time, so even the very rich become entitled to a partial Age Pension in their last few years.)

3.4 Impact on costs to government

For the government, lower accumulated superannuation savings at the point of retirement (driven by lower investment returns pre-retirement) mean higher eligibility for, and therefore higher fiscal expenditures on, the Age Pension. In Scenario 1 and Scenario 2 the present value[7] of extra Age Pension expenditure on the median earner is estimated to be $20,000 to $30,000 respectively, assuming current levels of population mortality.

The change in the long-term cost of the Age Pension is a function of both investment returns and population mortality rates.

The change in the long-term cost of the Age Pension is a function of both investment returns and population mortality rates. Higher mortality post-retirement, a potential consequence of climate change, would mean the Age Pension would be paid for fewer years on average and fiscal expenditures on the Age Pension would reduce. Lower investment returns pre-retirement will increase Age Pension eligibility for individuals whose accumulated superannuation savings fall below the means test limits (as shown in Figure 3). In addition, for a given level of Age Pension eligibility, lower long-term government bond yields (risk-free rates) increase the present value of government liabilities in respect of the Age Pension.

Table 3 shows how the present value of government liabilities in respect of the Age Pension (used here as a proxy for the cost to government of the Age Pension) changes as the risk-free rate and mortality rates change. The results show that with a 1 percentage point drop in the risk-free rate the annuity cost goes up, unless mortality rates increase by 1 percentage point or more. Vice versa, with a 1 percentage point increase in excess mortality the annuity cost goes down, unless the risk-free rate decreases by 1 percentage point or more.

Table 3: Present value of a lifetime annuity of $1 paid from age 67, shown for a range of discount and mortality rates

Excess mortality	**Risk-free discount rate p.a.**				
	1%	2%	3%	4%	5%
0% (ALT 2010-12 Males)	$16.3	$14.8	$13.4	$12.3	$11.3
1% (ALT 2010-12 Males + 1%)	$14.8	$13.4	$12.3	$11.3	$10.4
2% (ALT 2010-12 Males + 2%)	$13.5	$12.3	$11.3	$10.4	$9.6
3% (ALT 2010-12 Males + 3%)	$12.3	$11.3	$10.4	$9.7	$9.0
4% (ALT 2010-12 Males + 4%)	$11.3	$10.5	$9.7	$9.0	$8.4

Lower discount rates (long-term Aus. Govt bond rates) increase the present value of government liabilities in respect of the Age Pension

Higher pensioner mortality rates (ages 67+) decrease cost to government of Age Pension

Note: The annuity is not indexed. Mortality is ALT2010-12 Male rates, plus the excess mortality indicated in the first column. The yellow cell, with value $14.8, is the present value of a lifetime annuity of $1 paid from age 67, using mortality rates (ALT2010-12 Males) and the 10-year Australian Government bond rate current as at writing, in March 2019.

7 Present value is the lifetime cost in today's wage terms.

With ongoing improvement in public awareness and risk mitigation, the amount of excess mortality from climate change should be limited. Climate change, however, could have negative long-term return implications for investors and governments, and it is more complicated to mitigate this risk. In addition, a drop in long-term returns would have a compounding impact on government finances, increasing both Age Pension eligibility in the population and the present value of future Age Pension expenditures for a given level of eligibility. Conversely, higher long-term government borrowing rates would decrease the present value of Age Pension expenditure. It is possible that climate change could drive higher government borrowing costs if the government must borrow more to repair or rebuild infrastructure damaged by natural disasters or invest heavily in climate change adaptation (such as building levees in flood prone areas).

Failure to address climate change has been identified as one of the largest socio-economic risks to modern society and lack of action on climate change is no longer just a reputation risk; it is a core business issue being discussed in terms of physical risks, liability risks and transition risks.

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4. The role of Actuaries, the financial sector and public policy

Failure to address climate change has been identified as one of the largest socio-economic risks to modern society (World Economic Forum, 2016; Lloyd's of London, 2017). Lack of action on climate change is no longer just a reputation risk; it is a core business issue being discussed in terms of physical risks, liability risks and transition risks (The Geneva Association, 2018). The insurance industry plays a critical role in building socio-economic resilience and enabling entrepreneurial pathways for achieving climate change mitigation and adaptation (The Geneva Association, 2018). Internationally, the insurance industry is building this resilience by, for example, providing risk pricing expertise and offering innovative risk transfer products and services.

Due to the long-term nature of life insurance, superannuation and retirement incomes, actuaries will have to come to grips with the future effects of climate change and start efforts to limit the adverse effects of climate change on their organisations. In addition, there is mounting pressure on all financial institutions from investors and regulators to improve transparency and the disclosure of climate-related risk.

- In 2017, the Taskforce on Climate-related Financial Disclosures (TCFD) recommended a single international cross-industry standard for disclosing climate risk in the mainstream financial reporting of companies designed to assist financial markets to allocate capital more efficiently, and create more resilient economies (Paddam and Wong, 2017). While these disclosures are voluntary at present, several Australian financial institutions, such as VicSuper and UniSuper, have already released Climate Change Reports in accordance with the TCFD recommendations.

- In Australia both ASIC and APRA have made it very clear that they are increasing their scrutiny of how companies manage and disclose the risks that climate change poses (climate risks) to listed companies and regulated entities. APRA will be increasing the intensity of its supervisory activity to assess the effectiveness of entities' climate risk identification, measurement and mitigation strategies (Paddam and Meyricke, 2019).

In light of these developments, insurers, superannuation funds and institutional investors should embed climate change as a core business issue and continue to build their financial resilience to climate change, thereby protecting individuals.

In terms of public policy, the wide-ranging consequences of climate change on mortality, public health and the economy mean that system-wide policy responses (across the health system, aged care services, emergency services and other social services) are necessary to mitigate the risks posed. In relation to the risks posed by more frequent and intense heatwaves, a number of health related bodies have begun to respond to climate change in Australia; current responses include measures to prepare the public for heatwaves and natural disasters and building infrastructure for a hotter climate (O'Shea, 2017).

Climate change and population ageing are the perfect storm. It is now time to act.

Climate change and population ageing are the perfect storm. Without proper risk management these megatrends have the potential to overwhelm individuals, private companies and government balance sheets over the course of this century. Enough forewarning has been given, it is now time to act.

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