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Retirement explainer series

Longevity uncertainty

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David Bell, Gaurav Khemka[1] & Geoff Warren

Technical rating

Boffin

Industry professional

Novice

Brief synopsis: We explore the nature of uncertainty over how long that retirees might live and its implications for longevity risk, modelling of retirement outcomes, retirement solution design and member communications. We explain the measurement of life expectancy and survival/mortality probabilities, and the implications for providers addressing a member pool and individual retirees. Two treatments of horizon are outlined, including working to a fixed planning horizon and applying survival weights; and the impacts on retirement solution design are illustrated. We discuss addressing longevity risk through retirement solutions, and engaging with members over longevity risk and related concepts. Finally, we argue superannuation (super) industry practices around longevity need uplifting.

Questions addressed:

1. What is longevity uncertainty?
2. What are implications for management of longevity risk and the horizon over which retirement outcomes such as income should be delivered?
3. How might the planning horizon be treated when modelling and presenting retirement outcomes?
4. What are the implications for design of retirement solutions?
5. How might super funds engage with members over longevity uncertainty?

Key terms: Retirement Income Covenant, longevity uncertainty, longevity risk, life expectancy, survival and mortality, planning horizon, time preference, retirement solutions, longevity protection, engagement and communications

Who should be interested? Retirement specialists, retirement leads, financial modellers, product designers, member experience personnel, financial advisers, regulators, aspiring actuaries, people wanting a career in retirement income.

Introduction

No-one knows for sure when they are going to die. The consequence of this 'longevity uncertainty' is that a retiree does not know how long their assets need to last. This in turn gives rise to 'longevity risk' or the possibility that they might outlive their savings and thus be unable to sustain a desired level of spending. This explainer outlines the implications of longevity uncertainty for super funds and their retired members. We consider why this topic matters, how longevity uncertainty is measured, and how it might be addressed when modelling retirement outcomes, designing retirement solutions and engaging with members.

[1] Dr Gaurav Khemka is an Associate Professor of Actuarial Studies at the Australian National University.

Why this topic matters

Longevity uncertainty is a fundamental issue in retirement that needs to be addressed by both super funds and their members. The Retirement Income Covenant[2] (RIC) intersects with longevity uncertainty in two ways. First, trustees are required to assist beneficiaries to achieve and balance three objectives of maximising expected income, managing risks to that income and providing flexible access to funds "*over the period of retirement*", which needs to be defined. Second, the RIC lists longevity risk as first on the list of risks to be managed.

The RIC obligation to assist members with their retirement requires super fund trustees to address longevity uncertainty from at least three directions. First, is that the meaning of the period of retirement – which we refer to as the 'horizon' – must be determined under conditions of uncertainty of how long members may live.[3] Second, super funds need to establish how horizon is addressed when modelling retirement outcomes and then presenting them to members. Third, super funds should ideally be assisting members to understand longevity uncertainty and the trade-offs that it generates. This explainer aims to unpack these issues.

Measuring longevity uncertainty

A guide to longevity uncertainty is found in the 'life tables' compiled by the Australian Government Actuary (AGA), which provide estimates of both life expectancy and the probability of survival or death with age for average Australian males and females. Figure 1 presents the AGA estimates of probability of surviving to selected ages viewed from the perspective of a female at age 67. Figure 2 plots the probability of death in each year up to age 110. Note that life expectancy for males is projected at about 2-3 years less than females.

The AGA tables suggest that an average female aged 67 is expected to live to about age 89, or age 90-91 with 'mortality improvement', i.e. adjusting for the rate that life expectancy has increased historically. However, an individual might (and indeed is likely) to die earlier or later than their life expectancy. For example, the typical female has around a 41% chance of living to age 92 and 17% to age 97 allowing for mortality improvements. Figure 2 shows that the probability of dying in any year rises progressively and moves above 25% after age 99.

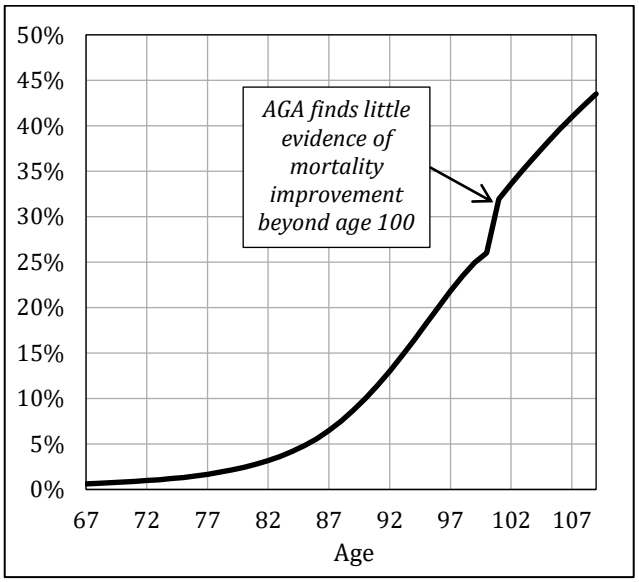
Figure 1: Probability of survival to selected ages for average Australian female currently aged 67

Survival to age:	No. of years	Mortality improvement	
		None	Included
72	5	96.0%	96.3%
77	10	89.5%	90.6%
82	15	78.3%	81.1%
87	20	60.0%	65.2%
92	25	34.7%	41.0%
97	30	12.3%	16.6%
102	35	2.3%	3.8%
107	40	0.2%	0.4%

From Australian Government Actuary, Life Tables 2020-22
Mortality improvements based on 125-year factors

Figure 2: Probability of death per age

For Australian females, with mortality improvement



The key implication of longevity uncertainty is the horizon that a retiree should be planning for is uncertain and indeed should be considered random (i.e. stochastic). Below we focus on the implications of this uncertainty in practical settings, including how it might be addressed in retirement solution modelling and design as well when engaging and communicating with members.

Breakout box #1 overviews some concepts around life expectancy including mortality improvements, how life expectancy varies with age and other personal characteristics, and how life expectancy differs for groups of people and individuals.

[2] See Section 52AA of the SIS Act (1993).

[3] Determining the period or retirement and hence planning horizon becomes even more complicated for couples, when the concern may shift to the time of death for the last surviving partner.

Break-out box #1: Life expectancy - Key concepts

- *Life tables* – Life tables are created by the AGA using historical mortality data. They provide estimates of the probability of death/survival over a given future age for male and females of all ages. Medium and long-term mortality improvement factors are also provided.
- *Mortality improvement* – Over time people have tended to live longer due to improvements in lifestyle and medical advances. Hence, when using life tables to project future mortality rates, allowance should be made for potential improvements in mortality to provide better estimates.
- *Conditional life expectancy* – This is the number of years an individual is expected to live given their current age. As individuals age, their expected age of death increases while their remaining years of life expectancy decreases. For example, life expectancy for Australian males is currently about 81 years at birth; but 67-year old males are expected to live to about 85.5 years equating to a life expectancy of 18.5 years without mortality improvement. If a male makes it to 85 years old, they are expected to live to 92.5 and their life expectancy is about 7.5 years.
- *Life expectancy varies with personal characteristics* – The AGA mortality estimates represent 'average' mortality rates across the entire population of Australian males and females. Studies show that individual level mortality experience may vary with other characteristics[4]. For example, smokers and blue-collar workers tend to die younger; while those with higher education, more wealth and in white collar jobs tend to live longer. Providers of longevity insurance need to take into account the characteristics of the pool of members being insured.
- *Population vs. individual longevity uncertainty* – An insurance company or a super fund that is providing longevity insurance through say a lifetime income stream (see Explainer #9) may average across members to arrive at expected population mortality on the basis that individual characteristics will tend to 'average' out for the group. However, individual members are exposed to uncertainty over how long they themselves will live, i.e. they carry idiosyncratic longevity risk. Population life expectancy is hence of much less relevance for individuals, who need to consider the risk that they could either die earlier or live longer than their life expectancy. For instance, they may live to age 100 or die in the next year. This provides unique challenges for retirement planning and how individuals view the issue of horizon.

Perspectives on longevity uncertainty

For context, we first distinguish the differing implications of longevity uncertainty for individual members, providers of retirement products and solutions, and those guiding or advising members.

- **Members** – Retirees individually face longevity risk as a consequence of not knowing how long they (or their partner) will live. The possibility of outliving their finances and being unable to support a desired standard of living means that individual retirees might be concerned with managing the possibility of surviving to a quite old age. Meanwhile, the concept of life expectancy is of limited use to members, except as a general guide.
- **Providers** – Providers of retirement solutions and products, including super funds and insurers, need to consider two issues:
  - Lifetime income stream (LIS) providers should be concerned with the mortality experience of pools. For them, life expectancy for the pool is a meaningful concept.
  - Providers of retirement solutions such as super funds and financial advisers are catering for individuals (or couples). They need to incorporate and cater for the longevity uncertainty faced by the member in designing the retirement solutions they offer.
- **Advice, guidance and education** – Those providing financial guidance, advice and education – including super funds, financial advisers, and others – face various challenges in communicating issues around longevity. These include describing longevity uncertainty and its implications, soliciting preferences over the trade-offs around longevity, and accordingly recommending a suitable retirement solution.

Two approaches to addressing horizon

Super fund trustees need to determine how horizon is treated to meet their obligations under the RIC and assist members in understanding their choices and options for retirement. Two broad approaches are assuming a fixed planning horizon and weighting outcomes by the probability of survival.

Approach #1: Fixed planning horizon

This entails setting a notional target age that acts as a 'planning horizon'. This is the more common approach in the super industry for modelling and presenting retirement outcomes. Horizon is often struck beyond life expectancy with the intent of allowing for a confidence interval, e.g. modelling to an age with x% probability of survival. A common choice is age 92, which ASIC uses in Moneysmart and has nominated as the default setting for financial calculators[5]. Issues under this approach include:

[4] For example, see Clarke and Leigh (2011).

[5] See RG 276, Superannuation Forecasts.

- *Simplicity* – A key advantage of a fixed planning horizon is that it is easy to understand. Also, the modelling can be more straightforward under the goal of delivering income to a specific age.
- *Draws attention away from what could happen beyond the horizon* – Planning to a specific age like (say) 92 excludes and hence draws attention away from what could happen beyond the horizon, including the consequences of living to older ages. While this issue might be partly overcome by placing value on having some residual assets left over at the end 'just in case', this is a very blunt way of addressing longevity risk. The value of LIS for hedging longevity risk beyond the horizon also becomes obscured.
- *Adopting a planning horizon to a very old age creates other issues* – Analysis of what happens at older ages may be facilitated by adopting a very long horizon with a small chance of survival, say age 100 to age 110. The problem is that presenting income across time as if it is equally valuable may encourage underspending during retirement to ensure that income lasts. This may occur because two aspects are being obscured. First, income incurred earlier in retirement may be more valuable as members are more likely to be alive and capable of enjoying that income. Second, is how longevity protection mechanisms like the Age Pension and social security benefits such as health and home care act to help hedge against the consequences of loss of other income at older ages.

Approach #2: Survival (mortality) weighting

This approach entails weighting outcomes by the probability of survival to each age, i.e. adjusting for the likelihood the outcomes will be enjoyed. This supports generation of an 'expected' outcome (or perhaps expected utility of those outcomes), which may be used to compare candidate retirement solutions. Survival weighting is widely used in the academic literature but is much less common in industry. Issues with this approach include:

- *Coherent treatment of 'value' across time* – Survival weighting accounts for the differing 'value' of outcomes that are spread across time by adjusting the likelihood that they might be experienced.
- *Harder to understand* – Generating an expected outcome (or expected utility) by applying survival weights can seem like a black box. Most members (and perhaps management and boards) may be confused by probability weighted outcomes presented as a single overall 'score'.
- *Favours strategies that deliver to life expectancy* – Applying survival weights has a similar impact to applying population life expectancies. For example, indications of the appropriate income to draw tend to be similar under survival weights and fixed horizons equal to life expectancy (see example 1 below). The potential value of restricting income to hedge against longevity risk thus becomes obscured. On the other hand, survival weighting still places value on a LIS by accounting for the (probability-weighted) benefit that arises if the retiree lives to older ages.

Which approach is better?

There is no 'best' treatment of horizon for modelling and presenting retirement outcomes. Neither a fixed planning horizon nor survival weights adequately address the fact that the actual age to which a retiree will live is unknown and this needs to be managed.

Fixed planning horizons are easier to understand. But by creating an impression that outcomes over time of equal value, they run the risk of misrepresenting longevity uncertainty and related trade-offs. A shorter horizon such as age 92 fails to reveal and value what could potentially happen beyond the planning horizon. Modelling to a very old age like 100 to 110 can inadvertently lead to placing too much weight to outcomes late in retirement that are unlikely to be experienced.

Survival weighting aligns with RIC notion of focusing on 'expected income'. However, it does not gel with how members often think about retirement. Weighting by survival can inadvertently obscure the value of protecting against the (idiosyncratic) risk of the member surviving to a very old age by weighting outcomes towards life expectancy, even though this value is embedded in the expected outcome.

There may be scope for applying differing approaches in different settings. For instance, survival weighting could be used for purpose of modelling retirement solutions, while a fixed planning horizon is used when presenting the resulting retirement outcomes to members and others. We discuss engaging with members below.

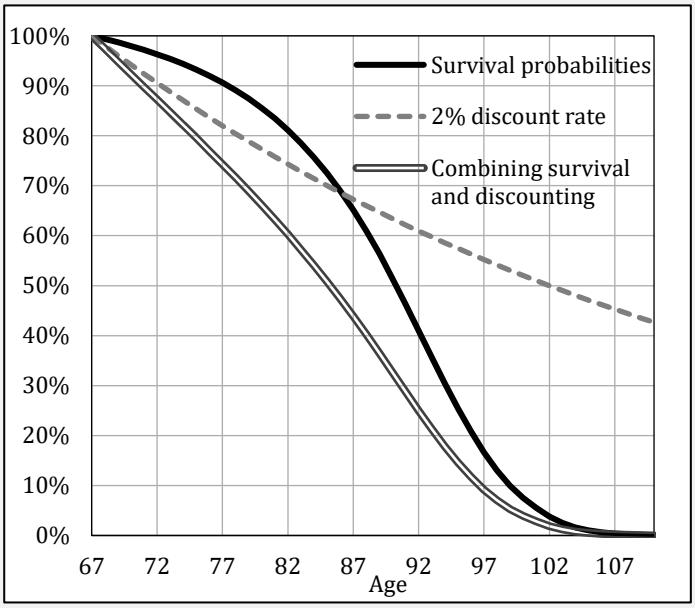
Time preference

The issue of weighting outcomes over time extends to the question of whether adjustments should also be made for time preference, i.e. the possibility that members prefer outcomes sooner rather than later. We discuss this matter in Break-out box #2 (see over), including the possibility that a time discount rate might be applied in conjunction with survival weighting (as applied in most academic research). In the box we argue the case for incorporating only survival weights and excluding time discounting.

Break-out box #2: Applying time preference

Discounting for 'time preference' is common in the academic literature, and is done on the basis that individuals prefer spending sooner rather than later. The effect of applying time preference in conjunction with survival weighting would be to compound the discounting of outcomes occurring at older relative to younger ages. Figure 3 plots the weights placed on future outcomes arising from applying survival probabilities, a 2% discount rate and the combination of both, viewed from the perspective of a female aged 67. For example, the weights applied to outcomes when both adjustments are applied falls below 20% after age 93 and continues to decline. Under the combined approach, outcomes earlier in retirement would tend to be the dominant contributor to the expected outcome.

Figure 3: Outcome weights from combining survival probabilities and time preference



There is an argument that incorporating time preference might discount outcomes later in retirement too heavily. The contrary position is that retirement surveys point to high concern over the risk of running out of assets and hence income, hinting that retirees may consider income later in retirement of equal importance to that experienced earlier in retirement. While academic research often finds evidence to support time preference more broadly, there is a lack of research on preferences around present versus future in a retirement context when drawing more income earlier may lead to cessation rather than just less income later on.

Meanwhile, the justification for survival weighting is that it directly speaks to the probability of experiencing the outcome and hence is consistent with the idea of estimating an expected value. Nevertheless, these are just our thoughts. More research is required to better understand the issue of how time-weighting might be applied in retirement.

Longevity risk and retirement solutions

When it comes to designing and offering retirement solutions (see Explainer #7), a key issue to be addressed is the member's need for longevity protection and how it is best delivered. This will depend on the member's situation and preferences. Here we scope out the issues that come into play.

Longevity protection can arise from various sources, including the following:

- Age Pension and other forms of social security, including subsided healthcare, aged care support such as home care packages and government-supported aged care, and senior discounts.
- Allocating to a LIS (see Explainer #9).
- 'Self-insuring' by restricting spending (or saving more during accumulation).
- Potential to receive support from other sources, e.g. bequests from aging parents and scope to rely on family or friends, if the need arises.

The question arises over whether it suffices for a member to rely on the Age Pension or other support mechanisms if they happen to live to a very old age, versus the need for taking longevity protection within their retirement solution such as allocating to a LIS or limiting income that is drawn. Treatment of horizon can play a role in how these various options are modelled, evaluated and presented to members. We say more on communications further below.

Also relevant is that the income required to be delivered by a retirement solution often declines later in retirement for two reasons. First, retiree spending tends to decline with age[6]. Second, social security support tends to grow, most notably the Age Pension. Care thus needs to be taken not to overstate the call for longevity insurance based on the notion that income needs to remain unchanged.

Illustrative examples

We construct two examples to demonstrate how the treatment of horizon can indicate differing retirement solutions. Example 1 focuses on drawdowns, while example 2 examines the impact on allocation of available assets.

Example 1 – Horizon and drawdowns

Our first example is a simplified demonstration of how the treatment of horizon matters for the income drawn and hence the pattern of income over time.

[6] A range of academic and other research confirms the tendency for actual spending to decline with age. There is evidence that this occurs in part due to less desire or willingness to spend at older ages. A good reference on the latter is Hurd and Rodwedder (2023). For Australian evidence, see the Retirement Income Review (2020, pp.486-493) and Asher et al. (2017).

We form 'deterministic' projections by assuming a 'known' real return of 3% for an account-based pension (ABP) that is the only financial asset of a member who retires at age 67. We allow for access to the Age Pension (see example 2 for assumptions), although the Age Pension is not integrated into the drawdown calculations. Our analysis involves identifying the *static* real income amount that can be drawn from the ABP each year to just exhaust the account over a given planning horizon. The analysis is run for balances at retirement of $300,000 and $600,00 for three planning horizons:

- Age 87 or 20 years, which approximates life expectancy for a male aged 67 years
- Age 92 or 25 years, as used by ASIC Moneysmart and others in the industry
- Age 107 or 40 years, to cover the possibility that the member might live to a very old age

Figure 4 reports the real income drawn each year from the ABP under these differing assumptions. The longer the planning horizon the less income is drawn so that income will last the distance. Higher income is affordable with a higher balance.

Figure 4: Income to exhaust ABP over fixed planning horizon with deterministic modelling

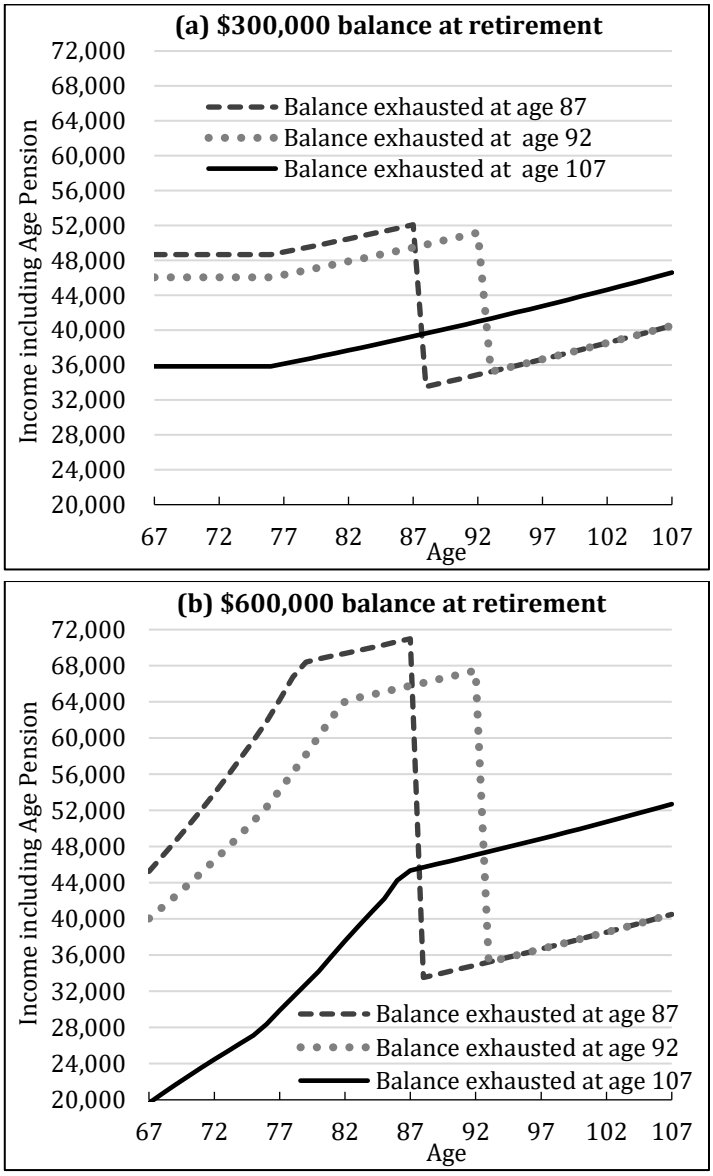
Planning horizon	Balance at retirement	
	$300,000	$600,000
Age 87	18,895	37,789
Age 92	16,293	32,585
Age 107	6,099	12,197

Figure 5 shows the shape of total income that may be experienced as the member ages. Modelling to shorter horizons boosts income earlier in retirement, but creates exposure to longevity risk beyond the planning horizon as income dislocates down to the Age Pension. Lengthening the planning horizon shuffles income from earlier in retirement to later in retirement, which is experienced *only if* the member happens to survive.

The upward slope in income for the $300,000 balance is attributable to Age Pension indexation. For the $600,000 balance, interaction with the Age Pension under means testing acts to reduce income earlier in retirement and then generate increased income later as Age Pension payments rise as the balance runs off and indexation kicks in. (This shows what might happen if the Age Pension access is not integrated into drawdown decisions!)

Implicit in this analysis is a message that treatment of horizon can embed assumptions about how income should be traded off across time. Modelling to longer horizons implicitly assumes that the retiree is happy to reduce the income drawn and hence their expected income in order to protect against living to an old age. This increases the likelihood of a member dying without having fully enjoyed their savings by spending them while alive. Modelling to shorter horizons aligns with a member being content to spend earlier and bear some longevity risk and/or rely on the Age Pension if they survive. Of interest is that age 87 approximates life expectancy and generates similar results to analysis under survival weights[7].

Figure 5: Total income including the Age Pension over fixed horizons and deterministic modelling



[7] We estimated the fixed amount of income that maximised survival weighted expected income. The indicated amount was indeed the same as for the fixed planning horizon to age 87.

The above results are unsurprising. But they serve to underline that treatment of horizon is far from innocuous and can embed implicit assumptions about how spending earlier is traded off against restricting spending to help address longevity risk.

Example 2 – Horizon and allocation of assets

The aim of our second example is to illustrate how treatment of horizon can impact on asset allocations within retirement solutions under uncertainty over investment returns. Our analysis identifies 'optimal' allocation of the balance at retirement between a growth portfolio, a defensive portfolio and a real fixed LIS for a member with an income target (see Explainer #2) of $50,000 real income sourced from a combination of the Age Pension, LIS payments and drawdowns from an ABP containing the growth and defensive assets. We identify optimal allocations for a female aged 67 years with a $400,000 balance at retirement across four treatments of horizon:

- Fixed planning horizon of 20 years to age 87 (probability of survival to this age is 65%)
- Fixed planning horizon of 25 years to age 92 (probability of survival 41%)
- Fixed planning horizon of 35 years to age 102 (probability of survival about 4%)
- Applying survival weights

The full set of key modelling assumptions are set out in Break-out box #3 at top right.

Figure 6 presents the results. There is a considerable variation across treatments. A key differentiator is how the modelling picks up on and then manages the risk of failing to sustain the income target over the horizon, and hence by implication longevity risk. As the retiree has insufficient assets to sustain the income target with confidence, the modelling favours growth exposure as it offers high expected returns and thus boosts the chances of sustaining the income target. However, it also suggests taking exposures to limit the possibility of shortfall versus the target through allocating to either the defensive portfolio and/or the real LIS.

Figure 6: Optimal allocations for $400,000 balance

Allocation of assets available at retirement	Horizon treatment			
	Fixed, age 87	Fixed, age 92	Fixed, age 102	Survival weights
Growth portfolio	61%	87%	76%	82%
Defensive portfolio	32%	0%	0%	0%
Real LIS	7%	13%	24%	18%
TOTAL	*100%*	*100%*	*100%*	*100%*

Break-out box #3: Key modelling assumptions

- Single female retiring at age 67
- Super of $400,000 is the only financial asset
- Homeowner
- Income target of $50,000 p.a. (real)
- Available investments:
  - Growth portfolio, E[return] 5.5%, SD 12%
  - Defensive portfolio, E[return] 1%, SD 4%
  - Real fixed LIS

  Note: Investment fee of 1%; LIS loading of 20%[8].
- Age Pension and supplements; existing rules, 1% real growth occurs from age 77 (to account for Age Pension currently exceeding the ratio of male total full-time average weekly earnings at which wage-based indexation becomes operable)
- 125-year mortality improvements applied
- Preferences:
  - Reference dependent (prospect theory) utility[9]
  - No time preference
  - No value placed on flexible access to funds
  - No value placed on bequests
- We undertake 'time zero' optimisation where the allocation strategy is set at age 67 that provides maximum expected utility looking forward. Rebalancing the growth/defensive mix back to target weights is the only subsequent adjustment.

The main takeaway is that the way in which the allocation to defensive exposure occurs varies with treatment of horizon. Under the shortest planning horizon to age 87, a 32% allocation to the defensive portfolio is favoured, coupled with 7% to the real LIS. This implies that risk of shortfall can be adequately managed through using defensive assets to dilute investment risk and hence limit the possibility that the ABP runs out before age 87.

Under other horizon treatments, only the real LIS is used. This reflects that the LIS helps to hedge longevity risk over longer periods through access to 'mortality credits' (see Explainer #9). The LIS ensures that some income is sustained, whereas assets within the ABP face the risk of running out at older ages. The allocation to the real LIS reaches its maximum of 24% over the fixed planning horizon to age 102, where the greatest value is placed on being able to secure income through mortality credits. Applying survival weights acts to dilute the benefit of sustaining income to older ages, but nevertheless results in an 18% allocation to the real LIS.

[8] For details, see Ai, Butt and Khemka, G. (2024).

[9] Tversky and Kahneman (1992).

Engaging with members

Engaging with individuals that have potentially poor longevity literacy in ways that help them understand the risks and trade-offs they face can be quite challenging. We initially discuss longevity literacy before addressing communicating with members.

Longevity literacy is poor

Most people have very poor understanding of how long they are likely to live, often having either no idea or distorted expectations[10]. Research finds that people tend to underestimate life expectancy prior to and earlier in retirement, and then overestimate how long they have remaining to live at older ages[11]. There is a case for super funds to provide education on longevity and longevity risk[12], which studies[13] show can have an impact. More research on longevity literacy is needed to better understand the issues and how to best deliver education.

Communicating with members

We offer some thoughts on how super funds might engage with their members over longevity risk and related trade-offs when communicating options for retirement. We do so with the caveat that how to best communicate with members over longevity uncertainty and its implications is an important gap in the literature and industry knowledge that requires further research, including member testing.

We suggest it is important to **convey four concepts** to members:

1. How long they could survive is uncertain. There is a chance they might live to a very old age.
2. The implications of surviving to an old age are not as straightforward as merely struggling to sustain the income that they currently draw. The potential adverse consequences may be limited by significant government support (Age Pension, etc), while most people spend less at older ages.
3. Self-insuring against living to an old age by cutting back spending can have a cost in terms of potentially not fully enjoying their assets when more able to do so, and possibly dying with a large amount of unspent savings. It is a trade-off.
4. Longevity protection may be accessed via a LIS, if they still remain concerned about running out of income after the above are considered. However, this entails sacrificing some access to funds.

When communicating **outcomes** from a retirement solution to members, we see a case for presenting the potential outcomes extending out to a very old age. However, this should be done along with clearly conveying that outcomes at older ages will *only* be experienced if the member happens to survive, potentially coupled with information about the probability of living to older ages. For instance, income layering and percentile charts[14] could be shown to describe how expected income and its distribution plays out over time. The caveat is that, while charts and tables may help some members, others may misunderstand or misinterpret them.

Another possibility could be providing 'what if' scenarios, e.g. show the member what happens if they live to (say) age 100 rather than age 92.

Our take: Uplift needed in industry practice

The super industry needs a significant uplift in practice around how longevity uncertainty is being addressed and communicated to members. While the industry could do more to improve longevity literacy, it is perhaps more important to help members understand the options and trade-offs involved in protecting against living to a very old age. Suggestions for four concepts to convey were presented in the previous section. Issues that the industry could do a better job at bringing to light include the significance of government support, the possibility that they may not need as much as they may think and the existence of LIS; as well as the fact that restraining spending can come at a cost.

When it comes to modelling and presenting outcomes from retirement solutions, we consider a fixed planning horizon to age 92 as not good enough *especially* if combined with deterministic modelling. Doing so brushes longevity risk under the table when it needs to be outlined and managed. A better approach might be presenting outcomes to a very old age coupled with clearly communicating that the outcomes would *only* be enjoyed upon survival; or presenting scenarios. Meanwhile, survival weights may be used for modelling and then comparing candidate solutions, without needing to directly communicate the results to members.

Longevity is poorly understood by most members, and from what we can see, is not well addressed. The super industry can do better.

[10] See Yakoboski, Lusardi and Hasler (2022).
[11] See for instance Wu, Stevens and Thorp (2015).
[12] Optimum Pensions provides an example.
[13] See Hurwitz, Mitchell and Sade (2022).
[14] See pages 9-10 of the 2023 Conexus Institute report *How to Approach Quantitative Assessment of Retirement Income Strategies* for examples.