Survival pessimism and the demand for annuities[*]

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Abstract

We quantify the importance of mis-perception of survival probabilities for the choice of whether to annuitise retirement savings. We use individuals' reported expectations about their probability of survival to certain older ages, finding significant survival 'pessimism', on average. We estimate individual subjective survival curves based on these reports and embed them in a model of wealth decumulation with an annuitisation choice. Under plausible parameterisation, subjective expectations have the capacity to explain significant rates of non-annuitisation, yielding a quantitaitively important explanation for the 'annuities puzzle'.

Keywords: Annuity Puzzle, Expectations Data

JEL Codes: D14, D84, D91, J14

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1 Introduction

Annuities insure individuals against longevity risk by allowing them to exchange wealth for an income stream guaranteed until death. Theory predicts that under general conditions, risk-averse individuals with accurate perceptions of their survival probabilities will purchase a fairly priced annuity (Yaari (1965); Davidoff et al. (2005)). However, in many advanced economies, annuity purchases are limited and annuity markets are not well-developed. A number of explanations for this 'puzzle' have been posited including adverse selection (Finkelstein and Poterba (2004); Brugiavini (1993)), bequest motives (Gan et al. (2015); Lockwood (2012)), buffer saving for medical and long-term care expenses (Ameriks et al. (2011)), annuity provision from social security income (Pashchenko (2013)), and costs of administration (see Brown (2007) for a review).

This paper uses directly measured expectations data to evaluate the quantitative importance for annuity demand of the widely-held assumption that individuals have accurate survival expectations.[1] We examine survey data on individuals' reported beliefs about their probabilities of surviving to certain older ages and find a pattern of significant underestimation of their chances of survival through their 50s, 60s and 70s, and over-estimation of survival through their 80s and beyond, on average. By embedding subjective survival curves in a lifecycle model of annuitisation choice, and with plausible levels of risk aversion and patience, we are able to explain high rates of non-annuitisation. This result does not depend on other explanations that have been given for non-annuitization – in our model, individuals do not have bequest motives and face no medical cost risk, and annuity products are priced fairly given objectively-measured survival rates. The difference between objective 'life table' and individual-specific 'subjective' survival curves is large enough to outweigh the insurance value of an annuity for a large proportion of individuals.

These results are of potential importance for government policy in relation to annuities.

[1] Following the literature, for ease and where there is no ambiguity, we use the term "expectations" as a shorthand for "(subjective) probability distribution".

Optimal policy in the case where low demand is explained by individuals being mis-informed would clearly be very different to that where lack of annuitisation is a rational choice in response to particular preferences (i.e. bequest motives) or is the result of market failure (i.e. asymmetric information leading to adverse selection), for example.

A number of papers have examined self-reported expectations of survival at older age. Hurd and McGarry (1995) uses data from the US Health and Retirement Survey (HRS) to document that the average of individuals expectations is not far away from period life table estimates. However, using more recent life tables, actual mortality data, and additional waves of the HRS, Elder (2013) finds that individuals are, on average, pessimistic about survival up to around age 85 and gradually more optimistic thereafter. Wu et al. (2015) finds further evidence of survival pessimism at younger ages, combined with increasing survival optimism at older ages. Hurd and McGarry (2002) demonstrate that subjective expectations update in response to relevant new information and are predictive of actual mortality.

Subjective expectations of survival have been shown to be empirically important in the context of a number of economic decisions. Hurd et al. (2004) find that those with particularly low expectations of survival are more likely to retire earlier and to claim social security benefits earlier. Bloom et al. (2006) find that a higher subjective probability of survival is associated with higher wealth levels. Gan et al. (2015) finds that a model of wealth decumulation and bequests including subjective survival expectations better fits decumulation and bequest behaviour than does one with life table survival probabilities. Examining the voluntary market for annuities in England, Finkelstein and Poterba (2004) find that private information about longevity is driver of individual choices and Inkmann et al. (2011) find that those with higher expectations of survival are more likely to purchase an annuity.

Heimer et al. (2015) builds a life-cycle model with subjective mortality beliefs and shows that 'pessimism' about survival to older age, combined with 'optimism' at the oldest ages can explain both under-saving for retirement and slow decumulation of wealth at the end of life. However, thus far no paper has quantified the importance of the observed divergence between average reported survival expectations and life table survival rates for the annuitisation decision, which is the focus of this paper.

This rest of this paper is organised as follows. Section 2 outlines the data, compares average reported survival expectations to official life tables, and sets out our method for constructing 'subjective' survival curves from stated beliefs. In Section 3 we outline the model of annuitisation and the impact of introducing subjective survival curves on predicted rates of annuitisation. Section 4 concludes.

2 Data

We draw on data from the English Longitudinal Study of Ageing (ELSA), a biennial panel representative of the English household population aged 50 and above. ELSA is part of a network of longitudinal ageing studies around the world – modelled on the Health and Retirement Study. Seven waves of the survey are currently available, covering the period 2002/03 to 2014/15. One module of the survey asks individuals about their expectations that certain events will happen in future, including whether or not they will leave an inheritance, whether they will still be in work at a certain age and whether at some point in the future they will not have enough resources to meet their financial needs. This section opens with the following statement:

"Now I have some questions about how likely you think various events might be. When I ask a question I'd like you to give me a number from 0 to 100, where 0 means that you think there is absolutely no chance an event will happen, and 100 means that you think the event is absolutely certain to happen."

As part of this module, individuals are asked a question of the form *"What are the chances that you will live to be age X or more?"*, where the age X depends on the current age of the respondee. All individuals aged 65 and under are asked about survival to age 75. Those aged 66 or older are asked about the age which is between 11 and 15 years ahead of their current age and is a multiple of 5. For example, those aged 75-79 are asked about survival to age 90. Additionally, from wave 3 onwards, all individuals aged under 70 were asked a second question about survival to age 85.

Over the seven waves of ELSA, 16,345 unique individuals are asked one or more survival questions in 67,201 separate interviews.

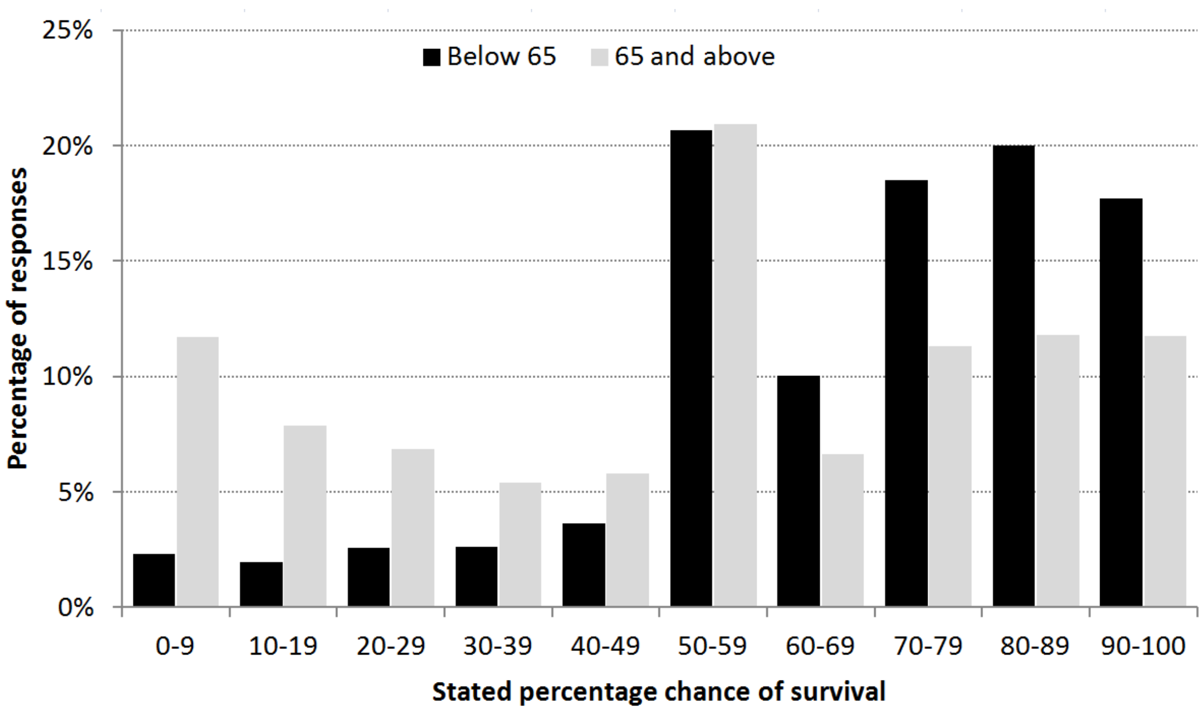
2.1 Evaluating the content of subjective reports

Before using indiviudal reports to survival probability questions in analysis, we wish to assess whether individuals appear to understand the meaning of these questions and to be able to engage with the probabilistic concepts involved. Secondly, assuming that the nature of these questions is understood, we would like to establish as far as possible whether answers constitute considered, reflective judgements that might plausibly guide behaviour, or are instead picked with little prior thought.

In just 1.5% of interviews, individuals answer "Don't know" to one or more questions, suggesting a willingness to answer in almost all cases. Figure 1 shows the distribution of reported survival probabilities for the full sample of first questions asked by 10 percentage point categories. We split the sample into those aged below 65 and those aged 65 and above, with the younger group much more likely to report high chances of survival.

Some individuals answer "0%" or "100%" to the survival questions (5.3% and 6.8% respectively). While answers of 0% chance of survival may be consistent with understanding of the question (in cases of terminal illness for example), an answer of 100% chance of survival over an 11-15 year period strongly suggests a lack of understanding of the question. When individuals are asked two survival questions, they can give an answer that is impossible if they report a higher chance of survival to the older age than to the younger age. This happens in 8.3% of interviews. Overall, individuals give answers that indicate a lack of understanding of the question in at least one of these two ways in 13.9% of interviews. We choose to remove these individuals from our sample in all of the following analysis.

Figure 1: Distribution of answers given to first survival question by age-group



Source: ELSA waves 1–7. 66,210 answers from 16,345 unique individuals

We may have reservations about the high proportion - 20.5% - of answers that are 50 percent. There could be a concern that individuals pick this focal answer when wanting to give a response but not understanding the question. We assess this by examining these individuals' answers to other probability questions. Those individuals who answer "50%" almost always give a range of answers to other questions and are no more likely to answer "50%" to other probability questions than are the rest of the sample (Appendix A.1 gives further details). Of the 16,345 individuals who answered one or more survival questions, only 41 individuals (0.2%) answered "50%" to all survival questions in all waves. On the basis of this evidence, we retain answers of "50%" in our main sample but show sensitivity of results to their removal.

Given that the overwhelming majority of individuals give answers that do not indicate a lack of understanding of probabilities, we perform three further "tests" aimed at assessing the informational content of responses. Firstly, we find that responses are correlated with known mortality risk factors (e.g. smoking, drinking and health conditions) in the way that is consistent with theory. For example, current smokers report a 6-7 percentage points lower probability of survival over the 11-15 year horizon, relative to current non-smokers.[2] Secondly, using the panel nature of the survey we find that reports 'update' over time in response to news relevant to mortality such as diagnoses with new health conditions. For example, a new cancer diagnosis was associated with a 5 percentage point reduction in the stated probability of surviving to an age 11 to 15 years ahead.[3] Third, exploiting a link to administrative death records from the National Health Service, we find that reported expectations are correlated with actual subsequent mortality over a 10 year horizon.[4] While it is possible that individuals answers to survival expectations questions could represent individuals actual expectations even if there was no association with the above outcomes, these findings can be seen as additional evidence that answers represent meaningful, reflective judgements (Hurd and McGarry (2002)).

2.2 Comparing individual subjective survival probabilities to official life tables

In this section, we describe the patterns in subjective reports and compare them to official life table data. Clearly, heterogeneity in survival probabilities (and their dependence on host of unobserved factors) means we cannot assess at the individual level if stated expectations are "accurate". However, if all individuals had unbiased expectations about their survival probabilities, then average subjective reports would match life tables.[5]

[2] This result is obtained using linear regression of reported probability on smoker status, controlling for a range of other risk factors, demographic variables, health conditions and self-reported health. Full details are given in in Appendix A.2.

[3] This result is from a linear fixed effects regression of reported survival probability on a range of variables for whether individuals have been diagnosed with particular health conditions, as well as other risk factors and demographic variables. Full details are given in in Appendix A.2.

[4] Full details are given in in Appendix A.2.

[5] Note that is true if actual mortality risk amongst the ELSA sample is the same as in the wider population. Using the fact that we have linked administrative records for all deaths of ELSA sample members

We firstly compare mean subjective reports to UK Office for National Statistics life tables to assess whether particular age-sex-cohort groups have positively biased ('optimistic') or negatively biased ('pessimistic') expectations of survival to various "target ages" (i.e. the age about which the individual is asked the question).[6] We conduct this analysis at the most granular level for which comparisons with official life tables are possible: we calculate for each combination of year of age, year of birth, sex, and target age, the average reported survival probability, and compare this to the relevant life table probability. A clear pattern emerges: individuals are, on average, 'pessimistic' about their chances of survival to ages 75, 80 and 85 and then become increasingly optimistic about survival at older ages. While the degrees of 'optimism' and 'pessimism' vary slightly between cohorts, these patterns are consistently found across those born in the 1920s through to the 1950s. Comparing men and women, we see that women tend to be slightly more pessimistic on average, than men.

Figure 2 illustrates the comparison between mean subjective reports and life tables for men and women born in the 1930s. We see that individuals in their early 60s under-estimate survival to age 75 by around 20 percentage points while those in their late 60s and early 70s under-estimate survival to age 85 by 5 to 10 percentage points. Turning to those in their late 80s, we see that they over-estimate survival to age 95 by around 10 percentage points, on average.[7]

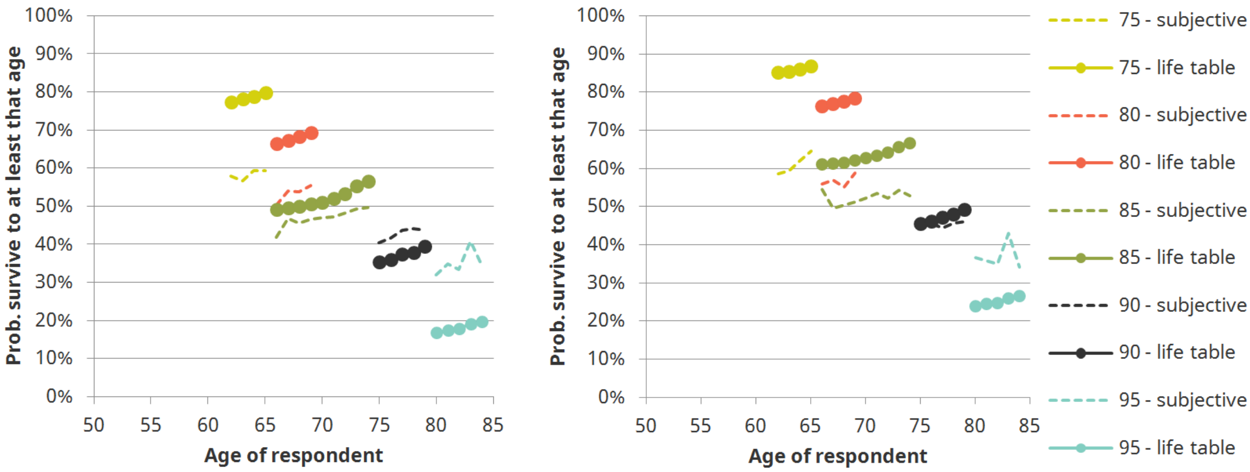
These findings are in line with those in existing literature, including Elder (2013) and Heimer et al. (2015), which establish in a number of settings the pattern of over-estimation of mortality hazard rates at ages until around the mid-80s, with under-estimation of mortality rates at older ages.

up until February 2013 we can compare actual mortality rates of the ELSA sample with the relevant life table probability. We find slightly lower mortality rates amongst the ELSA sample of men up until age 75, this difference amounts to at most an 8 percentage point difference between the life table and ELSA-implied survival curve.

[6]We use the ONS' 2014-based cohort life tables for England and Wales.

[7]Note that in Figure 2, each "subjective" data point corresponds to an average over respondents with different birth years. The "life table" data points are constructed by weighting the corresponding life table survival probabilities according to the proportions of individuals with each birth year in the sample.

Figure 2: Comparison of mean 'subjective' reports and ONS cohort survival rates/projections for men (LHS) and women (RHS) born 1930-39



Note: Different coloured series correspond to different ages about which respondents are asked questions. Source: ELSA waves 17 and ONS 2014-based cohort life tables for England and Wales.

2.3 Constructing subjective survival curves

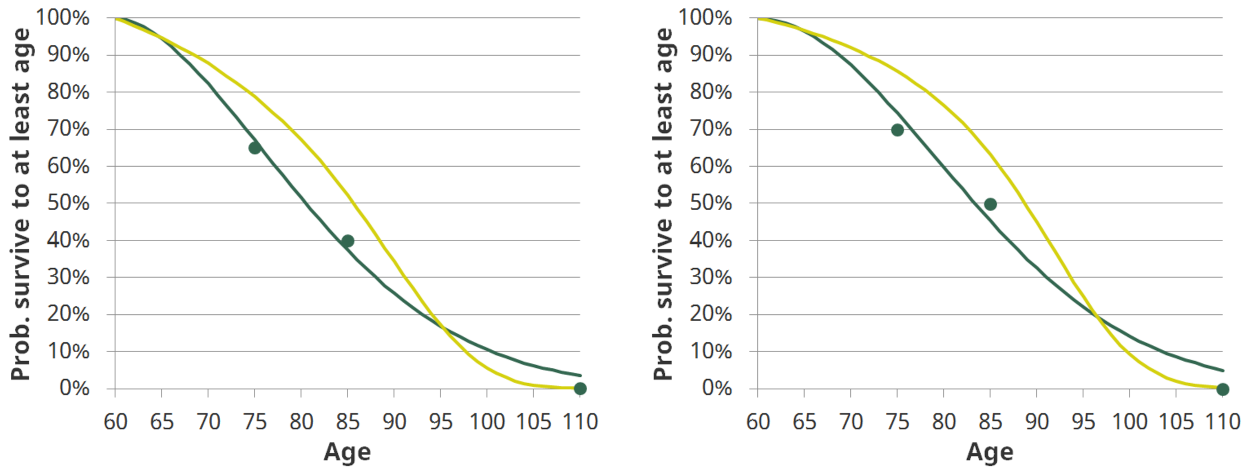
In this section, we use stated survival expectations to fit individual-specific subjective survival curves. This subjective survival curve allows us to derive the implications of expectations for behaviour using a life-cycle model.

In order to extrapolate from reports about survival to particular ages to a full survival curve, we assume that subjective survival probabilities are Weibull distributed. The Weibull distribution is widely used to model mortality in the epidemiological literature, and for modelling ageing processes generally. It is a 2-parameter distribution defined in the following way. Person age z, has prob of surviving to at least age α

$$S_i^s(\alpha) = exp\left[-\left(\frac{\alpha - z}{\lambda}\right)^k\right] \quad : \quad \lambda, k > 0 \tag{1}$$

We fit subjective survival curves to all individuals in our sample who answered two survival questions (i.e. all those aged under 70 who answered two questions). We add one a weak assumption - that individuals believe that they are almost certain not to live beyond age 110 - by including the relevant cohort life table survival probability for each individual

Figure 3: Comparison of median 'subjective' and 'objective' survival curves for men (LHS) and women (RHS) born 1940-49



Note: The darker coloured curve shows the "subjective" survival curve and the lighter coloured curve the "objective" survival curve. Each curve shows, conditional on survival to age 60, the probability of survival to older ages. "Dots" show median reported survival probabilities. Source: ELSA wave 3 and ONS 2014-based cohort life tables for England and Wales.

for target age 110 as a third point. We fit the Weibull distributed subjective survival curve to these three points using least squares.

Figure 3 illustrates the curve-fitting procedure for the median responses from men and women born in the 1940s and compares these subjective survival curves to the relevant life table survival curves. The subjective curve implies that at age 60, this group of individuals are pessimistic about survival to all ages up until the mid-90s and optimistic about survival to ages beyond this. The subjective life expectancy measures implied by these curves are 2.2 and 2.6 years lower than the life expectancies implied by the life table survival curves for men and women, respectively. This is equivalent to life expectancies that are 9% (for men) and 10% (for women) lower than those implied by life tables, on average.

Average overall pessimism of this magnitude is found across sexes and cohorts when interviewed in their 50s and 60s. Using the full sample of individuals for whom we have a subjective survival curve, we can compare 'subjective' and life table life expectancy at the individual level. Subjective life expectancy is lower than life table life expectancy by 2.1 years or 9% amongst men, and by 3.8 years, or 14%, amongst women, on average.

3 Subjective survival expectations and annuitisation

Annuities provide insurance against longevity risk. The decision about whether or not to purchase an annuity at a given price ought, according to a basic model, to depend on the individual's assessment of this longevity risk. Individuals who under-estimate their longevity may perceive an annuity as a worse deal than it 'truly' represents. This is a potential explanation for the unpopularity of even actuarially fairly priced annuities.

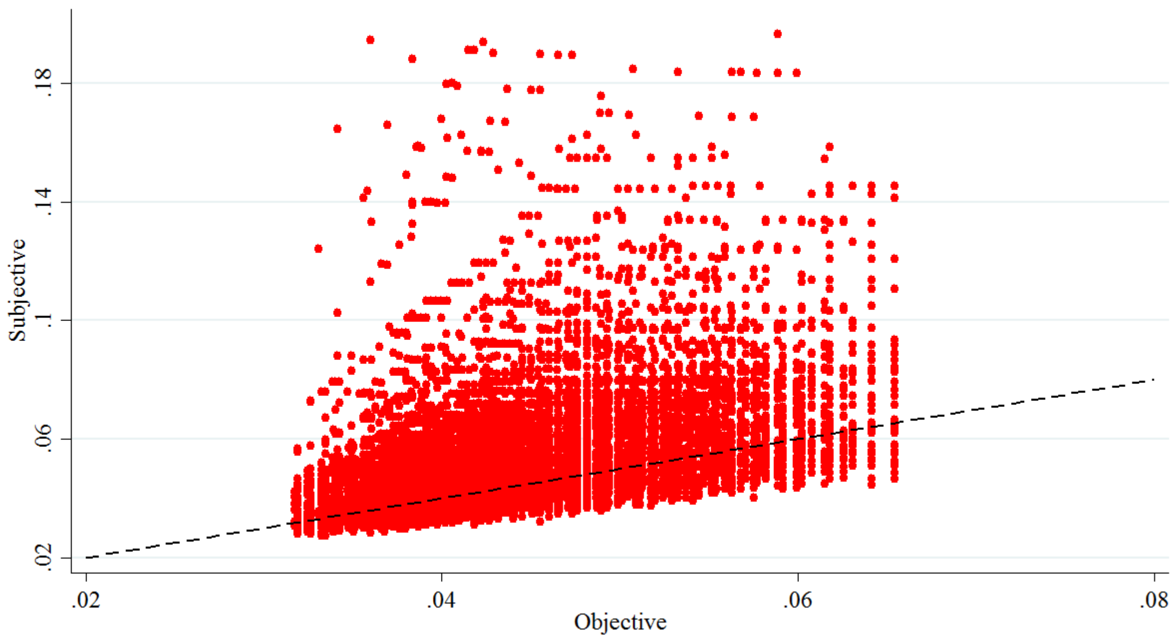
First, we can assess whether, given their subjective expectations, individuals would perceive an annuity as offering at least an actuarially 'fair' deal. An annuity rate is defined as actuarially fair with respect to a given discount rate and set of survival probabilities, if it enables the purchase of a guaranteed income stream until death that has expected discounted value equal to its price. For each individual for whom we have fitted a subjective survival curve, we calculate the actuarially fair annuity rate given their subjective survival curve and given their life table survival curve assuming a real interest rate of 1% in both cases. The actuarially fair annuity rate for an individual age z, given the survival curve $S_i(\alpha)$ is given by:

$$\theta = \left[\sum_{\alpha=z}^{110} \frac{S_i(\alpha)}{(1+r)^{\alpha-z}} \right]^{-1} \tag{2}$$

Figure 4 compares these 'subjective' and 'life table' annuity rates for our sample. [68%] of individuals would perceive an annuity that is priced fairly for the average person of their age, sex and cohort as offering a less than fair annuity rate.

An individual who perceives an annuity as being unfairly priced may, of course, choose to purchase if it offers sufficiently large insurance value. We therefore examine whether survival 'pessimism', and the implied divergence between subjective and life table-based annuity rates would be sufficient, given plausible levels of risk aversion (and discounting), to lead individuals to not annuitise their retirement savings. This requires us to explicitly model this decision by constructing a model of annuity choice and wealth decumulation and comparing results in the case where individual survival expectations are consistent with life

Figure 4: Comparison of 'objective' and 'subjective' based annuity rates



Note: 'Subjective annuity rates are the actuarially fair rate implied by the subjective survival curve constructed from the individuals responses to the survival expectations questions. 'Objective annuity rates are the actuarially fair rate implied by the survival curve derived from the cohort life table for the individuals sex, age and year of birth. Source: ELSA waves 37 and ONS 2014-based cohort life tables for England and Wales.

tables to those where they are consistent with their subjective survival curve. We account for the fact that individuals may have state pension entitlements and be home-owners, giving them some already annuitised income. We use data on private pension and financial wealth and model choice of whether to annuitise this at a rate that is actuarially fair given the individual's age, sex and cohort.

3.1 Model

In this section we outline the model of individual annuitisation choice. Just-retired agents have initial wealth, a_0, and receive public pension income (state pension/social security), p, and a flow of housing services h coming from any property that they own, in each period.

In period 0, agents can choose whether or not to annuitise all their pension and financial wealth. If an individual chooses not to annuitise, they then decide how much of their wealth to consume in each period.

Individuals make choices consistent with a survival curve, $S_i(\alpha)$. When beliefs are consistent with the *subjective* survival curve, an individual aged z believes that they have a probability of survival to each age $\alpha \leq 110$ that is described by a Weibull distribution:

$$S_i^s(\alpha) = exp\left[-\left(\frac{\alpha - z}{\lambda}\right)^k\right] \quad : \quad \lambda, k > 0 \tag{3}$$

All individuals believe that they will die at the end of their 110th year at the latest. Individuals have constant relative risk aversion utility within each period and they discount the future according to a geometric discount rate (β) so their *expected* lifetime utility is:

$$U = \sum_{t=0}^{110-z} \beta^t S_i(z+t) \frac{(c_t + h_t)^{1-\gamma}}{1-\gamma} \tag{4}$$

At time zero, individuals can irreversibly annuitise their wealth at rate θ, which is the actuarially fair annuity rate given $S_i^o(\alpha)$, the *life table* survival curve for someone of their sex, year of birth, and age:

$$\theta = \left[\sum_{\alpha=z}^{110} \frac{S_i^o(\alpha)}{(1+r)^{\alpha-z}}\right]^{-1} \tag{5}$$

An individual's problem is therefore to choose $\{c_t\}$ and b (whether to annuitise):

$$\max_{\{c_t\},b} \sum_{t=0}^{110-z} \beta^t S_i(z+t) \frac{(c_t + h)^{1-\gamma}}{1-\gamma} \tag{6}$$

$$s.t. \begin{cases} a_{t+1} = (a_t + p - c_t)(1+r) & if\ b = 0 \\ a_{t+1} = (a_t + p + \theta a_0 - c_t)(1+r) & if\ b = 1 \\ a_{t+1} \geq 0 \end{cases} \tag{7}$$

Individuals' optimal choice of consumption when not annuitising is characterised by the

Euler equation:

$$(c_t + h)^{-\gamma} = \beta(1 + r)s_i(z + t)(c_{t+1} + h)^{-\gamma} \tag{8}$$

Where $s_i(z+t) \equiv S_i(z+t+1)/S_i(z+t)$. When annuitising, optimal individual choice in each period is either characterised by the Euler equation (this happens when $\beta(1+r)s_i(z+t) > 1$), or consumption of all income, i.e. $c_t = \theta a_0$.

We solve the model for each individual in waves 4, 5 and 6 of ELSA who is above the eligibility age for the state pension and for whom we are able to construct a subjective survival curve.[8] This yields a total of 4,265 observations on 2,819 unique individuals. Each individual's initial level of wealth in the model is the sum of their household private pension wealth and gross financial wealth.[9] We use state pension income as reported.[10] Owner occupiers receive housing services (h) at a rate of 4% of the value of their primary residence. Income from the state pension and housing services are fixed in real terms. For each observation, we solve the model twice, using in one case the life table survival curve for that individual's sex, year or birth and age, and in the other their fitted subjective survival curve estimated from their survey responses.

3.2 Results

We illustrate the impact of 'subjective' survival expectations by comparing the predicted proportion of individuals annuitising in the case where they behave according to the life table survival curve for their age, sex and cohort with the case where they behave according to their own subjective survival curve.

Figure 5 shows the proportion of individuals annuitising at various parameter combinations, for both life table and subjective expectations. We find that at plausible parameter

[8]In this period, the male state pension age was 65 and the female state pension age increased from age 60 to age 62. The state pension age is the age at which individuals can first claim their state pension. Over 99% of individuals begin to claim at this age.

[9]This information is available in waves 4 to 6. For individuals in a couple, we take half of this wealth level.

[10]Note on pension credit.

combinations, including subjective expectations in the model has the capacity to 'explain' a large proportion of individuals choosing not to annuitise in a way that is not consistent with the model under life table expectations. For example, with a discount rate of 98% and a coefficient of relative risk aversion of 1, 90% of individuals are predicted to annuitise when using life table expectations, but 54% are predicted to annuitise when using subjective expectations.

Figure 5: Percentage of individuals annuitising at each parameter combination

(a) Life table expectations

Discount factor	Coefficient of relative risk aversion: 0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
95.0%	0%	0%	13%	38%	62%	77%	85%	88%	90%	90%	91%
95.5%	0%	0%	20%	51%	73%	84%	88%	90%	90%	91%	92%
96.0%	0%	3%	32%	65%	80%	88%	90%	90%	91%	92%	93%
96.5%	0%	9%	48%	78%	88%	90%	91%	91%	92%	93%	93%
97.0%	0%	19%	68%	86%	90%	91%	92%	93%	93%	93%	94%
97.5%	0%	40%	82%	90%	91%	93%	93%	93%	94%	94%	94%
98.0%	0%	74%	90%	92%	93%	94%	94%	94%	94%	95%	95%
98.5%	0%	90%	93%	94%	95%	96%	96%	96%	96%	96%	96%
99.0%	0%	98%	99%	99%	100%	100%	100%	100%	100%	100%	100%
99.5%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
100.0%	94%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

(b) Subjective expectations

Discount factor	Coefficient of relative risk aversion: 0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
95.0%	0%	2%	7%	20%	36%	48%	56%	66%	71%	74%	78%
95.5%	0%	3%	11%	27%	43%	52%	62%	69%	73%	78%	80%
96.0%	0%	4%	17%	35%	48%	58%	67%	71%	76%	80%	84%
96.5%	0%	7%	25%	43%	53%	63%	69%	74%	79%	83%	85%
97.0%	0%	12%	33%	49%	59%	67%	73%	78%	82%	85%	87%
97.5%	2%	22%	41%	53%	64%	71%	77%	81%	84%	87%	89%
98.0%	6%	30%	47%	59%	68%	75%	80%	83%	87%	88%	90%
98.5%	12%	41%	54%	65%	74%	79%	82%	86%	89%	90%	92%
99.0%	26%	47%	60%	70%	78%	81%	85%	88%	90%	92%	93%
99.5%	34%	54%	67%	74%	80%	84%	87%	90%	91%	93%	93%
100.0%	39%	59%	71%	79%	82%	86%	89%	91%	93%	94%	94%

Source: Model predictions using ELSA waves 4–6 and ONS 2014-based cohort life tables for England and Wales.

We see that in general, a larger proportion of individuals annuitise when risk aversion is higher and the discount factor is higher. The former fact is due to the insurance value of the annuity increasing with risk-aversion and the latter is explained by the fact that with a fixed real interest rate, the constant real terms income provided by the annuity becomes closer to individuals' preferred consumption profile as patience rises. To build some intuition, we note that when individuals are risk neutral, they care only about expected discounted value of income stream the annuity provides. If their survival expectations are the same as that of the annuity provider (panel (a) in Figure 5) then they will annuitise if and only if $\beta(1+r) > 1$.[11]

4 Conclusion

Using data on a representative sample of English individuals aged 50 and over, we have documented a pattern of significant under-estimation of survival probabilities, on average, through individuals' 50s, 60s and 70s and growing over-estimation of survival chances at the oldest ages. Overall, individuals tend to be 'pessimistic' about their life expectancy at older age.

This 'pessimism' is quantitatively significant in the context of the decision about whether to annuitise retirement savings. Incorporating individual 'subjective' survival curves, fitted to individual reported subjective survival probabilities, into a model of annuitisation and use of wealth at older ages has the capacity to rationalise low rates of annuitisation even when annuities are offered at an actuarially 'fair' rate. This demonstrates for the first time that individual biases in beliefs about survival may be an important factor behind the 'annuities puzzle'.

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[11]Given real interest rate of 1% is used, this means annuitise if and only if $\beta > 99.01\%$.

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A Appendix for online publication only: Details of further analysis and tests from Section 2

A.1 Analysis of "50%" answers

The following table details the distribution of individuals by the number of times they answered "50%" to questions in the expectations module other than the survival questions. The reporting patterns in the 20.5% of interviews in which individuals answered "50%" to the first survival question are very similar to distribution of responses amongst the whole sample.

Table 1: Distribution of number of expectations questions to which individuals answer "50%"

	Number of "50%" answers given					
	0	1	2	3	4	5
All individuals	55.42%	35.34%	8.07%	1.05%	0.12%	0.00%
Answered "50%" to 1st survival Q	52.09%	35.78%	10.20%	1.62%	0.30%	0.01%

Note: Other probability questions include those related to the probability of moving out of ones home in the future, of being in work in a number of years time, of having insufficient financial resources to meet needs at some point in the future, of it raining tomorrow and of giving and receiving an inheritance. Source: ELSA waves 17. 66,210 interviews from 16,345 unique individuals.

A.2 Correlation of subjective reports with risk factors, new information and subsequent mortality

Table 2 details the results of a regression of an individual's answer to the first survival question they are asked on a range of risk factors as well as a full set of wave*single-year-of-age dummy interactions. Results are split by gender and by whether or not self-reported health is controlled for. The coefficients reported are in percentage point deviations. For example, a male current smoker reports 6.7 percentage points lower chance of survival to an age 11–15 years ahead of their current age, on average, when compared to current non-smokers.

Table 3 reports the results of a fixed effects regression of individuals' answers to the survival expectations questions on a range of dummies for whether or not they have received a new diagnosis of a health condition since their last interview. We control linearly for age. We find that individuals do respond to new information by revising their survival expectations. For example, a new diagnosis of cancer or a case of a stroke cause large and

Table 2: Relationship between stated survival probabilities and risk factors

	Ex. self-reported health		Inc. self-reported health	
	Male	Female	Male	Female
Smoking (relative to non-smoker)				
Ex-occassional smoker	-3.0^{***}	-0.7	-2.8^{**}	-0.2
Ex-regular smoker	-1.9^{***}	-0.4	-1.4^{**}	-0.1
Ex-smoker (frequency: don't know)	-3.0^{***}	-1.9	-2.6^{**}	-1.4
Current smoker	-8.1^{***}	-7.5^{***}	-6.7^{***}	-6.4^{***}
Alcohol consumption (relative to once or twice a month)				
At least 3–4 days a week	0.1	0.1	-0.6	-0.4
Once or twice a week	0.1	0.2	-0.2	-0.1
A few times a year	-1.2	-1.3^{**}	-0.6	-1.0^{*}
Not at all	-2.5^{**}	-2.1^{***}	-1.5	-1.2

Coefficients represent percentage point deviations in mean response. Statistical significance at the 10%/5%/1% level is denoted by */**/***. Standard errors are clustered at the individual level. Other control variables, for which coefficients are not reported, are whether in a couple, income and wealth quintile, education level, whether working and dummy variables for whether diagnosed with Alzheimers, angina, arthritis, diabetes, lung disease, osteoporosis, Parkinsons and psychiatric disorders, whether the individual is white or non-white and a full set of dummy variables for each single year-of-age and wave interaction. Source: ELSA waves 17. 52,170 observations of 14,092 unique individuals.

statistically significant downward revisions in survival expectations of 5 and 6 percentage points respectively.

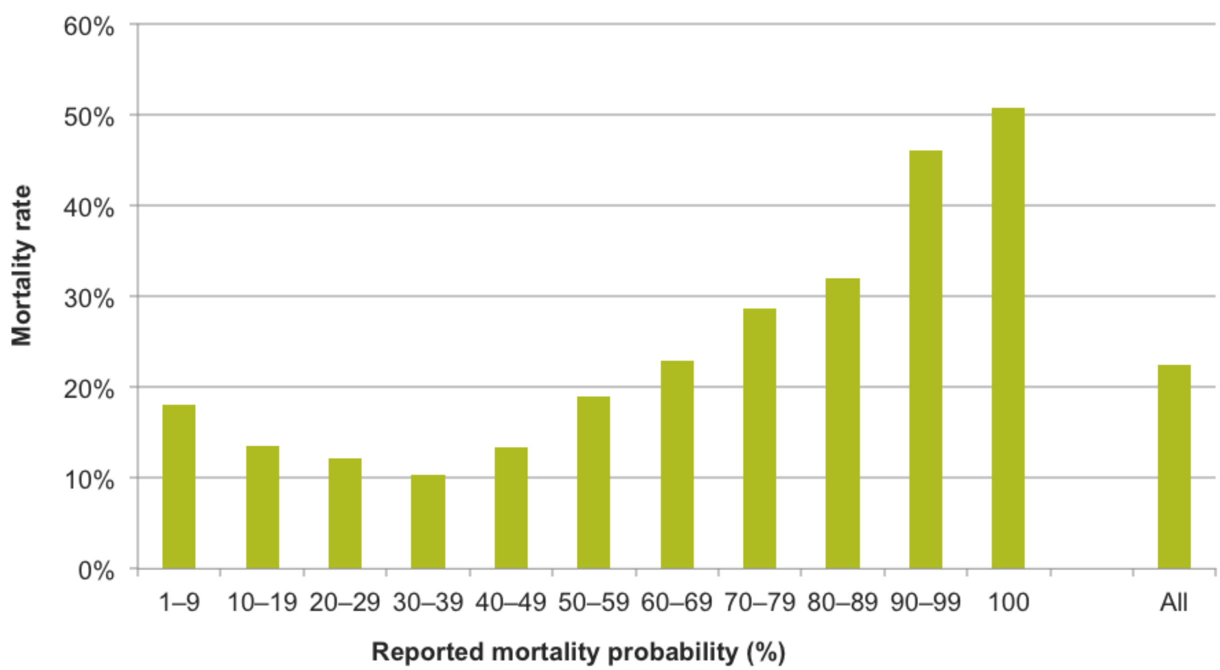
Finally, Figure 6 shows the 10 year mortality rates of individuals according to their answer to the first survival question. We use the linked death records which give us a 10-year horizon for those interviewed in wave 1 of ELSA. We see clear differences in mortality rates according to stated expectations. These differences are statistically significant. The correlation between expected and actual mortality remains even when we control for age and sex-specific average mortality risk and the range of health factors controlled for in the previous regressions.

Table 3: Revision to survival expectations following diagnosis with major health conditions

	1st surival question	2nd survival question
Alzheimers disease	−7.8*	−1.9
Cancer	−4.5***	−3.0*
Dementia	−7.4**	−2.6
Heart attack	−2.5	−1.3
Lung disease	−2.2	1.4
Parkinson's disease	−2.9	−8.6
Psychiatric problems	−2.0	−1.2
Stroke	−5.7***	−5.0*

Note: Coefficients represent percentage point deviations in mean response. Statistical significance at the 10%/5%/1% level is denoted by */**/***. Standard errors are clustered at the individual level. Source: ELSA waves 37. 37,760 observations of 12,027 unique individuals.

Figure 6: 10 year mortality rates by answer to survival question



Note: Reported probability of death is 100 minus the reported probability of survival in the first survival question the individual is asked. Source: ELSA wave 1 and linked death records. 6,225 individuals.