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How Deep is the Annuity Market Participation Puzzle?

Joachim Inkmann*, Paula Lopes and Alexander Michaelides*****

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Abstract

Using UK microeconomic data, we analyze the empirical determinants of voluntary annuity market demand. We find that annuity market participation increases with financial wealth, life expectancy and education and decreases with other pension income and a possible bequest motive for surviving spouses. We then show that these empirically-motivated determinants of annuity market participation have the same, quantitatively important, effects in a life-cycle model of annuity and life insurance demand, saving and portfolio choice. Moreover, reasonable preference parameters predict annuity demand levels comparable to the data. For stockholders, a relatively strong bequest motive is sufficient to simultaneously generate balanced portfolios and low annuity demand.

Keywords: Annuities, portfolio choice, life insurance, bequest motive.
JEL Classification: E21, H00.

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1 Introduction

Why are annuities not voluntarily taken up by a larger number of retirees? In the individual consumption/savings-portfolio choice literature, a very important participation puzzle arises from the revealed preference of households not to voluntarily buy annuities at retirement, despite the strong theoretical reasons that point towards high demand for these products. Specifically, as early as 1965, Yaari demonstrates that risk aversion is sufficient to induce a household to buy an actuarially fair annuity as protection against life expectancy risk. Yet, despite this strong theoretical result,[1] annuity demand remains very low in the data, what is known as the "annuity market participation puzzle".

It is important to understand why this puzzle arises from a theoretical perspective[2] but there is also another, equally strong, empirical reason to explain the puzzle. Specifically, there has been a large shift in pension provision from defined benefit (DB) to defined contribution (DC) plans both in the U.S. and in the U.K.. DB plans offer not only a fixed monthly payment but also offer it for life, therefore providing a natural insurance for life expectancy risk. On the other hand, DC plans place the decision of how fast to decumulate during retirement in the hands of the individual.[3] As a result, the issue of annuity provision could become very important for financial planning after retirement.

The pressing need to understand this puzzle has generated a large number of potential explanations. One prominent idea involves the lack of actuarially fair annuities. Mitchell et al. (1999) for the U.S. and Finkelstein and Poterba (2002, 2004) for the U.K make the case but on the other hand Mitchell et. al. (1999) also argue that annuity pricing is not sufficient to explain the low take-up because the "money's worth of individual annuities" is actually quite good. Moreover, the presence of some annuitization through state social security and private DB plans (Bernheim (1991), Brown et. al. (2001) and Dushi and Webb (2004)), and

[1] More recently, Davidoff et al. (2005) show that complete annuitization is optimal in a more general setting than Yaari (1965) when markets are complete.

[2] Davidoff et. al. (2005) imply that an explanation from the psychology and economics literature might be needed.

[3] In the U.K. during the sample period of the data used in this paper (2002-2004) there was mandatory annuitization by age 75 of three quarters of the accumulated assets in a DC plan.

the presence of uncertain medical expenditures (for instance, Sinclair and Smetters (2004) and Ameriks et. al. (2007)) have recently received substantial attention as determinants of annuity demand. Furthermore, the lack of flexibility in purchasing an annuity has also been recently emphasized by Milevsky and Young (2007) who argue that buying an annuity limits household flexibility to invest in the stock market, while Ameriks et. al. (2007) instead focus on the implications of irreversible annuity purchase decisions on the probabilities of ending up at a nursing home funded by the state. They argue that such "medicaid-aversion" may explain why households do not commit to the illiquid expenditure of buying an annuity. Flexibility in labor supply along with the existing annuity in the form of social security is the explanation offered by Benitez-Silva (2003) in a quantitative model. Another prominent idea is the presence of a bequest motive as the preference for leaving bequests may counteract the insurance benefits of annuities (Friedman and Warshawsky (1990)). Nevertheless, the lack of evidence stemming from comparing the choices of households with and without children (for example, Brown (2001)) has cast doubt on the empirical plausibility of this explanation. Other less prominent explanations include inflation risk,[4] habit formation in preferences,[5] non-actuarially fair annuity provision combined with minimum annuity size purchase requirements,[6] and rare events.[7]

Our primary contribution is to take many of the reasons for lower annuity holdings previously proposed in the literature and combine them in a quantitative model, while simultaneously checking that the empirical evidence is consistent with the inputs to, and predictions from, the model. Our strategy will be to first empirically examine which explanations can provide some empirical evidence for annuity market decisions. Next, we utilize

[4]In the presence of substantial inflation risk the demand for nominal annuities might be quite low. Nevertheless, this explanation would imply a large demand for real annuities, yet the take-up for real annuities, where they exist, has also been low. Lopes (2006) also finds that the load factors for real annuities are high, thereby negating the value from having real annuities.

[5]Davidoff, Brown and Diamond (2005).

[6]See Lopes (2006).

[7]Lopes and Michaelides (2007) argue that the possibility of a "rare event" like the default of the annuity provider cannot by itself explain the puzzle since such a rare event would change behavior for high risk aversion coefficients but a high risk aversion simultaneously makes annuity demand stronger.

a comprehensive quantitative model that allows us to assess the ability of different, empirically motivated, determinants to explain the observed empirical regularities. Thus, both our empirical (reduced form) and our estimated (structural) model can shed light on which explanations are more likely to justify the low annuity market participation in the data.

To achieve the stated goal we first empirically analyze the determinants of voluntary annuity market participation at the household level to determine the characteristics of households that participate (or not) in this market. We confirm that there appears to be a substantial voluntary annuity market participation puzzle, since less than 6% of households participate in this market. For our multivariate empirical analysis, we separate the sample between stockholders and non-stockholders. We take this route because wealthier and more educated households can better afford and understand annuities, and because we know that stock market participation increases with wealth and education (for instance, Campbell (2006)). Indeed, the annuity market participation rate for stockholders (9.6%) is three times the participation rate of non-stockholders (3.2%). In all regressions, we find that the factors determining participation are broadly the same for both groups. Specifically, annuity market participation increases with life expectancy, education and financial wealth. Pension income (or compulsory annuity income) crowds out annuity demand conditional on voluntary annuity market participation, while a possible bequest motive for surviving spouses is a hurdle for voluntary annuitization. We view these empirical findings as interesting in their own right since they increase our understanding of the factors determining annuity market participation.

Surprisingly, there are not many empirical studies investigating the correlates of annuity market participation.[8] One similar recent study is Brown (2001) who has a similar research objective based on the U.S. equivalent of the U.K. data we use, but instead focuses on first calculating the value of having access to an annuity market for each household (based on a life-cycle simulated model) and then relates this value to the intention to annuitize. The two approaches yield similar insights with regards to some of the empirical correlates of

[8]Recently, Brown and Poterba (2006) study variable (or equity-linked) annuities and focus on the impact of the household's marginal tax rate. Nevertheless, variable annuities only recently developed to a significant part of the total annuity market.

annuity market participation. For instance, as in Brown (2001) we do not find any evidence for a bequest motive when using the presence of children as a variable to proxy for an intentional bequest motive. Like Brown, we find a statistically and economically significant negative impact of being married on the probability to annuitize. With respect to other variables, our results differ from Brown's results. For instance, education and subjective survival probabilities turn out to be significant in our analysis while they are insignificant in Brown (2001). Most importantly, we find that wealth has a strong positive impact on the probability to annuitize while it turns out negative and significant in Brown's analysis. Moreover, Brown (2001) does not consider portfolio choice arguments, while we also consider the impact of stock and life insurance market participation on the probability to annuitize.

We next construct a quantitative model that may replicate these empirical findings, and that can therefore be used to quantify the strength of the annuity market participation puzzle. Specifically, we build a model of life-cycle saving, portfolio, life insurance and annuity market choice with Epstein-Zin (1989) preferences over a non-durable good and investigate whether reasonable preference parameters can replicate the observed annuity market participation rate, and the level of annuity demand. To do so, we use the wealth distribution and median pension level in the data as exogenous inputs to generate predicted annuity demand after retirement. We find that preference parameters like risk aversion, the strength of the bequest motive, the elasticity of intertemporal substitution and the decision to access the stock market are key determinants of the model's quantitative predictions. Financial wealth, a key endogenous state variable in the model, is directly affected by these parameters and is therefore a key predictor variable in assessing the model's quantitative implications. Contrary to frictionless theoretical models, we find that many households should not purchase an annuity partly because of the state pension income, partly because of the empirical wealth distribution (many households cannot afford an annuity), partly because of the bequest motive, and partly because of better opportunities and flexibility in saving through the stock market.

We next use a method of simulated moments to estimate the model separately for stockholders and non-stockholders. We separate the two groups both on account of our multivariate probit findings and due to the large difference in financial wealth profiles across the two groups in the data.[9] For the non-stockholders, we fix the coefficient of relative risk aversion to two and we estimate the bequest parameter and the intertemporal rate of substitution, to match the annuity and life insurance participation rates, and, conditional on annuity market participation, the amount of annuities purchased. For the stockholders we add the average share of wealth in stocks during retirement as a moment target and estimate the risk aversion coefficient as well. We find that the life-cycle model is consistent with the empirical findings for reasonable preference specifications. The estimated elasticity of intertemporal substitution is much lower for non-stockholders (0.08) than for stockholders (0.72). We view these parameter estimates as reasonable estimates for preferences, being consistent with the empirical evidence in, for instance, Gourinchas and Parker (2002), and, in particular, Vissing-Jorgensen (2002).

For both stockholders and non-stockholders, we need a bequest motive but this motive needs to be stronger for stockholders. The effect of a strong bequest motive in generating a balanced portfolio comprised of both stocks and bonds has not been stressed in the literature as a sufficient ingredient to explain portfolio allocations. Here, the bequest motive can generate a much slower decumulation of wealth during retirement, while for the same reason it can generate balanced portfolios. In the absence of a bequest motive, both financial wealth and the implicit riskless assets (annuities and state pensions) are being depleted at similar rates. A bequest motive, however, breaks the decumulation of financial wealth and therefore generates a balanced portfolio even at retirement. The need for a bequest motive to explain the data is consistent with recent evidence like De Nardi (2004) who emphasizes the effect for matching the observed wealth distribution and Kopczuk and Lupton (2007) who use this motive to better understand U.S. wealth data during retirement. Our results are also consistent with Yogo (2008) who needs a bequest motive to generate low welfare

[9] We do not model the endogenous decision of whether to participate or not in the stock market. Gomes and Michaelides (2005) and Alan (2006) calibrate and estimate, respectively, a life-cycle model and show that households with low financial wealth can be kept out of the stock market with a small fixed cost. Given that in our data the households that do not participate in the stock market are much poorer in terms of financial wealth than stock market participants, we think that a small fixed cost will keep these households out of the stock market as well. We do not model this endogenous choice explicitly here to keep the model relatively simple.

gains from annuity market participation in a model with health investments for the U.S. Health and Retirement Survey. Overall, comparing the predictions of the model with their empirical counterparts we find that reasonable calibrations can generate the low annuity demand observed in the data and that, therefore, the annuity market participation puzzle might not be as deep as previously thought.

The remainder of the paper is organized as follows. In Section 2, we present the multivariate probit (reduced form) results on the actual determinants of annuity market demand (defined as annuity market participation and the level of annuity demand conditional on participation). In Section 3 we perform a number of comparative statics exercises from a calibrated life-cycle model to understand what a quantitative model predicts about the annuity market. In Section 4 we estimate the structural parameters of this model and investigate the strength of the annuity market participation puzzle by comparing the moments in the data to the ones from the model. Section 5 concludes.

2 Empirical Analysis

2.1 Dataset

The empirical part of the paper is based on the English Longitudinal Study of Ageing (ELSA). ELSA is a biannual panel survey among those aged 50 and over (and their younger partners) living in private households in England in 2002. For most of the variables of interest we use data from the first wave of ELSA collected in 2002 and 2003. We restrict our analysis to households with either a retired single, or a couple with at least one retired person, since annuitization is likely to occur during retirement and we are interested in possible substitution effects between public and private pension income and annuities.[10] It is vital to focus on voluntary annuitization, which is recorded in ELSA as a part of the "Income and Assets" module. The survey gives a definition of annuity income, which should

[10]With this restriction, we exclude 2,206 non-retired households. We do not view this restriction as important for our analysis since we only observe 14 voluntary annuity contracts for these households in the first wave of ELSA.

prevent any misinterpretation: "Annuity income is when you make a lump sum payment to a financial institution and in return they give you a regular income for the rest of your life." Some further details are provided in Appendix A.

2.2 Descriptive Statistics

2.2.1 Annuities

Table 1 describes the annuity market participation decisions, and also presents a split of this decision between households that participate, or not, in the stock market. We do this based on the idea that stock market participation might be correlated with the decision to participate in the annuity market, since both decisions require a certain level of financial sophistication and financial wealth. According to Table 1, only 5.9% (309 observations) of the households in our sample received income from voluntary annuitization in either the first or second ELSA wave, illustrating "the annuity market participation puzzle".

Table 1 also indicates that there might be an interesting correlation between the decision to participate in the stock market and the decision to purchase an annuity. Stock market participation[11] is around 42.5% of the total sample but the percentage of stock market participants purchasing an annuity (9.6%) is three times the percentage of stock market non-participants (3.2%), with the difference highly statistically significant. Thus, there seems to be some connection between the decision to participate in the two markets.

Table 2 presents annuity demand statistics conditional on participating in the voluntary annuity market. Specifically, the table reports mean and median annual annuity income, also split across the stock market participation decision. Conditional on having an annuity, the mean annual annuity income is about $3,000$ GBP, but this is dominated by a number of very large annuities as the median of about $1,000$ GBP shows. Stock market participants tend to demand higher annuities as indicated by a mean (median) annual annuity income of about $3,650$ $(1,200)$ GBP.

[11] We define a stock market participant as a household that has stocks in an individual savings account (ISA), or a personal equity plan (PEP), or indirect stock holdings in an investment trust, or direct holdings of stocks. Indirect stock holdings in occupational or private pension schemes are not accounted for.

2.2.2 Life Insurance

Table 1 also provides participation rates in the life insurance market and this participation rate equals 40%. Hence, participation in the life insurance market is much more pronounced than participation in the voluntary annuity market. Given the inverse payout structure of the two financial products - a life insurance is often called an inverse annuity - a joint participation in both markets needs to be explained. There are no significant differences between stockholder and non-stockholder life insurance participation rates (37.5% and 42.2% respectively).

2.2.3 Wealth and Income

To be informative about annuity take-up decisions, financial wealth should be measured before annuitization takes place. For annuities already observed in the first wave we capitalize the value of the annuity by multiplying the annual annuity income with the annuity factor and add this to the household's financial wealth to get total financial wealth.[12] Moreover, observations without annuity income in the first wave, but with reported annuity income in the second wave, must have purchased their annuity in the time between the two surveys. By combining the second wave annuity information for these observations with the first wave household variables, we achieve the desired match between the annuity and the household characteristics immediately before voluntary annuitization occurs.

Table 2 reports the mean (median) financial wealth[13] of annuitants to be about $135,000$ ($65,000$) GBP, versus $50,000$ ($14,200$) for non-annuitants, already suggesting the importance of financial wealth in purchasing a voluntary annuity. More detailed evidence is displayed

[12] We use an annuity factor of 13. The annuity factor was calculated using the Financial Services Authority comparative tables. These tables show the monthly payments offered by the main annuity providers under the open market option. The monthly payments correspond to a purchase price of 100,000 GBP of a single life annuity, with no guarantee, for a 65-year old male. We use the average monthly payment across providers to calculate the corresponding annuity factor.

[13] Banks et al. (2007) provide evidence that British households do not reduce housing consumption with increasing age because they stay in their original residence. Correspondingly, we do not use housing wealth in our multivariate analysis because we view the relatively higher liquidity in financial wealth (with respect to housing) as a more relevant criterion for the household decision to annuitize or not.

in Figure 1. The figure shows average voluntary annuity market participation across the 2.5%, 10%, 25%, 50%, 75%, 90% and 97.5% percentiles of the wealth distribution. While average participation is less than 1% in the bottom 5% of the wealth distribution, it increases steeply to almost 20% in the top 5%. Given that the 10% and 25% percentiles of the wealth distribution are 700 GBP and $3,300$ GBP, respectively, it appears that these households have insufficient financial wealth to participate in the voluntary annuity market. Figure 1 also decomposes the sample across wealth percentiles into stock market non-participants and participants. Almost all households around the 75%, 90% and 97.5% percentiles of the wealth distribution are stock market participants. The mean (median) wealth of investors who participate in both markets is $174,000$ $(100,000)$ GBP (Table 2), considerably larger than the mean (median) wealth of annuity market participants.

The existence of other pension income offers another potential explanation for low annuity market participation. The institutional details of the U.K. pension system have been described elsewhere (for example, Blundell et al. (2002)) and we only summarize its main features. The first tier of the public pension system is the Basic State Pension (BSP). The second tier is earnings-related and can either be provided by the government or the private sector. Both occupational and personal private sector pensions in the U.K. are subject to compulsory annuitization laws (an annuity must be purchased within a certain time from retirement) during the sample period. These compulsory annuities must be distinguished from the voluntary annuities purchased from non-pension wealth that we focus on. Finkelstein and Poterba (2002) indicate that the compulsory annuity market in the U.K. is much larger than the voluntary annuity market: in 1998 the former had a size of 5.4 billion GBP versus 0.8 billion GBP for the latter.

Public pensions and the compulsory annuities from private pensions may be close substitutes for the voluntary annuity market. Indeed, Attanasio and Rohwedder (2003) find that the earnings-related tier of the U.K. public pension system serves as a perfect substitute for private savings. Table 2 shows mean and median annual pensions for the whole sample and different sub-samples of annuity and stock market participants. While the level of public pensions hardly changes over sub-samples, there is considerable variation in private pensions. Annuity market participants receive higher private pensions (mean $7,236$

GBP; median 3, 200 GBP) than annuity market non-participants (mean 4, 362 GBP; median 1, 350 GBP). Figure 2 decomposes the sources of pension income over different percentiles of the wealth distribution. The level of public pensions resembles a flat pension, despite the earnings-related tier of the system. This arises mostly from higher-earning employees opting out from the public second tier (in Figure 2 private (compulsory) pensions increase steeply over the wealth distribution). Compared to the level of public and private pensions, voluntary annuities are small in magnitude and only exist around the 75%, 90% and 97.5% wealth percentiles. Nevertheless, we cannot interpret these results as evidence against the hypothesis that other pension income crowds out voluntary annuities, since other variables (like financial wealth) need to be controlled for.

2.2.4 Health and Life Expectancy

Apart from wealth and existing pensions, an individual's health condition and her life expectancy should also affect the decision to annuitize since annuities hedge longevity risk. These products are in fact priced to reflect the average life expectancy of annuity market participants. If an individual has private information suggesting that she is unlikely to reach the age of an average annuity market participant, she will not buy an annuity simply because the product is overpriced for her. Finkelstein and Poterba (2002, 2004) indeed find evidence for adverse selection in the U.K.'s annuity market: participants in the voluntary annuity market tend to live longer than non-participants. More generally, Rosen and Wu (2004) find evidence from the Health and Retirement Survey that health status affects portfolio choice and stock market participation. Since annuities are a form of financial product that is even more explicitly linked to health status, we expect that health can be a strong predictor of participation in the annuity market.

ELSA allows us to use subjective survival probabilities as a determinant of the annuitization decision. The questionnaire asks individuals of age less than, or equal to, 65 (69, 74, 79, 84 and 89) "What are the chances that you will live to be 75 (80, 85, 90, 95 and 100, respectively) or more?" and gives a range from 0-100 for possible answers. We compare these subjective survival probabilities with gender- and age-specific objective survival probabilities from the Government Actuary's Department tables (2006). We see from Table 3 that annuity market participants report a survival probability higher than non-participants by five percentage points. The difference in objective GAD survival probabilities is three percentage points and thus slightly smaller. These results are in line with the Finkelstein and Poterba (2002, 2004) self-selection findings for the voluntary annuity market in the U.K and will justify one of the comparative statics in the structural model where the subjective survival probability is allowed to deviate from the objective one.

2.2.5 Socio-Economic Background

The final group of variables possibly affecting annuity market participation decisions is household composition and education. Education might matter since annuity products require a basic level of financial literacy.[14] We differentiate between three education levels: low, medium and high. Table 3 shows that annuity market participants are on average much better educated than non-participants. While 61% of the non-participants are in the lowest education group, only one-third of all annuity holders are in the low education category. For the high education level, the order changes: only 9% (25%) of non-participants (participants) have a higher education degree. We also investigate household composition to detect a possible bequest motive, which might be a barrier for voluntary irreversible annuitization. The unconditional statistics in Table 3 do not indicate that marital status or the number of children vary between participants and non-participants.

2.3 Econometric Analysis

We investigate the household's decision to participate in the voluntary annuity market and the amount of purchased annuities conditional on participation in a multivariate regression setup.

[14]Lusardi and Mitchell (2006) provide evidence that individuals planning for retirement generally exhibit a higher degree of financial literacy than non-planning individuals.

2.3.1 Annuity Market Participation

Panel A of Table 4 displays the results of a Maximum Likelihood estimation of a Probit model for the household's decision to participate in the voluntary annuity market or not. The previous section revealed systematic differences between stock market participants and non-participants, differences that might affect the annuitization decision. Therefore we present estimation results for the two groups next to the estimation results for the whole sample. We use as explanatory variables the following: wealth, income, life insurance market participation, household composition, age, health and life expectancy of the household. The regression for the whole sample contains in addition a stockholder dummy and its interaction with financial wealth. In presenting the results, since the estimated coefficient in the probit model only shows the qualitative impact of an explanatory variable, we also compute marginal effects to assess the quantitative impact in Panel B of Table 4. We do this for a baseline observation that is defined as a 65-year-old, single, male with medium education, no children, no life insurance holding, average reported survival probability, average pension income and financial wealth who does not participate in the stock market.

First, we note that the coefficient of the stockholder dummy in Panel A of Table 4 is negative with a confidence level of about 5%. However, the interaction of the stockholder dummy with financial wealth is positive and significant. Taken together, the two coefficients imply a positive marginal effect of stock market participation with a t-value of 1.86 in Panel B. Changing the baseline household from non-stockholder to stockholder, increases the participation in the voluntary annuity market by 2.3 percentage points.

Confirming the earlier descriptive statistics in Table 2, financial wealth is shown to be one of the most important predictors of annuity market participation.[15] A unit increase in log financial wealth, which roughly corresponds to a 100% increase in financial wealth relative to the baseline, significantly increases the annuity market participation probability for the whole sample by 2.3 percentage points. The effect is larger in the stockholder sub-sample (5.7 percentage points) than in the non-stockholders sub-sample (1.8 percentage points). On the

[15] For all financial variables, we test for possible nonlinearities by including a squared term. This term always turns out insignificant.

other hand, pension income turns out to be statistically insignificant for both stockholders and non-stockholders.

Turning to health and life expectancy, we find that the health indicators are insignificant once we control for the subjective survival probabilities. Correspondingly, we only include the self-reported survival probabilities in the regression, since these are a direct measure of the longevity risk targeted by annuities. This variable affects differently the annuitization decision of non-stockholders and stockholders. While statistically insignificant for non-stockholders, a ten percentage point increase in the baseline survival probability of stockholders significantly increases the annuity market participation probability by 0.74 percentage points.

Married financial units are significantly less likely to purchase an annuity. The marginal effect for the whole sample suggests that changing the marital status of the baseline household from single to married would significantly decrease the probability to participate in the voluntary annuity market by 3.6 percentage points. The result is more pronounced in the stockholder sub-sample than in the non-stockholder sub-sample. On the contrary, the number of children (or the presence of children or grandchildren in alternative unreported specifications) does not have a significant effect. This could mean that any bequest motive focuses on the spouse and not on the children.[16] Alternatively, the large impact of marital status could be interpreted as intra-household hedging of longevity risk, instead of relying on the annuity market. However, the explanatory financial wealth and pension income variables are measured on the household level and already comprise the wealth and income of the spouse. Therefore, the bequest motive appears to be the more suitable explanation of the importance of the marital status variable. The presence of a life insurance could be a

[16] The negative effect of being married could also be explained by "joint-and-last-survivor" or "joint-survivor" types of compulsory annuities, which provide payments until the death of the surviving spouse. Usually, annuity payments are reduced by one half or one third after the death of the first annuitant (Blake, 1999). Brown and Poterba (2000) show that the utility gains from annuitization are smaller for couples than for singles. ELSA does not provide details on the type of annuity a household has purchased. Stark (2003) presents evidence on the importance of joint survivor annuities in the U.K. from a survey of 500 annuitants in the compulsory market. She notes that only 12 percent of the annuities were of a joint type which suggests a moderate demand.

more direct measure of a bequest motive. However, the life insurance dummy variable turns out insignificant in all regressions which probably can be explained by a small number of observations (105) which engage in both the annuity and the life insurance market.[17]

We include dummies for low and high education levels as a measure of financial literacy. Changing the education level of the baseline household from medium to low significantly decreases the participation probability in the whole sample by 2.9 percentage points. This is a quantitatively large effect and underscores the importance of financial literacy.

2.3.2 Conditional Annuity Demand

We estimate a linear regression model for annuity demand measured in terms of log annual annuity income on the whole sample and the two sub-samples of stock market (non-) participants. Results are given in Table 4, Panel C. All non-financial background variables appear insignificant in the conditional annuity demand regressions. These variables affect participation but do not influence demand conditional on participation. The financial variables, however, remain significant predictors of annuity demand. The annuity demand elasticity of financial wealth is 0.33 for the whole sample, and 0.32 (0.63) for the sub-samples of non-stockholders (stockholders). While pensions do not significantly affect the annuity demand of non-stockholders, they have a marginally statistically significant and negative impact for stockholders. A 1% increase in compulsory annuities crowds out the demand for voluntary annuities by 0.22%. The stockholder dummy and its interaction with financial wealth in the regression based on the whole sample have the same signs as in the participation probit model, but are only significant at the 10% level.

2.4 Summary

We provide an in depth empirical analysis of the voluntary annuity market participation decision and the annuity demand conditional on participation. We reconfirm that there appears to be a substantial voluntary annuity market participation puzzle since less than 6%

[17] Using the amount of life insurance coverage instead of a life insurance dummy does not change this result.

of households participate in this market. Moreover, annuity market participation increases with financial wealth, life expectancy and education. Pension income (or compulsory annuity income) crowds out annuity demand conditional on voluntary annuity market participation, while a possible bequest motive for surviving spouses is a hurdle for voluntary annuitization.

3 Understanding the Implications of a Life-Cycle Model

In the next two sections we investigate the implications of a life-cycle model of annuity and life insurance demand and portfolio choice and assess the model's consistency with the empirical findings in the previous section. We first outline the most general version of the model; special cases arise by limiting the choices available to households.

3.1 The Model

3.1.1 Bond and Stock Market

The household can save through a riskless asset and the stock market. We use r_f to denote the one period interest rate, $\widetilde{r}_{t+1}$ the random return on the stock market and α_t the share of wealth in stocks, and assume that neither stocks nor bonds can be sold short, therefore α_t has to lie between zero and one.

3.1.2 Annuity Contracts

We study nominal annuity contracts but for simplicity we assume zero inflation.[18] One main component of the analysis involves calculating the expected present discounted value (EPDV) of the annuity, since the insurance company uses this value to calculate the price of the product. The EPDV will depend on the annual annuity payment, the survival probabilities and the term structure of interest rates at the time of retirement. For instance, if at retirement age the annualized interest rate on a bond with maturity t is r_f, p_t denotes the

[18] Recall that our data does not allow us to distinguish between nominal, real and variable annuities. While all of these annuity products are available in the U.K., Stark (2002) shows that more than 70 percent of all purchased annuities are of the nominal type.

probability that the household is alive at date t, conditional on being alive at date $t-1$ and the household purchases one unit of annuity, the expected present discounted value (EPDV) of the annuity payouts is given by:

$$EPDV = \sum_{j=1}^{T} \frac{\prod_{k=1}^{j} p_k}{(1+r_f)^j} \tag{1}$$

We use this EPDV to determine the cost of buying an annuity at retirement by multiplying the EPDV with one plus a load factor (P) which is greater than or equal to zero, obtaining a measure of the "money's worth" of the annuity. If the load factor is zero, then the annuity contract is actuarially fair and the "money's worth" equals one.[19] Empirical evidence by Mitchell et. al. (1999) illustrates that the load factor varies between 8% and 20% depending on different assumptions about discounting and mortality tables; a 20% value is suggested as indicative of the transaction cost involved and this is the baseline value we use in our calibration. Following the notation in Zeng (2008) we let the price of a unit annuity at time (age) t be denoted by a_t. Following the empirical evidence with regards to the timing of annuity purchases in our data set, we let households buy incremental annuities between the retirement date (age 65) and age 80.[20],[21]

3.1.3 Life Insurance Contracts

[19] The annuity premium/load factor (P) and the money's worth are therefore defined as:

$$Annuity\ Cost = (1+P) \times EPDV$$

and

$$Money's\ Worth = \frac{EPDV}{AnnuityCost}.$$

[20] We know the age at which a first annuity is purchased for those 102 observation that were observed without annuity in the first wave of ELSA but with an annuity in the second wave. Annuities are purchased troughout retirement. 84% of the annuity purchases occur before or at the age of 80. 26% take place at the state pension age or the year after.

[21] Life-cycle models which allow for gradual annuitization throughout retirement are proposed by Milevsky and Young (2007), Horneff et al. (2008), Zeng (2008), and Horneff et al. (2009). The latter two papers consider variable payout annuities. None of these papers attempts to estimate the structural parameters of the life-cycle model to match observed annuitization behaviour.

At time t the household can purchase term life insurance which will pay $\exp(r_f)$ at time $(t+1)$ if death arrives next period. The actuarially fair price of one unit of the life insurance product is then equal to $(1-p_t)$[22]. We use the same load factor as in the annuity market to avoid biasing our results in one direction or the other from this choice. Therefore, the price of life insurance equals

$$l_t = (1 + P_l)(1 - p_t) \tag{2}$$

3.1.4 Budget Constraint

During retirement the household has liquid financial wealth (cash on hand) X_t, which can be used to purchase the annuity, the life insurance product and save through the bond or the stock market. The household is also endowed with pension income in each period, L. The annuity decision is irreversible, even though the household can add positive amounts every period, while the household can also purchase only positive amounts of the life insurance product. At time t (in the most general version of the model), there are three state variables (age, cash on hand, and the amount of annuities) and four control variables (consumption/saving, the share of wealth in stocks (α_t), the share of wealth invested in new annuities (α_{At}) and the share of wealth allocated to the life insurance product (α_{lt})).

Cash on hand evolves according to

$$X_{t+1} = (X_t - C_t)[\alpha_t \exp(\widetilde{r}_{t+1}) + (1 - \alpha_t - \alpha_{At} - \alpha_{lt}) \exp(r_f)] + L + A_{t+1} \tag{3}$$

If the individual dies in period $t+1$, then next period cash on hand is augmented by the life insurance payout which equals $\alpha_{lt}(X_t - C_t)\exp(r_f)/l_t$ but the household does not receive a pension or an annuity payout in that instance[23].

[22] With probability p_t survival continues next period and the insurance gives a payout equal to zero. With probability $(1-p_t)$ the insurance pays out $\exp(r_{t+1,1})$ next period and therefore the current expected value of life insurance equals $(1-p_t)$.

[23] Consistent with Zeng (2008) we find that the timing of the inheritance or, in the context of the model, whether L and A_{t+1} is received at the time of death, can affect substantially the behavior of the household with an operable bequest motive. We think that this can be an interesting area for further research.

The annuity evolves as

$$A_{t+1} = A_t + (X_t - C_t)\frac{\alpha_{At}}{a_t} \tag{4}$$

3.1.5 Preferences

We model household saving, portfolio and annuity choices from retirement onwards at an annual frequency. The household lives for a maximum of T (35) periods after retirement. We allow for uncertainty in the age of death with p_{t+1} denoting the probability that the household is alive at date $t+1$, conditional on being alive at date t. Household preferences are then described by the Epstein-Zin (1989) utility function:

$$V_t = \left\{ (1-\beta)C_t^{1-1/\psi} + \beta\left(E_t(p_{t+1}V_{t+1}^{1-\gamma} + b(1-p_{t+1})X_{t+1}^{1-\gamma})\right)^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}} \tag{5}$$

where β is the time discount factor, b is the strength of the bequest motive, ψ is the elasticity of intertemporal substitution (EIS) and γ is the coefficient of relative risk aversion. The specification of the bequest motive is potentially a controversial issue in (5). Cocco et al. (2005) and Yogo (2008) make a similar assumption, De Nardi (2004) and Lockwood (2009) assume a more complicated version of this[24], while Kopczuk and Lupton (2007) assume that utility from leaving a bequest is linear in wealth. The state variables in each period are current cash on hand, the annuity payment, and age. In each period t, $t = 1, ..., T$, the household chooses optimal consumption C_t and the shares of saving allocated to new annuities (α_{At}), the stock market (α_t) and the life insurance product (α_{lt}) with all shares being between zero and one.

3.1.6 Wealth Distribution and Pension Income

To eventually compare the predictions of the model with the observed annuity demand and participation rates, we need (among other exogenous inputs) an initial wealth distribution and a reasonable pension level, and we take both of these from the data. At the same time, based on our empirical results, we also condition these exogenous inputs on stock market

[24]The specified function in De Nardi (2004) is $\phi_1(1+\frac{X}{\phi_2})^{1-\gamma}$.

participation status and solve two different models, one in which stock market participation is allowed and another where access to the stock market does not exist, therefore requiring different inputs for wealth and pension income depending on the stock market participation status. We make this choice following the literature that has shown that wealth and stock market participation are positively correlated and that, to a first approximation, non-stockholders are poorer than stockholders so that a small fixed cost of participation can keep non-stockholders out of the stock market (see, for example, Gomes and Michaelides (2005), Alan (2006) or the evidence summarized in Guiso et al. (2002) and Campbell (2006)). This assumption is consistent with our data with mean financial wealth at retirement for stockholders being approximately four times the mean wealth of non-stockholders.[25] Using these exogenous inputs we start a simulation from age 65 onwards and for each age compute the average annuity and life insurance participation rate, average portfolio demand and the aggregate demand for annuities.[26]

3.1.7 Solution Technique and Other Parameters

This problem cannot be solved analytically. Given the finite nature of the problem a solution exists and can be obtained by backward induction, the numerical appendix offers some details on the solution method. The maximum age that can be reached is 100, but agents will face a probability of death each period. We assume a constant interest rate equal to 2%. The mean equity premium is set at 4% with a standard deviation of 18%. In the baseline case we use a CRRA preference specification with a coefficient of relative risk aversion equal to 3 ($\psi = 1/3$) while to illustrate the effect of the bequest motive on life insurance demand we set $b = 1.0$.

[25] Median wealth differences are even more extreme with median wealth for non-stockholders being 5,000 GBP, while median wealth for stockholders equalling 48,000 GBP.

[26] To compute aggregate statistics we derive the demographic weights that would be implied by the survival probabilities used by the household. We then weight each cohort by the respective demographic weight. The conditional survival probabilities are taken from the U.K. GAD for 2002-2004.

3.2 Results

3.2.1 Annuity Policy Functions

We now report a series of comparative statics results to understand household choices according to this model. Figure 3 plots the annuity demand choice at age 80 (the last year for which annuity purchases are allowed) for stockholders and non-stockholders. For both cases, the demand for annuities is zero for low wealth levels reflecting mainly the annuity in the form of pension income received during retirement. Higher wealth levels generate an increasing demand for annuities over the early part of liquid wealth and decreasing at higher levels of cash on hand and previously purchased annuities. From the shape of the policy functions it should be noted that the wealth distribution is a necessary input before pronouncing the presence of an annuity market participation puzzle. In an economy where all households are very poor, the model predicts that no annuity demand will be generated and therefore the lack of annuity market participation becomes a prediction of the model. Moreover, stock market access makes the wealth level that warrants entry to the annuity market generally higher. This is consistent with the idea that households might value the flexibility that can be offered by investing in a higher mean return asset more than the security of an annuity payout.[27] The result is consistent with Milevksy and Young (2007) who point out the benefits of maintaining the flexibility of investing in the stock market.

Figure 4 plots (for non-stockholders) the three-dimensional annuity policy functions for age 65 (the retirement age) and age 80 (the last year for which incremental annuities can be purchased). The figure illustrates a number of intuitions raised in the literature. First, incremental annuitization is quite important as there are zero annuities purchased at retirement whereas there is large participation rate at age 80. The difference between the two ages implies (and this can be confirmed in unreported diagrams) that annuity market demand gradually increases with older age. Second, the share of wealth invested in incremental annuities is first increasing in wealth for a given annuity level and then decreases when a

[27] Variable annuities, which are linked to a broad stock market index, allow the investor to combine protection against longevity risk with stock market exposure. Koijen et al. (2009) show that access to variable annuities during retirement is welfare enhancing.

substantial amount has been accumulated. We can conclude that a certain wealth level needs to be reached before the household can purchase an annuity.

3.2.2 Life Insurance Policy Functions

In the absence of a bequest motive, there is no demand for life insurance products. In Figure 4 we can see that life insurance is (i) increasing in age so that life insurance demand rises with age and (ii) poorer households all participate in the life insurance market and the demand for life insurance decreases as liquid wealth rises. Thus, unlike the annuity demand schedule, life insurance allocations of wealth decrease with higher wealth levels. This implication points towards a prediction of the model that generally implies that annuity and life insurance demands should be negatively correlated as, for a given annuity level, richer households tend to mostly increase their annuity allocation and decrease their life insurance one.

3.2.3 Portfolio Choice Policy Functions

The share of wealth invested in the stock market as a function of cash on hand and age is familiar from the literature on life-cycle portfolio choice.[28] Specifically, pension income is treated like an implicit bond since it is certain and therefore the share of wealth in stocks is a decreasing function of cash on hand since for diversification purposes the investor allocates all financial saving to the stock market. For higher levels of financial wealth to pension income, the portfolio becomes more diversified with more riskless assets added to the portfolio but given that there is no background risk (like uncertainty about medical expenditures) in the model, the portfolio remains heavily invested in the stock market.[29] An additional (unreported) prediction here is that for a given level of cash on hand, a higher level of pre-purchased annuities increases the share of wealth invested in stocks as the annuity can be seen as an additional riskless asset.

Nevertheless, our results stress the importance of the bequest motive for asset allocation decisions. One might think that the presence of a bequest motive acts towards making

[28] For instance, see Cocco et al. (2005), Gomes and Michaelides (2005) and Polkovnichenko (2007).

[29] In fact, for low levels of risk aversion we have the well-known complete portfolio specialization in stocks result, see, for example, Heaton and Lucas (1997).

the horizon of the investor longer, therefore generating a higher allocation of the financial portfolio in stocks. We show that this intuition is wrong. In our model the fixed state pension (or the purchased annuity) is viewed as an implicit riskless asset. In the absence of a bequest motive, financial wealth gets decumulated but the presence of the fixed pension income still makes the portfolio heavily biased towards stocks for diversification reasons. In the presence of a strong bequest motive, however, the household optimally does not intend to decumulate financial wealth. The present value of state pension income does get depleted, however, since this is not determined by the preferences for bequests. Therefore, the portfolio becomes much more balanced between bonds and stocks. The tendency to reduce stock market risk over time exists but the portfolio might remain balanced throughout retirement in the presence of a strong bequest motive. This analysis confirms the findings in Cocco et al. (2005), who show the importance of the bequest motive in generating balanced portfolios, but we are going to show next that this behavior can coincide with low demand for annuities.

3.2.4 Simulated Consumption and Wealth Profiles

Given that we have computed policy functions for annuity demands as a function of financial wealth and given the initial observed wealth distribution in the data, we can simulate the evolution of individual consumption, portfolio choice, annuity demand and financial wealth for the remainder of a household's lifetime. In the interest of space we do not report any figures here as these will be reported later on for the final estimated parameters and can be partly inferred from Table 5 that we discuss next.

3.2.5 Participation, Annuity Demand and Annuity Value

Given that we have computed policy functions for annuity demands as a function of financial wealth at retirement age and given the observed wealth distribution in the data, we can combine this information to calculate the total level of annuity demand implied by the model, as well as the percentage of households that will participate in the annuity market. We also calculate and report the annuity equivalent wealth (AEW) that will make an individual without access to the annuity market indifferent between purchasing the optimal annuity for the given preference configuration and economic environment or staying outside the market.[30] The maximum welfare when annuities are set to zero is calculated by solving the consumer's problem by setting annuities equal to zero, giving a value function equal to V. The optimal decision with a potentially positive annuity is given by the value function V^* for the first time an annuity is purchased. We then solve for the percentage change in liquid wealth that will equate the two value functions for a given level of wealth as

$$V^*(X) = V(X + \Delta X) = V\left(\frac{X}{AEW}\right).$$

The AEW is therefore given by $X/(X + \Delta X)$; a number like 99% means that the household is willing to give up 1% of its wealth to be able to purchase an annuity, that is, annuities are welfare improving to individuals. Following the distinction we view as empirically relevant, we also condition on the stock market participation status when presenting these results.

Table 5, Panel A, reports various annuity demand statistics for non-stockholders for different perturbations of the preference parameters (risk aversion, the elasticity of intertemporal substitution and the bequest motive).[31] Annuity market participation (column 4) reports the percentage of households that participate in the annuity market, life insurance participation (column 5) reports the percentage of households that participate in the life insurance market, while voluntary annuity demand (column 6) reports the average annual annuity income in thousands of pounds conditional on participation. The last column reports average annuity equivalent wealth. Consistent with the policy function results, in the absence of a bequest motive, life insurance participation is zero while higher risk aversion increases annuity market participation and the total level of annuity demand.[32] A stronger bequest motive, on the other hand, generally decreases annuity demand, but not to the extent found when life insurance is not present. A stronger bequest motive increases life insurance partic-

[30] This calculation follows Brown (2001).

[31] We use a range of preference parameters that is deemed reasonable in the literature (see, for example, Gourinchas and Parker (2002) and Vissing-Jorgensen (2002)) and also consistent with the estimates presented later on in the paper.

[32] The reported average level of voluntary annuity demand falls but the total annuity demand rises since there are more participants now. We report this statistic because this will be more directly comparable to the empirical section which reports per capita annuity income conditional on participation.

ipation, which can be viewed as a negative position in annuities and therefore the bequest motive does not crowd out annuities to the extent found when life insurance purchases are not allowed.

The effect of a higher EIS depends on how the EIS affects total saving. This is in turn determined by the difference between the expected rate of return and the discount rate (as explained in Campbell and Viceira (1999)). In the current set of experiments, the discount rate is higher than the risk free rate and therefore a higher EIS generally decreases saving and therefore results in a lower annuity market participation and simultaneously to a higher life insurance participation. Furthermore, as annuity demand increases, the value of annuities is reflected in a lower AEW, in the absence of a bequest motive. In the presence of a bequest motive this is more complicated because of the change in life insurance demand. Specifically, as annuity demand increases typically life insurance participation drops. Therefore, if one compares the $b = 0$ with the $b = 0.1$ cases, annuity market participation mostly does not move much but the AEW moves quite dramatically reflecting the big change in life insurance demand generated by the bequest motive.

Quantitatively, the results illustrate that even in the absence of a bequest motive, there do exist configurations of parameters where the model still predicts low participation. When $\gamma = 2$ and $\psi = 0.1$, for instance, only 3.5% of households choose to participate in the annuity market. This result seems very surprising given the existing literature on the annuity market participation puzzle. What explains this finding? This preference parameter configuration implies a weak motive to save, the wealth distribution is skewed to the left for this group with many poor households, while the pension system already provides a substitute for the provision of longevity insurance. As a result, very few households choose to participate in the annuity market. This explanation is consistent with the other finding from the table that as risk aversion increases, the insurance value of annuities rises substantially and annuity market participation can rise up to 15.81% (for $\gamma = 5$ and $\psi = 0.1$). The table also illustrates that lower annuity demand can also be generated if one is willing to admit some preference for leaving bequests. Specifically, for ($\gamma = 2$, $\psi = 0.1$) and $b = 0.1$ annuity market participation is around 3.42% for non-stockholders.

Panel B of Table 5 reports similar results for stockholders with two differences. First we also report the share of financial wealth in stocks since the households in the data hold balanced portfolios (made up of both bonds and stocks). Thus, an explanation of the low annuity take-up that simultaneously generates a complete portfolio specialization in stocks would be explaining one puzzle at the cost of maintaining another one. Second, we expand the range of preference parameters for which results are being reported to reflect the range of estimated parameters from the next section. Thus, the bequest parameter rises from $b = 0.1$ to $b = 5$.

The basic qualitative results are similar as for the non-stockholders' case. Annuity demand and participation are both increasing in risk aversion and decreasing in the strength of the bequest motive. The effect of EIS is ambiguous/non-monotonic but is mostly decreasing annuity demand (for higher risk aversion coefficients). It is important to note that this is influenced by the (endogenous) portfolio choice that determines the rate of return on the portfolio and thus the difference between the rate of return and the discount rate. For low levels of risk aversion the household is more aggressive and earns a higher mean return on the portfolio, whereas this is reversed for higher levels of risk aversion. For the latter cases the discount rate is substantially higher and therefore a higher EIS generates lower saving and thus a lower annuity demand participation and a higher life insurance participation (when the bequest motive is present).

3.3 Summary

We use a life-cycle model to understand both qualitatively and quantitatively the importance of preference parameters in affecting the demand for annuities. Risk aversion, the strength of the bequest motive, the elasticity of intertemporal substitution and the decision to access the stock market are key determinants of the model's quantitative predictions. Financial wealth, a key endogenous state variable in the model, is directly affected by these parameters and is therefore a key predictor variable in assessing the model's quantitative implications. Contrary to frictionless theoretical models, there exist reasonable preference parameter configurations that generate very low annuity market participation.

4 How Deep is the Puzzle?

In this section we evaluate the extent to which the model's predictions are at odds with the data. We employ a method of simulated moments estimator to pick the structural parameters that minimize the distance between some selected moments in the data and in the model. Consistent with the empirical evidence from the previous sections, we separate our analysis between stockholders and non-stockholders. The main predictions that we focus on are the participation in the annuity and life insurance markets, and, conditional on participation, the amount of annuity demand at retirement. For stockholders we also focus on matching the share of wealth invested in the stock market. In the non-stockholder version of the model we have two parameters to match three moments. Specifically, we set risk aversion equal to two and estimate the bequest parameter and the elasticity of intertemporal substitution to match the voluntary annuity and life insurance market participation rates and the average annuity demand conditional on participation. We set risk aversion to two consistent with the available empirical evidence for large parts of the population (Gourinchas and Parker (2002), for instance). For the stockholders we match the same three moments plus the average share of financial wealth allocated to stocks during retirement and use the risk aversion coefficient as the extra parameter to match the extra moment.

4.1 Non-Stockholders

Given the wealth distribution for non-stockholders at retirement as an exogenous input, Table 6, Panel A, reports the estimated structural parameters from this procedure.[33] The elasticity of intertemporal substitution is estimated at 0.08 and there is evidence for a be-

[33] The parameter vector (θ) is chosen to minimize the quadratic form $Argmin_{\theta} D'\Omega^{-1}D$. Under regularity conditions given in Duffie and Singleton (1993), $\sqrt{T}(\hat{\theta}-\theta) \rightarrow N(0, W_H)$. The different components of the quadratic are defined as follows,

$$D = \left(\frac{1}{T} \sum_{t=1}^{T} m(Y_t) - \frac{1}{TH} \sum_{t=1}^{TH} m(\tilde{Y}_t) \right)$$

$$\Omega = Var\left(\frac{1}{\sqrt{T}} \sum_{t=1}^{T} m(Y_t)\right)$$

quest motive (0.02). Even though the bequest coefficient is near zero, bequests are essential in this model to match the life insurance participation rate in the data. The elasticity of intertemporal substitution is consistent with studies based on intertemporal Euler equations (Vissing-Jorgensen (2002)). The predicted annuity market participation rate for this group of households is 3.5% (versus 3.2% in the data). Conditional on participation, the annual annuity purchased is around $4,400$ GBP ($1,700$ GBP in the data) and life insurance participation is 71.9% (42.2% in the data). We think that the intuition for these results is clear. The wealth distribution for non-stockholders is concentrated very much to the left of the wealth distribution and poor households optimally choose not to annuitize, or annuitize a small fraction of their wealth, since pension income already provides a reasonable insurance against longevity risk. Figure 5, Panel A, compares the wealth evolution during retirement predicted by the model versus the one in the data, illustrating the close fit between the two. Correspondingly, Panel A of Figure 6 compares the cumulative annuity and life insurance participation between the model and the data and illustrates how annuity demand can be well captured by the model. Life insurance participation is slightly harder to match with the model predicting a stronger increase in participation over the remaining years of life than in the data.

It could be argued that our results arise from certain exogenous assumptions in the model. For instance, we use a load factor of 20% which might be considered very high. We therefore next investigate the robustness of our conclusions to such maintained assumptions. Table 7, Panel A, reports the results from changing these parameters while maintaining everything else as in the estimated model. A lower pension (set at the 25th percentile) increases annuity

$$W_H = (1+\frac{1}{H})\left(E\left[\frac{\partial m(\tilde{Y}_{[TH]})'}{\partial \theta}\right]\Omega^{-1}E\left[\frac{\partial m(\tilde{Y}_{[TH]})}{\partial \theta}\right]\right)^{-1}$$

$m(Y_t)$ denotes the different moments chosen, variables $Y, (\tilde{Y})$ denote actual (simulated) data, T is the sample size and TH is the total size of simulated data. Following the rules of thumb in Michaelides and Ng (2000) we use $H = 10$. The derivatives are computed numerically and E is the population average (sample analog used in the estimation). Following Pischke (1995) and De Nardi et. al (2006) we use a diagonal matrix for weighting the moment conditions. The idea is that even though the optimal weighting matrix is asymptotically efficient, it can be severely biased in small samples. The diagonal weighting scheme uses the inverse of the matrix that is the same as Ω along the diagonal and has zeros off the diagonal of the matrix.

market participation from 3.5% to 5.4%. Nevertheless, the results with regards to the three moments of interest are still relatively close to their empirical counterparts, if one takes into account the standard deviation of these moments in the data. We next investigate the implications of a lower subjective survival probability (the household expects the survival probability to be 10% lower than the objective one). This expectation drives annuity demand down to zero but increases dramatically the demand for life insurance from 71.9% to 87%. Thus, the expected decreased annuity demand is accompanied by the large increase in life insurance in this comparative static emphasizing the close link between life insurance and annuity products. We also investigate what happens when an actuarially fair annuity policy exists. This change increases annuity participation from 3.5% to 8.8% and voluntary annuity demand from 4,400 GBP to 4,800 GBP. One interesting comparative static involves reducing the number of years for which an annuity can be purchased. In particular, we can set that time to one year so that annuities can only be purchased at the time of retirement. We find that annuitizing only once reduces annuity participation from 3.5% to 3.3%, even though we do not include any time-varying inflation or interest rate considerations in the model. Overall, these results indicate that there is a range of possible outcomes that the model can generate depending on exogenous assumptions, but we view as robust the basic message that there exist preference parameters that can replicate the observed data as part of the posited structural model.

4.2 Stockholders

We follow the same estimation procedure for stockholders but add the average share of financial wealth in stocks during retirement as a target and estimate the coefficient of relative risk aversion (γ) as well. We report the results in Table 6, Panel B. The elasticity of intertemporal substitution is around 0.72 and the bequest parameter equals 4.74. The level of annuity market participation is around 13.5% (9.6% in the data), while life insurance participation equals 63.9% (37.5% in the data). The annual annuity income equals 2,800 GBP (3,600 GBP in the data). We view these predicted outcomes as quite close to their observed counterparts and Figures 5, 6 and 7 illustrate how closely predicted behavior matches its empirical counterpart. Figure 5, Panel B, shows that in the data the mean wealth profile shows only a relatively slight trend towards decumulation over the life cycle. The model cannot match the lack of any decumulation in wealth but we argue that given the substantial uncertainty surrounding these profiles (the average of the cross sectional standard deviation equals $90,400$ GBP), the model can be a good first approximation of the data. Figure 6, Panel B, illustrates that annuity market participation matches well with its empirical counterpart, while life insurance participation is again predicted to be stronger by the model than it is in the data. Figure 7 in turn reports the average profiles for the share of wealth in stocks over the life cycle between the model and the data and balanced portfolios become a key prediction of the model even right after retirement.[34] Interestingly, the household portfolio becomes a lot more aggressive after age 80, a prediction which is absent when access to a life insurance market is not allowed. The presence of a life insurance product in the model generates a very aggressive allocation to stocks as death approaches. Overall, the portfolio is relatively aggressive compared to the data but given the lack of any other background risk in the model, we view this graph as a relative success for the impications of the model.

In Table 7, Panel B, we offer some further comparative statics to illustrate that the conclusions are relatively robust to changes in the economic environment. A lower (25th percentile) pension level affects the annuity market participation rate in the expected way and roughly doubles participation from 13.5% to 25.6%, while it substantially crowds out the participation in the life insurance market. A lower subjective survival probability reduces mostly the amount of voluntary annuities purchased from $2,800$ GBP to $1,900$ GBP while keeping the participation rates at around the same level. The two comparative statics results that generate a large impact on the annuity market participation rate are the ones where markets become actuarially fair (and the annuity market participation rate rises from 13.5% to 53.5%) and when annuity purchases are only allowed to take place once (at retirement).

[34] A previous version of the paper ignored this dimension of the model and estimated the preference parameters keeping $\gamma = 2$. The portfolio held by the household in this specification is heavily invested in the stock market, since with the provision of reasonable pension income and a certain annuity income, the natural prediction of the model is that households would hold stocks to have a diversified portfolio (since annuities and pension income act implicitly like bonds/riskless assets).

In this case annuity demand falls to 6.9%. One interesting finding from these comparative statics is that the AEW is quite high and indicates a robust demand for annuities for this group of the population. We experimented by changing the timing of payments by assuming that both the annuity and the state pension are part of next period cash on hand when the agent dies (that is the agent dies after receiving the annuity and the pension). This is the experiment labelled “Death Pension”. In this instance, there is a substantial drop in the life insurance participation from 63.9% to 46.8% and a corresponding increase in the annuity market participation rate from 13.5% to 17.9%. Interestingly, the AEW now rises to 97.9% from 89.1% implying that the timing of pensions received can have a pronounced effect on the results. Nevertheless, the main predictions that are confronted with the data are still similar in magnitude to the ones reported in the baseline case. Overall, we interpret these findings as being supportive of the robustness of the results.

4.3 Do these Findings Square up with the Literature?

There are three types of ex-ante heterogeneity in preferences that we use to reconcile the low take-up of annuities. The first involves a low elasticity of intertemporal substitution for non-stockholders and a much higher elasticity of intertemporal substitution for stockholders. Finding a low magnitude for the elasticity of intertemporal substitution for non-stockholders, and a much higher one for wealthier households, is consistent with the empirical evidence offered in Vissing-Jorgensen (2002). Gomes and Michaelides (2005) calibrate a portfolio choice model and argue that this type of heterogeneity can explain saving behavior and stock market participation over the working part of the life cycle, while Gomes et al. (2009) estimate similar preference parameters to explain wealth accumulation through tax-deferred accounts in the U.S.. Guvenen (2006) uses this type of heterogeneity to explain the estimates of a low elasticity in studies using aggregate data. Overall, we view our EIS estimates as consistent with the empirical evidence.

The second type of heterogeneity we need is in risk aversion. Specifically, to generate balanced portfolios we need a higher risk aversion for stockholders than non-stockholders. We do not need to make this assumption if instead one is willing to allow ex ante heterogeneity in discount rates rather than risk aversion. Thus, we can keep the risk aversion coefficient the same across the two groups but instead decrease the discount factor for the non-stockholders. Making the non-stockholders more impatient will counteract the higher risk aversion and result in them decumulating wealth during retirement and demanding lower annuities. This observationally would have the same effect as heterogeneity in risk aversion with the same discount rate. Thus, this type of heterogeneity is not vital, assuming discount rate heterogeneity is permitted.

The third type of heterogeneity that is necessary to match the behavior of stockholders is the strength of the bequest motive. Most studies testing for bequest motives compare households with and without children or use the elicited responses of households expecting to leave inheritances and find little explanatory power for the annuitization decision (for example, Brown (2001)). Our results indicate that perhaps combining the predictions for another market (like life insurance) or focussing more on other implications of bequests through a more structural model can be another way to offer evidence for a bequest motive. In particular, we think that the effect of a strong bequest motive in generating a balanced portfolio in stocks has not been sufficiently stressed in the literature. Here, the bequest motive can generate a much slower decumulation of wealth during retirement, while for the same reason it can generate balanced portfolios. Essentially, as financial wealth gets depleted at a slower rate than the implicit riskless assets in the form of pensions, diversification dictates that the household holds a balanced portfolio. Cocco et al. (2005) find this effect for CRRA preferences but they do not compare the resulting profiles to asset allocation profiles from the data. Furthermore, the need for a bequest motive is also consistent with recent evidence like De Nardi (2004) who emphasizes the need for a bequest motive to match the observed wealth distribution and Kopczuk and Lupton (2007) who use this motive to better understand U.S. wealth data during retirement. Our results are also consistent with Yogo (2008) who needs a bequest motive to generate low welfare gains from annuity market participation in a model with housing and health investments for the U.S. Health and Retirement Survey.

The chosen discount factor also seems low at 0.88 and is indeed on the low end of the estimates in the literature. For example, Gourinchas and Parker (2002) estimate it between 0.93 and 0.96 while a recent paper by Love (2008) that includes life insurance choices estimates it between 0.9 and 0.92. We think that a higher discount rate during retirement can be a plausible mathematical representation of marginal utility shifts caused from adverse health shocks in that period of the lifecycle. Given the recent emphasis on medical/health shocks (for instance, Pang and Warshawsky (2007), Ameriks et. al. (2008) and Yogo (2008)) we think that a version of the model that more explicitly deals with how health affects wealth and in turn portfolio choice decisions may generate similar results with a slightly higher discount factor.

5 Conclusion

We provide an in depth empirical analysis of the characteristics of households that participate (or not) in the U.K. voluntary annuity market. We document that annuity demand increases in financial wealth, education and life expectancy, while it decreases in pension income and a possible bequest motive for surviving spouses. We then estimate a life-cycle model of household portfolio choice, life insurance purchases, and annuity demand after retirement. The model emphasizes the role of access to stock market opportunities, bequests, risk aversion and the elasticity of intertemporal substitution (and through these financial wealth) as the main determinants of annuity demand. Comparing the predictions of the model with their empirical counterparts, we find that reasonable preference parameters can generate the low annuity demand observed in the data. We emphasize that by assuming that all purchased annuities are of the nominal (fixed payout) type, we are assuming essentially an incomplete market. According to Davidoff et al. (2005) we should not expect full annuitization (and participation) in an incomplete market. We show that we can match the observed percentages once ex ante heterogeneity in risk aversion, the elasticity of intertemporal substitution and the bequest motive is permitted.

In this paper, we focus on matching average annuity and life insurance market participation rates and the average demand for annuities conditional on participation with our model. An ambitious future research project could try to match participation and demand statistics along different percentiles of the wealth and pension distribution with a more comprehensive version of our model.

Appendix A The Data

The "Income and Assets" module of ELSA is distributed to all financial units within a household. A financial unit is either a single person, or a couple if the latter declares to share their income and assets. If a couple treats their income and assets separately, it will consist of two financial units. Since we would like to use the annuity information on the least aggregated level, we prepare the data on a financial unit level and employ individual specific information (like age, gender, education, and health) of the person who filled in the "Income and Assets" module. Financial information (like wealth and income) is collected at the household level. The first wave of ELSA comprises 12,100 individuals and our sample consists of 5,233 households. The reduction is explained by excluding households without a member in retirement (2,206 observations), excluding partners from couples who report joint income and assets (3,536 observations) and excluding observations with missing values for our variables of interest to be discussed below (1,125 observations).

Appendix B Numerical Solution

There are three state variables (age, cash on hand and purchased annuities) and four control variables (consumption, share of wealth in stocks, in life insurance and in incremental annuities) in the most general version of the model. The household problem is therefore given by

$$V_t(X_t, A_t) = \underset{c_t,\alpha_t,\alpha_{At},\alpha_{lt}}{MAX} \left\{ (1-\beta)C_t^{1-1/\psi} + \beta \left(E_t(p_{t+1}V_{t+1}^{1-\gamma}(X_{t+1}, A_{t+1}) + b(1-p_{t+1})X_{t+1}^{1-\gamma}) \right)^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}}$$

where the evolution of the state variables is given in (3) and (4).

We solve the model recursively backwards[35] starting from the last period. In the last period ($t = T$) the policy functions are trivial and the value function corresponds to the bequest function. We need to solve for four control variables in every year. For every age t prior to T, and for each point in the state space, we optimize using grid search. From

[35] We use a value function approach to solve the problem (unlike the very nice exposition in Zeng (2008) who uses an Euler equation approach).

the Bellman equation the optimal decisions are given as current utility plus the discounted expected continuation value ($E_t V_{t+1}(.)$), which we can compute since we have just obtained V_{t+1}. We perform all numerical integrations using Gaussian quadrature to approximate the distributions of the innovations to the risky asset returns. We discretize the state-space along the two continuous state variables and use tensor product splines to perform the interpolation of the value function for points which do not lie on the state space grid, with more points used at lower levels of wealth where the value function has high curvature. Equivalently, we use a more dense set of grid points for low values of wealth for the two accounts because the consumption function exhibits a kink at the points where liquidity constraints are no longer binding. Once we have computed the value of each alternative we pick the maximum, thus obtaining the policy rules for the current period. Substituting these decision rules in the Bellman equation, we obtain this period's value function ($V_t(.)$), which is then used to solve the previous period's maximization problem. This process is iterated until $t = 1$.

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Tables

Table 1: Annuity, stock and life insurance market participation

	S = 1	S = 0	Total
A = 1	213	96	309
Col-%	9.6	3.2	5.9
A = 0	2007	2917	4924
Col-%	90.4	96.8	94.1
L = 1	832	1272	2104
Col-%	37.5	42.2	40.2
L = 0	1388	1741	3129
Col-%	62.5	57.8	59.8
Total	2220	3013	5233
Row-%	42.4	57.6	100.0

Notes to Table 1: The table presents the number of sample members in sub-samples defined by participation in the voluntary annuity market (A), the stock market (S), and the life insurance market. "A = 1" ("A = 0") refers to annuity market (non-) participants in 2002 or 2004, "S = 1" ("S = 0") refers to stock market (non-) participants in 2002, while "L = 1" ("L = 0") refers to life insurance market (non-) participants in 2002. The sample consists of retired households in the first (2002) wave of the English Longitudinal Study of Ageing (ELSA).

Table 2: Financial wealth and annual income by annuity and stock market participation

	All		A = 1		A = 0	
	Mean	Median	Mean	Median	Mean	Median
Financial wealth	55031	15800	135017	65000	50011	14200
Annual pension	9328	7305	12182	9036	9149	7228
Annual public pension	4796	4732	4945	4940	4787	4723
Annual private pension	4532	1440	7236	3200	4362	1350
Annual annuity income	179	0	3032	984	0	0
Life insurance amount	17154	3000	55936	10000	15177	2532
Stock share percentage	16	0	24	14	16	0
	S = 1		S = 1 and A = 1		S = 1 and A = 0	
	Mean	Median	Mean	Median	Mean	Median
Financial wealth	101937	47586	173619	99300	94330	44474
Annual pension	11523	9132	14142	11660	11245	8978
Annual public pension	4521	4628	4943	4948	4476	4628
Annual private pension	7002	4145	9199	6600	6769	4000
Annual annuity income	351	0	3656	1200	0	0
Life insurance amount	27523	5900	74984	10000	23027	5000
Stock share percentage	38	32	35	28	38	33
	S = 0		S = 0 and A = 1		S = 0 and A = 0	
	Mean	Median	Mean	Median	Mean	Median
Financial wealth	20470	5000	49368	18420	19519	5000
Annual pension	7711	6315	7832	6551	7707	6304
Annual public pension	4999	4784	4952	4940	5001	4784
Annual private pension	2712	500	2880	693	2706	500
Annual annuity income	53	0	1648	484	0	0
Life insurance amount	10372	2000	14376	2000	10266	2000

Notes to Table 2: The table presents mean and median wealth and income statistics (in GBP) and stock allocation percentages for the whole sample ("All") and sub-samples defined by participation in the voluntary annuity market (A) and the stock market (S). "A = 1" ("A = 0") refers to annuity market (non-) participants in 2002 or 2004 while "S = 1" ("S = 0") refers to stock market (non-) participants in 2002. The amount of life insurance is conditional on participation in the life insurance market. The sample consists of 5,233 retired households from the first (2002) wave of the English Longitudinal Study of Ageing (ELSA).

Table 3: Socio-economic background, health and life-expectancy

	All	A = 1	A = 0
Age	69.3	68.2	69.4
Female (%)	53	42	54
Married (%)	56	57	56
Number of children	2.04	1.98	2.04
Low education (%)	59	34	61
Medium education (%)	30	41	30
High education (%)	11	25	9
Survival probability (%)	52	57	52
Objective GAD probability (%)	53	56	53
Bad health condition (%)	19	14	19
Medium health condition (%)	62	60	63
Good health condition (%)	19	27	18

Notes to Table 3: The table presents averages for all sample members ("All"), voluntary annuity market participants ("A = 1") in either 2002 or 2004, and annuity market non-participants ("A = 0"). The sample consists of 5,233 retired households from the first (2002) wave of the English Longitudinal Study of Ageing (ELSA).

Table 4: Estimation results

A. Annuity market participation – Probit regressions

	All		Non-Stockholders		Stockholders	
	estimate	t-value	estimate	t-value	estimate	t-value
Intercept	-7.6489	-4.26	-4.0807	-1.53	-10.308	-3.87
Age / 10	1.3992	2.67	0.5997	0.77	1.7288	2.24
Age^2 / 100	-0.0993	-2.65	-0.0485	-0.89	-0.1183	-2.12
Low education	-0.2253	-3.13	-0.2217	-2.01	-0.2095	-2.15
High education	0.1788	2.09	0.2132	1.15	0.1567	1.56
Female	-0.1718	-2.62	-0.1695	-1.64	-0.1688	-1.91
Married	-0.2944	-4.08	-0.3078	-2.62	-0.2902	-3.08
Children	0.0444	0.56	0.1208	0.87	-0.0056	-0.06
Life insurance holder	-0.0484	-0.75	-0.0728	-0.70	-0.0187	-0.22
Survival probability	0.1804	1.48	0.0269	0.14	0.3203	1.98
Log pension	-0.0204	-0.60	-0.0784	-1.41	0.0292	0.59
Log financial wealth	0.1539	5.97	0.1573	5.62	0.2422	7.00
Stockholder	-0.8350	-1.94	-	-	-	-
Stockholder x fin. wealth	0.0914	2.24	-	-	-	-
Number of observations	5233		3013		2220	
Correct Predictions (in %)	94.10		96.81		90.41	

B. Annuity market participation – marginal effects

	All		Non-Stockholders		Stockholders	
	estimate	t-value	estimate	t-value	estimate	t-value
Age / 10	0.0162	1.88	-0.0035	-0.33	0.0448	2.48
Low education	-0.0289	-2.80	-0.0212	-1.71	-0.0437	-2.12
High education	0.0304	1.90	0.0287	1.02	0.0396	1.49
Female	-0.0229	-2.36	-0.0169	-1.49	-0.0360	-1.82
Married	-0.0359	-3.41	-0.0275	-2.13	-0.0579	-2.76
Children	0.0069	0.57	0.0152	0.90	-0.0013	-0.06
Life insurance holder	-0.0070	-0.75	-0.0079	-0.71	-0.0043	-0.22
Survival probability	0.0272	1.46	0.0031	0.14	0.0749	1.95
Log pension	-0.0031	-0.61	-0.0090	-1.40	0.0068	0.58
Log financial wealth	0.0232	4.62	0.0180	3.58	0.0566	5.58
Stockholder	0.0234	1.86	-	-	-	-

C. Conditional annuity demand – loglinear regression

	All		Non-Stockholders		Stockholders	
	estimate	t-value	estimate	t-value	estimate	t-value
Intercept	3.9301	0.84	5.0530	0.63	-0.5309	-0.09
Age / 10	-0.0433	-0.03	-0.7438	-0.31	0.7194	0.41
Age^2 / 100	0.0012	0.01	0.0561	0.33	-0.0567	-0.44
Low education	0.0391	0.19	0.2381	0.70	-0.0804	-0.31
High education	-0.1086	-0.55	0.2517	0.41	-0.1236	-0.60
Female	-0.0663	-0.37	-0.0112	-0.03	-0.1302	-0.62
Married	0.1363	0.68	0.2310	0.70	0.0940	0.37
Children	0.1786	0.87	0.4835	1.17	0.0848	0.35
Life insurance holder	-0.1446	-0.78	-0.2622	-0.78	-0.1231	-0.54
Survival probability	0.3672	1.07	0.3907	0.59	0.3325	0.83
Log pension	-0.1197	-1.61	-0.0409	-0.40	-0.2162	-1.90
Log financial wealth	0.3290	2.33	0.3213	2.11	0.6277	6.81
Stockholder	-2.8853	-1.71	-	-	-	-
Stockholder x fin. wealth	0.2839	1.74	-	-	-	-
Number of observations	5233		3013		2220	
R-square (in %)	22.48		14.57		22.48	

Notes to Table 4: Panel A reports estimation results from a Probit model for the annuity market participation decision. The Probit model is estimated with ML. Panel B shows marginal effects from the Probit model for a 65-year-old single male with medium education, no children, no life insurance, average subjective survival probability, average pension and average wealth who does not participate in the stock market. The asymptotic distribution of the estimated marginal effects is computed with the delta method. Panel C contains estimation results from a linear regression model for the (log) annuity demand conditional on participation. The linear annuity demand model is estimated with OLS using a heteroskedasticity-consistent estimator of asymptotic standard errors. The sample consists of retired households in the first (2002) wave of the English Longitudinal Study of Ageing (ELSA). All regressions are computed for the whole sample and the subsamples of non-stockholders and stockholders, respectively.

Table 5: Average annuity and life insurance market participation and average annuity demand

A. Non-Stockholders

b	γ	ψ	Voluntary annuity market participation	Life ins. market participation	Voluntary annuity demand	Annuity equivalent wealth
0	2	0.10	3.50	0.00	4.54	99.87
		0.30	3.41	0.00	4.61	99.87
		0.50	3.47	0.00	4.72	99.84
	3	0.10	7.83	0.00	3.25	99.40
		0.30	7.18	0.00	3.20	99.52
		0.50	6.18	0.00	3.38	99.53
	5	0.10	15.81	0.00	2.43	98.51
		0.30	12.70	0.00	2.32	99.06
		0.50	8.38	0.00	2.93	99.01
0.1	2	0.10	3.42	76.41	4.28	93.60
		0.30	3.30	80.40	4.19	89.62
		0.50	3.37	83.88	4.12	86.50
	3	0.10	7.55	75.00	3.13	89.78
		0.30	7.19	79.62	2.97	85.02
		0.50	7.38	83.61	2.64	82.40
	5	0.10	21.25	75.06	1.65	85.03
		0.30	13.43	81.27	2.00	80.43
		0.50	8.73	83.94	2.60	76.89

B. Stockholders

b	*γ*	*ψ*	Voluntary ann. market participation	Life ins. market participation	Voluntary annuity demand	Share of wealth in stocks	Annuity equivalent wealth
0	2	0.20	5.09	0.00	2.29	58.37	99.87
		0.50	6.29	0.00	2.89	52.84	99.79
		0.80	13.38	0.00	2.00	47.08	99.58
	4	0.20	25.90	0.00	3.76	61.40	98.46
		0.50	24.34	0.00	3.43	50.34	99.00
		0.80	21.35	0.00	3.00	45.15	99.37
	6	0.20	34.36	0.00	3.76	56.87	97.09
		0.50	28.89	0.00	3.48	45.64	98.58
		0.80	23.68	0.00	2.99	43.37	99.29
5	2	0.20	3.36	55.41	0.27	84.07	84.32
		0.50	2.70	65.18	0.25	70.73	80.77
		0.80	0.00	69.75	0.00	56.08	96.54
	4	0.20	16.44	51.92	3.64	75.75	89.59
		0.50	11.99	54.42	2.89	70.77	87.56
		0.80	8.89	60.18	2.32	68.31	86.79
	6	0.20	26.53	57.84	3.75	68.94	91.07
		0.50	18.92	60.77	2.91	65.65	89.44
		0.80	11.93	66.12	2.77	65.14	88.75

Notes to Table 5: Panel A (B) reports simulated results for the model without (with) access to the stock market, using the wealth distribution from the data as an exogenous input (2000 life-histories simulated). The risk free rate is set to 2%, the equity premium at 4% and the standard deviation of the risky asset return at 18%. Pre-existing pension income is set at each group's median value. Comparative statics are performed over preference parameters in a range consistent with the estimated parameters. The bequest parameter is denoted by b, relative risk aversion by γ and the elasticity of intertemporal substitution by ψ. The discount factor, β, is fixed at 0.88. Voluntary annuity market and life insurance market participation and for stockholders, the share of wealth invested in stocks are reported in percentage terms, voluntary annuity demand is defined as average annual annuity income in thousands of pounds, conditional on participation. The annuity equivalent wealth (AEW) reports the average wealth each individual is willing to give up in order to be able to access the annuity market.

Table 6: Estimated structural parameters using the Method of Simulated Moments

A. Non-Stockholders

Model	b	γ	ψ	Voluntary annuity market participation	Life insurance market participation	Voluntary annuity demand
Estimates	0.02	2	0.08	3.5	71.9	4.4
s.e.	0.003	--	0.002			
Data				3.2	42.2	1.7
s.d.				17.6	49.4	4.6

B. Stockholders

Model	b	γ	ψ	Voluntary ann. market participation	Life ins. market participation	Voluntary annuity demand	Share of wealth in stocks
Estimates	4.74	6	0.72	13.5	63.9	2.8	63.4
s.e.	0.002	0.01	0.02				
Data				9.6	37.5	3.7	38.0
s.d.				29.5	48.4	9.6	28.7

Notes to Table 6: Panel A (Panel B) reports estimated parameters for the non-stockholder (stockholder) model using a method of simulated moments to pick the structural parameters that minimize the distance between some selected moments in the data and in the model. For the non-stockholders the moments are the participation in the annuity market, the participation in the life insurance market, and, conditional on participation in the annuity market, the amount of annuity demand. For the stockholders the share of wealth in financial assets is a fourth moment to be matched. Standard errors are computed using a diagonal weighting matrix that is based on the inverse of the variance of the empirical moments. In both models the preference parameters that vary are b that captures the strength of the bequest motive and the elasticity of intertemporal substitution (ψ). For the stockholder model we also vary risk aversion (γ) to match better the share of wealth in stocks. The discount factor, β, is fixed at 0.88.

Table 7: Robustness of conclusions to changes in the economic environment

A. Non-Stockholders

Model	Voluntary annuity market participation	Life ins. market participation	Voluntary annuity demand	Annuity equivalent wealth
Data	3.2	42.2	1.7	-
MSM	3.5	71.9	4.4	97.5
Low Pension	5.4	61.5	3.7	99.4
Low Survival	0.0	87.0	0.0	97.2
Actuarial Fair	8.8	72.5	4.8	97.3
Annuitize Once	3.3	71.4	1.8	99.8

B. Stockholders

Model	Voluntary ann. market participation	Life ins. market participation	Voluntary annuity demand	Share of wealth in stocks	Annuity equivalent wealth
Data	9.6	37.5	3.7	38.0	-
MSM	13.5	63.9	2.8	63.4	89.1
Low Pension	25.6	45.4	2.4	69.0	93.9
Low Survival	13.5	62.2	1.9	56.8	81.6
Actuarial Fair	53.5	72.2	3.4	61.3	87.5
Annuitize Once	6.9	65.7	2.4	63.2	91.5
Death Pension	17.9	46.8	3.5	72.1	97.9

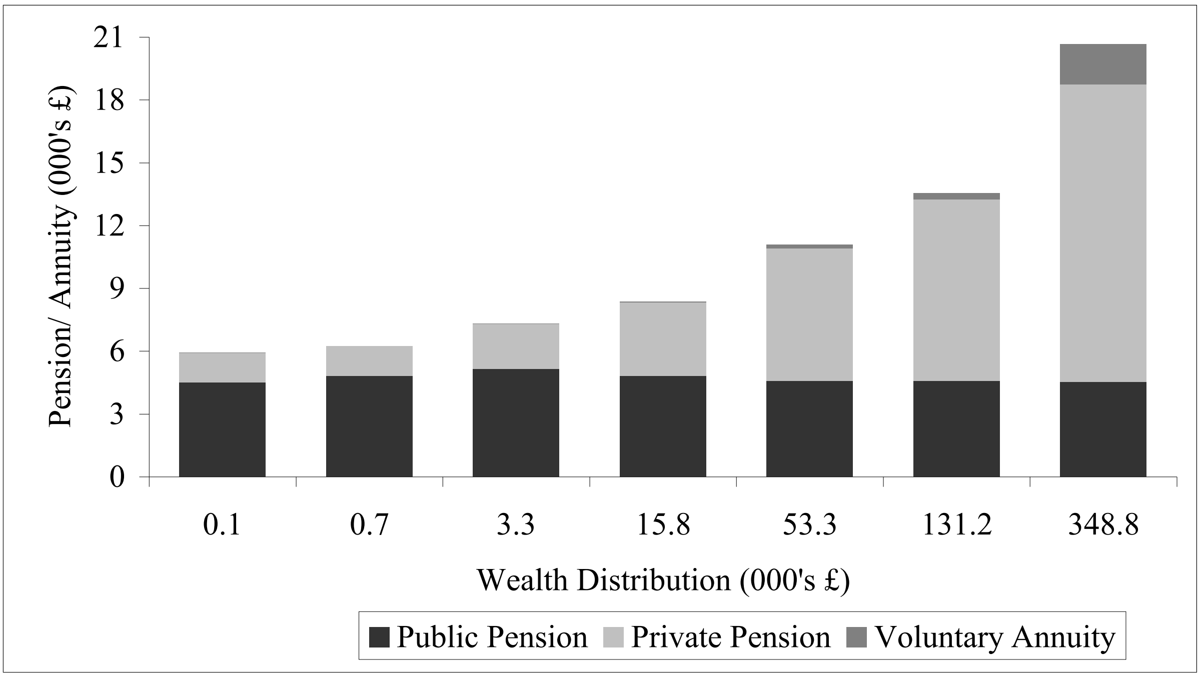
Notes to Table 7: Panel A reports simulated results using the non-stockholder model, and Panel B the simulated results using stock market participants. The risk free rate is set to 2%, the equity premium at 4% and the standard deviation of risky asset return at 18%. Pre-existing pension income is set at each group's median value. Comparative statics are performed over several parameter specifications. In particular, for the MSM parameters are set equal to estimated parameters reported in Table 6, in the Low Pension cases the 25th percentiles of pre-existing pension are used for each group. Low Survival is the case where individual's survival probabilities are reduced by 10% and Actuarial Fair is the case for annuities with a zero load factor. Death Pension describes the case where the individual dies after receiving the annuity and the pension. Voluntary annuity market and life insurance participation report average participation in each market in percentage terms, and voluntary annuity demand is defined as average annual annuity income in thousands of pounds, conditional on participation. The annuity equivalent wealth reports average AEW, which is defined as the wealth each individual is willing to give up in order to be able to access the annuity market.

Figures

Figure 1: Wealth distribution, annuity market participation and annual pension income over the wealth distribution

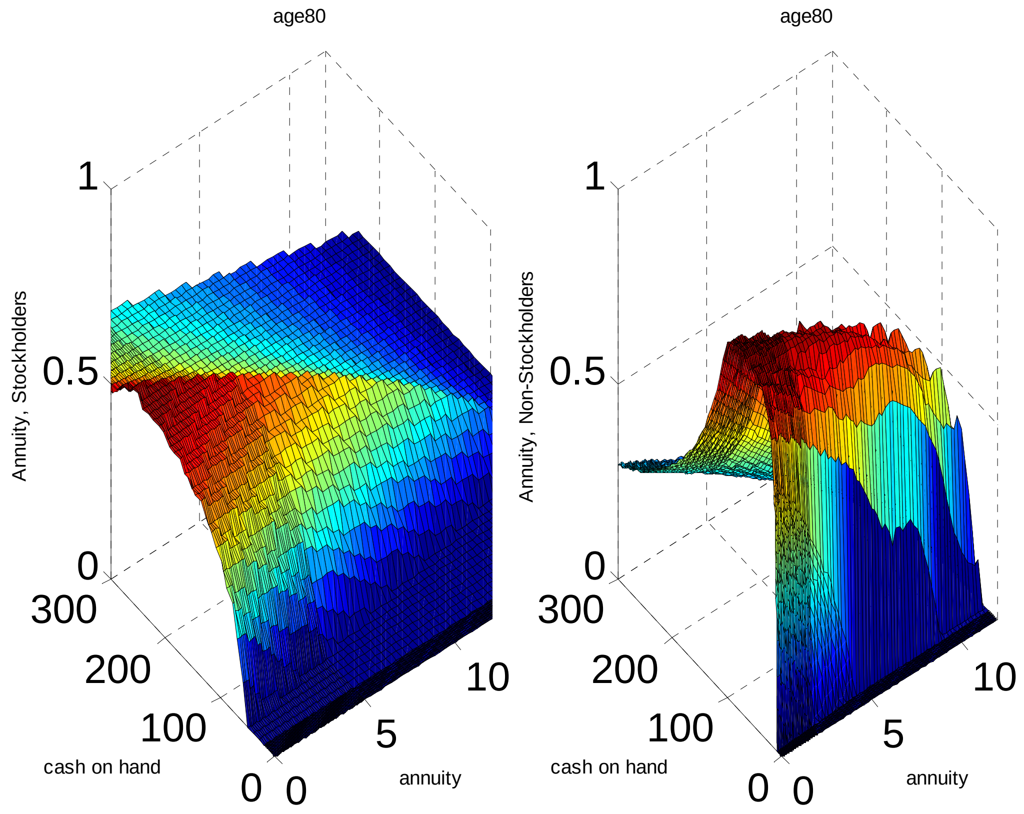
Notes to Figure 1: The columns show the number of households (measured on the ordinate on the left hand side) around the 2.5%, 10%, 25%, 50%, 75%, 90% and 97.5% percentiles of the wealth distribution in the whole sample ("All") and the sub-sample consisting of stock market participants ("S = 1"). The figure shows on the ordinate on the right hand side the average percentage of households participating in the voluntary annuity market ("A = 1") among the households located around a certain percentile of the wealth distribution. The sample consists of 5,233 retired households from the first (2002) wave of the English Longitudinal Study of Ageing (ELSA).

Figure 2: Decomposition of annual pension income into public and private sector pension income and annual annuity income over the wealth distribution



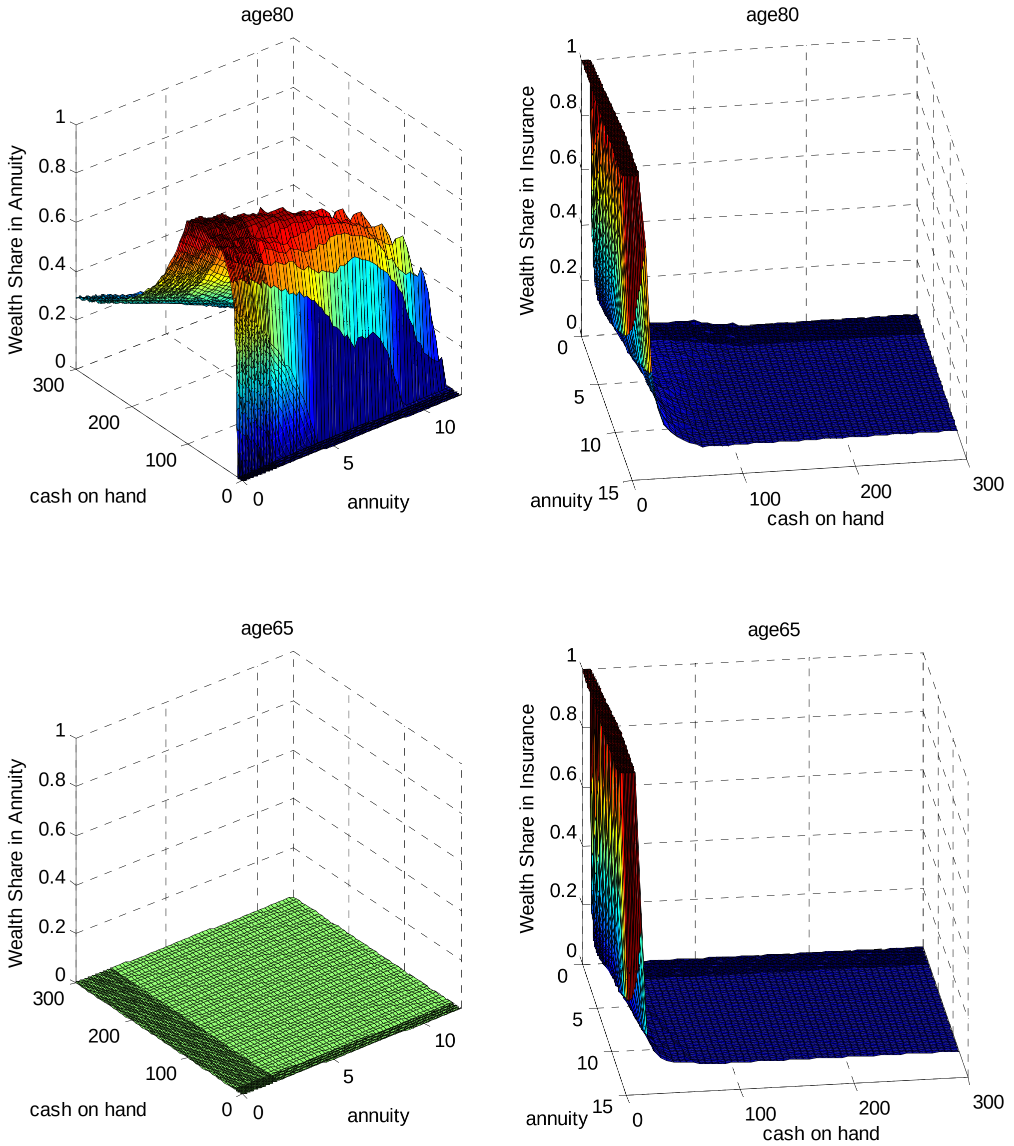
Notes to Figure 2: The figure decomposes the average total annual pension income of households around a certain percentile of the wealth distribution into income from public pensions, private (individual or occupational) pensions (excluding voluntary annuities) and voluntary annuitization. The wealth distribution is generated to represent from the left to the right 5%, 10%, 20%, 30%, 20%, 10%, 5% of the observations. Correspondingly, the abscissa shows the 2.5%, 10%, 25%, 50%, 75%, 90% and 97.5% percentiles of the wealth distribution. The sample consists of 5,233 retired households from the first (2002) wave of the English Longitudinal Study of Ageing (ELSA).

Figure 3: Annuity demand as a function of liquid wealth and annuity levels



Notes to Figure 3: This figure shows the policy functions for the share of wealth invested in annuities at age 80 (the last year for which annuities can be purchased) for stock market participants (Stockholders) and non-participants (Non-stockholders) for the baseline case outlined in Section 3.2.1.

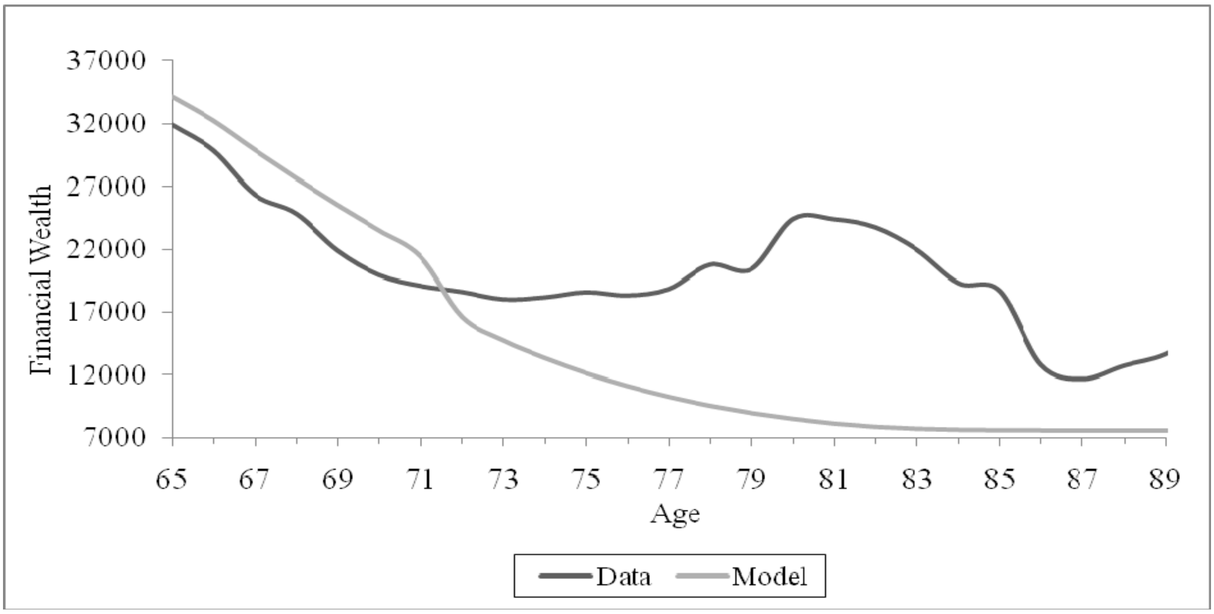
Figure 4: Policy functions for non-stockholders



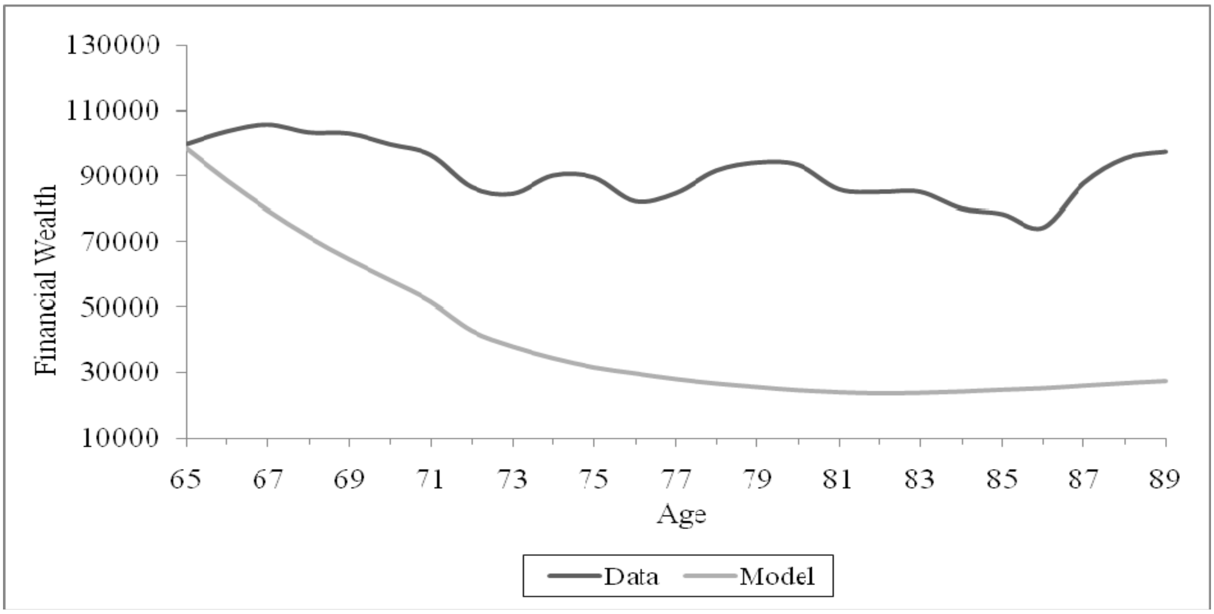
Notes to Figure 4: This figure shows the policy functions for non-stockholders for the share of wealth invested in annuities and life insurance at retirement (age 65) and during the last year for which annuities can be bought (age 80) for the baseline case outlined in Section 3.2.1.

Figure 5: Average wealth profiles: model and data

A. Non-Stockholders



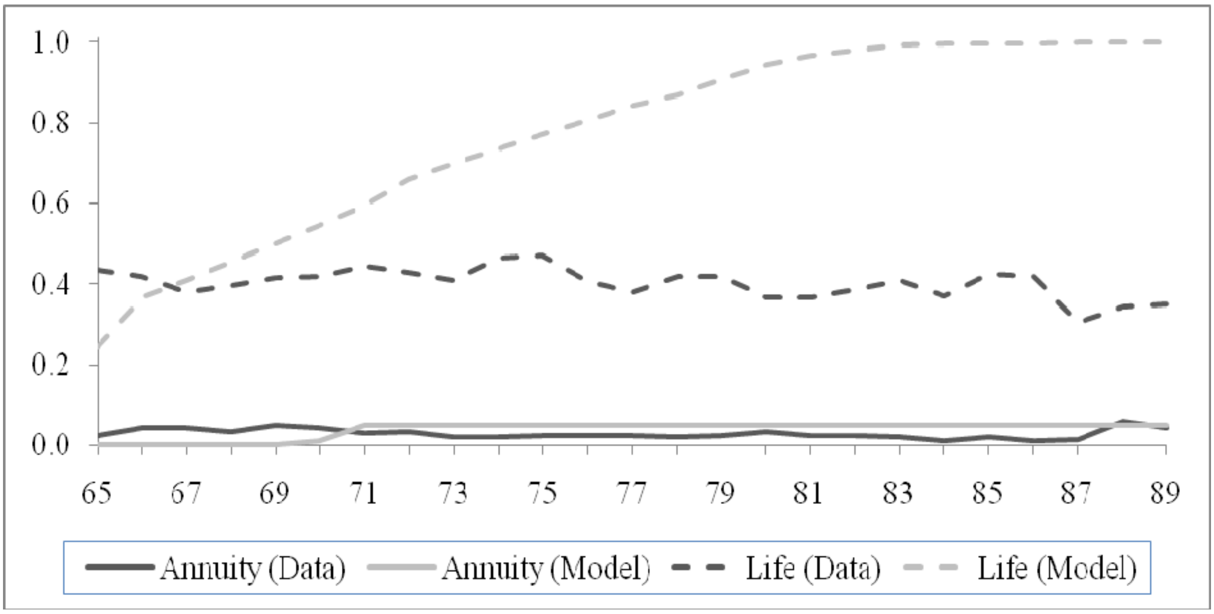
B. Stockholders



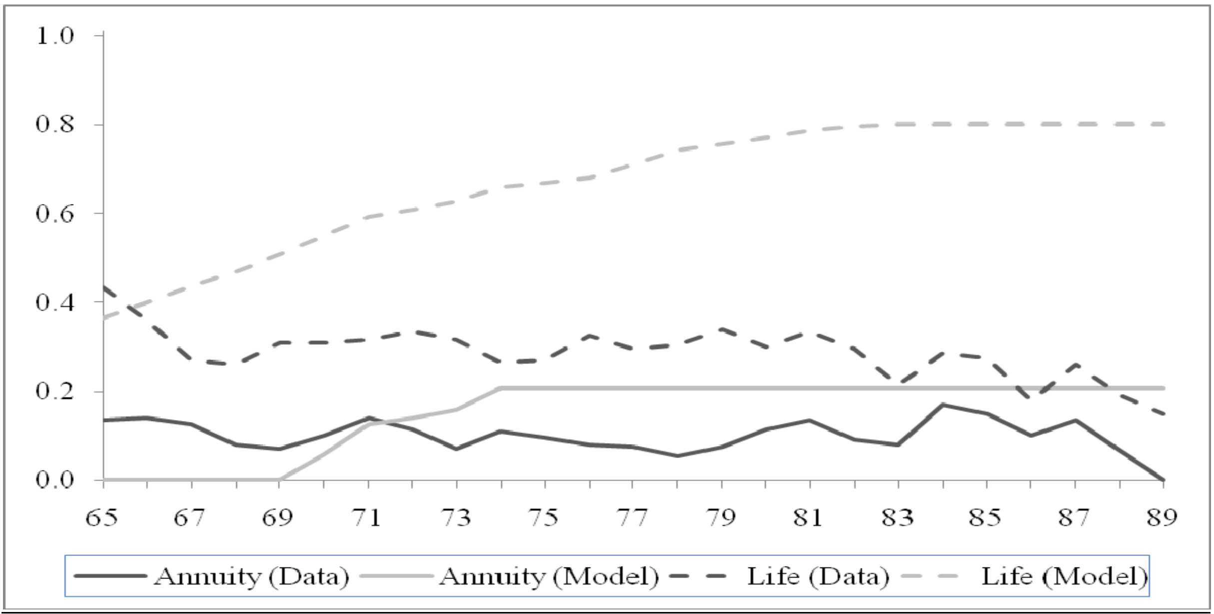
Notes to Figure 5: The figure plots the average age profile for wealth in the data against the model predictions using the baseline calibration in Table 6. The data stops at age 89 (all ages over 89 are coded as 90 in ELSA to avoid household identification issues) but the model has been solved on the assumption that households might live for a maximum of 100 years. The average standard deviation of financial wealth across age groups 65 to 89 in the data is 90,400 GBP.

Figure 6: Average annuity and life insurance market participation rate profiles: model and data

A. Non-Stockholders

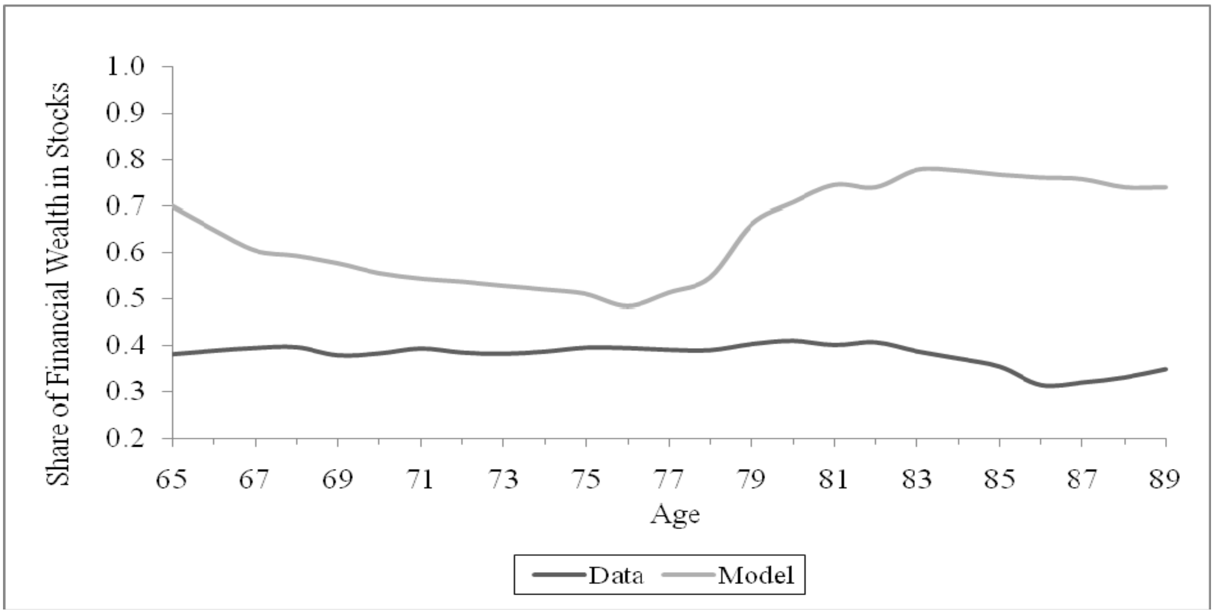


B. Stockholders



<u>Notes to Figure 6:</u> The figure plots the average age profiles for participation in the voluntary annuity (Annuity) and life insurance (Life) markets in the data against the model predictions using the baseline calibration in Table 6. The data stops at age 89 (all ages over 89 are coded as 90 in ELSA to avoid household identification issues) but the model has been solved on the assumption that households might live for a maximum of 100 years. The average standard deviations of participation in the voluntary annuity and life insurance markets across age groups 65 to 89 in the data are 21% and 48%, respectively.

Figure 7: Average portfolio allocation profiles for stockholders: model and data



Notes to Figure 7: The figure plots the average age profile for the share of financial assets allocated to the stock market in the data against the model predictions using the baseline calibration for stockholders in Table 6. The data stops at age 89 (all ages over 89 are coded as 90 in ELSA to avoid household identification issues) but the model has been solved on the assumption that households might live for a maximum of 100 years. The average standard deviation of the share of financial wealth in stocks across age groups 65 to 89 in the data is 38%.