How Deep is the Annuity Market Participation Puzzle?*

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Abstract

Using U.K. 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 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.

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Key Words: Annuities, portfolio choice, bequest motive.

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, annuity demand remains very low in the data,[1] 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.

Understanding this puzzle has generated a large number of recent papers that have attempted an explanation. Potential explanations involve the lack of actuarially fair annu-

[1] More recently, Davidoff, Brown and Diamond (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.

ities,[4] inflation risk,[5] a strong bequest motive,[6] habit formation in preferences,[7] the presence of some annuitization through state social security and private DB plans,[8] the presence of uncertain medical expenditures,[9] non-actuarially fair annuity provision and minimum annuity size purchase requirements,[10] rare events,[11] and flexibility.[12] Overall, however, the current conventional wisdom, as re-iterated by Davidoff, Brown and Diamond (2005), treats the limited voluntary annuity market participation as a puzzle that remains to be explained.

Nevertheless, very few studies have attempted to empirically analyze the determinants of voluntary annuity market participation at the household level.[13] What are the characteristics of households that participate (or not) in this market? Understanding the factors affecting the participation decision can potentially help us quantify the magnitude of the puzzle relative to the predictions from different models of economic behavior. In this paper we begin

[4]See, for instance, Mitchell, Poterba, Warshawsky and Brown (1999) for the U.S. and Finkelstein and Poterba (2002, 2004) for U.K.. Nevertheless, Mitchell et. al. (1999) argue that annuity pricing is not sufficient to explain the low take-up and argue that the "money's worth of individual annuities" is actually quite good, therefore questioning this potential explanation of the puzzle.

[5]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.

[6]The preference for leaving bequests may counteract the insurance benefits of annuities (Friedman and Warshawsky (1990), for example).

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

[8]Bernheim (1991), Brown et. al. (2001) and Dushi and Webb (2004).

[9]For instance, Sinclair and Smetters (2004).

[10]See Lopes (2006).

[11]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.

[12]Milevsky and Young (2002) argue that buying an annuity limits household flexibility to invest in the stock market. Ameriks et. al. (2007) find a significant aversion to ending up at a nursing home funded by the state; such "medicaid-aversion" may explain why households do not commit to the illiquid expenditure of buying an annuity.

[13]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.

by investigating empirically the determinants of household annuity market participation in the U.K. voluntary annuity market.[14]

Our empirical work provides an in depth analysis of what determines voluntary annuity market participation, and what affects the level of annuity demand conditional on participation. We first 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.

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 choice and annuity market participation with Epstein-Zin (1989) preferences over a non-durable good and investigate whether reasonable preference parameters can replicate the observed annuity market partic-

[14] We focus on U.K. data (the English Longitudinal Study of Ageing (ELSA, see Marmot et al., 2006)) due to the the large array of annuity market products available to the consumer in this market. Brown (2001) has a similar research objective based on the U.S. equivalent of the U.K. data we use, but undertakes a different research strategy. Specifically, Brown (2001) 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 observable characteristics. Instead, we try to find the parameters of a simulated model that may explain observed annuity demand and be consistent with the empirical characteristics of actual annuity market participants.

ipation 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 at 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 is 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.[15] For the nonstockholders, we estimate the bequest parameter and the intertemporal rate of substitution, fixing the coefficient of relative risk aversion to two to match two moments in the data: the annuity market participation rate, and, conditional on 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 (0.09) than for stockholders (1.64). We view these parameter estimates as reasonable estimates for preferences, being consistent with the

[15] 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.

empirical evidence in, for instance, Gourinchas and Parker (2002), Cagetti (2003) 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 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, see Marmot et al., 2006). 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.[16] 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 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."[17]

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. Financial units are to be distinguished from benefit units, which are either single persons or couples irrespective of sharing their financial means. 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.[18]

The first wave of ELSA comprises 12,100 individuals and our sample consists of 5,233

[16] 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.

[17] Note that there is no distinction between nominal, real and variable annuities in the data.

[18] This means that a couple with separate income and assets enters our dataset as two observations, while a couple with joint income and assets contributes one observation. Financial information for the household (like wealth, income) apart from annuities is collected at the household level.

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).

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 wave of ELSA (207 observations) or the second wave (102 observations). The annuity market participation puzzle refers to the fact that 309 voluntary annuity contracts among 5,233 possible customers remain a very small number. Moreover, the puzzle seems to exist even in the U.K. which is generally accepted to have the most mature annuity market in the world (see Finkelstein and Poterba, 2002, 2004).[19]

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[20] 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%). The difference is statistically highly significant with a t-test statistic of 9.1. Equivalently, Table 1 shows that more than two thirds (213 out of 309) of all annuity market participants also participate in the stock market. Thus, there seems to be some

[19] Banks and Emmerson (1999) use the family resources survey and report similar statistics for voluntary annuity market participation.

[20] 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.

connection between the decision to participate in the two markets and we will investigate this further in both the empirical and theoretical analysis that follows.

Table 2 presents annuity demand statistics conditional on participating in the voluntary annuity market. Specifically, the table reports mean and median annual annuity income statistics and splits the sample across the stock market participation decision as well. 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. These descriptive statistics give us an idea about the level of annuity demand that a structural model should be generating to match the empirical evidence.

The rest of this section will investigate what household characteristics determine voluntary demand for annuities.

2.2.2 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.[21] 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[22] of annuitants to be about 135,000

[21] 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.

[22] Banks et al. (2007) provide evidence that British households do not reduce housing consumption with

(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 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% among the 262 households in the bottom 5% of the wealth distribution, it increases steeply to almost 20% among the 262 households in the top 5% of the wealth distribution. Given that the 10% and 25% quantiles of the wealth distribution are 700 GBP and 3,300 GBP, respectively, it appears that households in the lower third of the wealth distribution are generally constrained by insufficient financial wealth to participate in the voluntary annuity market.

Figure 1 also decomposes the sample across wealth quantiles into stock market non-participants and participants. While stock market participants are still slightly outnumbered around the median wealth by non-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 Blake (2003)) 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

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.

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). The highest average and median private pensions are observed in the sub-sample of individuals participating both in the voluntary annuity market and the stock market. Figure 2 decomposes the sources of pension income over different quantiles of the wealth distribution. Quite strikingly, 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.

2.2.3 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 also 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 (GAD, 2006). Table 3 shows that average values for subjective and objective GAD probabilities are very close. This confirms prior evidence by Hurd and McGarry (1995, 2002) for the U.S. that subjective probabilities tend to aggregate well to population probabilities. However, we find that younger survey participants in ELSA underestimate population probabilities,[23] while older survey participants tend to overestimate these probabilities.[24]

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.. Table 3 also shows that annuity market participants slightly overestimate survival probabilities relative to the GAD probabilities by one percentage point, while non-participants tend to to underestimate survival probabilities by one percentage point which confirms the adverse selection hypothesis.

[23] This was already observed by Banks and Blundell (2005) for the same data.

[24] This is an example of the probability weighting function of Prelec (1998): individuals tend to overweight low probabilities and to underweight high probabilities.

2.2.4 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.[25] 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.

2.3.1 Annuity Market Participation

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 annuity market participation variable is comprised of existing annuities observed in the first wave of ELSA and new annuities observed in the second wave of ELSA.[26] The previous section revealed systematic differences (for example, with respect to wealth and existing pensions) between the two subsamples of stock market participants and non-participants which are likely to be reflected in the annuitization decision. For this reason, we present separately

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

[26] Estimating the model separately for existing and new annuities generates similar results.

the estimation results for stock market non-participants (Table 4, Panel A) from the results for participants (Table 4, Panel B). We use as explanatory variables the following: wealth, income, household composition, age, health and life expectancy of the household. 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. We do this for a baseline observation that is defined as a 65 year-old, single, male, without children, medium education, an average reported survival probability, average pension income and financial wealth.

Confirming the earlier descriptive statistics in Table 2, financial wealth is shown to be one of the most important predictors of annuity market participation,[27] for both non-stockholders and stockholders. An increase of 0.1 in log financial wealth, corresponding to an increase of about $1,200$ GBP for the average sample member, significantly increases the annuity market participation probabilities of non-stockholders (stockholders) by 0.23 (0.36) percentage points. On the 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 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 and economically insignificant for non-stockholders, the variable turns out to be the quantitatively most important predictor of the annuitization decision for stockholders. A one percentage point increase in the survival probability significantly increases the annuity participation probability by 0.47 percentage points as can be seen from Table 4.

Married financial units are significantly less likely to purchase an annuity. The marginal effects suggest 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 almost four percentage points. This turns out to be the quantitatively most

[27] For all financial variables, we tested for possible nonlinearities by including a squared term. This term always turned out insignificant.

important impact on the annuitization decision for non-stockholders. 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. 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.

We include dummies for low and high education levels as a measure of financial literacy. The low education dummy shows up significantly negative for both non-stockholders and stockholders. The high education dummy has the expected positive sign but turns out to be insignificant. Changing the education level of the baseline household from medium to low decreases the participation probability by roughly 2.6 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 sub-samples of annuity market participants. Results are again given in Table 4, Panel A, for non-stockholders and Panel B for stockholders. 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. A 1% increase in financial wealth increases the voluntary annuity demand of non-stockholders (stockholders) by 0.33% (0.63%). While pensions do not significantly affect the annuity demand of non-stockholders, they have a statistically significant negative impact for stockholders. A 1% increase in compulsory annuities crowds out the demand for voluntary annuities by 0.22%.

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% 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 demand and portfolio choice and assess the model's consistency with the empirical findings in the previous section.

3.1 The Model

3.1.1 Available Annuity Contracts

We study nominal annuity contracts but for simplicity we assume zero inflation.[28] 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 $r_{t,1}$, p_t denotes the probability that the household is alive at date t, conditional on being alive at date $t-1$ and the household purchases an annuity that makes an annual payment of A, the expected present discounted value (EPDV) of the annuity payouts is given by:

[28] 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.

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

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.[29] 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.

3.1.2 Retirement Income

At retirement the household has financial wealth X_1, which can be used to purchase an annuity. In addition, the household is endowed with pension income in each period, L, calibrated to be consistent with the available empirical evidence. Letting $r_{t+1,1}$ 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, the evolution of cash-on-hand can be written as:

$$X_{t+1} = (X_t - C_t)[\alpha_t \exp(\widetilde{r}_{t+1}) + (1 - \alpha_t) \exp(r_{t+1,1})] + L_{t+1} \tag{2}$$

We assume no borrowing in retirement and no short sales of stocks so that α_t lies between zero and one.

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

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

and

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

3.1.3 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:

$$V_t = \left\{ (1-\beta) C_t^{1-1/\psi} + \beta \left(E_t (p_{t+1} V_{t+1}^{1-\gamma} + b(1-p_{t+1}) X_{t+1}^{1-\gamma}) \right)^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}} \tag{3}$$

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 (3). Cocco, Gomes and Maenhout (2005) and Yogo (2008) make a similar assumption, De Nardi (2004) assumes a more complicated version of this[30], 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 which will optimally be chosen at retirement, and age. In each period t, $t = 1, ..., T$, the household chooses optimal consumption C_t and the share of saving to invest in the stock market subject to a budget constraint. In the first period of retirement, the household also chooses the level of annuity to be purchased.

3.1.4 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 on stock market 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

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

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) or the evidence summarized in Guiso, Haliassos and Japelli (2002)). 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.[31]

Using these exogenous inputs we then compute the average annuity participation rate, average portfolio demand and the aggregate demand for annuities. To match the definition of wealth in our model to the one in the data we add household pension income and financial wealth (wealth in financial assets, excluding retirement and housing wealth). Pension income is the median pension income received by retired individuals and for simplicity we set it to a constant that differs depending on stock market participation status.[32]

3.1.5 Mortality Probabilities

Period one is taken to be age 65 and conditional survival probabilities for the typical household are taken from the U.K. GAD for 2002-2004.

3.1.6 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, while we assume decisions are taken at an annual frequency. The maximum age that can be reached is 100, but agents will face a

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

[32] There is a positive relationship between pension income and financial wealth in the data but a flat pension here makes the model simpler to solve and serves a conservative approach. Specifically, since increasing private pensions crowds out annuity demand (both in the data and in the model) we create an upward bias in average annuity demand generated by the model when we use a flat pension.

probability of death each period.[33] 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 ($\psi = 1/3$) and a discount factor equal to 0.98.

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 as a function of wealth at the time of retirement for households that have access to the stock market (stockholders) and households that make annuity choices without access to the stock market (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 a monotonically increasing demand for annuities. From the shape of the policy function it should be immediately 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 is not a puzzle but rather a prediction of the model.

Access to the stock market makes the wealth level that warrants entry to the annuity market surprisingly 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.[34] We find this result quite surprising given the relatively

[33] Given the backward induction solution method, the value function in the last period (age 100) will equal

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

so that the investor first consumes and then dies deriving utility from the expected wealth that heirs will inherit.

[34] 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. (2006) show that access to

low equity premium (4%) and the fact that we ignore any stock market predictability that can make the risk/return trade-off from stock market investments even more advantageous. We also note that this result is consistent with the idea that stock market participation might be related to annuity market participation (an idea that received empirical support in the previous section). Nevertheless, the comparative statics result here could lead us to conclude that access to the stock market decreases the demand for annuities, contrary to what we observe in the data. This conclusion is incorrect, however, since simulations must also be done to compute the total annuity demand given that stockholders are richer and are therefore more likely than non-stockholders to be very much to the right tail of the wealth distribution and therefore generate a higher average demand for annuities. We investigate this issue later on.

3.2.2 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 wealth for the remainder of a household's lifetime.

Figure 4 graphs the consumption profile during retirement for a median-wealth non-stockholder for two cases (profiles for stockholders are qualitatively the same). The first is the baseline case. Optimal consumption is decreasing during retirement given the assumptions about the survival probabilities, the discount factor and the rates of return and consumption remains constant at the pension plus the annuity payout after a few periods. The wealth profiles (omitted for brevity) reflect these consumption choices. Wealth drops at retirement to purchase the annuity and is gradually decumulated to zero when consumption becomes equal to the pension plus the annuity payout. In the same figure we also report results assuming a 0% load factor (actuarially fair annuity pricing). Consumption is higher during retirement in this case. This reflects the higher level of annuities purchased at retirement at a lower price. Correspondingly, financial wealth drops by more at retirement.

variable annuities during retirement is welfare enhancing.

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.[35] 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.[36]

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 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, Gomes and Maenhout (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.

[35] For instance, see Cocco, Gomes and Maenhout (2005), Gomes and Michaelides (2005) and Polkovnichenko (2007).

[36] 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).

3.2.4 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.[37] 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, while the optimal decision with a potentially positive annuity is given by the value function V^*. 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).[38] Annuity market participation (column 4) reports the percentage of households that participate in the annuity market, while voluntary annuity demand (column 5) reports the average annual annuity income in thousands of pounds conditional on participation. Column 6 reports the share of wealth being annuitized at retirement. The last column reports average annuity equivalent wealth. Consistent with

[37] This calculation follows Brown (2001).

[38] We use a range of preference parameters that is deemed reasonable in the literature either through calibration or through estimation results (see, for example, Gourinchas and Parker (2002) and Vissing-Jorgensen (2002)).

the policy function results, higher risk aversion increases annuity market participation, the total level of annuity demand[39] and the share of wealth being annuitized at retirement. A stronger bequest motive, on the other hand, decreases all three measures of annuity demand, while the EIS generally increases annuity demand but the effect is non-monotonic when the bequest motive is operating. As annuity demand increases, the value of annuities is reflected in a lower AEW. In the absence of a bequest motive, this can rise to 11% of wealth (for $\gamma = 5$ and $\psi = 0.8$) illustrating the value of annuities for more risk averse households with a high EIS.

Quantitatively, the results illustrate that in the absence of a bequest motive, annuity market participation is quite high but there do exist configurations of parameters where the model still predicts low participation. When $\gamma = 2$ and $\psi = 0.2$, for instance, only 6.15% of households choose to participate in the annuity market and they annuitize around one third of their wealth. 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, 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 67% (for $\gamma = 5$ and $\psi = 0.5$ or $\psi = 0.8$).

The table also illustrates that lower annuity demand can also be generated for higher risk aversion if one is willing to admit some preference for leaving bequests. Specifically, for ($\gamma = 3$, $\psi = 0.3$) and $b = 1$ annuity market participation is around 10% and around one third of wealth is annuitized at retirement (38%). For this preference configuration, the average household is expected to leave around 22,000 GBP as bequests, if it lives until the end of its possible life.

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

[39] 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.

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 $b = 1$ to $b = 3$, risk aversion extends to 6 and the EIS extends to 1.70.

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 and depends on the presence of a bequest motive. In the absence of a bequest motive ($b = 0$) a higher EIS ceteris paribus generates a higher annuity market participation. This is related to the fact that in the absence of a bequest motive the average share of wealth invested in stocks during retirement is essentially 100%. Basically the combination of a state pension and the annuity purchased at retirement acts as a riskless asset generating a 100% investment in stocks that only mildly declines with age. With this asset allocation, the return on the portfolio is high and thus a higher EIS generates higher saving, and thus higher demand for annuities.

In the presence of a strong bequest motive, however, the share of wealth invested in stocks is substantially reduced. Basically, financial wealth is not being depleted now but the state pension is, as is the purchased annuity. Therefore, for the higher levels of risk aversion ($\gamma = 6$) the average share of wealth in stocks can fall to 40%. This portfolio choice effect is also responsible for the non-linear effects of the EIS in the presence of a bequest motive. The rate of return on the portfolio is endogenous and depends on the portfolio allocation decision. As the portfolio becomes more balanced, the rate of return on the portfolio falls and the distance between this rate and the discount rate also gets reduced, generating a non-linear relationship between the EIS and annuity demand. As before, the AEW decreases with higher annuity demand and can fall to 78.5% of wealth for $\gamma = 6$ and $\psi = 1.70$, in the absence of a bequest motive.

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 is 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 market, 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 two 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 market participation rate 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).[40] For the stockholders we match the same two moments plus the average share of financial wealth allocated to stocks during retirement and use the risk aversion coefficient as the extra parameter to

[40] In unreported estimations we also match the share of wealth annuitized conditional on participation by estimating the risk aversion coefficient. Our risk aversion estimates were between 1.5 and 2.2.

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.[41] The elasticity of intertemporal substitution is estimated at around 0.09 and there is evidence for a bequest motive (1.52). 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 3.2%. Conditional on participation, the annual annuity purchased is around 1,650 GBP and the share of wealth being annuitized is around 8.3% (versus 36.6% in the data, but with a standard deviation of 31.6%). 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

[41] 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,

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

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

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

$m(Y_t)$ 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.

already provides a reasonable insurance against longevity risk. Figure 5 compares the wealth evolution during retirement predicted by the model versus the one in the data, illustrating the close fit between the two.

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 market participation from 3.2% to 4.25%, whereas a higher pension (75th pension percentile) decreases participation to 1.15%. 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 to zero and the result is consistent with the multivariate probit analysis in Section 2. We also investigate what happens when an actuarially fair annuity policy exists. This change increases annuity participation from 3.2% to 6.75% and voluntary annuity demand from $1,650$ GBP to $6,270$ GBP. 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 use variation in the risk aversion coefficient to match this share. We report the results in Table 6, Panel B. The elasticity of intertemporal substitution is around 1.64 and the bequest parameter equals 2.75, while a higher risk aversion (6) is needed to generate a share of financial wealth in stocks equalling

on average 38%.[42] The level of annuity market participation is around 7.1% (9.6% in the data), with 20% of financial wealth being annuitized at retirement (26% in the data), giving an annual annuity income of around 5,040 GBP (3,656 GBP in the data). We view these predicted outcomes as quite close to their observed counterparts and Figures 6 and 7 illustrate how closely predicted behavior matches its empirical counterpart. Figure 6 shows that in the data the mean wealth profile shows only a 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 132,000 GBP), the model can be a good first approximation of 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.[43]

In Table 7, Panel B, we offer some further comparative statics to illustrate that the conclusions are robust to changes in the economic environment. Higher (the 75th percentile) and lower (25th percentile) pension levels affect the participation rate in the expected way and a lower subjective survival probability again reduces annuity market participation. Nevertheless, none of these comparative statics generates a substantial increase in annuity demand or a major departure from the other predictions of the model. Our conclusions, therefore, are robust to substantial changes in underlying parameters.

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

[42] Even though we are using three parameters to match three moments, we are not matching the moments exactly because we are constraining the bequest parameter to be less than five, as suggested by the calibrations reported in Cocco, Gomes and Maenhout (2005).

[43] 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).

non-stockhoders and a much higher elasticity of intertemporal substitution for stockholders. Finding a low magnitude for the elasticity of intertemporal substitution for non-stockhoders, and a much higher one for wealthier households, is consistent with the empirical evidence offered in Vissing-Jorgensen (2002). Gomes and Michaelides (2005) and Gomes, Michaelides and Polkovnichenko (2008) also 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. Guvenen (2006) uses this type of heterogeneity to explain the estimates of a low elasticity in studies using aggregate data. Specifically, if wealthier households have a higher elasticity, the aggregate estimates can still be determined by the very low elasticity of the majority of (poor) households. Overall, we view our EIS estimates as consistent with the empirical evidence, with the caveat that we estimate a slightly higher elasticity of intertemporal substitution than these authors.

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-stockhoders. 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-stockhoders. 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 definitely necessary to match the behavior of stockholders is the strength of the bequest motive. 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, Gomes and Maenhout (2005) find this effect for CRRA preferences but they do not

compare the resulting profiles to asset allocation profiles from the data. 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.

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 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, Brown and Diamond (2005) we should not expect full annuitization in an incomplete market. These authors provide simulations which suggest that households will tend to annuitize more than two-thirds of their wealth in incomplete markets, while we observe much smaller percentages (26 percent on average for stockholders) in our data. 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 allowed. In particular, a strong bequest motive is vital to generate simultaneously low wealth decumulation, low annuity demand and balanced portfolios for the richest part of the population. We can thus rationalize the

observed annuitization rates and therefore conclude that the annuity market participation puzzle might not be as deep as previously thought.

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Table 1: Annuity and stock market participation

	A = 0	A = 1	Total
S = 0	2917	96	3013
Row-%	96.8	3.2	100.0
Total-%	55.7	1.8	57.5
S = 1	2007	213	2220
Row-%	90.4	9.6	100.0
Total-%	38.4	4.1	42.5
Total	4924	309	5233
Total-%	94.1	5.9	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) 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. Percentages are either row percentages of the subsamples of non-stockholders and stockholders, respectively, or percentages of the total sample size. 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	-	-
Stock share percentage	16	0	24	14	16	0
	A = 1 and S = 1		S = 1		S = 0	
	Mean	Median	Mean	Median	Mean	Median
Financial wealth	173619	99300	101937	47586	20470	5000
Annual pension	14142	11660	11523	9132	7711	6315
Annual public pension	4943	4948	4521	4628	4999	4784
Annual private pension	9199	6600	7002	4145	2712	500
Annual annuity income	3656	1200	351	0	53	0
Stock share percentage	35	28	38	32	-	-

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 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. Non-stockholders

	Voluntary annuity market participation				Log annuity demand	
	Probit		Marginal effects		cond. on participation	
Variable	estimate	t-value	estimate	t-value	estimate	t-value
Intercept	-4.0431	-1.50	-	-	4.8683	0.59
Age / 10	0.5708	0.72	-0.0042	-0.35	-0.6805	-0.28
Age^2/ 100	-0.0462	-0.82	-	-	0.0527	0.31
Female	-0.1708	-1.77	-0.0214	-1.62	-0.0327	-0.10
Married	-0.3231	-2.98	-0.0361	-2.42	0.1729	0.52
Number of children	0.0390	1.58	0.0057	1.64	0.1053	0.84
Low education	-0.2254	-2.10	-0.0271	-1.87	0.1988	0.61
High education	0.2027	1.13	0.0331	1.04	0.1525	0.25
Survival probability	0.0290	0.18	0.0041	0.18	0.4178	0.63
Log financial wealth	0.1627	5.10	0.0231	3.56	0.3324	2.17
Log pension	-0.0783	-1.49	-0.0111	-1.49	-0.0463	-0.46
Number of observations	3013				96	
Fit of the model	Correct predictions: 96.81%				R-square: 13.60%	

Table 4 (continued): Estimation results

B. Stockholders

	Voluntary annuity market participation				Log annuity demand	
	Probit		Marginal effects		cond. on participation	
Variable	estimate	t-value	estimate	t-value	estimate	t-value
Intercept	-10.279	-4.65	-	-	-1.2919	-0.23
Age / 10	1.7066	2.58	0.0280	2.76	0.9186	0.57
Age^2/ 100	-0.1167	-2.40	-	-	-0.0706	-0.60
Female	-0.1666	-1.98	-0.0218	-1.77	-0.1179	-0.54
Married	-0.3026	-3.10	-0.0359	-2.69	0.0691	0.28
Number of children	0.0135	0.46	0.0020	0.47	0.0440	0.65
Low education	-0.2065	-2.23	-0.0263	-2.04	-0.0583	-0.22
High education	0.1587	1.64	0.0262	1.55	-0.1158	-0.56
Survival probability	0.3205	1.98	0.0473	1.92	0.3446	0.85
Log financial wealth	0.2439	7.08	0.0360	5.62	0.6303	6.88
Log pension	0.0292	0.63	0.0043	0.63	-0.2203	-1.99
Number of observations	2220				213	
Fit of the model	Correct predictions: 90.45%				R-square: 22.45%	

Notes to Table 4: The table reports estimation results from a Probit model for the annuity market participation decision and from a linear regression model for the (log) annuity demand conditional on participation. Panel A shows results for non-stockholders, Panel B for stockholders. The Probit participation model is estimated with ML using the Berndt et al. (1974) estimator of asymptotic standard errors. The marginal effects are calculated for a 65 years old single male without children, medium education, average subjective survival probability, average pension and average wealth. The asymptotic distribution of marginal effects is computed with the delta method. The linear annuity demand model is estimated with OLS using White's (1980) 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).

Table 5: Average annuity demand and annuity market participation

A. Non-stockholders

b	γ	ψ	Voluntary annuity market participation	Voluntary annuity demand	Share of wealth annuitized	Annuity equivalent wealth
0	2	0.20	6.15	5.79	34.12	99.75
		0.30	12.80	4.57	37.73	99.53
		0.50	34.50	2.93	54.16	98.73
		0.80	66.75	2.10	92.96	91.99
	3	0.20	22.10	3.62	44.30	99.11
		0.30	41.05	2.73	62.30	98.02
		0.50	66.50	2.10	93.31	94.98
		0.80	67.10	2.09	92.49	90.21
	5	0.20	51.00	2.42	68.98	96.87
		0.30	66.95	2.06	89.18	93.87
		0.50	67.10	2.09	92.53	91.57
		0.80	67.30	2.08	92.16	89.36
1	2	0.20	3.90	3.17	15.59	99.89
		0.30	4.00	3.39	16.73	99.88
		0.50	3.75	3.21	15.41	99.89
		0.80	1.05	0.65	2.51	99.90
	3	0.20	9.25	5.15	35.35	99.61
		0.30	10.05	5.19	37.61	99.58
		0.50	10.05	5.29	38.41	99.58
		0.80	6.95	5.55	31.94	99.76
	5	0.20	25.30	3.47	48.47	98.62
		0.30	29.40	3.23	50.69	98.34
		0.50	31.75	3.03	47.90	98.26
		0.80	22.10	3.61	40.41	98.95

Table 5 (continued): Average annuity demand and annuity market participation

B. Stockholders

b	γ	ψ	Voluntary ann. market participation	Voluntary annuity demand	Share of wealth in stocks	Share of wealth annuitized	Annuity equivalent wealth
0	2	0.20	5.45	2.79	99.83	11.62	99.83
		0.50	9.85	4.71	99.66	21.10	99.67
		0.80	18.40	5.58	100.00	28.50	99.29
		1.70	78.15	5.68	100.00	67.89	76.30
	4	0.20	31.05	4.87	97.34	32.45	99.78
		0.50	45.05	4.98	98.63	40.35	97.82
		0.80	58.50	4.97	100.00	48.07	96.75
		1.70	95.05	4.97	99.49	80.09	81.67
	6	0.20	53.25	4.84	95.16	43.82	96.83
		0.50	64.25	5.03	99.80	55.02	95.27
		0.80	73.25	4.92	100.00	59.76	92.52
		1.70	97.10	5.14	99.32	94.69	78.50
3	2	0.20	3.75	1.77	97.09	6.94	99.87
		0.50	4.30	2.91	96.93	11.44	99.86
		0.80	4.80	2.84	96.49	11.05	99.83
		1.70	3.45	1.65	95.76	6.21	99.87
	4	0.20	23.60	4.71	95.73	27.52	99.28
		0.50	26.85	4.85	87.97	29.04	99.13
		0.80	19.25	4.77	78.59	24.17	99.39
		1.70	4.85	3.32	63.64	12.65	99.81
	6	0.20	46.40	5.00	91.17	41.61	97.46
		0.50	54.55	4.91	72.72	44.38	96.69
		0.80	44.25	4.90	55.00	37.40	97.72
		1.70	6.90	4.90	39.64	19.36	99.67

Notes to Table 5: Panel A reports simulated results for the model without access to the stock market, using the wealth distribution from the data as an exogenous input to compute annuity demand statistics, while Panel B reports the simulated results using the model that allows access to the stock market and the respective empirical wealth distribution of stock market participants (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 several preference parameter combinations. Preference parameters are set in a range that captures the estimated parameters from the empirical section of the paper. Therefore, for non-stockholders the bequest parameter is set at b = 0 and 1, relative risk aversion γ is 2, 3, or 5 and the elasticity of intertemporal substitution (EIS) ψ is 0.2, 0.3, 0.5, and 0.8. For stockholders, the bequest parameter is set at b = 0 and 3, relative risk aversion γ is 2, 4, or 6 and the elasticity of intertemporal substitution (EIS) ψ is 0.2, 0.5, 0.8, and 1.70. Voluntary annuity market participation reports average participation in percentage terms, voluntary annuity demand is defined as average annual annuity income in thousands of pounds, conditional on participation, and the voluntary share of wealth annuitized is the optimal amount of purchased annuity at retirement as a percentage of total financial wealth at retirement. 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. For stockholders, the share of financial wealth in stocks is the average share of wealth allocated in the stock market during retirement.

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

A. Non-stockholders

Model	b	γ	ψ	Voluntary annuity market participation	Voluntary annuity demand	Share of wealth annuitized
Estimates	1.52	2.0	0.09	3.19	1.65	8.30
s.e.	0.02	--	0.004			
Data				3.19	1.65	36.61
s.d.				17.57	4.57	31.57

B. Stockholders

Model	b	γ	ψ	Voluntary ann. Market participation	Voluntary annuity demand	Share of wealth in stocks	Share of wealth annuitized
Estimates	2.75	6.0	1.64	7.10	5.04	39.50	20.00
s.e.	1.65	0.01	0.02				
Data				9.59	3.66	37.98	26.27
s.d.				29.45	9.58	28.73	25.77

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, and, conditional on participation, the amount of annuity demand at retirement. For the stockholders the share of wealth in financial assets is a third moment to be matched. The last column reports the predictions for an unmatched moment: the share of wealth annuitized. Standard errors are computed using a diagonal weighting matrix that is based on the inverse of the variance of the empirical moments. We constrain γ (risk aversion) to equal 2 for the non-stockholders but use variation in risk aversion to generate a balanced portfolio for the stockholders.

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

A. Non-stockholders

Model	Voluntary annuity market participation	Voluntary annuity demand	Share of wealth annuitized	Annuity equivalent wealth
Data	3.19	1.65	36.61	-
MSM	3.19	1.65	8.30	99.88
Low Pension	4.25	2.92	14.85	99.85
High Pension	1.15	0.93	3.78	99.89
Low Survival	0.00	0.00	0.00	100.0
Actuarial Fair	6.75	6.27	31.52	99.46

B. Stockholders

Model	Voluntary ann. market participation	Voluntary annuity demand	Share of wealth in stocks	Share of wealth annuitized	Annuity equivalent wealth
Data	9.59	3.66	37.98	26.27	-
MSM	7.10	5.04	39.50	20.00	99.67
Low Pension	8.20	4.78	39.26	19.04	99.65
High Pension	6.65	4.83	39.78	19.24	99.71
Low Survival	0.25	0.09	37.32	0.32	99.89
Actuarial Fair	9.95	7.53	39.53	26.29	99.40

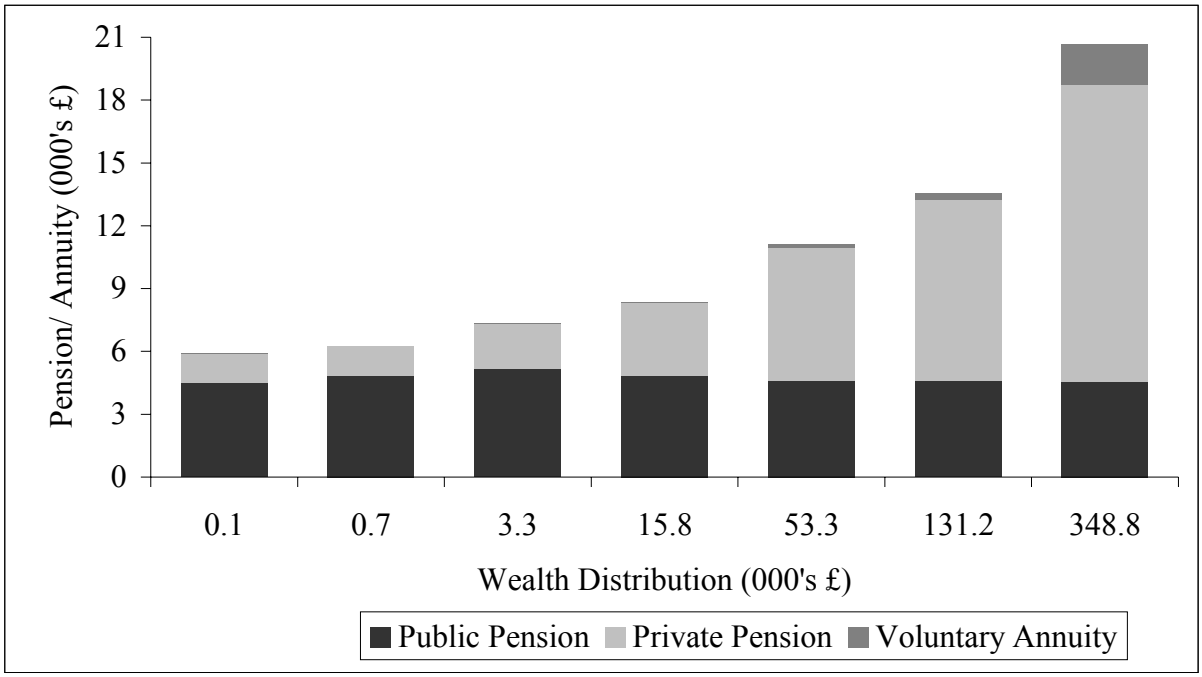
Notes to Table 7: Panel A reports simulated results using the non-stockholder model, and Panel B the simulated results using stock market participants. The risk free rate is set to 2%, the equity premium at 4% and the standard deviation of risky asset return at 18%. Pre-existing pension income is set 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 Low and High Pension cases the corresponding 25th and 75th 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 Actuar Fair is the case for annuities with a zero load factor. Voluntary annuity market participation reports average participation in percentage terms, voluntary annuity demand is defined as average annual annuity income in thousands of pounds, conditional on participation, and the voluntary share of wealth annuitized is the optimal amount of purchased annuity at retirement as a percentage of total financial wealth at retirement. 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

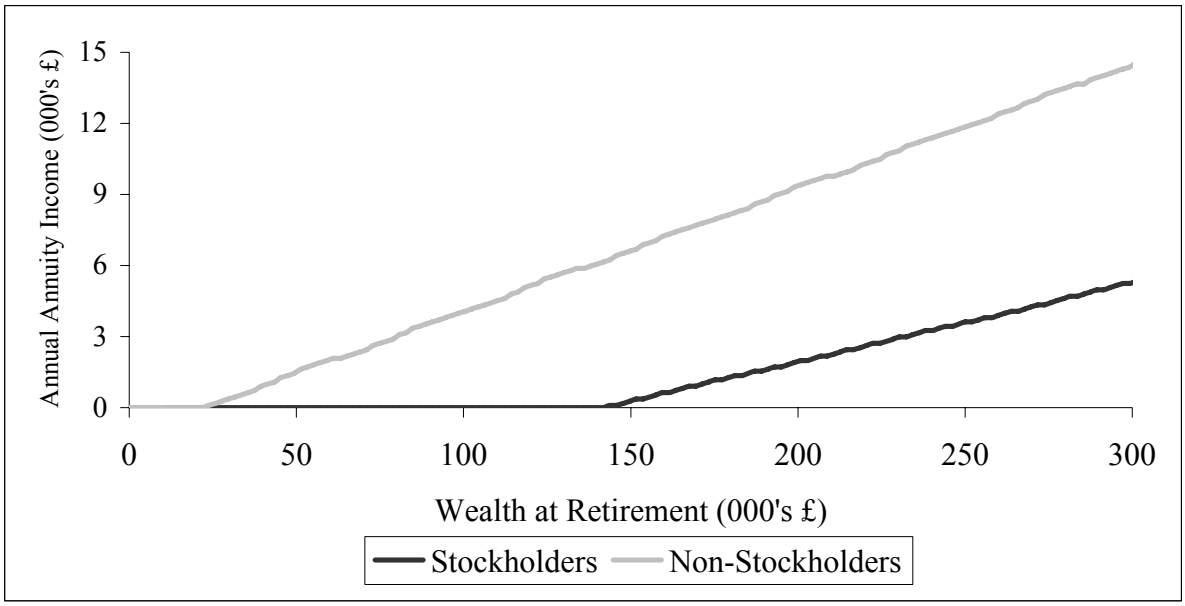
Notes to Figure 1: The columns show the number of households (measured on the ordinate on the left hand side) around the 2.5%, 10%, 25%, 50%, 75%, 90% and 97.5% percentiles of the wealth distribution in the whole sample ("All") and the sub-sample consisting of stock market participants ("S = 1"). The 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 quantile 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



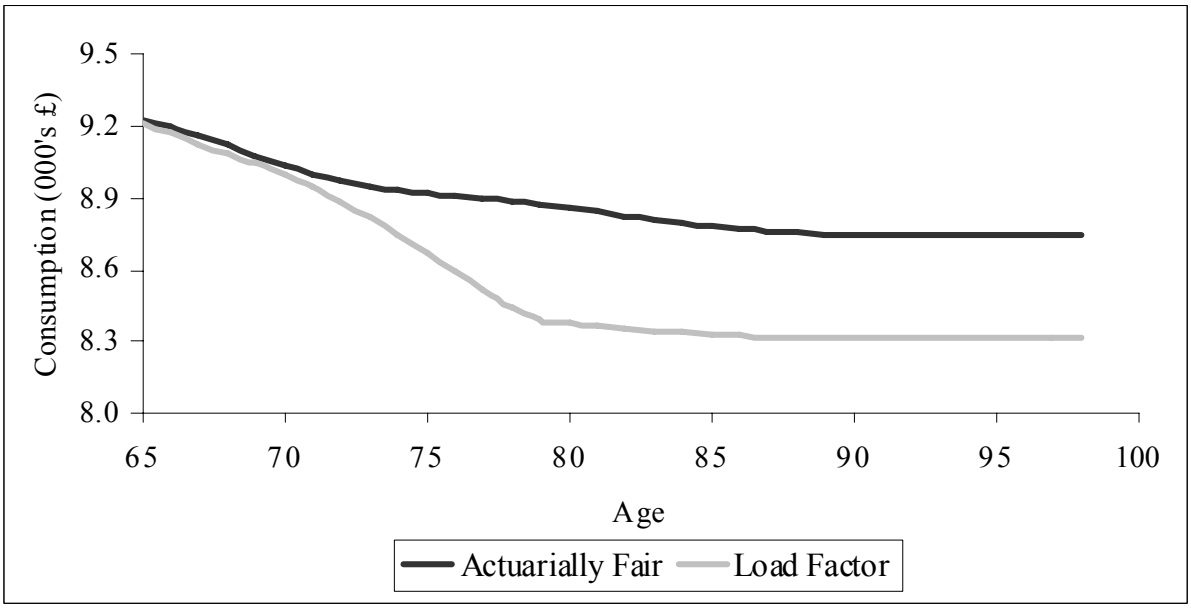
Notes to Figure 2: The figure decomposes the average total annual pension income of households around a certain quantile of the wealth distribution into income from public pensions, private (individual or occupational) pensions (excluding voluntary annuities) and voluntary annuitization. The wealth distribution 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 wealth at retirement



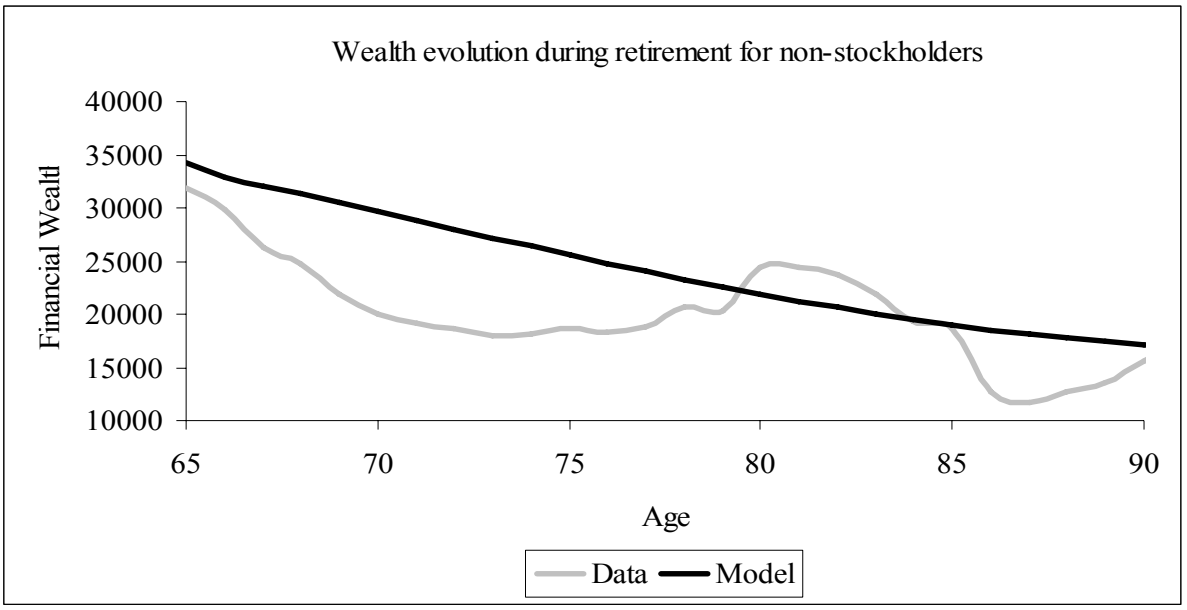
Notes to Figure 3: This figure shows the policy function for annuity demand as a function of wealth at retirement for stock market participants (Stockholders) and non-participants (Non-stockholders).

Figure 4: Average consumption profiles



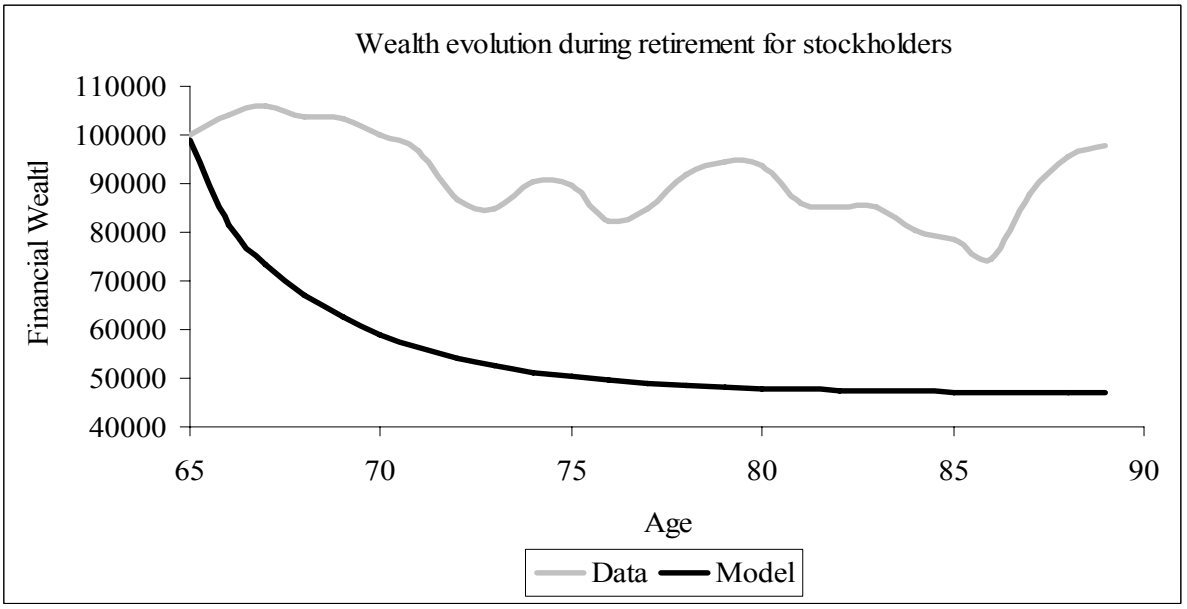
Notes to Figure 4: Actuarially Fair represents consumption for the model with access to actuarially fair annuities. Load factor represents consumption for the model with annuities subject to a load factor of 20%.

Figure 5: Average wealth profiles for non-stockholders: model and data



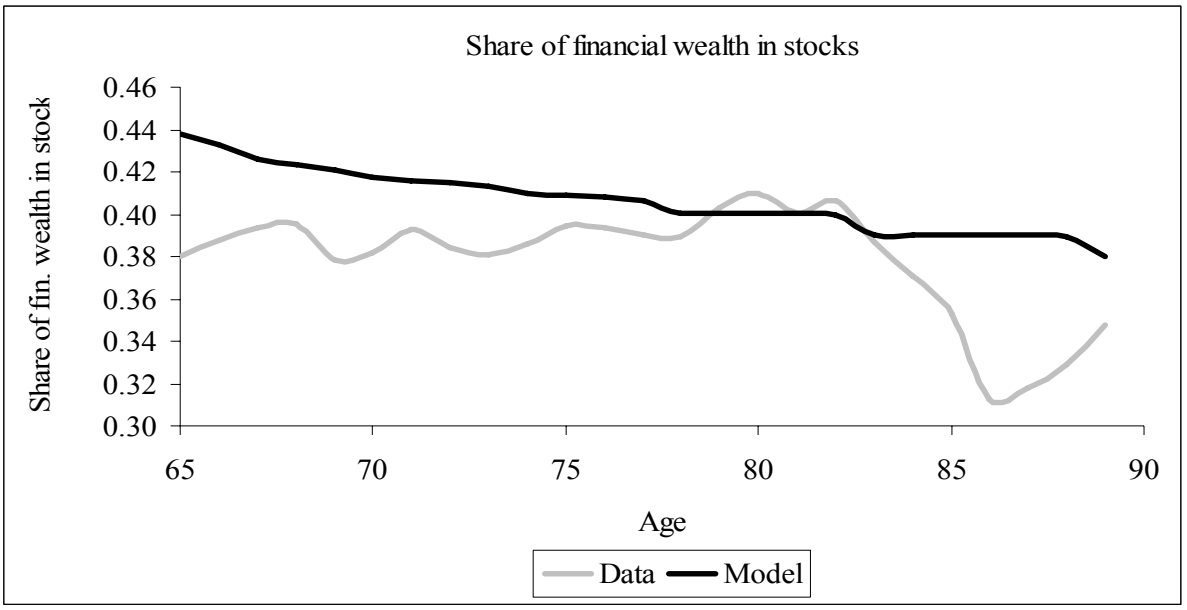
Notes to Figure 5: The figure presents the mean profile for wealth in the data against the model (for the estimated structural parameters for non-stockholders).

Figure 6: Average wealth profiles for stockholders: model and data



Notes to Figure 6: The figure presents the mean profile for wealth in the data against the model (for the estimated structural parameters for stockholders). The average of the cross sectional standard deviation of financial wealth for every age between ages 65 and 90 in the data is 132,000 GBP.

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



Notes to Figure 7: The figure presents the mean profile for the share of financial assets allocated in the stock market in the data against the model (for the estimated structural parameters for stockholders). The data stops at age 90 (this is where the ELSA data stop reporting to avoid household identification issues) but the model has been solved on the assumption that households might live for a maximum of 100 years. In the data, the average of the cross sectional standard deviation of the share of financial wealth in stocks between ages 65 and 90 is 29.5%.