Private Pensions and Public Pension Design*

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October 1, 2015

Abstract

In most developed countries spending on means-tested benefits in retirement is small relative to spending on contributory public pensions and subsidies of private pension saving. This paper investigates whether governments are getting this balance right. The framework used is a very rich lifecycle model which includes public and private pensions. Model features are estimated using a combination of survey data and linked administrative data. The model is then used to assess the optimal (from an ex-ante perspective) split between contributory and means-tested benefits in retirement under different systems of tax support for private pension saving. I find evidence, that, in the UK at least, means-tested payments to pensioners are too low, the tax treatment of private pensions is too generous, and that there exists the potential for revenue-neutral welfare-enhancing changes in the composition of support to the elderly.

Preliminary and with incomplete appendices

JEL Classification: D31, D91, E21, D12

Keywords: Pensions; Dynamic Programming; Savings; Social Security

1 Introduction

The provision of support for the elderly in retirement tends to be one of the most costly activities carried out by governments in the developed world. These costs are growing as life expectancies lengthen. Most developed countries offer support to the elderly by providing one or both of two types of schemes. The first is a payment whose level is contingent on contributions during working life and the second is a means-tested payment. Spending on contributory pension benefits in most countries is vastly greater than on means-tested benefits. The ratio of spending on the Basic and Additional State Pensions (UK contributory public pensions) to Pension Credit (the UK means-tested support to the elderly) is 9:1. The ratio of spending through the Canada Pension Plan (contributory) to Old Age Security (means-tested) is 20:1, while the ratio of Social Security spending to spending on Supplemental Security Income by the US federal government is 25:1.[1]

Spending on contributory public pensions and means-tested transfers to the elderly is not the only form of government support for income replacement in retirement. Government spending on *private* pensions

*Preliminary with incomplete appendices; This paper is my main paper in my doctoral thesis - thanks to Richard Blundell, Tom Crossley, Guy Laroque, and Hamish Low for comments, support and encouragement and to Orazio Attanasio, James Banks, Rowena Crawford, Mariacristina DeNardi, Eric French and seminar participants at the Institute for Fiscal Studies for very helpful discussions. Thanks to the Economic and Social Research Council (Centre for Microeconomic Analsyis of Public Policy at the Institute for Fiscal Studies- ref: RES-544-28-50001) for funding this work. Correspondence to cormac.odea@ifs.org.uk. Any errors are my own.

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[1]Australia is a notable exception where the Australia Age Pension - the main public payment to pensioners in means-tested

is indirect but tends to be large. It comes through the (different in different countries) favourable tax treatment of private pension saving. In the US, tax expenditures on private pensions will have a revenue effect of \$138bn in 2016[2] which is over twice the \$64bn projected cost of Supplemental Security Income in that year (Office of Social Security (2015)). In the UK, the estimated cost of tax relief on private pensions was £21bn in 2013/14 (HMRC (2015)) - approximately three times the £7.1bn spent on means-tested Pension Credit (Hood and Oakley (2014)).

The aim of this paper is to evaluate the optimality of the emphasis on spending on contributory public pensions and private pension subsidies rather than on means-tested support. The last of these can provide valuable insurance for households against low consumption in retirement (due to, for example, unfavourable realisations of earnings during working life, bad investment returns, or living to a very old age). By targeting that support on those with the worst outcomes, that insurance can be provided at lower cost than if the same insurance were provided through a contributory instrument. Providing this insurance though, has costs that go beyond the spending on the transfer. Means-tested payments are distortionary. They effectively tax private saving and so diminish the incentive for individuals to provide for themselves in retirement, and by distorting choices over intertemporal consumption, bring welfare costs. This paper develops and estimates a rich lifecycle model that can be used to value the insurance provided by means-tested support in retirement and to quantify the costs that it imposes. The paper's central contribution is to study the design of public pensions in a rich framework which contains private pensions. The framework is a lifeycle model, in which households (who are ex-ante heterogeneous in their education and access to Defined Benefit pensions) make choices over labour supply, consumption, their portfolio allocation between non-pension saving and a Defined Contribution pension (if they wish to hold one). The modelled policy environment reflects the current UK system. Preference parameters are estimated using the method of simulated moments and a combination of rich survey data and linked administrative data.

I find that, from the perspective of the start of life and leaving unchanged the generous treatment of private pensions, the optimal policy is to abolish the contributory component of the public pension in the UK and to use the resulting funds to increase the means-tested component. The increase in welfare comes from the fact that impact of the lower level of expected lifetime consumption that results from the change (due to an extension of the distortionary payment) is more than offset by the effect of the reduction in the variance of lifetime consumption and increases in time spent at leisure. If, further, the generosity of the tax treatment of private pension saving was reduced and the resulting funds spread optimally between means-tested and contributory components, the welfare gains double relative to the first experiment. In short, I find evidence, that, in the UK at least, means-tested payments to pensioners are too low, the tax treatment of private pensions is too generous, and that revenue-neutral welfare-enhancing changes in the composition of support to the elderly are possible.

The first branch of the literature to which this paper relates studies the effect that the provision of public insurance has on the propensity for households to privately insure themselves (in this case against poor outcomes in retirement). In a seminal article, Feldstein (1974) illustrated the incentives that social security systems can bring to bear upon private saving and on labour supply. Subsequently, there has been a sizable literature that has shown, using policy variation across jurisdictions and over time, the powerful effects of aspects of social security systems on saving and labour supply. Neumark and Powers (1998) and Neumark and Powers (2000) show that Supplemental Security Income (SSI) reduces pre-retirement saving and labour supply for those likely to be in receipt of the benefit. Earnings tests (which 'tax' public pension income if a pensioner has labour earnings) reduce male labour supply among pensioners (Disney and Smith (2002); Friedberg (2000); Haider and Loughran (2008)). The generosity of public pensions has been shown to crowd out private saving (Attanasio and Brugiavini (2003); Attanasio and Rohwedder

[2]This number is the sum (from Table 3 of US Department of the Treasury (2015)) of tax expenditures on Defined Contribution Plans, Defined Benefit Plans and Individual Retirement Accounts.

(2003); Hurd et al. (2012)).

While the exploitation of cross-sectional or time-series variation in public pension rules has allowed those papers to show that the design of social security systems certainly affects behaviour, reduced form estimates alone cannot facilitate concrete statements about consumption, saving and labour supply behaviour over the whole of the lifecycle, nor can they be used to assess the welfare implications of counterfactual systems of provision for the elderly. Structural lifecycle models have been used to address these questions. Hubbard et al. (1995) first showed the depressing effect on household wealth accumulation of means-tested consumption floors; Braun et al. (2015) emphasise this point in a richer setting; De Nardi et al. (2010) show that, in the presence of the large wealth shocks (such as those that come from healthcare needs at old ages), such floors can affect the behaviour even of those who have very high permanent income.

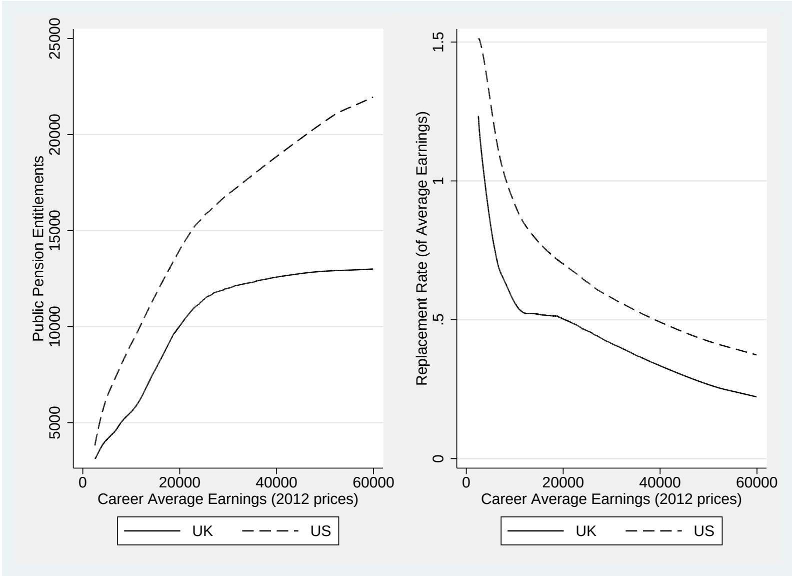
The second branch of the literature to which this work relates studies the design of public pensions. Following the work of Auerbach and Kotlikoff (1987) a large number of papers has studied the design of public pensions in a DSGE framework. This literature[3] has focussed on how Social Security in the US might be made affordable in light of the pressures imposed on it by changing demographics. Solutions that have been heavily studied include raising payroll taxes, delaying eligibility ages and reducing the generosity of benefits. The literature has, however, generally neglected to study the possibilities afforded by the means-testing of benefits. An exception is Kitao (2014) who studies four options to make Social Security sustainable - one of which involve an extreme form of means-testing (whereby Social Security benefits, after a small disregard are withdrawn at an effective tax rate of 100%). In evaluating the implications for welfare of the various reforms, the means-tested option, alone of the four, is not discussed as due to the "large negative effects on economic activities and fiscal burden, it is unlikely to be a viable option for the social security reform".

There is a lot of evidence, then, from both structural and reduced-form analyses, that the provision of means-tested retirement benefits is distortionary. However, there is also evidence, from a smaller set of papers that means-tested benefits can be valuable and can justify, or more than justify, their costs. Sefton and Van De Ven (2009), studying the UK, find that enhancing the generosity of the means-tested component of the public pension system would be welfare-improving. De Nardi et al. (2013) investigate the value of Medicaid in old age and find that, the costs justify the benefits (in their words - "Medicaid is about the right size"). Braun et al. (2015) investigate the role of old-age social insurance programmes more generally in old-age (Medicaid, Supplemental Social Security Income, Food Stamps and Energy Assistance programmes) and conclude that welfare gains of the current level of support are large and that current levels of provision are too small - that is an increase in their value of a third, funded through the payroll tax is welfare-increasing. Huggett and Parra (2010) and Golosov et al. (2013) both give evidence that making Social Security more progressive (ableit not by means-testing the benefits) would be welfare-enhancing. The contribution of the current paper, relative to these, is to study the design of public pensions in a setting where private pensions - their existence, the opportunities for insurance that they provide and the tax advantages typically associated with using them - are modelled.

The paper proceeds as follows. Section 2 introduces the system of public pensions and private pensions in the UK. Section 3 outlines the model used in the paper before Section 4 details the estimation procedures, gives parameters estimates and discusses model fit. Section 5 uses the model to evaluate counterfactual reforms and to find the optimal split between means-tested and contributory benefits. Section 6 concludes.

[3] A partial list of contributions is De Nardi et al. (1999), Conesa and Krueger (1999), Kotlikoff et al. (1999), Huggett and Ventura (1999), Nishiyama and Smetters (2007), Conesa et al. (2009), Kitao (2014).

Figure 1: Comparison of UK State Pensions with US Social Security



2 Pensions in the UK

In this section, I briefly describe the system of pensions in the UK - first describing the system of public pensions, and then private pensions.

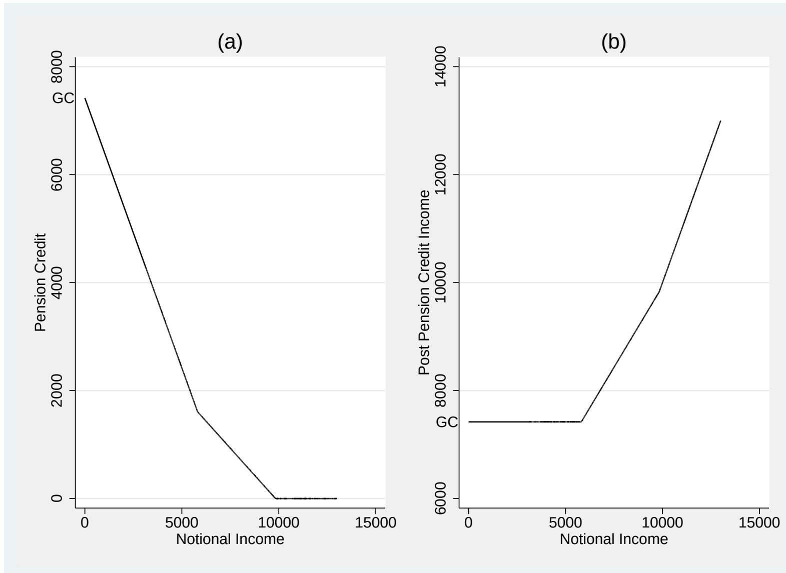
2.1 Public pensions in the UK

The UK system of public pensions has contributory components and a means-tested component.

Contributory component The contributory component of the system is complicated: there are a number of different schemes, and the rules have changed frequently over the last number of decades. I do not give many details here (for a detailed description of the system and its history, see Bozio et al. (2010a)), but describe the total effect of the various systems. Figure 1 summarises the relationship between the public pension payment for a sample of households born between 1935 and 1950. The left hand graph gives the level of the pension payment, the right hand graph gives the replacement rate out of career average earnings (where past earnings are uprated using the Retail Prices Index). The graphs also show, for the same sample of households, the Social Security payment they would receive if they had earned (and paid social contributions) in the US.[4] In the UK, the public pension system is related to earnings in a much weaker sense than is Social Security in the US. The figure shows that the level of the payment is higher across the entire distribution of lifetime earnings in the US, and is substantially higher for those with middle and higher levels of lifetime earnings. This implies (as shown in the right hand panel) that the US system replaces a substantially greater proportion of working-life income than does the system in the UK.

[4]This analysis is all carried out at an individual level and does not take into account (in either jurisdiction) of benefits that are earned on the basis of a spouse's contributions. UK entitlements include the Basic State Pension, the State Earnings-Related Pension Scheme, the Second State Pension and Graduated Retirement Benefit. For the US system, I use the Social Security notch points and maximum insurable earnings for 2012, convert US dollar figures to the average exchange rate in that year ($1 = £0.64), and index wages by UK earnings growth rather than US earnings growth. For the UK, I use actual entitlements calculated from administrative data. Average earnings are estimated from that same data. The relationship between benefits and earnings is estimated using locally-weighted regressions.

Figure 2: Pension Credit



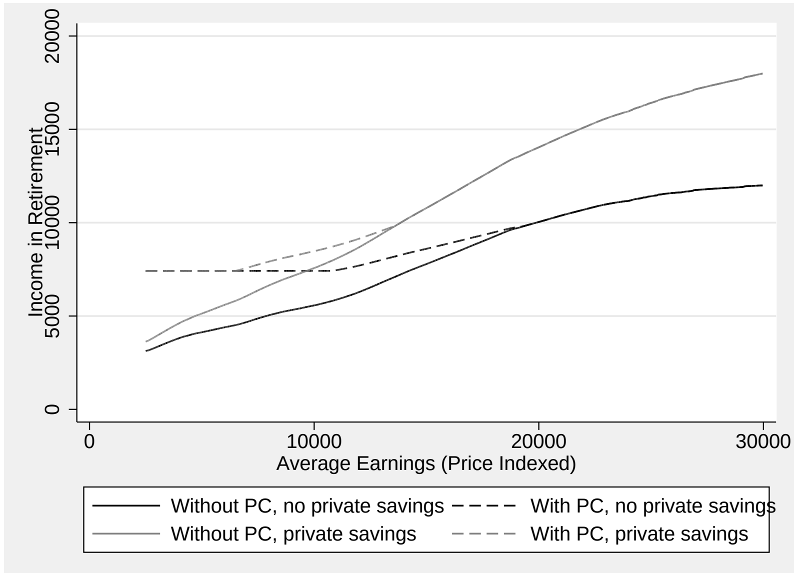
For the cohort of individuals studied in this paper (those born between 1935 and 1950), contributory public pensions were payable to men from the age of 65 and women from the age of 60 (though both these ages have been increasing recently for younger cohorts). In the following, I refer to this as this component of the public pension as the contributory component of the public pension or the 'state pension' (as it is often described in the UK).

Means-tested component Pensioners can also receive an income- and asset-tested payment known as Pension Credit (PC). This payment only depends on income and assets in retirement, there is no conditionality associated with contributions during working life. The payment depends on a pensioner (or pensioner household's) notional income. Notional income includes any earnings, private pension or state pension income as well as an imputed stream of income from asset stocks. That stream of income is calculated as 10% (annually) of the stock of non-pension wealth with some wealth exempted. Wealth held in the principle private residence (family home) does not generate a stream of notional income, nor does the first £10,000 of other non-pension wealth. Pensions which can be, but have not yet been, claimed are assumed to generate a notional income that is equal to that income that would be received if the pension was claimed.

For those with the lowest levels of resources, PC simply tops income up to a minimum income level (known as the Guarantee Credit level). The PC payment is equal to the difference between the Guarantee Credit level of income and notional income. In 2012/13 the Guarantee Credit level was £7,400 for a pensioner and £11,300 for a pensioner couple. As notional income increases, PC is withdrawn at an effective tax rate of 100%. Once notional income reaches £5,800 (£9,200) for singles (couples), the benefit is withdrawn at a lower effective tax rate of 40% until the benefit reaches zero at £9,830 (£14,400). Figure 2 illustrates this: Figure 2(a) shows the level of PC entitlement as a function of notional income for a single individual and Figure 2(b) shows post-PC income (the sum of notional income and PC). Both figures indicate the level of Guarantee Credit (GC) - the minimum annual income in retirement in the UK - on the vertical axis. The figures for couples have the same shape.

Interaction of contributory and means-tested components Figure 3 shows how the contributory and means-tested components operate together and is indicative of some of the incentives to save and

Figure 3: Interaction between Pension Credit and other Pension Income



supply labour introduced by PC. The graph shows income in retirement (vertical axis) as a function of career average earnings (horizontal axis) for two different individuals. The solid and dashed black lines represent, respectively, the pre- and post-PC retirement incomes of someone who does no private saving for retirement. The pre-PC line is simply the contributory public pension payment in this case. The grey lines represent the pre- and post-PC retirement income of someone who has accrued rights to a private pension worth 20% of his career average earnings.

To see some of the labour supply incentives induced by PC, consider first the black lines. For those who have low career average earnings, PC limits the marginal incentive to work in order to accrue benefits under the contributory public pension system by effectively taxing those additional benefits away (initially at a rate of 100% and subsequently at a rate of 40%). The effect of PC on the incentives to save can be seen by comparing the difference between the solid lines and the difference between the dashed lines. The former difference would be the return to undertaking private saving if the government did not provide PC, the latter difference is the return given the existence of PC. The difference with PC is sometimes zero and always (weakly) less than the difference without PC - PC effectively taxes the private saving.[5]

2.2 Private pensions in the UK

Private pensions in the UK (as in other most other countries can be grouped into two types - Defined Benefit (DB) pensions and Defined Contribution (DC) pensions. DB pensions pay a fraction of some function of earnings (e.g. career average earnings or final earnings). Employers can levy a charge on the employee for membership of the scheme. DC (401k-style) pensions are accounts owned by the individual. These funds are typically invested in a mix of risky and safe assets and can be used to purchase an annuity or otherwise provide an income in retirement. The pension payment is simply a function of fund size on annuitisation and the annuity rate - it doesn't depend on earnings. One can think of DB pensions giving a payment that is a deterministic function of the stream of career earnings, with DC pensions giving a payment that is a stochastic function of contributions (with employees typically choosing how much contributions to make).

[5]This discussion has centred around the substitution effects induced by Pension Credit. There are other effects - income effects on labour supply and saving due to the transfer, and incentives generated by whatever taxes are levied to pay for it.

Table 1: Household Types

1. Low Education, No DB Pension	2. Low Education, DB Pension
3. High Education, No DB Pension	4. High Education, DB Pension

In the rest of this section I discuss the tax treatment of private pensions in the UK - this treatment plays an important role in the rest of this paper. Private pensions attract four types of tax-advantage in the UK. These are:

1. Consumption tax treatment. Contributions into a pension are made out of pre-tax income (and so no income tax is levied on the income that is used to buy pension rights). While most (an exception is outlined in point 4 below) of the resulting pension is subject to income tax, the revenue raised by taxing pensions is less, for most households, than the tax foregone by allowing tax relief on contributions due to income tending to be lower in retirement than in working life and an income tax schedule that is progressive.
2. Exemption of investment returns from tax. The capital gains earned by funds held in a private pension are not subject to capital gains tax.
3. Exemption from National Insurance contributions (NI). These are the equivalent of the payroll tax in the US. No NI contributions are levied on the income that is paid into a private pension. Further, no national insurance contributions are levied on pension income.
4. Tax-free lump sum. One quarter of a DC private pension can be taken in a tax-free lump sum at an age of the individuals' choosing from the age of 55. Those with DB pensions also can (subject to the rules of their particular scheme) benefit from a tax-free lump sum.

These four tax advantages represent substantial government spending on subsidising private pensions - worth £21bn in 2013/14 (HMRC (2015)) or 1.3% of GDP. The treatment of private pension saving in the UK is substantially more generous than in the US where pension saving benefits from advantages (1) and (2) but the (US) payroll tax is levied on contributions into a pension, and there is no tax-free lump sum.

3 Model

In this section, I outline the model that is used to simulate household behaviour under different pension systems.

3.1 Household heterogeneity, composition and utility

Heterogeneity There are four household types. The types, depicted in Table 1, are each pairwise combination of low/high education and having access to a DB pension or not. Household types are determined ex-ante, before the start of working life. This determination happens exogenously - the education choice or the choice to enter a career in which employers typically provide a DB pension (such as the civil service) is not modelled. However, earnings processes differ by type (which is indexed by j below), and each type j is allowed to have different preference parameters. These differences will account for some of heterogeneity that leads households to select into these groups.

Household composition The decision-making unit in the model is the household. All households contain a married couple who start their working life already married. Working life starts when the male (whose age, t, indexes the household's age) is aged 20. Household members die stochastically. Household composition (h) takes a value of 1, 2, 3 or 4 indicating, respectively, that both spouses are still alive, only the male is alive, only the female is alive or that both spouses are dead.

Utility Households get utility from consuming, from having leisure time and from leaving bequests. The utility function, given in equation (1) is non-separable in consumption and leisure, has a Cobb-Douglas form, with weight on consumption ν and a coefficient of relative risk aversion (on utility) of γ. To preserve on notation, I do not, here, include an index j on preference parameters.

$$u(c,l) = \frac{(c^{\nu} l^{1-\nu})^{1-\gamma}}{1-\gamma} \tag{1}$$

Consumption (c) is the sum of non-housing and housing consumption (c^{nh} and c^{h} respectively), the role of each of which will be detailed below.

Households value bequests through a warm-glow bequest function, of a form used by French (2005) and given in equation (2). a^b are the assets bequested, θ determines the importance of bequest motives to households and K is a constant that determines the curvature of the bequest function and ensures that the marginal utility of leaving a zero bequest is finite.

$$b(a^b) = \theta \frac{(a^b + K)^{(1-\gamma)\nu}}{1-\gamma} \tag{2}$$

3.2 Employment, earnings and decisions

Employment and earnings Male household members face a choice of whether or not to supply labour if they are offered a job. However, they are not offered a job in each period. They sometimes are subject to an unemployment shock ($ue_t = 1$) which evolves according to a Markov process. The probability of an unemployed male remaining in unemployment (π_0) is a constant, varying only by household type (though here and with respect to productivity parameters below, I suppress the j subscript). When not unemployed in the previous period, the probability of unemployment $\pi_1(\tilde{e})$ depends on current productivity ($\tilde{e}$), the evolution of which I discuss below. In particular, the unemployment probability depends on productivity decile. The (conditional) Markov transition matrix is:

$$\begin{pmatrix} \pi_0 & 1-\pi_0 \\ \pi_1(\tilde{e}) & 1-\pi_1(\tilde{e}) \end{pmatrix}$$

When employed, males earn their productivity, whose log (equation (3)) is the sum of a deterministic component (a quadratic in age) and a stochastic component (u).

$$ln\ \tilde{e}_{it} = \delta_0 + \delta_1 t + \delta_2 t^2 + u_{it} \tag{3}$$

The evolution of the stochastic component in periods following an employment offer is shown in (4). u follows an AR(1) process with innovations distributed normally. The variance of these innovations differs in the first period (σ^2_{ζ}) and in subsequent periods (σ^2_{ξ}).

$$
\begin{aligned}
u_{it} &= \rho u_{it-1} + \xi_{it} \;\; \forall \;\; t \;\; \text{with} \;\; ue_{t-1} = 0 \\
\xi_t &\sim N\Big(0, \sigma^2_\xi\Big) \;\; \forall \;\; t > 1 \\
\xi_1 &\sim N\Big(0, \sigma^2_\zeta\Big) \\
u_0 &= 0
\end{aligned} \tag{4}
$$

In periods following a period of unemployment, households' productivity takes one of ten values (representing deciles of the productivity distribution). The probability distribution over these draws, which does not depend on past productivity realisations, is given by $E()$:

$$u_{it} \sim E() \;\; \forall \;\; t \;\; \text{with} \;\; ue_{t-1} = 1$$

I do not model female labour supply. Households receive a small fixed payment (e^f) that represents female earnings up to the age of 63[6].

Decisions In each period households make (up to) five decisions. They decide, i) whether the male works (if he has been given an employment offer), ii) how much to consume, iii) how much DC pension saving to do, iv) how much non-pension saving to do and v) whether to annuitise their DC pension. The three choices ii) to iv) (the consumption choice and the portfolio choice between pension and non-pension saving) reduce to two choices as given any two, the intertemporal budget constraint will imply the third.

3.3 Assets

Households can choose how much to save in each of two-assets. These are a Defined Contribution pension and a non-pension asset. Additionally, households, when working, accrue rights to the public pension system and (for those types eligible), the Defined Benefit pension. I now discuss these four assets.

Defined Contribution pensions Households can, each period, pay a proportion of their *pre-tax* income into a Defined Contribution (i.e. 401k-style) pension. The evolution of the stock of wealth in the DC fund (DC) depends on flows into the fund ($cont^{dc}$) and the return on the fund in each year (ϕ).

$$DC_{t+1} = (1 + \phi_{t+1})\big(DC_t + cont^{dc}_t\big) \tag{5}$$

The return on DC funds is assumed to be normally distributed (left-trucated at -100%):

$$\phi_t \sim N\left(\bar{\phi}, \sigma^2_\phi\right)$$

DC wealth cannot be drawn down until the age of 55 (mirroring current rules in the UK). Under rules that prevailed in the UK for decades[7], three-quarters of the stock of DC wealth must be used to purchase a (taxable) life annuity. The age (t^{ann}) at which this happens is a choice (in the model as in reality). Up to a quarter of the DC fund can, however, be taken as a (tax-free) cash lump sum. The lump sum is given by:

[6]The age of the household in the model is taken to be the man's age - and the median age gap between husband and wife in the cohort that I study is 3 years. The age of 60 has been the focal retirement age for women in the UK for many years - this occurs at a male (or 'household age') of 63

[7]This compulsion was removed in March 2014.

$$
\begin{aligned}
ls_t^{dc} &= (0.25)DC_{t^{ann}} \;\; for\ t\ = ann \\
&= 0\ \forall\, t\ \neq ann
\end{aligned}
$$

while the pension income stream is given by:

$$
\begin{aligned}
pp_t^{dc} &= q_{t^{ann}}(1-z)(0.75)DC_{t^{ann}}\ \ \forall\, t\ \geq ann \\
&= 0\ \forall\, t\ < ann
\end{aligned}
$$

where q is an (actuarially-fair) annuity rate and z accounts for that portion of the DC fund taken by the annuity-providers to cover their administrative costs and profits.

Defined Benefit pensions Defined Benefit pensions are available to two of the four household types. They must make some contribution ($cont_t^{db}$) to them each year. This is set at a fixed proportion of pre-tax earnings:

$$
\begin{aligned}
cont_t^{db} &= 0\ \ \forall\, t\ \geq 65 \\
&= \varsigma e_t\ \ \forall\, t\ < 65
\end{aligned} \tag{6}
$$

Once they reach the age of 65, they receive a taxable pension that is calculated as a quadratic, with a zero intercept, in average earnings at the age of 64:

$$
\begin{aligned}
pp_t^{db} &= db_1 ae_{64} + db_2 ae_{64}^2\ \ \forall\, t\ \geq 65 \\
&= 0\ \ \forall\, t\ < 65
\end{aligned} \tag{7}
$$

Those entitled to DB pensions receive a tax-free lump sum (ls_t^{db}) in cash which is a multiple (ϑ) of their pension payment:

$$
\begin{aligned}
ls_t^{db} &= \vartheta pp_t^{db}\ \ for\ t\ = 65 \\
&= 0\ \ \forall\, t\ \neq 65
\end{aligned}
$$

It will not necessarily be the case that the contributions collected over a working life (equation (6)) will be, with investment returns, sufficient to cover the pension payments (equations (7) and (8)). Typically, in DB schemes, the contributions remitted directly by employees will not fully cover the ultimate costs of their pensions - additional remittances will be made by their employers. While the ultimate incidence of the provision of a pension will not necessarily depend on who actually remits payments into the pension fund, I note here that the treatment of earnings and pension contributions in our data is consistent with the treatment here - that is the earnings measure includes remittances made by employees but not employers.

State pensions State pensions (the contributory component of the public pension system) are modelled as a quadratic (with a zero intercept) in average earnings at the age of 64.

$$
sp = sp_1 ae_{64} + sp_2 ae_{64}^2 \tag{8}
$$

Non-pension assets In addition to saving in a DC pension, households can also save in a non-pension asset (a) which is split into cash (a^c) and net housing (a^h):

$$\begin{aligned} a_t^c &= s_t^{liq} a_t \\ a_t^h &= (1 - s_t^{liq}) a_t \end{aligned}$$

The share (s^{liq}) is not a choice - but is a function that depends on several state variables. The function, embedded in a Normal CDF to constrain it be between 0 and 1, contains a quadratic in age, a quadratic in assets and an indicator for being in receipt of a private pension[8]:

$$s_t^{liq} = \Psi(\omega_0 + \omega_1 t + \omega_2 t^2 + \omega_3 a_t + \omega_4 a_t^2 + \omega_5 \mathbb{1}[pp > 0]) \tag{9}$$

Cash balances earn a return (r^c) and can be used to fund consumption in any period. The stock of housing wealth cannot be used to fund consumption - however, housing does yield two types of return. These are a capital return and a consumption flow. Considering first the capital return, I assume that *gross* housing accrues capital gains at an annual rate of growth of $r^{h_{cg}}$. This will not be the rate of return on *net* housing wealth for a mortgage holder; the fact that the housing wealth holdings are leveraged will magnify the gain and mortgage interest payments will reduce it. The variable $a_t^h = (1 - s_t^{liq})a_t$, defined above and which is the function of the state variable a that is kept track of in solving the model, is equal to net housing. If we had knowledge of the leverage ratio (the ratio of mortgage debt to gross housing wealth) we could calculate mortgage outstanding and gross housing wealth from net housing wealth. The approach taken here is to assume that the leverage ratio is a function of age:

$$lev_t = l_0 + l_1 t + l_2 t^2 \tag{10}$$

I can now give the expression for the total capital return on net housing, which depends on the capital gain on gross housing (a^h), the mortgage interest rate (r^m), gross housing wealth (gh) and mortgage outstanding ($mort$). The last two of these are simple functions of net housing wealth and the leverage ratio (the simple derivations of given in Appendix A.1.1) .

$$r^{h_c} a^h = r^{h_{cg}} \underbrace{\frac{1}{(1 - lev_t)} a^h}_{gh} - r^m \underbrace{\frac{lev_t}{(1 - lev_t)} a^h}_{mort} \tag{11}$$

Ownership of housing also yields a consumption flow (c_h) - this is equal to a rental yield (a parameter that will be estimated) multiplied by gross housing wealth.

$$c_h = r^{h_r} \underbrace{\frac{1}{(1 - lev_t)} a^h}_{gh}$$

The total return on net housing is therefore:

$$\left((r^{h_{cg}} + r^{h_r}) \frac{1}{(1 - lev_t)} - r^m \frac{lev_t}{(1 - lev_t)} \right) a^h \tag{12}$$

Equation (13) gives the intertemporal budget constraint for non-pension wealth:

[8] The rationale for including this last variable is that, at the time of receipt of private pensions, the cash lump-sum will increase the share of wealth that is held in a liquid form.

$$a_{t+1} = \left(1+r^c\right)\left(s^{liq}a_t + y_t - c_t^{nh} - cont_t^{dc} - cont_t^{db} + ls_t^{dc} + ls_t^{db}\right) + \\ + \left(1+r_t^{h_c}\right)\left((1-s^{liq})a_t\right) \tag{13}$$

where y is net income, described in the next section.

3.4 Taxes, Transfers and net income

Household net income is the sum of gross earnings plus benefits, less taxes. The tax and benefit function, modelled on the prevailing UK system is outlined in Appendix A.1.2.[9] It depends on taxable income (y^{gr}: the sum of male and female earnings (e, e^f), interest (r), state and private pension income (sp, pp)), contributions into pensions ($cont = cont^{dc} + cont^{db}$, which attract tax relief), asset holdings (DC, a^c, a^h), all of which have (different) implications for benefit entitlements), age (t: which determines some benefits - for example Pension Credit as well and the state pension), household composition (h) and average earnings (ae - which determines state pension entitlements).

$$y = y^{gr} - \tau(e_t, e_t^f, r, sp, pp, cont, DC, a^c, a^h, t, h, ae) \tag{14}$$

Bequests are also taxed - the bequest taxation function which returns net bequests (a^b) is also shown in Appendix A.1.2.

3.5 State variables and household's maximisation problem

State variables

The set of state variables differs before and after annuitisation. After annuitiastion, the state variables that summarise the household's problem are the households type, (j), age (t), non-pension assets (a), whether a household has not recieved an employment offer has been made in the current period (ue), productivity $(\tilde{e})$, income from a DC pension (pp^{dc}), household composition (h) and average earnings (ae)[10]. These state variables are summarised in the vector: $\mathbf{X}_t^1 = \{j, t, a_t, ue_t, \tilde{e}_t, pp_t^{dc}, h_t, ae_t\}$, where the superscript 1 indicates that any DC pension wealth has already been annuitised). Before annuitisation, the state variables are type (j), age (t), assets (a), unemployment (ue), productivity $(\tilde{e})$, Defined Contribution pension wealth (DC), household composition (h) and average earnings (ae). These state variables are summarised in the vector: $\mathbf{X}_t^0 = \{j, t, a_t, ue_t, \tilde{e}_t, DC_t, h_t, ae_t\}$, where the superscript 0 references that any DC pension wealth has not been annuitised).

The full set of state variables is: $\mathbf{X}_t = \{j, t, a_t, ue_t, \tilde{e}_t, DC_t, pp_t^{dc}, h_t, ae_t, ann\}$ where ann indicates whether DC wealth has been annuitised.

Household maximisation problem and value functions

Household's problem post-annuitisation Equation (15) gives the maximisation problem faced by a household with both spouses still alive which has already annuitised its DC wealth and their associated value function. Recall that there is uncertainty over whether an employment offer is received (ue), over productivity (e), over the investment return (ϕ) earned on the DC fund and over household composition

[9] The components of the tax and benefit system that are modelled are: Income Tax, National Insurance, Working Tax Credit, the Basic State Pension, Additional State Pensions and Pension Credit

[10] Up to and including the age of 64, the state variable ae represents average earnings up to the previous year. From the age of 65 onwards, it represents average earnings up to and including those earned at age 64).

(through mortality - h). Below, I denote the joint distribution of the first three of these as $F(\phi, ue, e)$. The stochastic processes underlying each of these are mutually independent, though the distributions of ue and e in period $t+1$ depend on their values in period t. $F(\phi_{t+1}, ue_{t+1}, e_{t+1}|ue_t, e_t)$ is the distribution conditional on these past values. s^m_{t+1} and s^f_{t+1} give, respectively, the probability that a man and a woman will survive to to period $t+1$ conditional on them having survived to period t.

After annuitisation, households choose their non-housing consumption (c^{nh}) and leisure (l), or, equivalently, whether the male works). Non housing consumption cannot be greater than the sum of income and cash assets (that is the capital value of housing cannot be consumed).

$$
\begin{aligned}
V_t(\mathbf{X}^1_t|h_t=1) = \max_{c^{nh}_t, l_t} \Big(u(c_t, l_t) \quad &+ \quad \beta s^m_{t+1} s^f_{t+1} \int V_{t+1}(\mathbf{X}^1_{t+1}|1) dF(\phi_t, ue_{t+1}, e_{t+1}|unemp_t, e_t) \\
&+ \quad \beta s^m_{t+1}(1-s^f_{t+1}) \int V_{t+1}(\mathbf{X}^1_{t+1}|2) dF(\phi_t, ue_{t+1}, e_{t+1}|ue_t, e_t) \\
&+ \quad \beta(1-s^m_{t+1})(s^f_{t+1}) \int V_{t+1}(\mathbf{X}^1_{t+1}|3) dF(\phi_t, ue_{t+1}, e_{t+1}|ue_t, e_t) \\
&+ \quad \beta(1-s^m_{t+1})(1-s^f_{t+1}) b(a^b_t)\Big) \\
s.t. \quad c_t = & \quad c^{nh}_t + c^h_t \\
c^{nh}_t \leq & \quad s^{liq} a_t + y_t \\
\text{and} & \quad \text{the intertemporal budget constraint in equation (13)}
\end{aligned} \tag{15}
$$

Household's problem pre-annuitisation The maximisation problem and associated value function faced by a household (again with both spouses still alive) which has not annuitised its DC wealth is given in (17). The problem differs from that of the post-annuitisation problem as there are now two additional decision variables - how much to contribute to the DC pension ($cont^{dc}$) and whether to annuitise (ann). Additionally there are now two intertemporal budget constraints (equations (5) and (13) - that relating to the DC fund and that relating to the non-pension wealth respectively).

$$
\begin{aligned}
V_t(\mathbf{X}^0_t|h_t=1) = \max_{c^{nh}_t, cont^{dc}_t, l_t, ann_t} \Big(\quad u(c_t, l_t) \quad &+\beta s^m_{t+1} s^f_{t+1} \int V_{t+1}(\mathbf{X}^0_{t+1}|1) dF(\phi_t, ue_{t+1}, e_{t+1}|ue_t, e_t) \\
&+\beta s^m_{t+1}(1-s^f_{t+1}) \int V_{t+1}(\mathbf{X}^0_{t+1}|2) dF(\phi_{t+1}, ue_{t+1}, e_{t+1}|ue_t, e_t) \\
&+\beta(1-s^m_{t+1})(s^f_{t+1}) \int V_{t+1}(\mathbf{X}^0_t|3) dF(\phi_{t+1}, ue_{t+1}, e_{t+1}|ue_t, e_t) \\
&+\beta(1-s^m_{t+1})(1-s^f_{t+1}) b(a^b_t)\Big) \\
s.t. \quad c^{nh}_t \leq & \quad s^{liq} a_t + y_t \\
\text{and} & \quad \text{the intertemporal budget constraints in equations (5) and (13)}
\end{aligned} \tag{16}
$$

4 Estimation and results

4.1 Estimation

Estimation of the model parameters follows a two-step procedure.[11] In the first step, some parameters are estimated outside the model, or are set with reference to the literature. In the second step, preference parameters and the earnings processes are estimated using the method of simulated moments. Sections 4.1.2 and 4.1.3 describe, respectively, these two steps. Before that, Section 4.1.1 briefly introduces the main data source, defines the sample used and describes how household 'types' are characterised.

4.1.1 Data, sample and definition of types

The main data used in this paper come from linked survey and administrative data. The survey data is the English Longitudinal Study of Ageing (ELSA) - a biennial longitudinal survey that contains a representative sample of the English private household population aged 50 and over. ELSA is one a number of 'ageing surveys' - modelled on the the Health and Retirement Study (HRS) in the US. ELSA contains detailed data on demographics, labour market circumstances, earnings and the level and composition of wealth holdings.

ELSA respondents were asked for their National Insurance number (equivalent to Social Security number in the US) and permission to link to their history of National Insurance contributions. Data on these contributions allows a panel of earnings in each year of working life for ELSA respondents to be built. I don't discuss here how these data on contributions are converted into a panel of earnings - detail is given in Appendix A.2.1. Almost 80% of ELSA respondents agreed to the linking of their survey records with their administrative data.[12] These earnings data are used, in a manner described below, to estimate earnings processes, while the survey data yields moments of assets and employment which are used to estimate preference parameters.

I focus on a sample of couples where the male member of the couple was born between 1935 and 1950. Single individuals, whether never married, widowed and divorced are not in this sample. There are 2,364 households headed by couples in the specified age range. Only those couples where we have linked National Insurance data are included in the sample and where National Insurance contributions were made in at least 5 years. I impose a number of additional sample restrictions. I exclude households where the education of male household member is not recorded, where either member of the couple didn't fully complete the survey, or where the sum of years of self-employment carried out by either member of the couple is greater than or equal to 5[13]. After applying these exclusions, I am left with 1,121 couples (47.4%) of the original sample. Table 2 shows the proportion of couples who satisfy each of the conditions for exclusion (though note that the proportion excluded is less than the sum of these as some couples have more than one of these conditions).

The model involves agents that differ (ex-ante) by education and whether they have access to a DB pension. In implementing this, I define low and high education as the male member of the couple having only compulsory schooling and having more than compulsory schooling respectively. For the cohort in question, it was compulsory to remain in school until the age of 15. In assigning sample households to the

[11]This two-step procedure is widely applied in papers that develop and estimate structural lifecycle models. See, among others, Gourinchas and Parker (2002) Cagetti (2003), French (2005), De Nardi et al. (2010), Blundell et al. (2013) and Lee et al. (2015).

[12]Linked administrative and survey data of this kind has been used before in the US (by for, example, Gustman and Steinmeier (2005), Scholz et al. (2006) and Bound et al. (2010)) but has only recently been been made available in the UK (see Bozio et al. (2011) for more detail on this data source).

[13]The National Insurance contributions owed on self-employment income in the UK are a flat cash figure - and so does not depend on the level of income. I therefore have data on whether an sample member earned self-employment income in a particular year but have no information on its level. It is due to this missing data that I make this sample restriction.

Table 2: Reasons for exclusion from the sample

	Number	Proportion
Partner no linked earnings data	605	28.6%
No linked earnings data	579	24.4%
>5 years self-employment	346	14.7%
<=5 years work	73	3.1%
No Education data	64	2.7%
Partner didn't complete ELSA survey	4	0.01%

Table 3: Proportion of each types in sample

	No DB Pension	DB Pension
Low Education	16%	32%
High Education	11%	41%

DB and No DB categories I make use of a variable in the administrative data set that records whether, in each year, individuals accrued rights to a DB pension. I define a household as being a DB pension type household if the male spent at least one-third of working years contributing to a DB scheme. Table 3 gives the proportion of the sample in each of the four types.[14]

4.1.2 Parameters estimated/set outside the model

This subsection gives details of the parameters set or estimated outside the model.

Deterministic component of earnings process To estimate the deterministic component of full-time earnings (the parameters of equation (3)) I first estimate the parameters of a fixed effects regression of male earnings on a quadratic in age and an indicator variable (pt) for working less than 20 hours per week.[15]

$$ln\ \tilde{e}_{it} = \hat{\delta}_0 + \hat{\delta}_1 t + \hat{\delta}_2 t^2 + \hat{\delta}_3 pt + r_{it} \tag{17}$$

The parameters $\{\hat{\delta}_0, \hat{\delta}_1, \hat{\delta}_2\}$ are not those of the true productivity process as simply running a regression on those with positive earnings ignores the effect of (non-random) selection in employment. These biased parameters will be used to estimate the true parameters during the implementation of the method of simulated moments using a procedure introduced by French (2005). Briefly (and further details can be found in Section 3.3 of that paper), the approach involves (i) performing the fixed-effects regression of observed wages on a quadratic in age (this returns the parameters in equation (17) - the earnings profile that is biased due to selection). (ii) Then the model is solved and behaviour simulated using this (biased) profile. (iii) With the simulated data (in the case of which, both accepted and rejected wage offers are observed), the bias due to selection can be calculated at age. (iv) With this estimated bias the earnings

[14]These should not be interpreted as population shares. My sample is not fully representative of the original population-representative population. Those with less education were less likely to give permission to link to the administrative records and so are under-represented. It is not possible to assess representativeness on access to the DB pension as information on the latter is not available for those who did not give permission to link to the administrative data. More detail on differences between my sample and the full ELSA sample are given in Appendix A.2.3.

[15]There is no option to work part-time in the model. Including this dummy controls for earnings observations where an individual is observed working part-time. More details on the construction of this variable is given in Appendix A.2.1.

process estimated in (i) can be 'corrected'. (v) This new earnings process can then be fed back into the model which is solved and behaviour is simulated once again. Steps (iii) to (v) are then repeated until convergence.[16] Though I describe this procedure here (in the section that is focussed on parameters set outside the model), this procedure is carried at each iteration during the implementation of the method of simulated moments.

Stochastic component earnings process I estimate the parameters of the stochastic component of earnings (the coefficient of autocorrelation and the variances in set of equations (4)) using the variance covariance matrix of $\hat{r}_{it}$ (the residuals from equation (17)) and minimum distance methods (see Guvenen (2009)). $\hat{r}_{it}$ will differ from the true stochastic component of earnings of individual i in period t, however, for three reasons. First, r_{it} is the difference between earnings and the biased, due to selection, estimate of the deterministic component of earnings rather than the true deterministic component. To deal with the this, I only use r_{it} for ages up to and including age 50. Given the very high rates of labour supply among prime age males, the effect on estimated earnings processes of neglecting it is least at these ages. Second, $\hat{r}_{it}$ contains the fixed effect for individual i, whereas there is no fixed effect in the model's earnings process.[17] This tension between the model and the treatment of the data is mitigated somewhat by the different variances in the first and subsequent periods for the innovation to u. This (highly persistent) initial shock will capture some of the variation in the (permanent) fixed effect. Third, earnings will be measured with error, and r_{it} will contain that error. I account for this by augmenting the process in (4) with an *iid* measurement error term m_{it}. The assumed data-generating process for my earnings data is (where the earnings is super-scripted with *data* to differentiate it from the true underlying earnings):

$$\begin{aligned} ln\ \tilde{e}_{it}^{data} &= \delta_0 + \delta_1 t + \delta_2 t^2 + u_{it} + m_{it} = ln\ \tilde{e}_{it} + m_{it} && (18) \\ u_{it} &= \rho u_{it-1} + \xi_{it}\ \ \forall\ t\ \text{ with }\ ue_{t-1} = 0 \\ \xi_t &\sim N\left(0, \sigma_\xi^2\right)\ \ \forall\ \ t > 1 \\ \xi_1 &\sim N\left(0, \sigma_\zeta^2\right) \\ u_0 &= 0 \\ m_t &\sim N\left(0, \sigma_m^2\right) && (19) \end{aligned}$$

The parameters of the wage process $(\rho, \sigma_\xi^2, \sigma_\zeta^2, \sigma_m^2)$ are obtained by choosing those values that minimise the distance between the empirical covariance matrix and that implied by (18). More details are given in Appendix A.3. Table 4 gives the estimates of these parameters for each type.

[16] As French (2005) points out, if the value function was concave, it would be possible to prove that this iterative procedure is a contraction and so a unique fixed point would exist. The value function here (as in French's paper) is not a contraction - however, using a number of simulations, it appears that I have found unique fixed points for each type.

[17] Introducing a fixed effect in the model would introduce another state variable at prohibitive computational cost, while neglecting to take account of a fixed effect in the data would forgo the opportunity afforded by panel data to identify the age trend in earnings from within-individual changes.

Table 4: Earnings Process Estimates

	Low Ed		High Ed	
	No DB	DB	No DB	DB
ρ	0.960	0.999	0.977	1.000
σ^2_ξ	0.007	0.004	0.018	0.008
σ^2_ζ	0.089	0.055	0.130	0.111
σ^2_m	0.053	0.027	0.573	0.023

Unemployment probabilities and re-employment productivity distribution I define an individual in the data as unemployed if they had less earnings in a year than Jobseekers Allowance (the main benefit to the unemployed in the UK in 2012/13 (£3,692)). I then calculate the probabilities in the Markov transition matrix. These are given in Table 5. Unemployment is a persistent state - the probability of remaining in unemployment once in that state (π_0) is greater than 65% for all types, and particularly so for the types without a DB pension. The probability of entering unemployment ($\pi_1(\tilde{e})$) is highest for individuals at the lowest productivity deciles, though the possibility does exist even at the top of the productivity distribution. Table 5 also shows the average probability of entering unemployment from a state of not being unemployed ($\overline{\pi_1(\tilde{e})}$), and the average rate of unemployment for each type ($\overline{ue}$).

Table 5: Unemployment probabilities

	Type			
	Low Ed		High Ed	
	No DB	DB	No DB	DB
	π_0			
	0.769	0.688	0.763	0.665
Productivity Decile	$\pi_1(\tilde{e})$			
1	0.213	0.100	0.184	0.067
2	0.047	0.026	0.024	0.015
3	0.032	0.010	0.061	0.010
4	0.011	0.012	0.029	0.006
5	0.004	0.010	0.031	0.004
6	0.007	0.010	0.034	0.003
7	0.014	0.005	0.020	0.005
8	0.018	0.002	0.005	0.001
9	0.007	0.003	0.009	0.004
10	0.011	0.000	0.005	0.000
	$\overline{\pi_1(\tilde{e})}$			
	0.036	0.018	0.040	0.011
	$\overline{ue}$			
	0.123	0.048	0.141	0.030

Table 6 shows the probability distribution over productivity deciles on exiting a state of unemployment. Most of those receiving new job offers get earnings offers towards the bottom of the distribution.

Table 6: Re-employment productivity distribution

	Type			
	Low Ed		High Ed	
	No DB	DB	No DB	DB
Productivity Decile				
1	0.593	0.557	0.487	0.699
2	0.174	0.182	0.141	0.108
3	0.093	0.045	0.180	0.060
4	0.023	0.057	0.064	0.024
5	0.012	0.045	0.051	0.024
6	0.012	0.045	0.038	0.024
7	0.058	0.045	0.013	0.036
8	0.000	0.011	0.013	0.012
9	0.000	0.011	0.013	0.000
10	0.035	0.000	0.000	0.012

Defined Contribution pension I base the mean and standard deviation of pension fund returns on an index known as the "DCisions index"[18]. This is an index of total fund return that reflects the asset allocation decisions made by leading DC pension plans in their default investment strategies. This index provides information on returns stretching back to 1994. For years prior to 1994 when the DCisions index is not available, I estimate ϕ_t using the FTSE all-share index (on which data is available back to the early 1960s) and the ratio between the FTSE all-share index and the DCisions index over the period where both are available (1994 - 2010). The estimation of this is discussed further in Crawford and O'Dea (2014). I use the mean and standard deviation of this time series. These parameters are, respectively, $\bar{\phi} = 3.97\%$ and $\sigma_\phi = 13.8\%$.

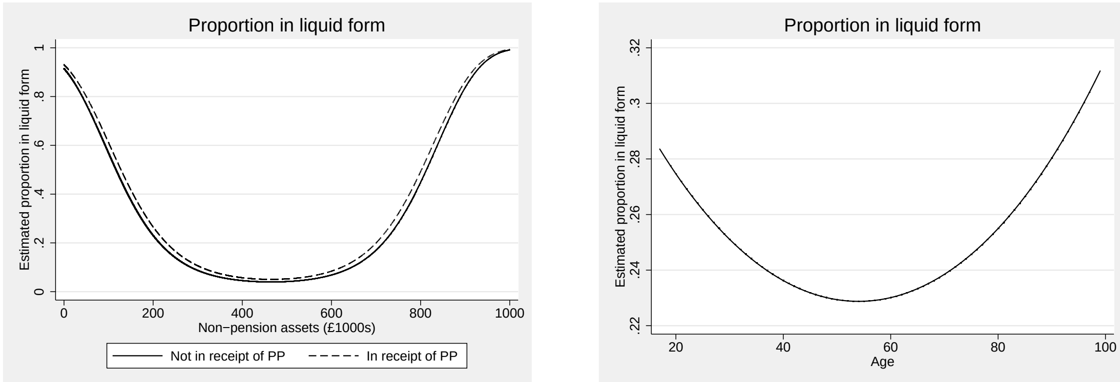
I set z, the administrative load on the annuity purchase at 10%. This estimate is taken from Murthi et al. (2000) who apply the methodology of Mitchell et al. (1999) to the UK.

Non-pension wealth parameters The return on cash r^c - is set at 1.6% - this is the average real return on cash balances was between 1952 and 2012 (see Table 1 of Barclays Capital (2012)). The capital return on housing ($r^{h_{cg}}$) is set at 2.8%. This is an average real appreciation of house prices from 1975 to 2013 calculated using data from Nationwide Building Society (2014). The mortgage interest rate (r^m) is set at 3.5%. This is an average real rate from 1975 to 2013 calculated using historical interest rate data from Bank of England (2013).

The parameters of equation (9), which determine the share of non-pension wealth held in liquid form (s^{liq}) are estimated using data from the Wealth and Assets Survey (further details are given in Appendix A.2). Figure 4(a) shows the predicted share of wealth held in liquid forms by non-pension wealth (holding age fixed at 50) for those both in receipt and not in receipt of a private pension. This shows that the share of wealth held in liquid form by age has a U-shape - those with the least and the most wealth tend to hold the most liquid portfolios while those with middle levels of wealth tend to hold large shares of their wealth in housing. Figure 4(b) shows the predicted share of wealth by age, holding wealth fixed at £200,000. The pattern by age is also U-shaped, though comparison of the scales of the two figures shows that the differences by age are of a more modest magnitude than the differences by wealth holdings.

The parameters of equation (10), which determine the leverage ratio (and therefore the return on housing) at a given age are estimated using data from the British Household Panel Survey (further details

[18]http://www.ftse.com/Indices/FTSE_DCisions_Index_Series/



(a) Share, by non-pension wealth

(b) Share, by age

Figure 4: Liquidity share of wealth held in liquid wealth (equation (9)

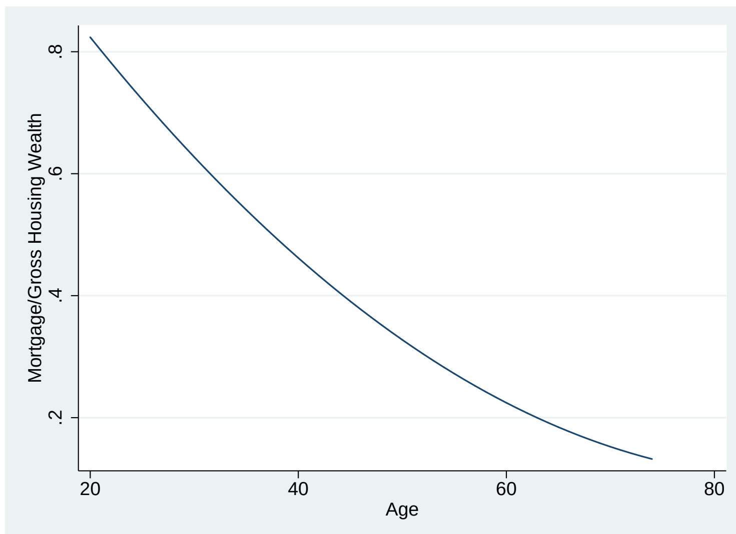
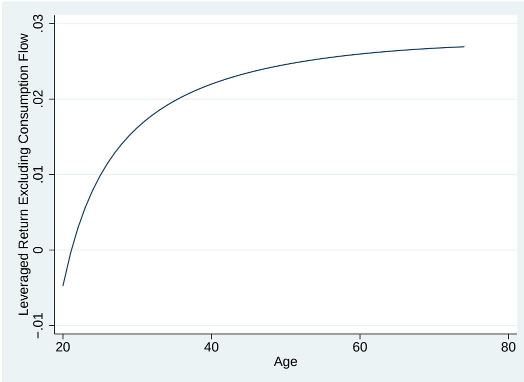


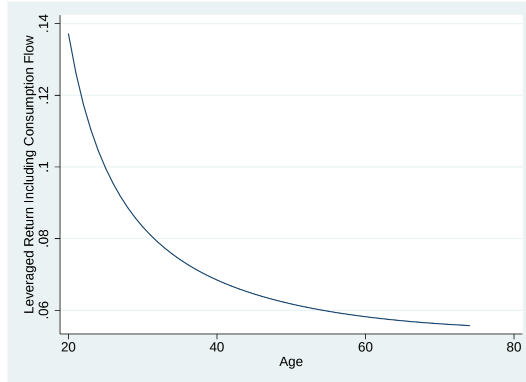
Figure 5: Leverage ratio (equation (10))

are given in Appendix A.2). Figure 5 shows that the leverage ratio (mortgage outstanding divided by gross housing wealth) declines with age. Figure 6 shows the implications of this age gradient for the return on housing. Figure 6(a) shows the capital return on housing, by age, excluding the consumption flow (equation (11)) while Figure 6(b) shows the total return on housing (equation (12)), including an example consumption flow worth 2% of the value of gross housing (the value of this parameter is estimated later as part of the method of simulated moments procedure).

Contributory public pensions The parameters that relate average earnings at the age of 64 to state pension income (sp_1, sp_2) are calculated using a regression (with no constant) of entitlements on average earnings for a sample of those aged 60 to 64. These entitlements are calculated using the rules of the state pension system and the history of contributions (see Bozio et al. (2010b) for more details). Figure 7 illustrates this relationship. This figure differs from Figure 1 which introduced the UK contributory public pension system in that it maps male average earnings into *household* pension entitlements rather than *individual* pension entitlements and the estimation is parametric rather than non-parametric.



(a) Leveraged return, excluding consumption flow (equation (11))



(b) Leveraged return, including 2% consumption flow (equation (12))

Figure 6: Leveraged return on housing wealth

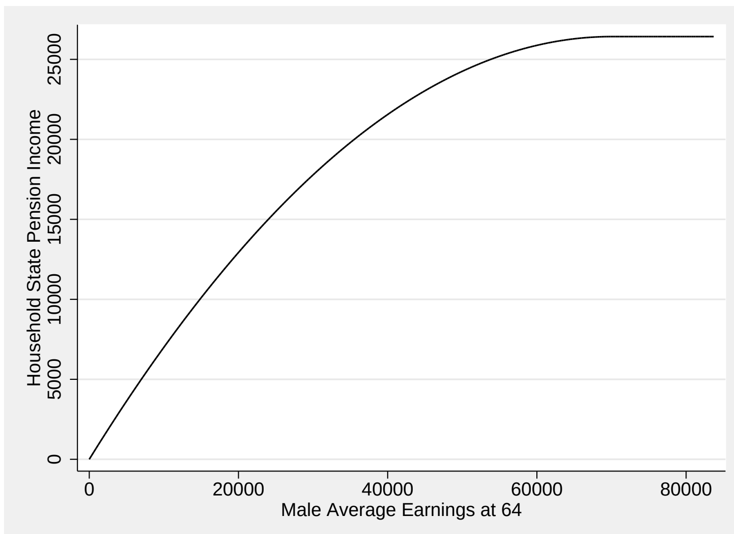


Figure 7: Modelled State Pension Entitlements

Defined Benefit pensions The parameters that relate average earnings at the age of 64 to Defined Benefit pension income (db_1^j, db_2^j) are, as with the state pension income process, calculated using a regression of projected DB income on average earnings for a sample of those aged 60 to 64. Projected DB pension income is estimated using survey responses (see Banks et al. (2005) for more details on the data on projected DB pension income). Figure 8 shows the estimated relationship between males earnings at the age of 64 and DB pension for both education types.

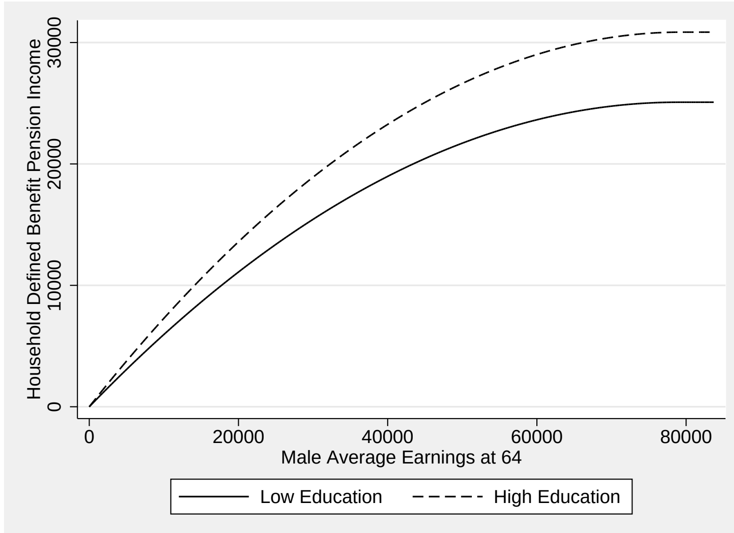


Figure 8: Modelled Defined Benefit Pension Entitlements

I set ϑ, the multiple of DB pension income that is received as a lump sum at the age of 65 to 3. This is the median value reported by DB members in ELSA.

Preference parameters γ, the coefficient of relative risk aversion on utility[19] and K, the parameter that determines the curvature of the bequest function are preference parameters that are set with reference to the literature.

The modal choices of γ in related papers is 2 in analyses where the utility function is non-separable in consumption and leisure (see Conesa and Krueger (1999), Nishiyama and Smetters (2007), Conesa et al. (2009), Golosov et al. (2013), Kitao (2014), Braun et al. (2015)), and is 4 when the utility function is non-separable in consumption and leisure, as it is in this paper (Auerbach and Kotlikoff (1987), Kotlikoff et al. (1999), Conesa et al. (2009)[20], Nishiyama (2011)). In spite of this, the value for γ that I use is, at 3, lower. I use this lower value for two reasons. First, where there are exceptions to these modal choices in the related literature, they typically involve a smaller value for γ[21]. Second, a lower choice of γ, which implies less risk aversion, is a conservative choice given the results of this paper - which support greater provision of means-tested benefits (and so protection from the risk of low consumption in retirement).

The other preference parameter that I set is K - the parameter that determines the curvature of the bequest function - which I set at £500,000.[22]

Summary Table 7 summarises the parameters that are set outside the model.

[19]The coefficient of relative risk aversion on consumption is

$$-\frac{\partial^2 U}{\partial C^2}\frac{C}{\frac{\partial U}{\partial C}} = -(\nu(1-\gamma)-1)$$

[20]This paper appears in both lists - the authors do analysis with both separable and non-separable utility functions with CsRRA of 2 and 4 respectively.

[21]Exceptions with non-separable utility functions are Huggett and Ventura (1999), İmrohoroğlu and Kitao (2009), where γ is set to 2 and French (2005) where γ in three of four specifications is estimated as less than 4. Exceptions where utility functions are separable include Golosov and Tsyvinski (2006), İmrohoroğlu and Kitao (2009) and Huggett and Parra (2010), where γ is 1, 1 and 1.66 respectively.

[22]French (2005) sets this at \$500,000 in 1987 prices which is approximately £650,000 in 2012 prices and average exchange rate.

Table 7: Parameterisation

Parameter	Symbol	Value	Source
Unemp., re-emp. probabilities	$\pi_0, \pi_1(\tilde{e}), E()$		Estimated using NI data
Annuity administrative load	z	10%	Murthi et al. (2000), Mitchell et al. (1999)
Survival probabilities	s_t^m, s_t^f		ONS Life Tables
Cash return	r^c	1.6%	Barclays Capital (2012)
Housing capital gain	$r^{h_{cg}}$	2.8%	Nationwide Building Society (2014)
Mortgage rate	r^m	3.5%	Bank of England (2013)
DC mean return	$\bar{\phi}$	3.97%	DCisions Index/Crawford and O'Dea (2014)
DC return variance	$\bar{\sigma}_\phi^2$	13.8%	DCisions Index/Crawford and O'Dea (2014)
State pension process	sp_1, sp_2		Estimated using NI data
DB pension process	$db_1^j, db_2^j, \vartheta$		Estimated using ELSA, NI data
DB lump sump multiplier	ϑ	3	Estimated using ELSA
Coeff. relative risk aversion	γ	3	See text
Curvature of bequest function	K	500,000	French (2005)

4.1.3 Method of simulated moments estimation

I estimate four preference parameters, each of which differ by type, by using the method of simulated moments and data on employment, wealth and portfolio composition. These parameters are the discount factor (β_j), the weight on consumption in the utility function (υ_j), the consumption flow value of housing ($r_j^{h_r}$) and the weight on bequests (θ_j). The vector of these parameters is denoted by $\chi_j = \{\beta_j, \upsilon_j, r_j^{h_r}, \theta_j\}$. The moments that I use are the proportion of men in work at each age between 52 and 75, mean non-pension holdings between the ages of 52 and 90[23] and (for those types without DB wealth), DB pension wealth between the ages of 52 and 75.[24] Wealth moments are top-coded in both data and simulations at the 95th percentile to mitigate the impact of the very wealthy, some of whose wealth will have been accumulated via means not modelled (e.g. inheritances). The parameters are estimated using standard GMM techniques.

It is not possible it models such as this to provide a constructive case for the identification of parameters (as the entirety of the structure will contribute to the identification of all parameters). However, it is worth noting which aspects of variation in the data will bear most heavily on which estimated parameter. Total wealth (the sum of pension and non-pension wealth) over the (matched part) of the lifecycle will contribute to the identification of β - the greater are holdings of wealth, the more patient are households and the higher will be the estimate of β. The trajectory of wealth (and in particular, the extent to which it is retained late into life) will contribute to the identification of the strength of the bequest motive (θ) - the greater the extent to which wealth is retained rather than consumed, the more households value the leaving of bequests and the higher will be the estimate of θ. The split in wealth between non-pension and pension wealth will contribute to the identification of the consumption flow value of housing ($r_j^{h_r}$). The higher is non-pension wealth relative to pension wealth, the more value that households are placing on the housing consumption flow, and the higher will be the estimate of r^{h_r}.

[23]Calculating these moments involves using data from individuals born before the cohort born between 1935 and 1950 - the cohort who form the basis for all other estimates. Data from older cohorts is used here as moments from the phase of life where wealth is being (or not being) decmulated is important to identify the strength of the bequest motive.

[24]The reason that I do not use moments on work after the age of 75 is that the numbers are very low and don't change much - and so the additional moments do not provide additional information. Similarly, after the age of 75, pension wealth is being decumulated in a mechanical manner (as the annuity stream becomes less valuable as few years of receipt are left in expectation), and so additional moments are not included.

4.2 Estimates and model fit

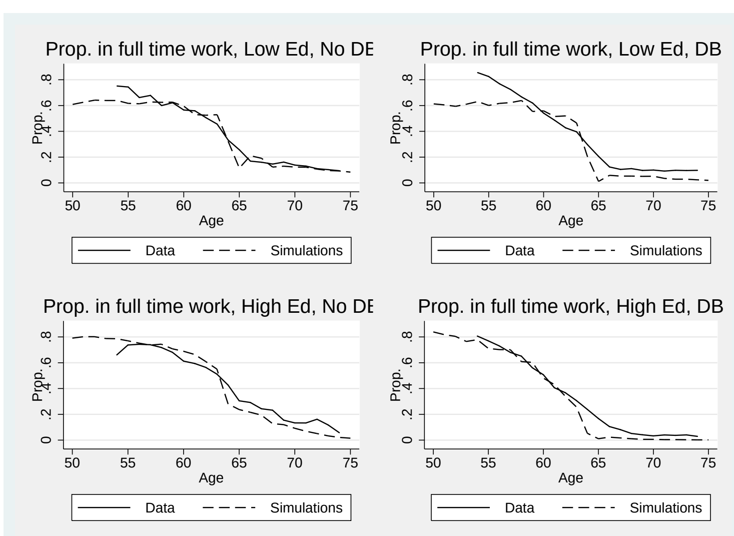
Table 8 gives the estimates of the preference parameters. Those with more education are found to be more patient (a frequently-found result - see Dohmen et al. (2010) and Alan and Browning (2010)). In both education groups, the estimates imply that those who select into DB pensions at the start of life are less patient than those who don't, although the former group's desire to accumulate and hold wealth is increased by the fact that they are estimated to value housing wealth more. The parameter on the strength of bequests (θ) can be given an intuitive interpretation by calculating its implication for the average propensity to consume in the last period of life (when death by next period is certain). The estimated parameter implies an APC out of final period wealth of, for example, £200,000, respectively, for the four types of 0.03, 0.07, 0.11 and 0.10 respectively.

Table 8: Preference Parameter estimates

Type	Low education		High education	
	No DB	DB	No DB	DB
β	0.981	0.967	1.012	0.990
	(0.002)	(0.002)	(0.003)	(0.002)
υ	0.385	0.421	0.499	0.454
	(0.004)	(0.002)	(0.013)	(0.004)
r^{h_r}	0.016	0.0401	0.0177	0.0345
	(0.001)	(0.002)	(0.013)	(0.002)
θ	0.021	0.008	0.017	0.008
	(0.002)	(0.001)	(0.013)	(0.002)

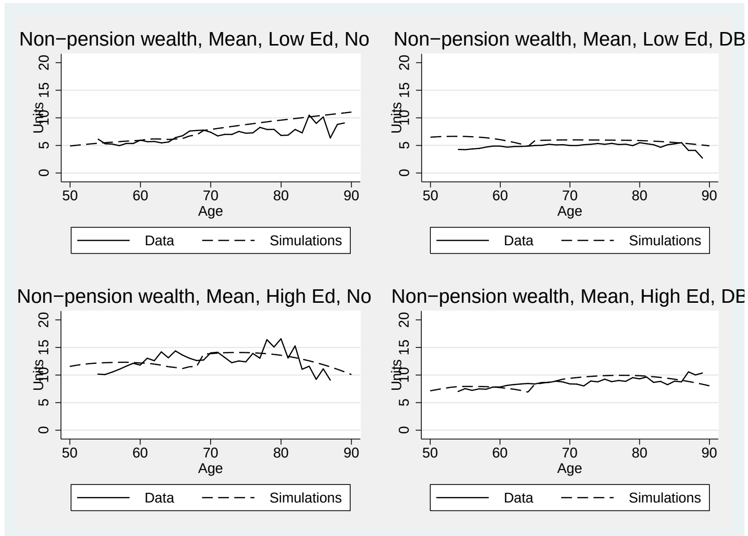
Figures 9, 10 and 11 show, respectively, a comparison of the profiles of labour supply, non-pension wealth and Defined Contribution wealth in both the data and the simulations. The wealth quantities in Figures 10 and 11 are expressed as ratios to (type-specific) average productivity between the ages of 20 and 60 (the average income over all households if they always accepted employment offers).

Figure 9: Fit: Labour supply



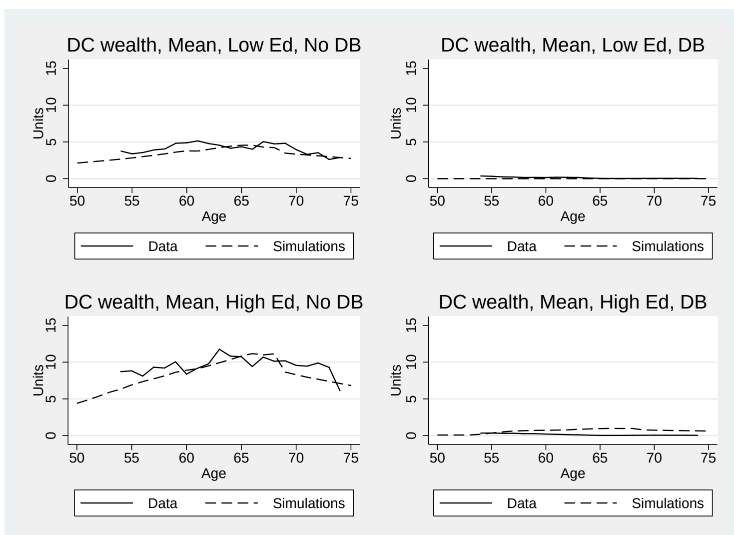
Cash figures are expressed as a ratio to average (type-specific) earnings between the ages of 20 and 60.

Figure 10: Fit: Non-pension wealth



Cash figures are expressed as a ratio to average (type-specific) earnings between the ages of 20 and 60.

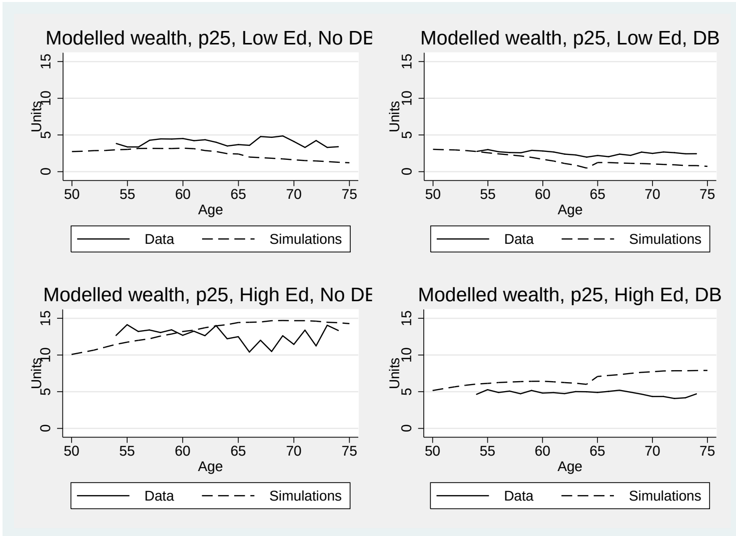
Figure 11: Fit: DC pension wealth



Cash figures are expressed as a ratio to average (type-specific) earnings between the ages of 20 and 60.

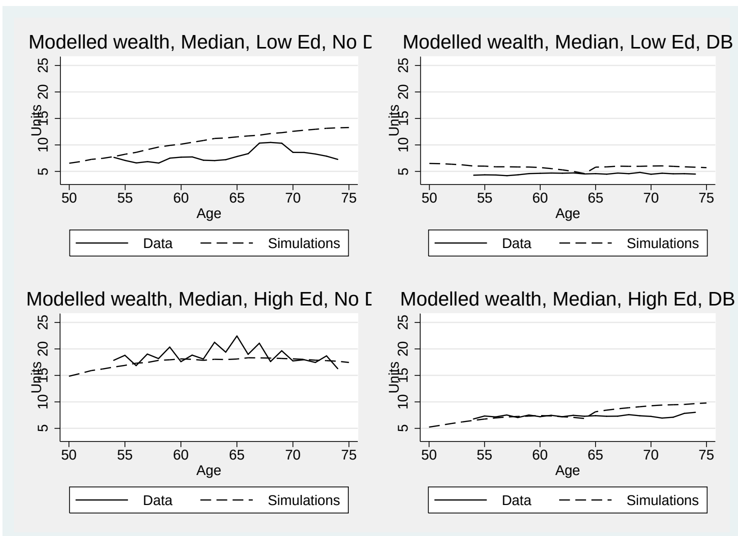
The data profiles in Figures 9 to 11 are the moments that have been used to estimate the preference parameters, and therefore the close match between data and simulations is somewhat to be expected. Figures 12 to 14 show the 25th, 50th and 75th percentiles of modelled wealth (the sum of Defined Contribution pension wealth and non-pension wealth). These moments are not used to estimate preference parameters. That the match is close indicates that the model is doing a good job of capturing the heterogeneity in wealth accumulation that exists in the population.

Figure 12: Modelled (DC and non-pension) wealth, p25



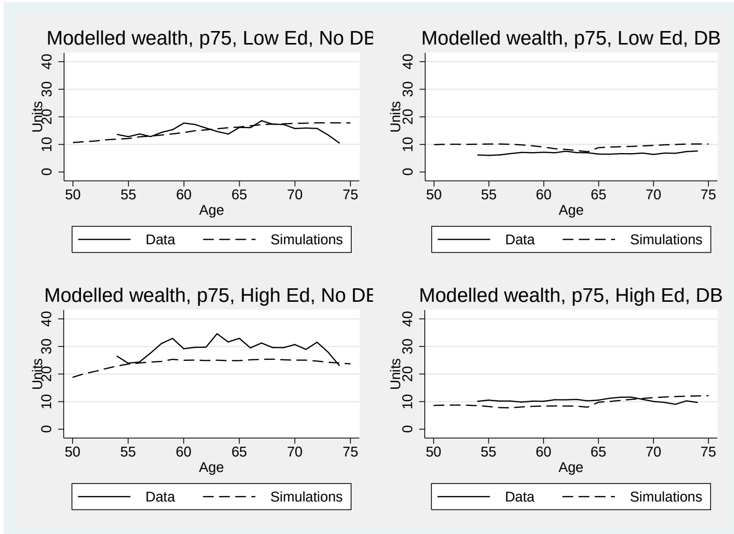
Cash figures are expressed as a ratio to average (type-specific) earnings between the ages of 20 and 60.

Figure 13: Modelled (DC and non-pension) wealth, p50



Cash figures are expressed as a ratio to average (type-specific) earnings between the ages of 20 and 60.

Figure 14: Modelled (DC and non-pension) wealth, p75



Cash figures are expressed as a ratio to average (type-specific) earnings between the ages of 20 and 60.

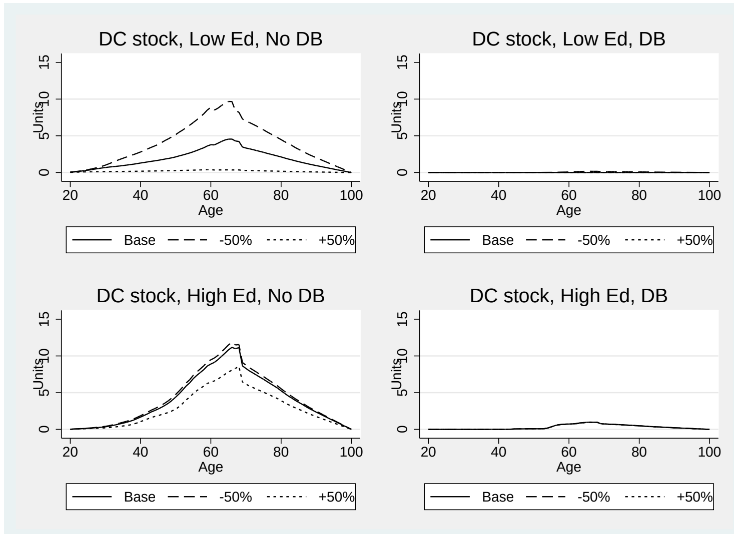
5 Counterfactual analysis

In this final section I use the model and estimated preference parameters to investigate the optimal split between means-tested and contributory pensions in the public pension system. Before formally outlining the design problem (in Section 5.2), I look (in Section 5.1) at the extent to which the provision of means-tested Pension Credit (PC) distorts labour supply and saving choices.

5.1 How distortive are means-tested retirement benefits?

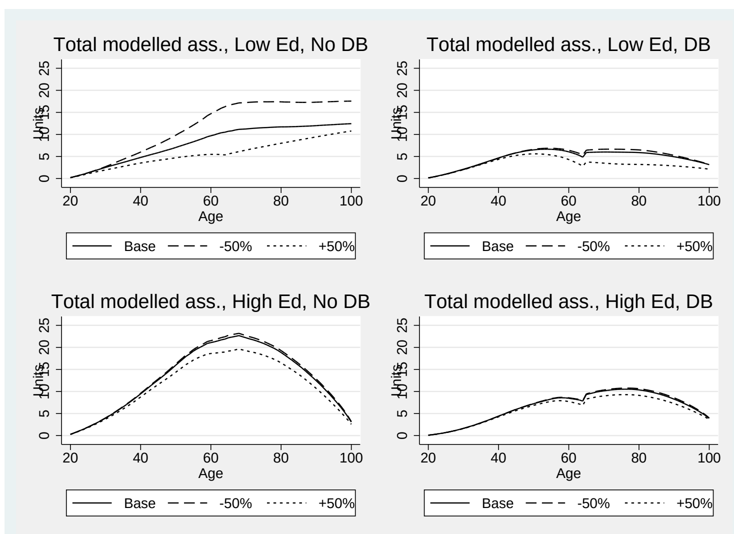
Figure 15 shows mean DC wealth under the baseline simulation and under counterfactual scenarios where the Guarantee Credit minimum income is reduced by 50% and increased by 50%. The effect on DC wealth is substantial for the low educated without DB pensions. Reducing GC by 50% would mean that many of these households would receive less from the state in retirement and so choose to save more privately. Additionally, the reduction in the value of the safety net provided by PC will induce these households to do additional precautionary saving. When GC is reduced, DC wealth, at its peak, doubles from just under 5 units of average productivity to 10 units. Figure 16 which shows the effect on all modelled wealth (the sum of DC and non-pension wealth) shows that most of this is additional saving rather than substitution from non-pension to pension wealth. An increase in the level of GC by 50% would reduce almost to 0 the DC saving of the low educated with no DB pension and reduce DC wealth at its peak for highly educated households by approximately 25%. Those with DB pensions, do not hold much DC wealth under the baseline and this fact is unaffected by either reform. However an increase in GC would cause both groups to reduce their holdings of non-pension wealth.

Figure 15: DC wealth with and without Pension Credit



Cash figures are expressed as a ratio to average (type-specific) earnings between the ages of 20 and 60.

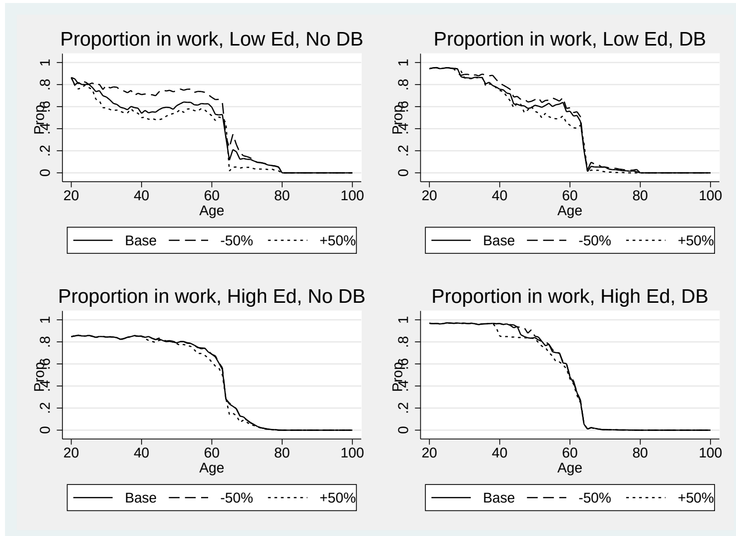
Figure 16: Modelled wealth (DC plus non-pension wealth) with and without Pension Credit



Cash figures are expressed as a ratio to average (type-specific) earnings between the ages of 20 and 60.

Turning to the effect that PC has on labour supply, Figure 17 shows the proportion of men of each type in work under the baseline simulation and the two counterfactuals. The effect of PC on the labour supply of low educated men with no DB pensions is substantial. The proportion of men in this group who are in work increases by more than 10 and up to 20 percentage points at each age between 30 and 60 when GC is reduced, with smaller increases seen by other groups. Increases in GC would further reduce labour supply.

Figure 17: Labour supply with and without Pension Credit



These figures confirm the fact (reported by e.g. Hubbard et al. (1995) and Kitao (2014)) that the provision of means-tested support to the elderly can bear heavily on behaviour. The next section turns to whether the costs that these distortions impose on households are justified by the insurance value of PC, and whether more or less means-testing in retirement is justified.

5.2 Design problem

The experiment that I consider involves assessing whether welfare improvements can be obtained by the government changing the generosity of PC, with the budget balanced by changes in the generosity of the contributory component of the public pension system. The next four subsections define exactly what is involved - first outlining the instruments over which the government optimises, second giving the constraints on this optimisation, third outlining the government's objective function, and finally summarising all this by writing down the the problem solved by the government.

5.2.1 Policy instruments

Recall that τ is the function that calculates the net tax/transfer tax due. Two components of this function are the state pension ($sp(ae, h, t)$) - which depends on average earnings, household composition and age and Pension Credit ($pc(y, DC, a^c, a^h, h, t; gc)$), which depends on income, asset components, household composition, age and where I also make explicit the dependence of the payment on the government's choice of guarantee credit (gc) - the guaranteed minimum income in retirement. To ease notational burdens below, I define a residual tax function ($\tilde{\tau}$) that gives taxes and benefits net of the state pension and PC payments as follows (and I suppress the arguments of the tax and benefit function (see equation (14) for these)):

$$\tilde{\tau}(.) = \tau(.) - sp(ae, h, t) - pc(gc; y, DC, a^c, a^h, h, t; gc)$$

so that I can write the tax function as (suppressing most arguments):

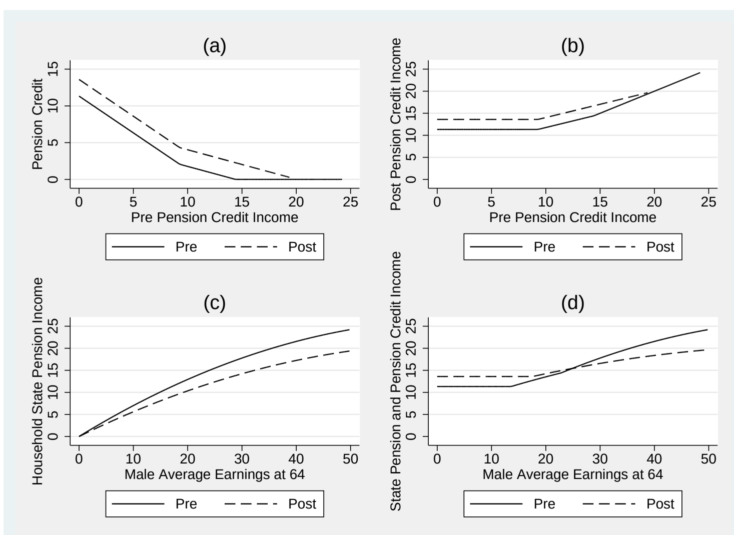
$$\tau^0() = \tau(sp^0(.), pc^0(.; gc), \tilde{\tau}^0(.))$$

The functions are superscripted with a zero to indicate they represent the baseline tax function. I consider new tax functions ($\tau^1()$) of a form given in (20). These differ from the baseline tax functions through the introduction of two parameters. These are λ_{sp}, which will scale, proportionately, at each level of average earnings, state pensions and λ_{gc}, which will scale the level of guarantee credit. $\lambda_{sp} > (<)1$ will make the state pension more (less) generous - similarly, $\lambda_{gc} > (<)$ will increase (decrease) Guarantee Credit and therefore make PC more (less) generous. The design problem facing the government is to choose λ_{sp} and λ_{gc}. All other parameters of the tax and benefit function stay the same (though the quantity of other taxes levied will, of course, change as behaviour changes in response to alterations in the incentives provided by the public pension system).

$$\tau^1() = \tau(\lambda_{sp} sp^0(.), pc^0(.; \lambda_{gc} gc), \tilde{\tau}^0(.)) \tag{20}$$

To illustrate this, Figure 18 shows one particular change: with $\lambda_{sp} = 0.8$ (a 20% reduction in state pension benefits at all levels of annual earnings) and $\lambda_{gc} = 1.2$ (a 20% increase in the level of Guarantee Credit)[25]. Figure 18(a) shows the relationship between pre-PC income and PC entitlement under the pre-reform and post-reform systems while Figure 18(b) shows the relationship between pre-PC income and post-PC income under both systems. Figure 18(c) shows the pre- and post- reform relationship between average earnings at age 64 and state pension entitlements. Figure 18(d) illustrates the combined effect of both reforms. It shows the relationship between career average earnings at the age of 64 and the sum of state pension and PC payments (PC is calculated here under the assumption that the household has no income (or wealth) other than that coming from the contributory public pension). This reform would increase pension payments for those with the lowest career average earnings and would reduce it for those with more.

Figure 18: Hypothetical reform to Pension Credit and State Pensions



All cash figures are expressed in £1000s per year (2012/13 pension system)

5.2.2 Constraints

Equation (21) gives R^0, the revenue collected by the government under the base tax and benefit function. τ^0_{it} represents the net taxes paid by individual i in period t, and $\bar{\phi}$ is the interest faced by the government - which I set equal to the mean return on the risky assets in which DC pensions are invested.

[25]These parameters were chosen arbitrarily to illustrate a particular change, they are not chosen to ensure revenue-neutrality.

$$\Sigma_t \Sigma_i \frac{\tau_{it}^0}{(1+\bar{\phi})^{T-t}} = R^0 \tag{21}$$

I only consider reforms that impose no new costs on the government. That is, the government will only consider new tax functions τ^1 that satisfy:

$$\Sigma_t \Sigma_i \frac{\tau_{it}^1}{(1+\bar{\phi})^{T-t}} \geq R^0$$

5.2.3 Objective

Households obtain utility from consuming, from time at leisure and from leaving bequests. I define, in equation (22) a function w that gives utility from the first two of these for time periods, t, where at least one household member is alive (t with $h_t \leq 3$) and utility from leaving a bequest in the period immediately following death (t with $h_t = 4$ and $h_{t-1} < 4$). $s_t \in S_t$, which enters the function w is a history of realisations of all stochastic variables (unemployment shock, productivity, investment returns and mortality) and so contains both h_t and h_{t-1}.

$$w_j\bigg(c_t, l_t, a_t^b, s_t\bigg) = \begin{cases} u_j(c_t, l) & \text{if} \quad h_t \leq 3 \\ b_j(a_t^b) & \text{if} \quad h_t = 4 \;\text{ and }\; h_{t-1} < 4 \\ 0 & \text{otherwise} \end{cases} \tag{22}$$

Let $q_t(s_t)$ be the cumulative distribution function of s_t and $c_t(s_t)$ be the mapping from any state of the world in period t to optimal consumption (the policy functions for leisure and bequests ($l_t(s_t)$ and $a_t^b(s_t)$ respectively) are similarly defined and boldface letters indicate the collection of policy functions for all t). I can now write the expected discounted utility for a household of type j. W_j in equation (23) represents the utility that such a household can expect immediately after its type, j, has been revealed but before the realisation of any other stochastic components.[26]

$$W_j(\mathbf{c}, \mathbf{l}, \mathbf{a^b}) = \Sigma_t \beta^t \int w_j\bigg(c_t(s_t), l_t(s_t), a_t^b(s_t), s_t\bigg) q_t(s_t) ds_t \tag{23}$$

Let me now define W_j^0 where the superscript 0 on W and on the policy functions indicate that these pertain to the base system of taxation.

$$W_j^0 = W_j(\mathbf{c}^0, \mathbf{l}^0, \mathbf{a}^{\mathbf{b}0}) = \Sigma_t \beta^t \int w_j\bigg(c_t^0(s_t), l_t^0(s_t), a_t^{b0}(s_t), s_t\bigg) q_t(s_t) ds_t$$

I can now define how I measure and express the utility difference for an agent j from a move from one tax and benefit system to another. My objective here is to have a measure that is expressed in units more salient than utility and which is comparable across households of different types (and with different utility functions). Common in the related literature is to express utility differences as a consumption equivalent variation (CEV) - the proportionate increase in consumption in each state of world under the base scenario that would obtain the same utility as in the reform scenario. I will not use that measure here. For a given utility difference, the CEV will tend to be larger the lower is the consumption weight on utility (as the less valuable is consumption to an agent the more additional consumption that will be needed to

[26] $W_j(\mathbf{c}, \mathbf{l}, \mathbf{a^b})$ is equal to the expected value function equation (17) for the first period, from the perspective of just before the first stochastic realisations are revealed. Writing the value as a function of policy functions (as in equation (23)) rather than as the state variables (as in equation (17)) will facilitate the discussion in the rest of this section.

obtain a particular level of utility). If the government's objective function involved averaging these CEVs across different household types, the utility difference of those household types with the lowest weights on consumption would bear most heavily on that objective. I do not wish the government's objective function to have this characteristic, so I define instead a consumption/leisure/bequest equivalent variable (CLBEV)[27]. This is the proportionate increase in each of consumption, leisure and bequeathed assets in each state of the world in the base scenario that give the agent the same utility as under the new tax and and benefit function. The CLBEV for agent j (α_j) for a move from tax and benefit system 0 to tax and benefit system 1 is defined implicity in equation 24:[28]

$$W_j((1+\alpha_j)\mathbf{c}^0, (1+\alpha_j)\mathbf{l}^0, (1+\alpha_j)\mathbf{a}^{\mathbf{b}0}) = W_j(\mathbf{c}^1, \mathbf{l}^1, \mathbf{a}^{\mathbf{b}1}) \tag{24}$$

5.2.4 Government's problem

The problem solved by the government is to maximise a weighted-average over j (where the weights - sw_j - give a social welfare function) of α_j, the CLBEVs over each j. In the design problem below, I set the each of the weights equal to $\frac{1}{4}$ - that is a utilitarian social welfare function in a world where there are equal numbers of each types of household. The constraint on that maximisation problem is that, under any reform, the government balance must be at least R^0.

$$\begin{aligned}
\Omega &= \max_{\lambda_{sp},\lambda_{gc}} \Sigma_{j=1}^{4} sw_j \alpha_j \left(\lambda_{sp}, \lambda_{gc}; W^0, \mathbf{c}^1, \mathbf{l}^1, \mathbf{a}^{\mathbf{b}^1}\right) \\
& s.t. \\
\lambda_{sp}, \lambda_{gc} &\geq 0 \\
\Sigma_t \Sigma_i \frac{\tau_i^1}{(1+\phi)^{T-t}} &\geq R^0
\end{aligned}$$

5.2.5 Optimal system

Table 9 gives the result from the solution to the government's problem. The objective function is maximised by abolishing the contributory component of the public pension ($\lambda_{sp} = 0$) and using the resulting funds to make PC more generous by increasing Guarantee Credit by 56% ($\lambda_{gc} = 1.562$). The unweighted average of the CLBEV ($\bar{\alpha}$) is 0.35%. Those who gain are those with low education, among whom those with no DB pension and those with a DB pension gain by 1.2% and 0.4% respectively. Those with high education would experience modest losses from the reform.

[27] Note that this is not a true equivalent variation, which is the additional money that would have to be given to the agent that would allow him, after re-optimisation, to obtain a new level of utility.

[28] If there was no value on bequests, it would be trivial to show (as Conesa et al. (2009) note) that:

$$\alpha_j = \left(\frac{W_1}{W_0}\right)^{\frac{1}{1-\gamma}} - 1$$

The bequest function means that that there is no closed-form expression for α_j and I calculate it numerically.

Table 9: Optimal public pension

	Type			
	Low Ed		High Ed	
	No DB	DB	No DB	DB
λ_{gc}		1.562		
λ_{sp}		0.000		
$\bar{\alpha}$		0.35%		
α_j	1.20%	0.38%	-0.05%	-0.13%

To understand where these effects are coming from, it is possible to decompose the CLBEV into an effect coming through each of consumption, leisure and bequests (with a further decomposition of each of these derived from the effect on the level and the distribution). The decomposition is in the spirit of that of Conesa et al. (2009), extended slightly to allow for bequests.[29] Table 10 gives these effects. Falls in the level of consumption reduce utility for each type, with offsetting increases in utility coming from changes in the distribution of consumption for all but the low education households with no DB pensions.[30] These effects on the level and distribution of consumption reflect, respectively, the distortions induced by a more generous PC and the additional insurance that it provides. The effect on utility of the labour-supply distortions, however, are mitigated by increases in the quantity of leisure enjoyed. The effect is largest for the low educated/no DB type, for whom the distortions are greatest. All types suffer utility losses from leaving lower bequests (as more generous PC reduces the extent to which households hold bequeathable assets).

[29] Let α^c, α^l and α^b be defined as:

$$\begin{aligned} W(c^1, l^0, a^{b0}) &= W\big((1+\alpha^c)c^0, (1+\alpha^c)l^0, (1+\alpha^c)a^{b0}\big) \\ W(c^1, l^1, a^{b0}) &= W\big((1+\alpha^l)c^1, (1+\alpha^l)l^0, (1+\alpha^l)a^{b0}\big) \\ W(c^1, l^1, a^{b1}) &= W\big((1+\alpha^b)c^1, (1+\alpha^b)l^1, (1+\alpha^b)a^{b0}\big) \end{aligned}$$

Let $\alpha^{c,lev}$ and $\alpha^{c,dist}$ be defined as:

$$\begin{aligned} W(\hat{c}^{01}, l^0, b^0) &= W\big((1+\alpha^{c,lev})c^0, (1+\alpha^{c,lev})l^0, (1+\alpha^{c,lev})a^{b0}\big) \\ W(c^1, l^0, b^0) &= W\big((1+\alpha^{c,dist})\hat{c}^{01}, (1+\alpha^{c,dist})l^0, (1+\alpha^{c,dist})a^{b0}\big) \end{aligned}$$

where $\hat{c}^{01} = (1+g_c)c_0$ is the consumption allocation in the base scenario scaled by the change in aggregate consumption between the base and the reform scenarios $(1+g_c)$. $\alpha^{l,lev}$, $\alpha^{l,dist}$,$\alpha^{b,lev}$ and $\alpha^{b,dist}$ are similarly defined. If the bequest function had the same curvature as the utility function (i.e. if $K = 0$, it would be the case that $\alpha = (1+\alpha^c)(1+\alpha^l)(1+\alpha^b)$ or $\alpha \approx \alpha^c + \alpha^l + \alpha^b$. The fact that the bequest function has a different curvature from the utility function means that the equality will not be exact, but in all reforms analysed here it very nearly holds).

[30] For this group of households, the (slightly) negative effects on utility from the distribution of consumption are due to the fact that those households with the lowest realised resources choose to respond to more generous PC by increasing their leisure to a greater extent than their consumption.

Table 10: Decomposition of welfare effects

		Type			
		Low Ed		High Ed	
		No DB	DB	No DB	DB
Total Change (α_j)		1.20	0.38	-0.05	-0.13
Consumption	Total	-1.58	-1.16	-0.85	-1.28
	Level	-1.23	-2.83	-3.00	-2.75
	Distribution	-0.35	1.71	2.22	1.51
Leisure	Total	4.16	1.62	1.13	1.26
	Level	7.82	5.39	2.20	2.44
	Distribution	-3.41	-3.58	-1.04	-1.15
Bequest	Total	-1.28	-0.06	-0.33	-0.09
	Level	-1.13	-0.05	-0.21	-0.07
	Distribution	-0.15	-0.01	-0.12	-1.15

The results of the experiment above suggests a rather extreme reform - the outright abolition of the contributory public pension in the UK. Some intuition for what is driving this result can be obtained by looking directly at how the government balance responds to changes in the level of GC. Figure 19 shows the change in government balance per household (on the vertical axis) for different levels of λ_{gc} (horizontal axis), keeping the contributory public pension unchanged ($\lambda_{sp} = 1$). As GC is increased, the government balance deteriorates (due to greater outlays on PC combined with a fall in tax revenues as the quantity of labour supplied falls). However, reductions in GC, surprisingly, also lead to a deterioration in the government balance. This is due to the tax advantages associated with *private* pension saving in the UK. Reductions in government-provided insurance against low consumption in retirement lead households to self-insure by increasing their private pension saving (as was seen in Section 5.1). This self-insurance is (aggressively) subsidised in the UK and the revenue-enhancing effects of reductions in PC are more than offset by the greater tax expenditures on subsidising private saving.

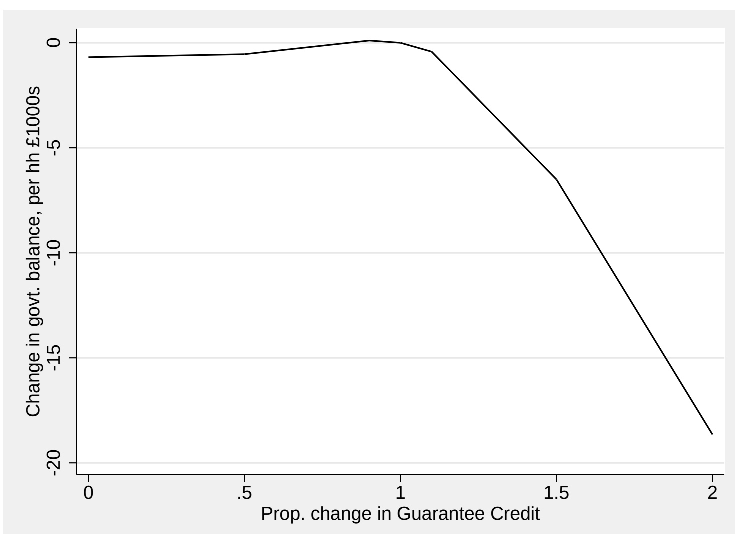


Figure 19: Fiscal implications of changing generosity of means-tested benefits

Figure 20 shows a similar calculation under different sets of rules around the taxation of private pension saving. Reform I abolishes the tax-free lump sum and levies National Insurance contributions on the income saved in a private pension. This reform involves removing tax advantages (3) and (4) listed in Section 2.2 and would make the UK treatment of private pensions similar to that in the US. Reform 2 goes further and levies income tax on the income saved in a private pension (and then exempts private pension income from income tax) - that is, it removes the consumption tax treatment of private pension saving. Under these rules saving in a private pension has the same tax treatment as saving outside a pension. In both these cases reducing the generosity of PC improves the government's fiscal position as the resulting substitution towards private pension saving is no longer so costly for the government.

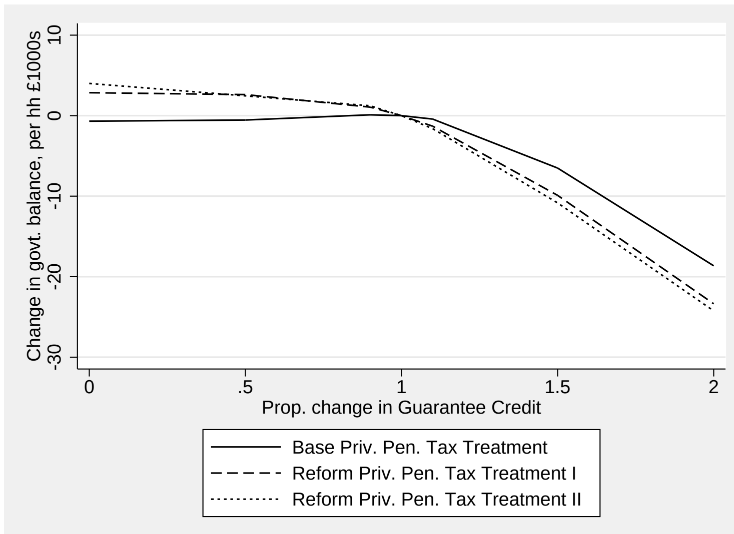


Figure 20: Fiscal implications of changing generosity of means-tested benefits - different tax treatment

Tables 11 and 12 consider the optimal split between the means-tested and contributory components of the public pension system under these two reformed tax treatment of private pensions (Tables 13 and 14 in the appendix show the analogous tables to Table 10 - the decomposition into level and distribution effects on each of consumption, leisure and bequests). Comparing the optimal split under tax reform I with that under the current private pension tax treatment, the optimal increase in GC is slightly smaller than it was previously (55% compared to 56%), with the bulk of the revenue saved from the reforms to the taxation of private pension used to retain some contributory benefits (relative to the current system, there is a reduction in the generosity of these of almost a quarter ($\lambda_{sp} = 0.758$) rather than outright abolition). The average CLBEV is 0.61%, almost double what is achieved while maintaining the current private pension tax-treatment. The implications of this result are that, ex-ante, households would rather that the revenue used in subsidising private saving be instead used in a manner that provides some insurance against poor outcomes in old age.

Table 11: Optimal public pension: reformed tax relief I

	Type			
	Low Ed		High Ed	
	No DB	DB	No DB	DB
λ_{gc}	1.547			
λ_{sp}	0.758			
$\bar{\alpha}$	0.61%			
α_j	1.36%	0.36%	0.86%	-0.14%

The second reform of private pension saving removes the consumption tax treatment of private pension saving. The extra revenue that is raised in removing this aspect of pension taxation could be optimally used to provide substantially greater PC than under reform I (an almost 80% increase in baseline GC compared to 55%) with a smaller state pension ($\lambda_{sp} = 0.706$ compared to 0.758). These CLBEV for this reform is slightly higher than under reform I (0.65% compared to 0.61%) though the benefits are concentrated to a much greater extent on those who do not have DB pensions.[31]

Table 12: Optimal public pension: reformed tax relief II

	Type			
	Low Ed		High Ed	
	No DB	DB	No DB	DB
λ_{gc}	1.797			
λ_{sp}	0.706			
$\bar{\alpha}$	0.65%			
α_j	2.01%	-0.24%	1.49%	-0.65%

6 Conclusion

In terms of support for the retired, the UK (and US) governments spend on (in order of the quantity of spending) contributory public pensions, subsidies to private pension saving and means-tested public support for the elderly. This paper gives evidence that they might not be getting the balance right

[31]The analysis of these reforms assume that employer behaviour with regard to the provision of DB pensions is unchanged. Allowing employer behaviour to re-optimise after a tax reform would likely increase the well-being of those with DB pensions relative to the numbers presented here (as presumably employee remuneration would be provided in a more tax-efficient manner). However, the loss of government revenue associated with such re-optimisation would result in less new revenue to allocate between the means-tested and contributory components of the public pension systems, which would mitigate these gains, and reduce the gains available for the households without a DB pension. It is unclear whether the overall gains from the reform would be more or less than those reported here. Modelling the effect of employer behaviour in response to changes in the tax-treatment of private pensions is interesting but is left for future work.

between these. Extending means-tested support at the expense of contributory public pensions is shown to be welfare improving from an ex-ante perspective. The reform would reduce the expected level of consumption over the lifecycle but the utility cost of this is more than offset by increases in the value of leisure and the greater insurance provided by the reform against the worst consumption outcomes. Abolishing subsidies to private pensions and using the newly-available revenue to provide a combination of means-tested and contributory pensions is shown to increase welfare to an even greater extent.

The lifecycle framework used to study the design of public pensions in this paper is a rich one - containing public and private pensions, consumption, saving, portfolio and labour supply choices and estimation of preference parameters using linked survey and administrative data. Future work could extend it, however, by investigating the role of (different) public pension systems in determining the supply of labour of both men and women, by looking at the response of employers to the taxation of private pensions, by studying the behaviour of younger cohorts and by embedding the design problem within a General Equilibrium framework.

This paper's results suggest that while a greater emphasis on means-tested support for pensioners (as exists in Australia), is distortionary, these distortions are less costly to households, viewed from the start of working life, than the benefits associated with the insurance that extending such support would provide.

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A Appendix (incomplete)

A.1 Model Supplemental Details

A.1.1 Leverage, Gross Housing Wealth, Net Housing Wealth and Outstanding Mortage

$$
\begin{aligned}
\frac{1}{(1-lev)}a^h &= \frac{1}{1-\frac{mort}{gh}}a^h \\
&= \frac{gh}{gh-mort}a^h \\
&= \frac{gh}{a^h}a^h \\
&= gh
\end{aligned}
$$

$$
\begin{aligned}
\frac{lev}{(1-lev)}a^h &= \frac{\frac{mort}{gh}}{1-\frac{mort}{gh}}a^h \\
&= \frac{mort}{gh-mort}a^h \\
&= \frac{mort}{a^h}a^h \\
&= mort
\end{aligned}
$$

A.1.2 Tax and Benefit Function

A.2 Data

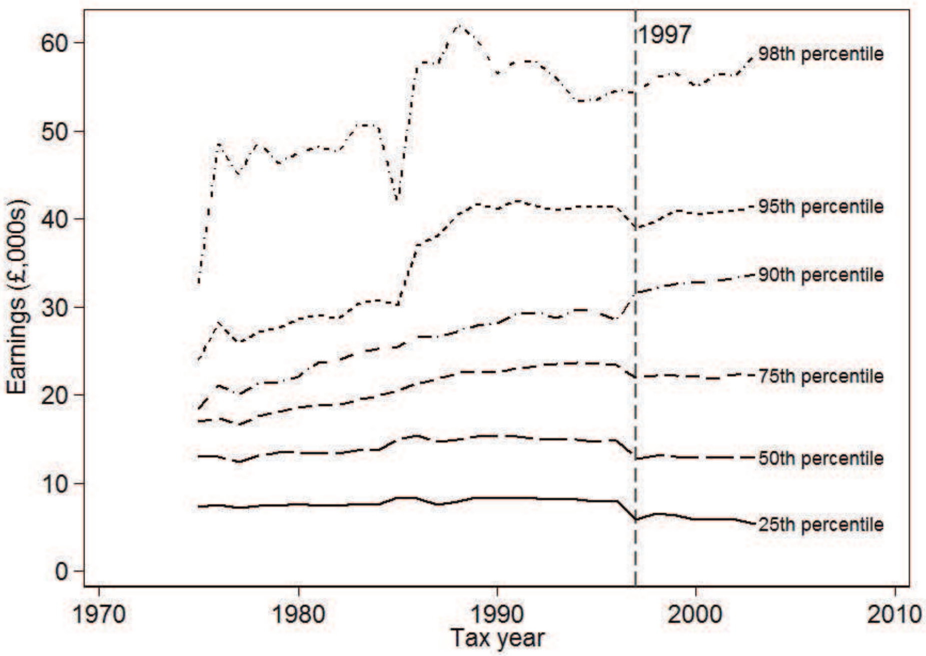
A.2.1 Earnings data

To estimate the parameters of equations that determine earnings capacity (given in equations) and ()), I need panel data on earnings for each of my four types. This data comes from two sources - earnings data from before 2002 (when the survey started) is calculated using linked administrative data (as described in the section A.2.1). This is combined with survey data from ELSA for years after 2002 (described in section A.2.1)

Administrative data The national insurance (NI) data are the administrative record of individuals' national insurance contributions, and the dataset that is used by the UK government to establish individuals' rights to claim contributory benefits such as the state pension. I use this data to estimate ELSA respondents history of earnings. The NI records cover the years 1948 to 2003, though there are different levels of of information for each of three sub-periods: 1948-1974, 1975-1996 and 1997 to 2003.

Taking the most recent period first, the NI records contain uncensored data on annual earnings as, in these years, employers were required to report the total earnings of their employees. For the middle period - years between 1975 and 1996 - the NI records contain data on employee National Insurance contributions. National Insurance payments in that interval were levied as a proportion of earnings between two values which are known as the Lower Earnings Limit (LEL) and the Upper Earnings Limit (UEL). For the period under consideration these values have been located at approximately the 8th and 80th percentile of the distribution of (positive) earnings. This data on NI contributions therefore allow us to calculate earnings,

Figure 21: Selected quantiles of earnings



subject to right-censoring at the UEL and conditional on there being some earnings above the LEL. Prior to 1975 the NI records contain only data on the number of weeks that an individual earned above the LEL (and therefore paid NI contributions) and not the level of earnings. (This is because during this period the level of earnings was not relevant to the accrual of rights to state benefits or the state pension.)

To predict censored earnings in the years 1975 to 1996, I estimate the coefficients of a fixed-effect Tobit on earnings from 1975 to 2003 with the censoring point in each year up to 1996 equal to UEL (from 1997 there is no censoring). I use these coefficients to predict earnings for those who are affected by the censoring. The fixed-effect Tobit, when the length of the panel is fixed, is known to yield inconsistent results due to the incidental parameters problem (see Neyman and Scott (1948) for a general discussion of this problem). However Greene (2004) investigates, using Monte Carlo methods, its properties and finds that parameters of the fixed effects Tobit model are little affected by this problem even with panel of lengths substantially shorter than our panel (which has length 29). Further, Figure 21 shows a plot of selected quantiles of earnings through time using the censored and imputed data prior to 1997 and the uncensored data from 1997 onwards. This shows only a very small discontinuity in 1997.

To simulate earnings before 1975 I follow broadly the methodology used by Bozio et al. (2010a). Using the NI data, I calculate an individual's mean earnings over the years 1975 to 2003 in which they are observed working, and then estimate potential previous years' earnings by adjusting for average economy-wide earnings growth and individual level earnings growth given their age, sex and education level. Having obtained this measure of potential earnings in each year, we then need to predict the years in which the individuals were working. The NI data records how many weeks the individual made NI contributions between 1948 and 1975. For men we assume they worked those weeks immediately prior to 1975 (therefore any periods not working were at the start of working life). To take account of the diminished propensity for women to work after having children, we assume that they worked those weeks from the point of leaving full-time education (therefore any periods not working were immediately prior to 1975). The combination of the estimates of potential earnings in a particular year for each individual and the years in which they were working yields our earnings estimates for years prior to 1975.

Household earnings are calculated by summing in each year the earnings for each individual in the household.

The discussion above relates only to earnings in employment and not income earned in self-employment. National insurance payments are levied on self-employment income- but in a different manner than on earnings. As a result, the NI records enable us to identify years in which self-employment income was earned, but not the level of that income. Our measure of earnings therefore excludes income from self-employment.

Combining administrative data on earnings with ELSA data The earnings data described will be used to estimate the parameters of the productivity earnings process. The first step in this will be to estimate the parameters of equation (A.2.1). This equation has the same form as the productivity process in equation (A.2.1) but the parameters are given with hats to indicate that, in making no accounting for selection into the labour market, these parameters will be biased. I correct for this bias using a procedure introduced by French (2005), which I describe in section 4.1.3.

$$ln\ \tilde{e}_{it} = \hat{\delta}_0 + \hat{\delta}_1 t + \hat{\delta}_2 t^2 + \hat{u}_{it} \tag{25}$$

Estimating the parameters of equation A.2.1 using data only on earnings rather than wages (and the administrative data only allows a calculation of the latter) will induce an additional bias. Transitions into part-time work (which happen, for males at least, to a greater extent towards the end of working life) will bias the estimates of earnings at older ages down. To mitigate this problem, the panel that I use is combined of administrative data on earnings for years before 2002 and data on earnings from ELSA for years after 2002. This allows me to introduce into the estimating equation, a new dummy variable, pt, which indicates that the male is in part time employment (measured as working 20 hours or less per week). I can measure for the period from 2002. For earlier years, only covered by the administrative data, I assume that all male work was full time. The equation that is used to estimate the (still biased, due to selection in the labour market) is given below:

$$ln\ \tilde{e}_{it} = \hat{\delta}_0 + \hat{\delta}_1 t + \hat{\delta}_2 t^2 + \hat{\delta}_3 pt + \hat{u}_{it}$$

A.2.2 Wealth measures in the ELSA

The ELSA data contains detailed information on the components of household wealth. Considering non-pension wealth first, the main components are net financial wealth (cash, stocks and shares less any outstanding financial debt), net primary housing wealth (gross housing wealth less any associated mortgages), other net property wealth, business wealth and physical wealth (land, antiques and collectibles). Moments of the sum of these (that is moments of non-pension wealth) are used in the method of moments procedure to match simulated non-pension wealth (a).

Defined Contribution wealth is equal to the accrued fund value. Moments of this are used in the method of moments procedure to match simulated Defined Contribution wealth (DC).

The model requires estimates of the relationship between average earnings in working life and each of state pension and Defined Benefit pension. Average earnings for sample members is obtained using the linked administrative data. Data on projected state pension income from are obtained from Bozio et al. (2010b) who calculate them using the rules of the state pension system and the same administrative data on contributions that I use. Projected DB pension income is estimated using survey responses (see Banks et al. (2005) for more details). The calculation of each needs to tackle the fact that when those in the sample that I use are interviewed (when they will be aged as young as 50), their actual pension income will depend on labour market outcomes that have not yet been realised. The assumption that underlies the estimates that I use assume that individuals who are not working when interviewed do not return to the labour market, whereas those that are working when interview continue to work until their current pension's normal retirement age (for those with DB pensions) or their state pension age (for those without).

The model splits households into DB and no DB types with the latter type not having any DB wealth. The reality is somewhat less stark; very few households of the cohort I study have no DB pension wealth at all (which would occur if neither spouse worked a single year in a job with a DB pension). Therefore some of the households who are in the 'No DB' sample have some DB wealth. My approach is to treat this wealth as if it were DC wealth. To covert future DB *income* (which is what the data contain) into DC *wealth* I do the following calculation:

$$DC_t = \underbrace{\frac{db_{65}}{q_{65}}}_{A} \underbrace{\frac{yw_t}{yw_{65}}}_{B} \underbrace{(1+r)^{t-65}}_{C}$$

The first term (A) is projected DB income at the age of 65 divided by the annuity rate at 65- this is a measure or DB wealth at the age of 65. The second term (B) accounts for the fact that, by age t, individuals will not have accrued all the DB pension wealth in A and scales it down by a factor equal to the ratio of the number of years worked in period t to the number of years assumed to be worked at the age of 65 yw_{65}. Finally, the product of A and B is wealth that will not be realised until the age of 65, so the obtain its value in period t we must discount it back using the risk-free interest rate (term C).

A.2.3 Representativeness of sample

A.3 Estimation of stochastic component of earnings

A.4 Computational appendix

A.5 Additional detail on counterfactual experiments

Table 13: Decomposition of welfare effects - reformed tax relief I

		Type			
		Low Ed		High Ed	
		No DB	DB	No DB	DB
Total Change		1.36	0.36	0.86	-0.14
Consumption	Total	-1.00	-0.68	0.19	-1.16
	Level	-0.19	-2.48	-2.08	-2.97
	Distribution	-0.81	1.84	2.31	1.87
Leisure	Total	3.07	1.12	0.95	1.15
	Level	5.53	3.93	2.17	2.14
	Distribution	-2.34	-2.70	-1.19	-0.96
Bequest	Total	-0.66	-0.07	-0.27	-0.13
	Level	-0.53	-0.06	-0.22	-0.11
	Distribution	-0.14	-0.01	-0.05	-0.96

Table 14: Decomposition of welfare effects - reformed tax relief II

		Type			
		Low Ed		High Ed	
		No DB	DB	No DB	DB
Total Change		2.01	-0.24	1.49	-0.65
Consumption	Total	-0.69	-1.45	0.48	-2.18
	Level	0.59	-2.74	-2.02	-3.25
	Distribution	-1.27	1.33	2.55	1.10
Leisure	Total	3.19	1.32	1.37	1.71
	Level	5.83	4.00	3.16	2.96
	Distribution	-2.49	-2.58	-1.74	-1.22
Bequest	Total	-0.46	-0.09	-0.35	-0.14
	Level	-0.38	-0.07	-0.30	-0.09
	Distribution	-0.08	-0.02	-0.06	-1.22