The Effects of Myopia on Retirement Savings Decisions*

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Millions of people are not currently saving enough to meet their expectations for income once they retire. There are persistent and powerful barriers to people taking the long-term savings decisions that would be needed to address this problem. These include inertia, financial myopia, the cost of pension saving and the complexity of the decisions involved. Department for Work and Pensions, "Security in retirement: towards a new pensions system", Pensions White Paper, (2006, p. 31).

1 Introduction

Recent pensions policy debate in the United Kingdom has emphasised the role of behavioural myopia in justifying state involvement in retirement provisions (e.g. Pensions Commission, 2005, pp. 68-69, and op.cit.). In this regard, it appears that the public debate has gotten slightly ahead of the economic literature, as there currently exist very few studies that consider the empirical support for myopia on field data, or the practical implications of myopia for behavioural responses to policy alternatives. As a consequence, it is not possible to say how far myopia creates a need for publicly sponsored pensions, or whether a particular pension scheme is well suited to the needs of myopic individuals. This study explores the empirical support for myopia on field data for the UK. It then considers the implications of myopia for behavioural and welfare responses to the National Employment Savings Trust (NEST), which is a Defined Contribution (DC) pension scheme that will be introduced in the UK from 2012.[1]

The introduction of the NEST reflects a contemporary trend toward greater reliance on DC pension provision in the (third tier) private sector in the UK, and a similar trend among OECD countries more generally.[2] It is being introduced following recommendations made by the Pensions Commission (2005), which found that administration costs made it unprofitable for the existing system of private sector pension provision to serve employees on modest incomes. The NEST is consequently designed to

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[1] Previously known as Personal Accounts (DWP, 2006b), and before that the National Pension Savings Scheme (Pensions Commission, 2005).

[2] Switzerland stands out from most other OECD countries (with the possible exception of the Netherlands) in having a long established funded DC pension scheme. Australia, New Zealand, Sweden, Denmark, Hungary, Norway, Poland, Italy, and the Slovak Republic, now also include some form of publicly sponsored DC pension scheme. On pension contemporary pension arrangements in OECD countries, see OECD (2009).

improve saving incentives by reducing management charges, and by requiring all employers to offer a 3% matching pension contribution on banded earnings to partcipating employees. It has been forecast that the scheme will serve between 6 and 10 million people, equal to one out of every four people of working age, and will receive contributions worth £8 billion annually, 60% of which is projected to be new saving.[3]

The long term viability of the NEST will depend upon the extent of voluntary participation among eligible employees. The success or failure of the scheme will profoundly influence the future of pensions provion in the UK, and will have important implications for the wider group of countries that face similar pension challenges to those of the UK.[4] Nevertheless, despite the role played by myopia in motivating the NEST's introduction, little is currently understood about the implications of myopic preferences for pensions design in a realistic policy environment.

One study that does shed some light on these issues is by Laibson et al. (1998), who consider the influence of quasi-hyperbolic discounting on responses to a DC pension that is designed to reflect IRA and 401(k) plans for the US. Laibson et al. focus upon long-run responses to the introduction of a DC pension from a pre-reform state in which no DC pension exists. The findings that Laibson et al. report are striking: their preferred specification of myopia amplifies the increase in steady-state net national saving rates in context of a DC pension scheme, by a factor of between 1.2 and 1.6 depending upon the terms of the pension scheme. Furthermore, they find that the beneficial welfare effect at age 20 of the option to invest in a DC pension scheme increases by a multiple in excess of 3 in context of myopic preferences.

If (sophisticated) myopia does have an important bearing upon retirement planning, then the above cited results strongly support the premise that government should work toward facilitating public access to DC pension schemes. But two principal issues arise when interpreting the results that Laibson et al. report. First, their study is based upon a structural model of household decisions over liquid savings and pension contributions; labour supply is taken to be exogenous. This is a concern because savings and labour supply decisions – particularly in relation to the timing of retirement – are likely to be jointly determined. Many households that hold less wealth than they would like to late in the working lifetime, for example, can presumably choose to work a little longer to off-set their funding short-fall. Omitting either savings or labour supply decisions in relation to a study of retirement behaviour is consequently likely to result in excess sensitivity of behavioural responses – a form of omitted variable bias. It is consequently pertinent to ask how far the behavioural responses that are reported by Laibson

[3] The mid-2008 estimate for the resident population in the UK was 61.4 million people, 62% of whom were of working age (Office for National Statistics).

[4] A forerunner to the NEST that was introduced in 2001 (the Stakeholder pension) failed to generate sufficient take-up, and has since been marginalised in the system of private pension provision in the UK.

et al. are sensitive to the assumption of exogenous labour supply.

Secondly, the structural model considered by Laibson et al. is based upon a time-separable isoelastic function in current period consumption, which is fully described by three preference parameters: two discount rates that reflect the (now familiar) model of quasi-hyperbolic discounting, and the parameter of relative risk aversion. The empirical literature has reported a very wide range of estimates for the parameter of relative risk aversion; Laibson et al. exogenously assume a value of 1.0 (log utility) for this parameter, and test associated sensitivity to the alternative value of 3. The results that they report are highly sensitive to assumptions over this parameter, and indicate less pronounced responses in context of the higher rate of risk aversion. Furthermore, Laibson et al. exogenously assume a value for the excess short-run discount factor of 0.85, stating that they would like to have considered values as low as 0.6, but were not able to do so due to associated analytical complications. To explore the sensitivity of their results to the scale of the assumed myopia, Laibson et al. consider the alternative value of 0.8 for the short-run discount factor. Finally, they adjust the long-run exponential discount factor to match their model against the median ratio of wealth to income for individuals between the ages of 50 and 59. Given the likely importance of the value judgements upon which these decisions are based, it is useful to consider the alternative where parameters of the model used are tied down objectively by the data.

This study addresses each of the issues that are identified above. It is based on a structural model of decisions regarding savings, labour supply, and contributions to a DC pension scheme. These decisions are considered to be made in context of uncertain wages, employment opportunities, demographics, and mortality. The assumed wage process includes an experience effect, which is introduced to obtain a better match between the model and survey data, and has the added advantage of providing an alternative commitment mechanism through which myopic agents can mitigate the welfare penalties associated with time-inconsistent preferences.

The current focus on endogenous labour supply motivated the inclusion of relationship status as an additional household descriptive characteristic, with relationship transitions between adjacent years described as a stochastic process. This is not a common feature in the associated literature, and facilitates a more accurate reflection of tax and benefits policy, which has an important bearing upon retirement decisions. The parameters of the model were estimated on data for a broad segment of the UK population, omitting public sector employees who are eligible to non-contributory pensions[5], and the self-employed whose circumstances upon reaching retirement often depend upon the sale of their respective businesses. The omitted population subgroups accounted for just under 20 percent of the total work force in the UK in 2007/08.[6]

[5] These include employees of the armed forces, national government, local government services, justice, police, fire, and social security departments.

[6] Calculated on 2007/08 FRS data, which indicates 12 percent of all workers self employed, and 7.6 percent employed

Section 2 describes the model that was used to conduct the analysis, including a detailed description of the pension scheme with which the analysis is concerned. Section 3 reports parameter estimates for the model, and responses to introduction of the DC pension are analysed in Section 4. A summary and directions for further research are provided in a concluding section.

2 The Structural Model

The unit of analysis is the household, defined as a single adult or partner couple and their dependant children. Household decisions regarding consumption, labour supply, and pension scheme contributions are considered at annual intervals throughout the life course, which is assumed to run from age 20 to a maximum potential age of 120. Endogenous decisions are based on the assumption that households maximise expected lifetime utility, given their prevailing circumstances, preferences, and beliefs regarding the future. A household's circumstances are described by its age, number of adults, number of children, earnings, net liquid worth (cash on hand), pension rights, and time of death. The belief structure is rational in the sense that expectations are consistent with the intertemporal decision making environment, and the model is a partial equilibrium in that the distribution of wages and returns to saving are independent of agent decisions. The rationality of the belief structure also extends to expectations over future preferences, so that the analysis focuses exclusively on myopic consumers who are aware of the time-inconsistency of their preferences.

Of the seven characteristics that define the circumstances of a household, four are stochastic (earnings, relationship status, number of children, and time of death), and three deterministic (age, pension rights, and net liquid worth). This section gives an abbreviated description of the structural model; for a more detailed description, see van de Ven (2009).

2.1 Preferences

Expected lifetime utility of household i at age t is described by the time separable function:

$$U_{i,t} = \frac{1}{1-\gamma}\left\{u\left(\frac{c_{i,t}}{\theta_{i,t}}, l_{i,t}\right)^{1-\gamma} + \beta E_t\left[\sum_{j=t+1}^{t_{death}} \delta^{j-t} u\left(\frac{c_{i,j}}{\theta_{i,j}}, l_{i,j}\right)^{1-\gamma}\right]\right\} \tag{1a}$$

$$u\left(\frac{c_{i,j}}{\theta_{i,j}}, l_{i,t}\right) = \left(\left(\frac{c_{i,j}}{\theta_{i,j}}\right)^{(1-1/\varepsilon)} + \alpha^{1/\varepsilon} l_{i,t}^{(1-1/\varepsilon)}\right)^{\frac{1}{1-1/\varepsilon}} \tag{1b}$$

so that intratemporal utility u takes a Constant Elasticity of Substitution form, where $\alpha > 0$ is the utility price of leisure, and $\varepsilon > 0$ the (period specific) elasticity of substitution between equivalised consumption ($c_{i,t}/\theta_{i,t}$) and leisure ($l_{i,t}$). u is combined in the intertemporal specification through an isoelastic transformation. Households choose over discretionary composite consumption, $c_{i,t} \in R^{+}$, and

in public sector (SIC code 75).

time spent in leisure, $l_{i,t} \in [0,1]$. Although the consumption decision is taken over a continuous domain, labour status is chosen from a set of discrete alternatives that represent full-time, part-time, and non-employment of adult household members. To the extent that this limits employment decisions relative to reality, it will dampen the responsiveness of labour supply behaviour implied by the structural model, and dampen variation in employment incomes. These effects may result in a form of omitted variable bias in the parameters that match the model to survey data.

The discount factors β and δ are assumed to be time invariant and the same for all households. Quasi-hyperbolic discounting that reflects a present bias in consumption applies when $\beta < 1$. The analysis that is reported in Section 4 explores how alternative values of β influence responses to a DC pension scheme. Important issues of interpretation frame the estimations that are reported in Section 3, and are consequently returned to there.

$\theta_{i,t} \in R^+$ is adult equivalent size based on the "modified" OECD scale. It is included in the preference relation, because household size has been found to be an important determinant of the evolution of consumption during the life course. E_t is the expectations operator at time t, t_{death} is the age at death, which is assumed to be uncertain. Define $\phi_{j-t,t}$ as the probability of surviving to age j given survival to age t, where $\phi_{T-t,t} = 0$ for all t. Then it is possible to replace t_{death} by T, bring the expectations operator into the summation sign, and include $\phi_{j-t,t}$ as an additional discount factor. $\phi_{j-t,t}$ is assumed to be non-stochastic for all j, t.

Although not explicitly included in the preference relation, accidental bequests do occur due to the uncertainty assumed over the time of death. Where a household dies with positive wealth balances, these are assumed to accrue to the state in the form of a 100% inheritance tax.

2.2 The liquidity constraint

Define $w_{i,t}$ as liquid net worth. This accounts for total non-pension wealth, including the value of housing, cash balances, and other tradeable assets. Equation (1) is maximised, subject to the age specific liquidity constraint, $w_{i,t} \geq D_t$ for all (i,t), where:

$$w_{i,t} = \begin{cases} \hat{w}_{i,t} & t \neq t_{SPA} \\ \hat{w}_{i,t} + \pi^p w^p_{i,t} & t = t_{SPA} \end{cases} \tag{2a}$$

$$\hat{w}_{i,t} = \begin{cases} \pi_{div}\left(w_{i,t-1} - c_{i,t-1} + \tau_{i,t-1}\right) & n^a_t < n^a_{t-1}, t < t_{SPA} \\ w_{i,t-1} - c_{i,t-1} + \tau_{i,t-1} & \text{otherwise} \end{cases} \tag{2b}$$

$$\tau_{i,t} = \tau(l_{i,t}, x_{i,t}, n^a_{i,t}, n^c_{i,t}, r_{i,t} w_{i,t}, pc_{i,t}, t) \tag{2c}$$

$w^p_{i,t}$ denotes wealth held in personal pensions. π^p is the proportion of pension wealth that is taken as a tax free lump-sum at age t_{SPA}. π_{div} is the proportion of net liquid worth that is lost upon marital dissolution (to capture the impact of divorce). These two factors are exogenously defined.

$\tau(.)$ is disposable income net of non-discretionary expenditure. Equation (2c) indicates that taxes and benefits are calculated with respect to labour supply, $l_{i,t}$; private non-property income, $x_{i,t}$; the numbers of adults, $n^a_{i,t}$, and children, $n^c_{i,t}$; the return to liquid assets, $r_{i,t}w_{i,t}$ (which is negative when $w_{i,t} < 0$); private contributions to pensions, $pc_{i,t}$; and age, t.

2.3 Disposable income

The lifetime is divided into two periods when calculating disposable income: the working lifetime $t < t_{SPA}$, and pension receipt $t_{SPA} \leq t$; t_{SPA} denotes state pension age. Throughout the lifetime, household disposable income is calculated by:

1. evaluating aggregate *take-home pay* from the taxable incomes of each adult member of a household – this reflects the taxation of individual incomes in the UK

2. calculating *benefits* receipt (excluding adjustments for childcare and housing costs) from aggregate household take-home pay – this reflects the fact that benefits tend to be provided at the level of the family unit

3. calculating non-discretionary *net childcare costs* (after adjusting for childcare related benefits) from aggregate take-home pay – of separate importance because of their bearing upon labour supply decisions

4. calculating non-discretionary *net housing costs* (after adjusting for relevant benefits receipt) from aggregate take-home pay plus benefits less childcare costs – this reflects the fact that 'Housing Benefit' and 'Council Tax Benefit' in the UK are means tested with respect to income net of most other elements of the tax and benefits system

5. household *disposable income* is then equal to aggregate take-home pay, plus benefits, less net childcare costs, less net housing costs.

Calculation of taxable income for each adult in a household depends on the household's age, with property and non-property income treated separately. For all $t < t_{SPA}$, household non-property income $x_{i,t}$ is equal to labour income $g_{i,t}$ less pension contributions. For $t \geq t_{SPA}$, $x_{i,t}$ is equal to labour income plus pension annuity income:

$$x_{i,t} = \begin{cases} g_{i,t} - pc_{i,t} & t < t_{SPA} \\ g_{i,t} + pp_{i,t} + sp_t & t \geq t_{SPA} \end{cases} \tag{3}$$

$$\text{where} \quad : \quad pp_{i,t} = \begin{cases} \chi \left(1 - \pi^p\right) w^p_{i,t} & t = t_{SPA} \\ \left(\frac{\pi^s + (1-\pi^s).(n^a_{i,t}-1)}{\pi^s + (1-\pi^s).(n^a_{i,t-1}-1)}\right) pp_{i,t-1} & t > t_{SPA} \end{cases} \tag{4}$$

$pp_{i,t}$ denotes private pension annuity, sp_t denotes state pension income, and χ is the annuity rate. The annuity purchased at age t_{SPA} is inflation linked, and reduces to a fraction π^s of its (real) value in the preceding year if one member of a couple departs the household, which reflects the impact of spousal mortality. This treatment of pension contributions and pension annuity income is based on the EET form of taxation that is applied in the UK, in common with most other OECD countries.

Where the household is identified as supplying labour, and is younger than state pension age, then non-property (employment) income is split between spouses (in the case of married couples) on the basis of their respective labour supplies. A household without an employed adult has all of its non-property (pension) income allocated to a single spouse. Similarly, property income is only allocated between spouses for households below state pension age, and who supply some labour. In this case, property income is allocated evenly between working couples. Property income, $y_{i,t}$, is equal to the return from positive balances of liquid net worth:

$$y_{i,t} = \begin{cases} r_{i,t} w_{i,t} & \text{if } w_{i,t} > 0 \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

Hence, the model assumes that the interest cost on loans (when $w_{i,t} < 0$) cannot be written off against labour income for tax purposes.

The interest rate on liquid net worth is deterministic, and depends upon whether $w_{i,t}$ indicates net investment assets or net debts:

$$r_{i,t} = \begin{cases} r^I & \text{if } w_{i,t} > 0 \\ r_l^D + \left(r_u^D - r_l^D\right) \min\left\{\frac{-w_{i,t}}{\max\left[g_{i,t}, 0.7g(h_{i,t}, l_{i,t}^{ft})\right]}, 1\right\}, r_l^D < r_u^D & \text{if } w_{i,t} \leq 0 \end{cases}$$

where $l_{i,t}^{ft}$ is household leisure when one adult in household i at age t is full-time employed. This specification for the interest rate implies that the interest charge on debt increases from a minimum of r_l^D when the debt to income ratio is low, up to a maximum rate of r_u^D, when the ratio is high. The specification also implies that households that are in debt are treated less punitively if they have at least one adult earning a full-time wage than if they do not.

Disposable income is given by:

$$\tau_{i,t} = \begin{cases} \hat{\tau}_{i,t} & \text{if } w_{i,t} \geq 0 \\ \hat{\tau}_{i,t} + r_t w_{i,t} & \text{otherwise} \end{cases} \tag{6}$$

$$\hat{\tau}_{i,t} = \begin{cases} x_{i,t} + y_{i,t} - tax_{i,t} + benefits_{i,t} - cc_{i,t} - hsg_{i,t} & \text{if } t < t_{SPA} \\ x_{i,t} + y_{i,t} - tax_{i,t} + benefits_{i,t} - hsg_{i,t} & \text{if } t \geq t_{SPA} \end{cases} \tag{7}$$

where $tax_{i,t}$ denotes the simulated tax burden, $benefits_{i,t}$ welfare benefits received, $cc_{i,t}$ non-discretional childcare costs net of associated benefits, and $hsg_{i,t}$ non-discretional housing costs net of associated benefits.

2.4 Pension saving

As is implicit in the above discussion, pensions are modelled at the household level, and are defined contribution in the sense that every household is assigned an account into which their respective pension contributions are (notionally) deposited. Pension wealth accrues a (post-tax) rate of return, r^p, which is certain. Prior to age t_{SPA}, all households with some employment in the prevailing year choose whether, and what fraction of their labour income, $\pi^{pc}_{i,t}$, to contribute to their pension, subject to the lower bound π^{pc}_0. Households that choose to participate in the pension during a given year also receive a matching employer contribution, equal to a fixed fraction of their employment income, π^p_{ec}. All pension contributions are tax exempt. The balance of household i's pension account at any age, $t < t_{SPA}$, is given by:

$$\begin{aligned} w^p_{i,t} &= \begin{cases} \pi_{div}\hat{w}^p_{i,t} & n^a_t < n^a_{t-1} \\ \hat{w}^p_{i,t} & \text{otherwise} \end{cases} \\ \hat{w}^p_{i,t} &= \begin{cases} (1+r^p)\, w^p_{i,t-1} + \left(\pi^{pc}_{i,t-1} + \pi^p_{ec}\right) g_{i,t-1} & \text{if } \pi^{pc}_{i,t-1} \geqslant \pi^{pc}_0 \\ (1+r^p)\, w^p_{i,t-1} & \text{otherwise} \end{cases} \end{aligned} \tag{8}$$

where $g_{i,t}$ denotes aggregate household labour income in period t, and all other variables are as defined previously.

2.5 Labour income dynamics

Three household characteristics influence labour income: the household's labour supply decision, the latent wage, $h_{i,t}$, and whether a wage offer $wo_{i,t}$ is received.[7] A wage offer is received at any age t with a relationship specific (exogenous) probability, $p^{wo}\left(n^a_{i,t}\right)$, which is included to capture the incidence of (involuntary) unemployment. If a household receives a wage offer, then its labour income for the respective year is equal to a fraction of its latent wage, with the fraction defined as an increasing function of its labour supply. A household that receives a wage offer and chooses to supply the maximum amount of labour receives its full latent wage, in which case $g_{i,t} = h_{i,t}$. A household that does not receive a wage offer is assumed to receive $g_{i,t} = 0$ regardless of its labour supply (implying no labour supply where employment incurs a leisure penalty).

Latent wages evolve as a random walk with drift:

$$\begin{aligned} \ln(h_{i,t+1}) - \ln(h_{i,t}) &= f_h\left(n^a_{i,t}, t\right) + \kappa\left(n^a_{i,t}, l_{i,t}\right) + \omega_{i,t} \\ g_{i,t} &= \mu\left(emp_{i,t}\right) h_{i,t} \end{aligned} \tag{9}$$

where $\kappa(.)$ is an experience effect, and $\omega_{i,t} \sim N\left(0, \sigma^2_{\omega, n^a_{i,t}}\right)$ is a household specific disturbance term. $\mu\left(emp_{i,t}\right)$ is a multiplicative adjustment factor that defines the proportion of the latent wage h obtained as an observed wage g, varying by employment status emp.

Most of the associated literature omits an experience effect from the wage process as this complicates solution of the utility maximisation problem by invalidating two-stage budgeting. Related studies have,

[7] Defining wage potential at the household level rather than at the level of the individual significantly simplifies the analytical problem by omitting the need to take account of a range of issues including the sex of employees, imperfect correlation of temporal innovations experienced by spouses, and so on.

however, found it difficult to match the high rates of labour market participation that are reported in survey data among the young relative to the old in context of the strong wage growth that is typically observed with age. French (2005) suggests that this consideration was behind the high estimated values that he reports for the discount factor. Career building appears to be a plausible explanation for the high rates of employment participation that are observed among people early in the working lifetime, and an experience effect is included to capture this. We have found this to be a useful device in matching profiles of employment participation in previous work; see Sefton et al. (2008) and Sefton & van de Ven (2009).

2.6 Household demographics

Household relationship status is modelled explicitly, and is uncertain from one year to the next. The probabilities of relationship transitions are described by the reduced form logit equation:

$$s_{i,t+1} = f_s(t) + \alpha^A s_{i,t} \tag{10}$$

where $s_{i,t}$ is a dummy variable, that takes the value 1 if household i is comprised of a single adult at age t and zero otherwise. The number of children in a household evolves in a deterministic fashion, based upon a household's age and relationship status, so that: $n_{i,t}^c = n^c\left(n_{i,t}^a, t\right)$.

2.7 Model solution

The allowance for uncertainty in the model implies that an analytical solution to the utility maximisation problem does not exist, so that numerical solution routines need to be employed. Starting in the last possible period of a household's life, T, uncertainty plays no further role and the optimisation problem is simple to solve for given numbers of adults n_t^a, liquid net worth w_T, and annuity income p_T, omitting the household index i for brevity. We denote the maximum achievable utility in period T, the value function, by $V_T(n_T^a, w_T, p_T)$:

$$V_T(n_T^a, w_T, p_T) = u\left(\frac{\widehat{c}_T\left(n_T^a, w_T, p_T\right)}{\theta_T}, 1\right) \tag{11}$$

$$W_T(n_T^a, w_T, p_T) = V_T(n_T^a, w_T, p_T) \tag{12}$$

where $\widehat{c}_T$ denotes the optimised measure of consumption, and leisure $\hat{l}_T = 1$ by assumption. V_T is solved at each node of the three dimensional grid over the permissable state space (n_T^a, w_T, p_T). W_T is an intermediate term that is stored to evaluate utility maximising solutions in period $T-1$; it is necessarily equal to V_T (as indicated above) in the final period, but may differ from V_T in earlier periods as is described below.

At time $T-1$, the problem reduces to solving the Bellman equation:

$$V_{T-1}(n^a_{T-1}, w_{T-1}, p_{T-1}) = \max_{c_{T-1}} \frac{1}{1-\gamma} \left\{ u\left(\frac{c_{T-1}}{\theta_{T-1}}, 1\right)^{1-\gamma} + \beta\delta\phi_{1,T-1} E_{T-1}\left[W_T(n^a_T, w_T, p_T)^{1-\gamma}\right] \right\} \quad (13)$$

$$W_{T-1}(n^a_{T-1}, w_{T-1}, p_{T-1}) = \frac{1}{1-\gamma} \left\{ u\left(\frac{\widehat{c}_{T-1}}{\theta_{T-1}}, 1\right)^{1-\gamma} + \delta\phi_{1,T-1} E_{T-1}\left[W_T(n^a_T, w_T, p_T)^{1-\gamma}\right] \right\} \quad (14)$$

subject to the intertemporal dynamics that are described above. Note that, $W_{T-1} \neq V_{T-1}$, if $\beta \neq 1$, which indicates the influence of time inconsistency in the context of myopic preferences. This optimisation problem is solved for the $T-1$ value function V_{T-1} and intermediate term W_{T-1} at each node of the three dimensional grid over the permissable state-space. Solutions for ages less than $T-1$ then proceed via backward induction, based upon the solutions obtained for later ages. Where labour supply is permitted, the state space expands to include latent wages h_t and wage offers wo_t. For ages under t_{SPA}, solutions are also required for pension contributions, and pension wealth replaces annuity income in the state space. A more complete description of the analytical problem, including the treatment of boundary conditions, is reported in van de Ven (2009).

Solutions to the optimisation problem are identified by searching over the value function, using Powell's method in multiple dimensions and Brent's method in a single dimension (see Press et al. (1986)). The expectations operator is evaluated in context of the log-normal distribution assumed for wages using the Gauss-Hermite quadrature, which permits evaluation at a set of discrete abscissae (five abscissae are used). Linear interpolation methods are used to evaluate the value function at points between the assumed grid nodes throughout the simulated lifetime.

Although the search routines that are used are efficient when the objective function is reasonably well behaved, they are not designed to distinguish between local and global optima. A supplementary search routine is consequently used, which tests over a localised grid above and below an identified optimum for a preferred decision set. If a preferred decision set is identified, then the supplementary routine searches recursively for any further solutions. This process is repeated until no further solutions are found. Of all feasible solutions, the one that maximises the value function is selected.

Having solved for utility maximising behavioural responses at grid nodes as described above, the life-courses of individual households are simulated by running households forward through the grids. This is done by first populating a simulated sample by taking random draws from a joint distribution of all potential state variables at the youngest age considered for analysis. The behaviour of each simulated household, i, at the youngest age is then identified by interpolating over the decisions stored about their respective grid co-ordinates. Given household i's characteristics (state variables) and behaviour, its characteristics are aged one year following the processes that govern their intertemporal variation. Where these processes depend upon stochastic terms, new random draws are taken from their respective distributions (commonly referred to as Monte Carlo simulation). This process is repeated for the entire simulated life of each household. The data generated for the simulated cohort are then used as the basis for estimation and analysis.

3 Parameter Estimates

3.1 Estimation method

The parameters of the model described in Section 2 were estimated by the Method of Simulated Moments (MSMs), which is now fairly standard in comparable analytical contexts.[8] The approach estimates the model in two discrete stages. In the first stage, parameters that are exogenously observable are estimated without reference to the structural model. Estimates for unobserved parameters are then estimated endogenously to the model in a second stage, taking the parameter estimates calculated in the first stage as given. The endogenous estimation of the second stage is conducted by matching the population moments for a selected set of characteristics that are implied by the structural model (simulated moments) to associated moments estimated from survey data (sample moments). This matching is undertaken by minimising a weighted loss function of the difference between the simulated and sample moments, where the weighting matrix is optimally designed to capture uncertainty over the model parameters estimated in the first stage.

3.2 Data

One of the most important tasks involved in estimating the model by the MSMs is the identification of the moments upon which the second stage of the estimation is based. This task is complicated here by the fact that it is not immediately clear what moments are likely to provide useful descriptive power for identifying quasi-hyperbolic discount rates. The statistical analysis that is reported here is structured around the observation that sophisticatedly myopic consumers will attach some value to commitment mechanisms that resolve the conflict between the preferences of different intertemporal selves[9] in favour of the present self. To this end, the second stage of the estimation includes moments over decisions regarding pension scheme participation and labour supply, given the wage processes that are described in Section 2.5. See Laibson et al. (2007) and Fang & Silverman (2007) for closely related empirical studies.

Accommodating endogenous labour supply decisions complicates the analysis because such decisions have an important bearing on marginal tax rates, which in turn bear upon coincident savings and investment decisions. These considerations mean that it is not possible to abstract from the tax and

[8] See, for example, Gourinchas & Parker (2002), Cagetti (2003), French (2005), Chatterjee et al. (2007), Nardi et al. (2009).

[9] Diamond and Köszegi, 2003, p. 1840

benefits structure by focussing exclusively on disposable income, so that taxes and benefits must be explicitly accounted for (as described in the preceding section). Allowing for taxes and benefits complicates estimation of the model because of the scale and frequency of tax policy reform. The current estimates are based on data for a population cross-section, because these describe decision making in context of a single policy environment (controlling for time effects). Financial statistics reported in the cross-sectional data are adjusted to reflect real wage growth, to capture expectations that individuals may reasonably have over how financial circumstances evolve with age (controlling for age effects). And, the estimates are based on data for a generational age band of 25 to 45 year olds because cross-sectional data do not describe the heterogeneous circumstances of different birth cohorts (controlling for cohort effects). This last observation is particularly relevant in the current context, where recent reforms to the UK pensions system substantially alter the circumstances of workers distinguished by year of birth. The 25 to 45 year old age band was selected because it is the period in life when the illiquidity of pension wealth is likely to have the most pronounced influence on behaviour in context of time inconsistent preferences.

3.3 First stage parameter estimates

The structural model is based upon a total of 395 parameters. 3 of these describe interest rates on liquid net worth; 13 parameters describe the evolution of household demographics (relationship status and dependant children); 101 parameters describe age specific probabilities of mortality; 50 parameters describe the earnings processes for singles and couples; 210 parameters describe the tax and benefits system; 13 parameters describe the nature of personal pensions; and 5 parameters describe household preferences. All but the five preference parameters were estimated exogenous of the structural model.

The 390 parameters estimated in the first stage are reported in Tables 1 to 4.

3.3.1 Credit constraints, real interest rates, and growth rates

Households cannot borrow in excess of £2,000 at any age, subject to the condition that all debts be repaid by age 65, as reported in Table 4. Real interest and growth rates are reported in the top panel of Table 1. The lower limit cost of debt $\left(r_l^D\right)$ was set to 11.5 percent per annum, and the upper limit $\left(r_u^D\right)$ to 19.8 percent, which reflects the range of average real interest charges applied between January 1996 and January 2008 to credit card loans and overdrafts in the UK. Positive balances of liquid net worth were assumed to earn a return $\left(r^I\right)$ of 2.7 per cent per annum, equal to the average real return on fixed rate bond deposits held with banks and building societies during the period between January 1996 and January 2008. The return to pension wealth $(r_t^p = r^p)$ was set equal to 4.1 per cent per annum based on the average return to capital described in the UK National Accounts between 1988

Table 1: Exogenously estimated model parameters – various characteristics

real interest & growth rates (% p.a.)

	credit cards	overdrafts	fixed rate deposits	return to capital	wages	benefits	tax threshold
average	15.28	13.92	**2.73**	**4.05**	**1.27**	**-0.08**	**0.33**
std deviation	3.15	1.31	1.21	0.79	0.97	1.73	0.84
minimum	12.08	**11.52**	1.25	2.59	-0.31	-3.79	-0.79
maximum	**19.81**	15.34	4.66	5.29	2.75	4.40	1.43
sample period	'96-'08	'96-'08	'96-'08	'88-'06	'90-'07	'78-'08	'97-'07

household demographics

logit regression for singles / couples		
variable	coefficient	std. error
constant	**-6.40607**	0.34372
age	**0.17634**	0.02226
age^2	**-3.76E-03**	4.47E-04
age^3	**2.66E-05**	2.79E-06
single	**6.89326**	0.03963
sample	97619	
R squared	0.7947	

proportion of households single at age 20*	**0.45**
all households single from age*	**100**

non-linear regressions for number of children	singles		couples	
variable	coefficient	std. error	coefficient	std. error
param0	**0.67268**	0.00041	**1.54100**	0.00053
param1	**-0.00776**	0.00001	**-0.00711**	0.00001
param2	**38.2792**	0.0056	**39.7949**	0.0037
sample	13527		10438	
R squared	0.203		0.5258	

*mortality probabilities from age 40**

age	probability	age	probability	age	probability	age	probability
40	**0.0001**	60	**0.0006**	80	**0.0105**	100	**0.2964**
41	**0.0000**	61	**0.0005**	81	**0.0116**	101	**0.3607**
42	**0.0000**	62	**0.0007**	82	**0.0129**	102	**0.4278**
43	**0.0001**	63	**0.0012**	83	**0.0167**	103	**0.4951**
44	**0.0000**	64	**0.0011**	84	**0.0176**	104	**0.5607**
45	**0.0001**	65	**0.0014**	85	**0.0225**	105	**0.6230**
46	**0.0001**	66	**0.0016**	86	**0.0243**	106	**0.6810**
47	**0.0000**	67	**0.0012**	87	**0.0262**	107	**0.7341**
48	**0.0001**	68	**0.0023**	88	**0.0310**	108	**0.7818**
49	**0.0002**	69	**0.0021**	89	**0.0408**	109	**0.8237**
50	**0.0002**	70	**0.0020**	90	**0.0503**	110	**0.8598**
51	**0.0001**	71	**0.0025**	91	**0.0548**	111	**0.8904**
52	**0.0002**	72	**0.0033**	92	**0.0610**	112	**0.9157**
53	**0.0003**	73	**0.0036**	93	**0.0632**	113	**0.9363**
54	**0.0002**	74	**0.0051**	94	**0.0834**	114	**0.9527**
55	**0.0003**	75	**0.0045**	95	**0.0935**	115	**0.9654**
56	**0.0004**	76	**0.0049**	96	**0.1139**	116	**0.9752**
57	**0.0003**	77	**0.0068**	97	**0.1449**	117	**0.9826**
58	**0.0005**	78	**0.0085**	98	**0.1865**	118	**0.9879**
59	**0.0008**	79	**0.0095**	99	**0.2375**	119	**0.9918**

Notes: model parameters in bold
* no standard errors obtained
benefits growth rate estimated on historical rates for unemployment benefits and the basic state pension
relationship status modelled as a logit regression, describing the risk of being single as a function of age, and whether single in preceding year
number of children by age described by the density function of the normal distribution:
param0 exp(param1 (age - param2)) - see Section 5.5
mortality probabilities calculated on cohort life expectancies for couples where both members aged 35 in 2007.

Source: credit card interest, Bank of England IUMCCTL; overdraft interest, Bank of England IUMODTL
fixed deposit interest, Bank of England, IUMWTFA; wages growth, Office National Statistics, LNMQ
return to capital derived from Khoman and Weale (2008), based on National Accounts data income flows
historical data on value of unemployment benefits, basic state pension, and tax thresholds obtained from the Institute for Fiscal Studies
logit for relationship status estimated on weighted pooled data from waves 1 to 17 of the BHPS
equation for the number of children by age estimated on weighted data from the 2007/08 FRS
mortality rates based on historical survival rates to 2006 and ONS principal projections thereafter.

Table 2: Exogenously estimated model parameters – earnings process

*probability of low wage offer^*			
	mean	std dev	sample
singles	**0.29382**	0.45551	3939
couples	**0.06523**	0.24694	3531

*weekly wages and working hours by relationship and employment status^*						
relationship status	couple	couple	couple	couple	single	single
adults full-time emp	2	1	1	0	1	0
adults part-time emp	0	1	0	1	0	1
working hours						
mean	**85.10**	**67.09**	**44.73**	**19.03**	**42.40**	**20.07**
std. deviation	12.54	13.08	10.49	8.55	8.50	9.28
log wages						
mean	**6.822**	**6.612**	**6.175**	**4.841**	**5.924**	**4.707**
std. deviation	0.475	0.511	0.724	0.756	0.569	0.722
sample	2530	1814	1840	509	4352	1360

*distribution of wages at age 20^*	singles		couples	
	coefficient	std. error	coefficient	std. error
mean of (log) full-time wage, age 20	**5.74605**	0.00043	**6.29821**	0.00161
standard deviation of full-time wage, age 20	**0.39571**	.	**0.10445**	.

*wage dynamics for households changing marrital status**	newly weds		newly single	
	coefficient	std. error	coefficient	std. error
target equation				
constant	**0.06442**	0.06714	**0.02537**	0.08270
age	**-0.00797**	0.00198	**0.00016**	0.00180
employment (single) / employment (couple)				
part time / 1 part time	**-0.14154**	0.06627	**-0.02215**	0.12454
part time / 1 full time	**0.47775**	0.29080	**-1.55863**	0.21295
part time / 1 part time & 1 full time	**1.44259**	0.13195	**-1.50337**	0.06714
part time / 2 full time	**1.87653**	0.19665	**-1.65264**	0.21921
full time / 1 part time	**-1.61412**	0.42382	**0.65706**	0.04307
full time / 1 part time & 1 full time	**0.29650**	0.06387	**-0.34763**	0.04923
full time / 2 full time	**0.64900**	0.03275	**-0.63573**	0.03626
selection equation				
age	0.04772	0.02525	0.12171	0.02444
age squared	-0.00085	0.00032	-0.00156	0.00030
degree	-1.08084	0.12228	1.24433	0.11370
other further education	-1.07942	0.11253	1.15538	0.09038
higher school qualification (A level)	-1.07025	0.11781	1.10500	0.10204
lower school qualification (O level)	-1.12394	0.11623	1.01499	0.09083
other education	-1.61396	0.15082	0.82185	0.10304
poor health	-0.27916	0.11064	-0.30229	0.10154
accident	-0.17709	0.09139	0.45756	0.08773
childcare	-0.37326	0.09748	-0.27075	0.07306
care (other)	-0.10474	0.10116	0.00110	0.08468
woman	-0.80629	0.07546	1.51969	0.18730
constant	0.68686	0.46202	-5.81684	0.50812
summary statistics				
correlation	0.69441	0.07586	-0.09977	0.102915
standard error	**0.40089**	0.02385	**0.36413**	0.015331
Number of (weighted) observations	2742		2517	
Censored observations	2163		2012	
Uncensored observations	579		505	
Log pseudolikelihood	-1194.495		959.637	
Wald test of independent equations				
Chi squared statistic	34.17		0.93	
p value	0.00		0.34	

Notes: model parameters in bold
prob of low wage offer = proportion of households aged 25-45 with no adult employment
mean log income at age 20 estimated using sample selection model - reported in Appendix
std of log income at age 20 calculated from raw survey data, no std errors obtained
dependent variables in equations for wage dynamics = (ln(observed wage(t+1)) - ln(observed wage(t)))

Source: ^ author's calculations on data from 2007/08 wave of the FRS
* author's calculations on data from waves 1 to 17 of the BHPS

Table 3: Estimated wage dynamics for households not changing marital status

	singles		couples	
	coefficient	std. error	coefficient	std. error
target equation				
age*	**-0.0018**	0.0001	**-0.0012**	0.0001
experience effect				
1 full-time & 1 part-time emp	.	.	**-0.0101**	.
1 ful-time employed	.	.	**-0.0120**	.
1 part-time employed	**-0.0170**	.	**-0.0144**	.
not employed	**-0.0350**	.	**-0.0200**	.
constant	**0.1047**	0.0054	**0.0777**	0.0043
selection equation				
age*	0.0911	0.0072	0.1013	0.0061
age squared*	-0.0012	0.0001	-0.0012	0.0001
highest education qualification				
no education qual recorded	-0.1467	0.0889	-0.1303	0.0537
lower school (O-level D-E)	0.0494	0.1266	-0.0055	0.0664
mid school (O-level A-C)	0.1763	0.0726	0.0228	0.0445
higher school (A-level)	0.1360	0.0809	0.0520	0.0561
post-school qualification	-0.0795	0.0646	-0.0748	0.0528
poor health	-0.6752	0.0701	-0.3693	0.0407
accident	-0.0173	0.0527	-0.0581	0.0295
childcare	-0.8101	0.0737	-0.2820	0.0369
care (other)	-0.0636	0.0675	-0.1411	0.0323
woman	-0.0709	0.0615	.	.
Standard Occupational Classification				
manager, admin, prof	1.9272	0.0783	0.7528	0.0509
assoc prof, technical, clerical	1.4495	0.0727	0.6791	0.0481
craft, personal protective	1.6056	0.0720	0.6975	0.0464
sales, plant, machinery	1.6544	0.0793	0.7077	0.0497
constant	-3.9136	0.2534	-3.7755	0.2456
summary statistics				
correlation*	0.0706	0.0336	0.1078	0.0312
standard error*	**0.1153**	0.0023	**0.0928**	0.0013
Number of (weighted) obs	12671		20682	
Censored observations	6346		8385	
Uncensored observations	6325		12297	
Log pseudolikelihood	-5471.04		-8021.352	
Wald test of independent equations				
Chi squared statistic	4.38		11.75	
p value	0.0364		0.0006	
Wald test of linear constraints				
Chi squared statistic	2.42		2.87	
p value	0.2979		0.5791	

Source: Wage dynamics estimated on data from waves 1 to 17 of the BHPS

Notes: model parameters in bold
Estimates using a sample selection model with robust standard errors
Endogenous variable = (log emp inc in period (t+2) - log emp inc in period (t))
Experience effect calculated on observed labour market status in periods t and (t+1)
Wage dynamics equation based on dummy variables, except those denoted by *

Table 4: Pension parameters and credit constraints distinguished by estimation scenario

	singles	couples
maximum credit	£2,000	£2,000
all debts repaid by age	65	65
state pension age*	68	68
value of flat-rate state pension (£2006 per week)	121.50	243.00
*means tested retirement benefits***		
maximum value (£2006 per week)	31.76	41.89
withdrawal rate of benefits on private income	40%	40%
terms of private pensions		
employee contribution rate (% of earnings)	8	8
employer contribution rate (% of earnings)	11	11
min earnings threshold for eligibility (% median)	75	75

Source: Terms of state retirement benefits based on Pensions White Paper, DWP (2006b)
Notes: * See DWP (2006b), paragraph 3.34
** paid on top of flat-rate state pension
no standard errors obtained

and 2006, as reported by Khoman & Weale (2008). The real rate of wage growth, used to adjust cross-sectional sample statistics, was set to 1.3 percent per annum, equal to the real growth observed for the average earnings index between 1990 and 2007. Welfare benefits were assumed to fall very marginally with time (annual rate of 0.1%), to reflect historical data over the period 1978 to 2008 on the value of unemployment benefits and the basic state pension. Similarly, real tax thresholds were assumed to rise by 0.3 percent per annum, based on growth of the income threshold for the highest rate of income tax over the period 1997 to 2007.

3.3.2 Household demographics

It was assumed that a household can be comprised of one or two adults to age 99, and of a single adult from age 100. The logit function that governs relationship transitions in the model was selected after considering various alternatives, and is described by equation (15). The intertemporal dynamics of relationship status that is described by equation (15) require data with a time dimension for estimation. The parameters of this logit model were consequently estimated on pooled data from waves 1 (1991) to 17 (2007) of the British Household Panel Survey (BHPS), reorganised by family unit, and screened to omit any unit by year that had missing data, or that had adult members who were either self employed or employees in public sector organisations with access to non-contributory occupational pensions.[10] The parameter estimates of this logit model are reported on the left hand side of the middle panel of Table 1.

The numbers of children by age and relationship status were described by equation (16) (the density function of the normal distribution). This function provides a close reflection of the average numbers of children of singles and couples by age described by survey data. As estimation of equation (16) does

[10] Public sector employees omitted from analysis were identified under Standard Industrial Classification codes 9100-9199 (1980) / 75 (1992).

not require data with a time-series dimension, associated estimates were calculated on cross-sectional data from the 2007/08 Family Resources Survey (FRS). As for the BHPS data referred to above, the FRS data were organised at the level of the family (benefit) unit, and screened to omit observations with inconsistent data. Estimates for equation (16) are reported on the right hand side of the middle panel of Table 1.

$$s_{i,t+1} = \alpha_0^A + \alpha_1^A t + \alpha_2^A t^2 + \alpha_3^A t^3 + \alpha_4^A s_{i,t} \tag{15}$$

$$n_{i,t}^c = \alpha_0^C \exp\left\{\alpha_1^C \left(t - \alpha_2^C\right)^2\right\} \tag{16}$$

3.3.3 Mortality probabilities by age

The survival probabilities assumed for estimating the model are based upon the cohort expectations of life published by the Office for National Statistics (ONS). These data were used to calculate the age specific probabilities of survival for a couple, where both members of the couple were aged 35 in 2007 (the middle of the target age band for estimation). The life expectancies are based on historical survival rates from 1981 to 2006, and calendar year survival rates from the 2006-based principal projections that embody official estimates for the trend improvement of future survival rates.

The official data permit survival rates to be calculated to age 94, whereas a maximum age of 120 is assumed in the model. Age specific survival probabilities between 95 and 120 were exogenously adjusted to describe a smooth sigmoidal progression from the official estimate at age 94 to a 0 per cent survival probability at age 120. The mortality rates considered for analysis are reported at the bottom of Table 1.

3.3.4 The probability of a low wage offer

Previous experience in use of the structural model revealed that wages tend to be sufficient to motivate some labour supply by almost all households during the prime working years spanning ages 25 to 45. The probability of a low wage offer (see Section 2.5) was consequently set to the proportion of single adults and couples that were identified as not working within this age band, as described by data reported by the 2007/08 wave of the FRS (described in subsection 3.3.2). The associated sample statistics are reported in the top panel of Table 2.

3.3.5 Distinguishing the implications of alternative labour supply decisions

Single adults were considered to choose between full-time employment, part-time employment, and not employed. Couples were considered to choose between 2 full-time employed, 1 full-time and 1 part-time employed, 1 full-time employed and 1 not employed, 1 part-time employed and 1 not employed, and 2 not employed; the option to allow for 2 part-time employed adults in a household was omitted because very few households take up this option in practice. The influence of alternative labour supply decisions on leisure and income from employment were defined as non-stochastic and age invariant proportions of the respective statistics associated with the maximum employment decision (full-time employment of all adult household members). These proportions were estimated using data for households aged between 20 and 59 from the 2007/08 FRS, organised and screened as described in subsection 3.3.2. Weighted averages were calculated for the number of hours worked and log wages, distinguishing population sub-samples by the number of adults in a household and labour market status.[11] These statistics are reported toward the top of Table 2.

3.3.6 The distribution of wages at age 20

Each simulated household that is generated by the model (discussed in Section 2.7) was allocated a latent wage at age 20 by taking a random draw from a log normal distribution. The mean and variance of the distribution for singles and couples of log latent wages at age 20 were estimated on the same FRS data that were used to estimate the implications of alternative labour supply decisions (described above). A sample selection model that describes log wages as a cubic function of age was estimated separately for singles and couples.[12] These estimates were used to calculate the means for singles and couples of log full-time wages at age 20 that were assumed in the second stage estimation. The standard deviations of the log-normal distributions were set equal to the FRS sample statistics observed for the respective population subgroups at age 20. These statistics are reported in the middle panel of Table 2.

3.3.7 Labour income dynamics

An experience effect was only taken into consideration where relationship status remained unchanged between adjacent periods. To estimate an experience effect over the extensive labour margin, recursive substitution was used to restate equation (9) as:

$$\begin{aligned} \ln\left(g_{i,t+2}\right) - \ln\left(g_{i,t}\right) &= \ln\left(\mu\left(emp_{i,t+2}\right)\right) - \ln\left(\mu\left(emp_{i,t}\right)\right) + .. \\ &\quad + f_h\left(n_{i,t}^a, t\right) + f_h\left(n_{i,t+1}^a, t+1\right) + .. \\ &\quad + \sum_{k=t}^{t+1}\sum_{j=1}^{n}\kappa_j\left(emp_{i,k}^j\right) + \omega_{i,t+1} + \omega_{i,t} \end{aligned} \tag{17}$$

where n is the number of potential labour states, $emp_{i,t}^j$ is a dummy variable that is equal to 1 if household i engages in employment state j at age t and zero otherwise, and κ_j denotes the respec-

[11] The International Labour Organization (ILO) definition of labour market status was used for the estimations. Age invariant statistics were applied after observing little systematic variation by age.

[12] The sample selection model controlled only for the incidence of non-employment. Households with adults who were less than full-time employed had their aggregate wage adjusted up on the basis of the respective statistics discussed in subsection 3.3.5.

tive experience effect; all other variables are as defined previously.[13] Where relationship status was observed to change between adjacent periods, omission of an experience effect enabled equation (9) to be estimated directly.

The time dimension that is embedded in the specification of the equations that govern intertemporal wage dynamics made the FRS an unsuitable data source for estimation. Data from the BHPS for households aged between 20 and 64 were consequently used for estimation, organised and screened as described in subsection 3.3.2. The sample for estimation was extended beyond the 25 to 45 year old age band to limit the influence of boundary effects in relation to estimated polynomials by age, and to provide a plausible description for agent expectations regarding later ages.

The pooled BHPS data were divided into four population sub-groups distinguished by the marital transitions observed in adjacent years. Each sub-sample was then censored to omit extreme observations on the respective dependent variable ($\ln(g_{i,t+2}) - \ln(g_{i,t})$ or $\ln(g_{i,t+1}) - \ln(g_{i,t})$), resulting in sample sizes for estimation of 18,631 for continuously single adults, 27,831 for continuously married families, 3,850 newly married families, and 3,705 newly single families. Separate estimates were calculated on the data for each of these population subgroups, correcting for sample selection and heteroscedasticity of error terms.[14]

The results of unrestricted estimations are reported for newly married and newly single households in Table 2. In the case of continuously single / married households, unrestricted estimates indicate that the effects of experience on prospective wages were estimated with relatively high standard errors. These were amended to the extent permitted by the data, to ensure that experience was a monotonically increasing function of employment. The regression parameters obtained after restricting the effects of experience are reported in Table 3.

3.3.8 Taxes and benefits

The wedge between gross private income and disposable income was calculated by dividing the life course into two periods. Taxes and benefits during the working lifetime, $t < t_{SPA}$, were structured to fully reflect the schedules for alternative household demographic categories that are reported in the April 2007 edition of the *Tax Benefit Model Tables* (TBMT), issued by the Department for Work and Pensions (see http://www.dwp.gov.uk/asd/tbmt.asp). During the period of pension receipt, $t_{SPA} \leq t$, the model was designed to reflect income taxes in 2007, and was loosely defined around the system of retirement benefits set out in the 2006 Pensions White Paper (DWP, 2006b). This last decision reflects the fact that the White Paper was both freely available and widely publicised during the period

[13] Estimates were also obtained for two recursive substitutions (a dependent variable of $\ln(g_{i,t+3}) - \ln(g_{i,t})$), which were found to be qualitatively the same as those reported here.

[14] Full maximum likelihood estimation was undertaken using the "heckman" command in STATA 10, adjusting for enumeration weights, and allowing for clustering by enumerated individual in the error terms.

covered by the estimation, and represents a sensible information source upon which an individual from the target cohort could have based their expectations during the sample period covered by the data. In line with the pensions White Paper, the model assumes a state pension age of 68. At this age, all individuals are assumed to be eligible to a full flat-rate state pension, which reflects the expanded coverage of state pensions implemented by the reforms described in the 2006 White Paper, and the coincident amendments to make state pensions a flat-rate benefit worth around £135 per week to a single pensioner in 2006 earnings terms. Means-tested benefits subject to a 100% clawback rate are assumed to keep pace with the increased generosity of the flat-rate state pension, so that they can be ignored. The (real) value of means tested benefits subject to a 40% clawback rate are set out by the 2006 White Paper to grow with wages between 2008 and 2015, and to be frozen in real terms thereafter. The model applies a 10% discount to the value of these state retirement benefits, to reflect on-going concerns over their sustainability.[15]

3.3.9 Private pensions

Pension contributions and associated investment returns were assumed to be tax exempt. The annuity rate, χ, was specified as actuarially fair, given the assumed mortality rates, the return on pension wealth, and subject to a one-time capital charge of 4.7 per cent to reflect administration expenses and uncertainty over mortality rate projections.[16] The proportion of pension wealth used to purchase an annuity at state pension age was set to 75%, based on the maximum pension wealth that could be taken as a tax free lump-sum at retirement in 2006.

3.4 Estimated Preference Parameters

3.4.1 Moments for the second stage estimation

The unobserved preference parameters of the model were estimated by minimising the disparity – as measured by a weighted loss function – between simulated and sample moments over four sets of population characteristics. A set of age and relationship specific rates of *pension scheme membership* were included on the hypothesis that these might be important in identifying the short-run discount factor. Age and relationship specific means of log household *consumption* are important in determining discount factors and the isoelastic parameter γ, given first-stage estimates for rates of investment return. Moments of *employment status by age* and relationship status relate closely to the utility price of leisure, and may also bear upon the short-run discount factor (due to the commitment mechanism

[15] The benefits adopted for analysis apply a discount relative to the following: a state pension of £135 per week per adult in current earnings terms, a means tested benefit subject to a claw back rate of 40% that is worth up to £35.29 per week for singles and £46.54 per week for couples. The upper bounds of means tested benefits were obtained by adjusting the maximum value of the savings credit payable in 2006 by a real growth rate of 1% per annum for 17 years (between 2008 and 2015).

[16] This resulted in an annuity rate of 6.06% for estimation. The 4.7% capital charge is based on "typical" pricing margins reported in the pension buy-outs market in the UK. See Lane et al. (2008), p. 22.

offered by wages that respond to an experience effect). And rates of *employment participation by wealth quintile* observed late in the working lifetime were considered to improve identification over the intratemporal elasticity ε, following Sefton et al. (2008). All but the last set of moments conditions describe circumstances over the target age band 25 to 45, with the last focussing on the age band 50 to 59 to capture retirement behaviour.

Data on the magnitude of pension contributions, and the contributions of employers in particular, are not available at the household level in the UK. The endogenous pension decision was consequently restricted to focus upon pension participation when conducting the estimation, and was later relaxed to consider the scale of pension contributions for the policy analysis that is reported in Section 4. The pension contribution rate for employees who choose to participate in a private pension was set to 8 per cent of employee earnings, which is the 'normal' contribution rate stated in the guidance to interviewers for the FRS. The rate of matching employer contributions (paid into pensions of participating employees) was set to 11 percent of employee earnings, which is the average contribution rate to employer sponsored pensions that is reported in Forth & Stokes (2008). The moments considered for estimating the model preference parameters are reported in Table 5.

3.4.2 Parameter estimates

Table 6 reports estimation statistics for regressions over the full set of preference parameters. Starting with the results reported for the model specification based on the assumption of exponential discounting, the point estimate of the discount factor implies a discount rate of 3.2 percent per annum, which is insignificantly different from the estimated rate of return to positive balances of liquid net worth described in Section 3.3. The relative values of the point estimates obtained for the isoelastic parameter γ and the intratemporal elasticity ε imply that leisure and consumption are direct complements in utility.[17] But the large standard errors obtained for these parameter estimates imply that this relationship between consumption and leisure is not statistically significant. The estimated parameters also imply an intertemporal elasticity of substitution in consumption of 0.13 measured at the population means. This lies within the (admittedly wide) range of values that have been reported for this behavioural relation in the associated empirical literature.

Relaxing the specification to allow for quasi-hyperbolic discounting obtains an estimate for the excess short-run discount factor of 0.846, which is significantly less than one. The fall in the short-run discount factor is partly off-set by a coincident rise in the estimate obtained for the long-run discount factor from 0.969 to 0.976. Hence the regression results provide empirical support to the proposition that the discount rate associated with the first prospective year – at 21 percent – exceeds the long-run

[17] The assumed preference relation implies that the sign of the partial derivative of utility with respect to both consumption and leisure is given by $(1/\varepsilon - \gamma)$, so that it is positive based on the point estimates reported here.

Table 5: Moments considered for second stage estimation

	estimate	variance	sample
males aged 50 to 59 not economically active: lowest wealth quintile / highest wealth quintile	2.2429	0.0650	379

	proportion participating in employer sponsored pensions						*mean ln(consumption)*					
	singles			couples			singles			couples		
age	estimate	variance	sample	estimate	variance	sample	estimate	variance	sample	estimate	variance	sample
25	0.1483	0.1263	262	0.4071	0.2414	78	5.2273	0.7022	61	6.1993	0.4252	16
26	0.1980	0.1588	287	0.4012	0.2402	95	5.2845	0.8906	58	5.9442	0.4234	21
27	0.1988	0.1593	224	0.4294	0.2450	135	5.2998	0.9692	61	6.1538	0.5407	35
28	0.2464	0.1857	192	0.4934	0.2500	147	5.5013	0.6704	62	6.1765	0.5091	43
29	0.3242	0.2191	195	0.5494	0.2476	105	5.3634	0.9119	58	6.3905	0.4750	45
30	0.2247	0.1742	178	0.5770	0.2441	146	5.6775	0.8520	44	6.2908	0.4693	46
31	0.3536	0.2286	163	0.5428	0.2482	127	5.6052	0.7938	42	6.3497	0.5038	49
32	0.2827	0.2028	156	0.5325	0.2489	156	5.5502	0.7894	38	6.5598	0.3619	49
33	0.3203	0.2177	161	0.5174	0.2497	162	5.5827	0.7678	44	6.4610	0.4157	43
34	0.3336	0.2223	171	0.6308	0.2329	174	5.8206	0.6098	25	6.3963	0.5789	54
35	0.2910	0.2063	180	0.5582	0.2466	191	5.7254	0.9171	51	6.3657	0.5303	58
36	0.2907	0.2062	196	0.6112	0.2376	201	5.5911	0.8021	50	6.5152	0.5086	67
37	0.2581	0.1915	171	0.5291	0.2492	230	5.4818	0.8427	34	6.5286	0.4897	57
38	0.2924	0.2069	193	0.5885	0.2422	206	5.7905	0.6925	48	6.5678	0.4835	61
39	0.2521	0.1886	163	0.5664	0.2456	234	5.6120	0.8574	51	6.6305	0.4655	50
40	0.3029	0.2112	170	0.5840	0.2429	205	5.7306	0.7470	44	6.6838	0.5741	58
41	0.2951	0.2080	178	0.6234	0.2348	214	5.7790	0.6744	48	6.5583	0.4752	77
42	0.3581	0.2299	215	0.5788	0.2438	252	5.9342	0.7383	52	6.5614	0.6287	59
43	0.3268	0.2200	210	0.6386	0.2308	220	5.8971	0.8861	48	6.4836	0.4362	51
44	0.3986	0.2397	171	0.6795	0.2178	171	5.7790	0.8138	54	6.6471	0.5647	61
45	0.3434	0.2255	185	0.6209	0.2354	207	5.5147	0.7423	48	6.6077	0.5090	69

	proportion employed full-time						*proportion employed part-time*					
	singles			couples			singles			couples		
age	estimate	variance	sample	estimate	variance	sample	estimate	variance	sample	estimate	variance	sample
25	0.6649	0.2228	262	0.7202	0.2015	78	0.1059	0.0947	262	0.1088	0.0969	78
26	0.6063	0.2387	287	0.7057	0.2077	95	0.1199	0.1055	287	0.1051	0.0941	95
27	0.6131	0.2372	224	0.7097	0.2060	135	0.1059	0.0947	224	0.1170	0.1033	135
28	0.6737	0.2198	192	0.7731	0.1754	147	0.0949	0.0859	192	0.0757	0.0700	147
29	0.6018	0.2396	195	0.7002	0.2099	105	0.1056	0.0944	195	0.1105	0.0983	105
30	0.6259	0.2341	178	0.7345	0.1950	146	0.0758	0.0700	178	0.1044	0.0935	146
31	0.6936	0.2125	163	0.7148	0.2039	127	0.0618	0.0580	163	0.1305	0.1134	127
32	0.6559	0.2257	156	0.7366	0.1940	156	0.0858	0.0784	156	0.0930	0.0844	156
33	0.6240	0.2346	161	0.6490	0.2278	162	0.0834	0.0765	161	0.1324	0.1149	162
34	0.6573	0.2253	171	0.7117	0.2052	174	0.0820	0.0753	171	0.1347	0.1165	174
35	0.6089	0.2381	180	0.6710	0.2208	191	0.0926	0.0840	180	0.1062	0.0949	191
36	0.5826	0.2432	196	0.6611	0.2240	201	0.1022	0.0918	196	0.1456	0.1244	201
37	0.5726	0.2447	171	0.6512	0.2271	230	0.1144	0.1013	171	0.1553	0.1312	230
38	0.5400	0.2484	193	0.6304	0.2330	206	0.1644	0.1374	193	0.1525	0.1292	206
39	0.4748	0.2494	163	0.6334	0.2322	234	0.1688	0.1403	163	0.1776	0.1461	234
40	0.5264	0.2493	170	0.6080	0.2383	205	0.1480	0.1261	170	0.1802	0.1477	205
41	0.5029	0.2500	178	0.6114	0.2376	214	0.1569	0.1323	178	0.1753	0.1445	214
42	0.5444	0.2480	215	0.6503	0.2274	252	0.1484	0.1264	215	0.1808	0.1481	252
43	0.5759	0.2442	210	0.6494	0.2277	220	0.1720	0.1424	210	0.1947	0.1568	220
44	0.5404	0.2484	171	0.6232	0.2348	171	0.1477	0.1259	171	0.1811	0.1483	171
45	0.5009	0.2500	185	0.6398	0.2304	207	0.1448	0.1239	185	0.1881	0.1527	207

Source: employment and pension statistics estimated on FRS data, 2007/08
all consumption moments estimated on 2007 EFS data, for households aged 25 to 45
economic activity by wealth quintile derived from Marmot, *et al.* (2003, p. 156).

discount rate – at 2.5 percent per annum. Comparing the target moments that are reported in the bottom half of the panel reveals that allowing for quasi-hyperbolic discounting improves the match obtained between the model and sample moments over pension participation and labour supply; the match to moments for consumption, by contrast, deteriorate very slightly. These results are consistent with the set of hypotheses upon which the empirical study is based; that an allowance for sophisticated myopia might help to better explain observed behaviour over margins that have the potential to serve as commitment mechanisms, consumption obviously not being one of these.

It is of note that the current results reflect less pronounced myopia than is implied by the estimated discount rates reported in the small number of studies that exist. Laibson et al. (2007), for example report estimates for the short-run discount factor of 0.674 / 0.687 compared with 0.958 / 0.960 for the long-run discount factor, and Fang & Silverman (2007) report 0.296 / 0.308 compared with 0.875 / 0.868. This disparity with the results that are reported here is probably explained by the fact that the current estimates are based upon a broader subgroup of the population than is considered by either Laibson et al. or Fang and Silverman.

The analyses reported in Section 4 are principally based upon the parameter estimates reported in Table 6. To facilitate sensitivity analysis of the results obtained to the degree of myopia, δ was re-estimated for a given set of parameter values $(\gamma, \varepsilon, \alpha, \beta)$. Starting from the estimates set out in Table 6, the isoelastic parameter γ was restricted to 1.4, the intratemporal elasticity ε to 0.55, and the utility price of leisure to 1.3983.[18] Seven alternative values of the short-run excess discount factor β are considered, centered over 0.85, and spaced evenly over the domain $[0.70, 1.00]$. These parameter pairs (β, δ) are designed to control for the fact that a fall in β, *ceteris paribus*, implies both greater disparity between short-run and long-run discount rates, and higher discount factors over all prospective time horizons. The former of these effects (time inconsistent myopia) is a focus of concern in this paper, and it is consequently useful to provide a control for the second (impatience). The estimates obtained for δ, given the parameter restrictions set out above, are reported in Table 7.

Measures reported for the loss function in Table 7 indicate that the best overall fit to the sample moments is obtained for $\beta = 0.85$, which is consistent with the results reported in Table 6. As anticipated, estimates for δ monotonically rise as the assumed value for β falls, offsetting the impact that a fall in β has on impatience over all prospective time horizons. The "term to equivalence" that is reported in the bottom row of Table 7 provides a measure of the extent to which the rise in the estimated δ off-sets the associated fall in β. Define δ_0 as the exponential discount factor associated with $\beta = 1$, and δ_1 as the exponential discount factor with $\beta = \beta_1$. Then the term to equivalence is the time horizon at

[18] In the case of the utility price of leisure, the parameter value was set to the average between the point estimates obtained for for the exponential and quasi-hyperbolic models, imposing the additional restrictions $\gamma = 1.4$ and $\varepsilon = 0.55$. These supplementary regression statistics are available from the author upon request.

Table 6: Structural estimation of full set of preference parameters

parameter	exponential estimate	exponential std error	quasi-hyperbolic estimate	quasi-hyperbolic std error
short-run excess discount factor	1.0000	.	0.8458	0.0401
long-run (exponential) discount factor	0.9693	0.0053	0.9760	0.0041
intertemporal isoelastic parameter	1.4380	0.5212	1.3760	0.2964
intra-temporal elasticity	0.5485	0.0909	0.5500	0.0453
utility price of leisure	1.4003	0.0940	1.3900	0.0336
target moments				
consumption	1.270E-02		1.305E-02	
pension participation	8.308E-03		7.762E-03	
part-time employment	3.675E-03		3.471E-03	
full-time employment	7.313E-03		6.678E-03	
non-emp of 1st to 5th wealth quintiles	4.407E-02		1.583E-02	
Loss function	5.5339		5.0291	
J statistic	866.37		775.86	
*Test of over-identifying restrictions**	0.0000		0.0000	

Notes: * p-values

Table 7: Structural estimates of the exponential discount factor, for restricted values of the excess short-run discount factor

parameter							
long-run (exponential) discount factor	0.9690	0.9717	0.9737	0.9767	0.9782	0.9818	0.9824
	(0.0044)	(0.0058)	(0.0033)	(0.0032)	(0.0014)	(0.0026)	(0.0022)
restricted preference parameters							
short-run excess discount factor	1.00	0.95	0.90	0.85	0.80	0.75	0.70
intertemporal isoelastic parameter	1.40	1.40	1.40	1.40	1.40	1.40	1.40
intra-temporal elasticity	0.55	0.55	0.55	0.55	0.55	0.55	0.55
utility price of leisure	1.3983	1.3983	1.3983	1.3983	1.3983	1.3983	1.3983
Loss function	5.6246	5.4859	5.4844	5.3038	5.6171	6.8948	7.3733
J statistic	882.47	851.60	839.30	806.98	868.76	1049.01	1157.77
*Term to equivalence**	.	18.10	21.65	20.34	23.56	21.81	25.92

Notes: standard errors reported in parentheses
* defines the time horizon at which the implied discount factor is equivalent to the exponential discount factor (the left-most column)

which the discount factors under each form of discounting are equivalent, $\hat{t} = \ln(\beta_1) / [\ln(\delta_0) - \ln(\delta_1)]$. The statistics that are reported at the bottom of Table 7 all imply a term to equivalence of around 20 years, which implies that quasi-hyperbolic discount factors will exceed the exponential discount factor over prospective time horizons less than 20 years, and vice versa for longer time horizons.

4 Behavioural and Welfare Effects of the National Employment Savings Trust (NEST)

4.1 Terms of the NEST

As noted in the introduction, the NEST is designed to improve incentives to save for retirement by reducing management charges, and by requiring all employers to offer minimum matching pension contributions to eligible employees. To meet the first of these objectives, the NEST is designed to shift the focus of competition among private sector pension providers from individual pension members, to pools of managed funds. It is hoped that this centralisation will achieve administration charges that are similar to those levied by large occupational pension schemes. In the current context, this represents an average fall in the annual capital charge of approximately 1 percent, to 0.3 percent per annum. Furthermore, all employees with earnings in excess of a minimum threshold and between 16 and 74 years of age will have the right to participate in the scheme. An employee who participates in the NEST will be required to pay an annual contribution into the scheme worth at least 5% of their gross earnings within an earnings band, and their employers will be required to pay a matching contribution worth at least 3% of banded gross earnings. All pension contributions are exempt from income tax, so that an employee who pays tax at the marginal rate of 20% (the basic rate) will effectively pay a contribution out of post-tax income that is worth 4% of gross earnings, and will receive tax relief worth a further 1%. Contributions to personal pensions in the UK are accessible from age 55, at which time up to 25% of the accrued fund can be taken as a tax free lump sum, with the remainder used to purchase a life annuity. The income stream that is generated by pension annuities is subject to income taxation.

4.2 Policy counterfactuals

The analysis reported here is based upon repeated simulations for a cohort of 10,000 households, where each simulation assumes that households (accurately) expect that they will be subject to a single policy environment throughout the course of their lives. Behavioural responses to policy are identified by comparing household decisions made under one policy environment with those made under another, where the only variable between simulations is the considered policy environment.[19] A small open economy is assumed, so that there are no feed-back effects of aggregate savings and labour supply on interest rates or wages.

The analysis is structured around two principal policy environments that are distinguished from one another by the existence of a DC pension scheme. The focus on differences between a policy environment in which a DC pension exists, relative to one in which there is no pension asset reflects the fact that the NEST is being introduced specifically for people who are not served by the existing system of private pension provisions in the UK. Furthermore, the terms of the DC pension are specified to reflect the broad strokes of the NEST, as outlined in Section 4.1. Where the DC pension exists, then all employees under age 68 must decide whether to participate in the scheme. If they do choose to participate, then they must also specify the proportion of their labour income to contribute to the scheme during the given year, subject to the lower bound of 5%. Any employee who chooses to participate in the DC pension receives a matching employer contribution worth 3% of earnings, and all contributions are exempt from income tax. At age 68, 25% of each individual's pension fund is returned as a tax free lump sum dividend, with the remainder used to purchase a life annuity, paying an actuarially fair dividend

[19] Note that each simulated household is subject to the same age specific innovations between alternative policy simulations.

subject to a capital charge of 4.7% (as set out in Sections 2.4 and 3.3). These terms differ from NEST in four respects.

First, the assumption that the pension fund is illiquid until 68 contrasts with the minimum pensionable age of 55 that is currently imposed. The pension age assumed for the DC pension was aligned with state pension age, in the absence of a clear view about how the minimum pensionable age is likely to evolve during the next few decades. The uncertainty is highlighted by policy changes implemented in 2006 that required all pension schemes in the UK to raise their minimum age of retirement from 50 to 55 by 2010. The influence that this assumption has on the analysis will depend upon how it affects the value of the DC pension as a commitment mechanism to myopic agents.

Second, auto-enrolment is an aspect of the design of the NEST that is omitted from the current analysis. There is extensive empirical evidence to suggest that auto-enrolment has an important bearing on rates of pension scheme participation.[20] In the current context, however – where decisions are the product of maximising behaviour subject to rational expectations and in the absence of decision making costs – auto-enrolment has no role to play. I return to this issue in the concluding remarks.

Third, to limit competition between the NEST and the existing market of private pension providers in the UK, NEST accounts will be subject to a series of constraints on the band of income from which contributions can be made (as noted above), the aggregate value that can be contributed in any one year, and the transfers that can be made into the scheme from alternative pension plans. These issues are omitted from the analysis because they are orthogonal to our subject of interest.

Finally, the NEST is designed to provide low cost access to professional funds management, and will allow a degree of flexibility over the assets into which pension contributions are invested. The current analysis abstracts from the detailed asset allocation problem, by focussing only upon fixed rates of investment return. To the extent that investment flexibility is an important factor determining savings held in pensions, the model will consequently tend to understate contribution rates, and ultimately rates of pension participation.

Introducing the DC pension scheme described above acts to raise the effective return to labour supply, directly through the employer contribution, and indirectly through the preferential tax treatment of pension contributions. Adjustments to off-set the pecuniary impact of the DC pension scheme were administered through the government budget constraint, under the assumption that the matching pension contributions were paid for by the government. Two forms of tax adjustment to maintain neutrality of the aggregate government budget were explored: a fixed proportional tax on all labour income; and adjustment of the upper two rates of income tax of the four rate schedule that was applied

[20] See, for example, Madrian & Shea (2001) and Choi et al. (2002).

in the UK in 2007. The second of these two alternatives leaves lower rate tax payers unaffected, and was selected to off-set the regressivity that is otherwise consequent on the introduction of a DC pension (discussed further below). As similar results were obtained under both methods of tax adjustment, results obtained assuming the fixed proportional tax on labour income are reported below, and those obtained under the alternative tax adjustment can be obtained from the author upon request.

The analysis begins by focussing upon effects of the DC pension simulated under the preference parameters reported in Table 6, subject to a fixed proportional tax on all labour income to maintain government budget neutrality. Section 4.3 reports responses on the assumption of exponential discounting, and Section 4.4 explores the effects of myopia on the assumption of quasi-hyperbolic discounting. Sensitivity of the analysis to the extent of myopia are then explored with reference to the preference parameters that are reported in Table 7.

4.3 Behavioural responses in context of time-consistent preferences

Table 8 reports the long-run behavioural and welfare effects of introducing the DC pension set out in Section 4.2, given the model parameters reported for exponential discounting in Table 6. I report the effects of a DC pension in per-capita terms because the policy counterfactual that is considered here (as discussed in subsection 4.1) is explicitly designed to address the needs of individual employees in the UK, rather than an economy-wide reform.

Table 8 divides the population into quintile groups based upon average disposable household income earned between ages 20 and 67, so that each quintile follows the same group of households through their respective lives. Working down from the top of Table 8, the reported statistics indicate that the tax advantages of the pension asset and the 3% matching employer pension contribution are sufficient incentives to generate widespread participation in the pension scheme. It is of little surprise that the highest rates of pension scheme participation toward the end of the working life are observed amongst households at the top of the income distribution. Less intuitive, however, is the observation that the reverse is true at the beginning of the working life, when rates of pension participation are particularly high among households in the bottom two income quintiles. This second observation is of note, given that the NEST is explicitly designed for employees on low to modest incomes.

The relatively high rates of pension scheme participation that are observed early in life among households in the bottom two income quintiles are attributable to the forward looking nature of the decision framework. Households toward the top of the lifetime income distribution anticipate stronger wage growth early in the life course than those toward the bottom, due to the specification that is assumed to govern the intertemporal development of human capital (see Section 2.5). Furthermore, households toward the bottom of the lifetime income distribution that expect weak wage growth, also

Table 8: Long-run effects of introducing a defined contribution pension where a pension asset did not previously exist and preferences are time consistent

age group	lowest income quintile	2nd quintile	3rd quintile	4th quintile	highest income quintile	average
proportion of decile contributing to private pension (%*)						
20 to 34	31	21	13	10	14	18
35 to 49	62	52	45	54	74	57
50 to 67	37	40	62	80	86	61
change in employment (%*)						
45 to 54	-0.4	0.1	0.4	0.8	0.7	0.3
55 to 64	-0.6	1.1	1.5	0.4	-0.7	0.3
65 to 74	-5.0	-2.2	-3.7	-14.8	-29.8	-11.1
average pension wealth (%**)						
20 to 34	6	5	3	3	5	4
35 to 49	82	86	79	100	162	102
50 to 67	192	225	291	513	957	436
change in total net worth (%**)						
20 to 34	5	3	1	0	2	2
35 to 49	81	82	72	90	157	96
50 to 67	189	210	242	404	707	350
compensating variation of pension introduction (%**)						
20	10	15	16	17	16	15
68	-43	-61	-98	-182	-383	-154

Responses to a DC pension paying a real return to invested funds of 2.7% per annum

Quintile groups distinguished by household disposable income between ages 20 and 67

Table reports statistics simulated with a DC pension, less statistics simulated without a pension asset

Simulations with a DC pension also apply a tax adjustment to ensure government budget neutrality

Tax adjustment applied as a fixed rate on all wage income, equal to 5.9%

* denotes % of population subgroup

** denotes % of median annual household disposable income between ages 20 and 67 in the simulation where a DC pension does not exist, equal to £52,548 in 2007 prices anticipate to retire sooner – households in the bottom quintile work for 38 years on average under the policy counterfactual without pensions, which is 10 years less than households in the top quintile. These factors motivate high income households to consume more early in life and delay their saving to later ages, relative to households with lower wage expectations.

The statistics that are reported for employment in Table 8 indicate that labour supply rises very marginally on average prior to pension age in response to the DC pension, but falls substantially following pension age. The slight rise in employment prior to pension age indicates that, on average, the price effect associated with higher effective returns to labour supply weakly dominates the associated income effect. Following pension age, the release of pension funds amplifies the associated income effect of the DC pension scheme, resulting in a substantial fall in labour supply. The most pronounced effects are observed among households with the highest incomes, for whom the pension asset is most important.

The statistics reported for pension wealth and total net worth indicate that most pension saving represents new saving in the model, rather than a transfer of saving from liquid assets. This is particularly true for households in the lowest two lifetime income quintiles, for whom the NEST is designed, but it also applies to households throughout the income distribution. Unsurprisingly, the largest degree of off-setting is generated by the model for households at the top of the income distribution and late in the working lifetime. But even among these households, average off-setting between ages 50 and 67 does not exceed 30 percent, well below the 40 percent average off-set of current government projections. Furthermore, average rates of pension contributions (not reported in the table) tend to exceed the 5% minimum imposed by the pension scheme by a multiple of 4 on average throughout the income and age distribution. This is of note, given the contribution limits to which the NEST will be subject.

Welfare effects in the form of compensating variations are reported at the bottom of Table 8. These statistics indicate that DC pensions tend to depress welfare at the beginning of the simulated lifetime for households throughout the earnings distribution, with the most pronounced effects reported toward the top of the distribution. This is an intuitive and important result: in context of the decision environment and time-consistent preference structure that are assumed here, there is no welfare justification for the pension scheme. In this case, the illiquidity of the DC pension reduces decision making flexibility, and only survives in context of voluntary participation to the extent that participants are subsidised through tax advantages and matching employer contributions. In a closed financial system where the cost of any subsidy must be met without recourse to borrowing (as is the case here), the DC pension will be regressive to the extent that it transfers resources from (poorer) non-savers to (richer) savers. As such, the DC pension requires a consideration beyond the scope of the current analysis to merit its introduction.

The fact that the welfare effects of a DC pension become positive (negative compensating variations) as age increases, reflects the increase in saving that is motivated by the DC pension scheme. Furthermore, the observation that the profile of the welfare effect is reasonably flat through the income distribution at age 20 reflects the uncertainty that is associated with how lifetime prospects will evolve with time. This disparity widens with age, as the magnitude and inequality of the distribution of wealth rises, as the period of illiquidity of pension wealth reduces, and as lifetime uncertainty declines.

The finding that DC pensions depress welfare measured from the start of the simulated lifetime is in direct contrast with Laibson et al. (1998), who report strictly positive welfare gains to the introduction of a DC pension throughout the life course. The difference between the two studies in this respect is primarily attributable to differences in the proportional adjustments to employment income that are made to ensure budget balance, and indirectly to the allowance for endogenous labour supply in the current analysis. The proportional tax on labour earnings that is required to maintain budget balance here is equal to 5.9 percent. This is almost twice the value of the matching employer contribution of 3 percent that is received by the population subgroup who choose to participate in the DC pension. As Laibson et al. (1998) adjust only for the matching employer pension contribution, they apply a much smaller proportional adjustment to wages, resulting in a net welfare surplus to employees.

Although some of the difference between the rates of the matching employer pension contribution and the tax adjustment that is required to maintain budget neutrality is accounted for by the fiscal burden of tax incentives to pension saving, this is a relatively minor consideration. Furthermore, the size of the proportional tax adjustment is not exaggerated by behavioural responses to the tax adjustment. The proportional tax on earnings actually increases rates of employment – relative to a counterfactual where no proportional tax is applied (not reported) – by 0.7 percent on average over all households between ages 20 and 79. This increase in employment is skewed toward the top of the earnings distribution, where the income effects are more pronounced, which tends to dampen the tax on earnings that is required to maintain budget balance. The principal reason that larger compensating adjustments are imposed in the current study, relative to Laibson et al. (1998), is the reduction in labour supply that is generated in context of the DC pension from state pension age. The earlier retirement ages that are implied reduce tax receipts levied on the foregone labour income, and increase the fiscal burden of welfare payments to retirees.

4.4 Responses when preferences are myopic

This section explores the influence of myopia on the behavioural and welfare effects of a DC pension. The policy counterfactual that is considered here is identical to that considered in the preceding subsection, except that behavioural responses are generated assuming the estimated model parameters that describe quasi-hyperbolic discounting reported in Table 6.

Table 9: Long-run effects of introducing a defined contribution pension where a pension asset did not previously exist and preferences are myopic

age group	lowest income quintile	2nd quintile	3rd quintile	4th quintile	highest income quintile	average
	proportion of decile contributing to private pension (%*)					
20 to 34	35	23	14	11	13	19
35 to 49	64	54	51	61	77	61
50 to 67	38	38	60	79	86	60
	change in employment (%*)					
45 to 54	-0.1	0.1	0.5	0.8	1.0	0.5
55 to 64	-0.5	1.1	2.8	2.1	-0.3	1.0
65 to 74	-9.4	-10.3	-10.3	-18.0	-33.8	-16.4
	average pension wealth (%**)					
20 to 34	8	6	4	3	5	5
35 to 49	102	102	87	106	162	112
50 to 67	232	264	311	502	883	438
	change in total net worth (%**)					
20 to 34	8	5	4	3	5	5
35 to 49	102	101	87	108	163	112
50 to 67	231	260	287	436	748	393
	compensating variation of pension introduction (%**)					
20	3	4	5	5	4	4
68	-51	-64	-92	-167	-349	-145

Responses to a DC pension paying a return to invested funds of 2.7% per annum
Quintile groups distinguished by household disposable income between ages 20 and 67
Table reports statistics simulated with a DC pension, less statistics simulated without a pension asset
Simulations with a DC pension also apply a tax adjustment to ensure government budget neutrality
Tax adjustment applied as a fixed rate on all wage income, equal to 5.6%
* denotes % of population subgroup
** denotes % of median annual household disposable income between ages 20 and 67 in the simulation where a DC pension does not exist, equal to £52,154 in 2007 prices

Comparing the top panel of Tables 8 and 9 reveals that the allowance made for myopia tends to exaggerate rates of participation in the DC pension scheme, which increase by 2.5% on average between ages 20 and 49. The largest increases in participation are generated for households in the third and fourth population quintiles between ages 35 and 49, which possess both reasonably strong saving incentives, and additional capacity for pension participation under time-consistent preferences (reported in Table 8). That these same households also tend to reduce their pension participation later in life in context of myopic preferences, reflects the fact that savings accrued early in life are most at risk of premature consumption in context of present biassed preferences.

Employment prior to retirement (not reported in Tables 8 or 9) is not much affected by the allowance made for quasi-hyperbolic discounting; average rates of employment between ages 20 and 55 increase by 0.2 percent in response to the DC pension under quasi-hyperbolic discounting, and by 0.3 percent under exponential discounting. Hence the alternative commitment mechanism considered by the model (labour supply in context of a positive experience effect on prospective wages) does not appear to influence responses to the DC pension in this case. The employment statistics that are reported in the Tables 8 and 9 indicate that employment participation between ages 45 and 64 increases by 0.75%

on average in response to the DC pensions when preferences are myopic, as compared with 0.3% in context of time consistent preferences. After households gain access to their pension wealth (age 68 in the analysis), however, employment rates fall fairly sharply – by 11% on average under the assumption of exponential discounting, and by over 16% under quasi-hyperbolic discounting. The more pronounced reduction in employment from pension age that is generated under quasi-hyperbolic discounting is consistent with the fact that the time inconsistency of myopic preferences detracts from incentives to save, so that myopic individuals without access to an illiquid pension find that they are less well placed to afford retirement later in life – DC pensions help to mittigate this effect.

The importance of the role payed by the commitment mechanism in motivating responses to the pension asset in the context of myopia is highlighted by the statistics that are reported for pension wealth and total net worth. The statistics reported for pension wealth in Tables 8 and 9 indicate that savings in pensions are brought forward when preferences are myopic. This is consistent with the rates of pension participation that are discussed above, and reflects the fact that the commitment mechanism provided by the pension asset is strongest early in the working lifetime and falls away toward pension age.

The statistics for total net worth reveal that aggregate saving rises in response to a DC pension by almost 10% more on average between ages 50 and 67 when preferences are myopic, relative to the case of exponential discounting[21]. The distributional statistics that are reported in the respective tables indicate that this excess savings response in context of myopic preferences is spread reasonably evenly across all households when measured in absolute (per capita) terms. Myopia consequently has a more pronounced influence on the saving responses of households on low to modest incomes when measured relative to *a priori* savings, which is of note as it is this population subgroup for whom the NEST is designed. The exaggerated savings responses of lower income households, relative to those on higher incomes, is attributable to the fact that low income households have weaker life-cycle saving motives, which are more easily overwhelmed by the distortions of present biassed preferences.

Furthermore, the statistics for pension wealth and total net worth taken together reveal that there is a reduced tendency for households to off-set pension saving against other liquid assets when preferences are myopic. This is explained by the fact that the imperfect substitutability between pension wealth and liquid wealth is exaggerated in context of myopic preferences by the commitment mechanism offered by the illiquidity of pension wealth.

Finally, welfare statistics are reported at the bottom of Tables 8 and 9. These indicate that myopia tends to improve the welfare effect of the DC pension scheme at the beginning of the simulated lifetime among households throughout the income distribution. Nevertheless, the influence of myopia is insuf-

[21] An increase of 42% of average lifetime earnings over and above the 350% increase observed for exponential discounting.

Table 10: Savings responses to the introduction of a pension asset, by short-run excess discount factor and the return to pension wealth

short-run excess discount		0.7	0.75	0.8	0.85	0.9	0.95	1
*pension wealth between ages 35 and 49**								
pension return	2.0	0.638	0.744	0.625	0.663	0.598	0.639	0.578
(% p.a.)	2.5	0.864	1.078	0.962	1.013	0.927	0.950	0.853
	3.0	1.121	1.308	1.227	1.317	1.272	1.299	1.196
	3.5	1.308	1.541	1.446	1.556	1.503	1.569	1.504
	4.0	1.508	1.671	1.617	1.715	1.709	1.793	1.738
	4.5	1.625	1.793	1.757	1.873	1.856	1.959	1.920
	5.0	1.735	1.903	1.839	1.961	1.952	2.070	2.036
*pension wealth between ages 50 and 67**								
pension return	2.0	2.959	3.317	3.087	3.293	3.151	3.269	3.204
(% p.a.)	2.5	3.744	4.196	3.951	4.135	4.008	4.086	3.961
	3.0	4.493	4.881	4.673	4.874	4.784	4.856	4.737
	3.5	5.082	5.454	5.257	5.448	5.362	5.462	5.377
	4.0	5.569	5.888	5.694	5.870	5.828	5.929	5.860
	4.5	5.934	6.221	6.075	6.253	6.174	6.296	6.230
	5.0	6.246	6.535	6.341	6.519	6.445	6.589	6.503
percentage of pension wealth off-set against liquid wealth between ages 50 and 67								
pension return	2.0	7.63	9.78	11.05	14.93	17.86	21.38	23.80
(% p.a.)	2.5	6.07	8.08	9.16	12.83	14.88	18.20	20.52
	3.0	5.29	7.11	7.95	11.22	12.88	15.78	17.65
	3.5	4.80	6.49	7.27	10.15	11.58	14.15	15.74
	4.0	4.52	6.17	6.85	9.57	10.75	12.91	14.34
	4.5	4.38	5.94	6.52	9.03	10.08	12.01	13.28
	5.0	4.23	5.75	6.31	8.71	9.67	11.35	12.50

Table reports saving responses to a DC pension, relative to a policy environment w ith no pension asset

* Wealth expressed as % of median annual household disposable income betw een ages 20 and 67, w orth £52,043

ficient to imply that the DC scheme is welfare improving at age 20: households in the bottom lifetime income quintile would still require a lump-sum payment equivalent to 2.7 percent of median annual household disposable income at age 20 in context of the DC pension to be as well off as in the absence of the scheme, and this payment increases to between 4 and 5 percent for households on higher lifetime incomes. Furthermore, between ages 20 and 49, the welfare effect of a DC pension switches from being more pronounced under myopic preferences, to more pronounced under exponential preferences. This bias toward younger ages under quasi-hyperbolic discounting reflects the importance of the commitment mechanism that is offered by pensions, which diminishes with the time horizon to pension receipt.

4.5 Sensitivity to extent of quasi-hyperbolic discounting

A more general appreciation of the implications of myopia for behavioural responses to a DC pension is made possible by considering the sensitivity of responses over the short-run excess discount factor, β, and the rate of return to the pension asset r^p. The current section focuses upon the effects of the pension asset on population average statistics, based upon the alternative preference parameters that are reported in Table 7. All aspects of the policy environment other than β, r^p, and the exponential discount factor δ, were held fixed between the simulated policy counterfactuals.

Statistics that describe the effects of the introduction of the pension asset on savings behaviour are reported in Table 10. The top and middle panels of this table reveal a clear positive relationship between the rate of return assumed for pension wealth and the scale of pension wealth, for all seven of the alternative values considered for the short-run excess discount factor β. As the rate of return to pension wealth is increased from 2 to 5 percent per annum, the average pension wealth increases by a factor of 3 between ages 35 and 49, and by a factor of 2 between ages 50 and 67. This intuitive response is more than a passive consequence of the higher investment income consequent on an increased rate of return; high rates of return to pension wealth motivate increased involvement in pensions early in the working lifetime. When $\beta = 0.85$, a rise in the rate of return to pension wealth from 3 percent per annum (approximating the rate considered in Table 9) to 4 percent per annum (which approximates the target reduction in management costs for the NEST) increases average pension wealth between ages 35 and 49 by approximately 30 percent (from 1.32 to 1.72 times average annual disposable income), and increases average rates of pension scheme participation between ages 20 and 35 by 25 percent (from 22.5 to 28.3 percent).

The top panel of Table 10 suggests that the extent of myopia tends to have a less pronounced influence on pension saving early in the working lifetime than the rate of return to pension wealth. Nevertheless, a close inspection of the statistics reported in the top panel of the table does reveal some interesting variation to the policy parameters. When the return to pension wealth is low, the top panel of Table 10 indicates that saving in pensions early in the working lifetime tends to increase with the extent of behavioural myopia. As the rate of return to pension wealth increases, however, this relationship between myopia and pension saving is reversed.

As noted in the introduction, the illiquidity of a pension fund in context of myopic preferences can be welfare improving to the extent that it represents a commitment mechanism that favours current preferences over future preferences. Importantly, the potential for a pension fund to be used in this way depends upon the nature of its illiquidity, and is independent of the rate of return paid to pension savings. Hence, the observation that pension savings early in the working lifetime tend to respond positively to the extent of myopia when the return to pension wealth is low suggests that the DC pension does help to resolve the intra-personal conflict that arises in context of time-inconsistent preferences in favour of the present self. The additional observation that pension savings tend to respond negatively to the extent of myopia when the return to pension wealth is high then indicates that the parametrisation of myopia is relatively inelastic to the return on pension wealth. Put another way, relative to time-consistent exponential discounting, the myopic agents represented by the model favour the illiquidity of the DC pension for the commitment mechanism that it represents. But at the same time, the present bias of their preferences makes them less inclined to respond positively to an increase the return paid to pension wealth.

The middle panel of Table 10 indicates that average pension wealth between ages 50 and 67 tends to fall at a fairly stable rate as β is reduced below 1.0, for all five rates of return to pension wealth reported in the table. This is consistent with the present bias in consumption that is associated with a lower β, and with the declining role of the pension asset as a commitment mechanism as the pension age draws near.

Discussion in subsection 4.4 suggests that myopia tends to dampen the extent to which pension saving is off-set against saving in other forms. This impression is reinforced by the statistics reported in the bottom panel of Table 10, which indicate that the off-set of pension saving late in the working lifetime falls monotonically with both the extent of myopia and the return to pension wealth, with myopia having the most pronounced influence over the range of policy parameters reported in the table. As noted in subsection 4.4, the scope for myopic households to off-set pension saving is limited by the small balances of liquid wealth that such households accrue in the absence of a pension asset, and by the desire to maintain precautionary balances. The first of these considerations becomes more acute as the extent of myopia increases, which is the driving factor behind the fall in the pension off-set generated at lower values of β.

The reported decline of the savings off-set to the pension asset as the return to pension wealth rises is attributable to four factors. First, high returns to the pension asset motivate stronger pension participation early in life (as discussed above) when liquid savings are relatively thin. Second, the wealth effect associated with a rise in the return to pension wealth motivates higher consumption during the working lifetime. Third, the higher consumption during the working lifetime motivates larger precautionary balances to insure against an adverse shock. And fourth, the measures of average pension wealth increase with the return to the pension asset, so that the off-set actually increases in absolute terms.

An important conclusion of the discussion reported in subsection 4.3 is that the DC pension is associated with a net welfare loss equivalent to 15 percent of average annual household disposable income at the beginning of the simulated lifetime. Although this loss is reduced to 4 percent under the myopic specification considered in section 4.4, it is nevertheless reported for households throughout the earnings distribution. Table 11 reports how these welfare effects vary by the interest rate on pension wealth and the degree of myopia. The table indicates that average effect of the DC pension on the welfare of households at age 20 improves with both the return to the pension asset, and with the extent of behavioural myopia. The former of these responses is of little surprise, but the latter indicates that the structure of the pension asset does help to mitigate the welfare costs associated with the time-inconsistency of a myopic preference structure as is posited above. Hence, *myopia provides a plausible justification for the DC pension considered here*, consistent with one aspect of the policy premise upon

Table 11: Average compensating variations at age 20 to the introduction of a pension asset, by short-run excess discount factor and the return to pension wealth

short-run excess discount		0.7	0.75	0.8	0.85	0.9	0.95	1
pension return	2.0	-2.08	0.28	4.89	6.85	10.18	13.69	15.48
(% p.a.)	2.5	-2.88	-2.34	1.37	6.12	9.01	13.13	14.28
	3.0	-3.10	-2.96	-1.20	2.76	6.92	11.28	13.18
	3.5	-3.19	-3.12	-2.83	-1.81	2.50	7.27	10.54
	4.0	-3.19	-3.15	-3.07	-2.91	-1.59	2.36	6.34
	4.5	-3.19	-3.15	-3.13	-3.07	-2.85	-1.92	1.74
	5.0	-3.19	-3.15	-3.14	-3.12	-3.05	-2.89	-2.17
	7.0	-3.19	-3.15	-3.14	-3.12	-3.11	-3.09	-3.06

Table reports Compensating Variations at age 20 under a DC pension, relative to a policy environment with no pension asset
Compensating Variations reported as % of median annual household disposable income between ages 20 and 67, worth £52,535

which the NEST is based. Indeed, if the NEST achieves its target economies on management costs, then the analysis that is reported here suggests that the scheme may be welfare improving ($\beta = 0.85$, and pension return of 3.5-4.0 % p.a.).

Table 11 reveals that the largest differences for the welfare effects of the DC pension between alternative specifications for myopia are observed with the return to the pension asset is low. The welfare effect of a rise in the return to the pension asset trails off at higher rates of return due to the diminishing marginal utility of consumption, and because, at high interest rates, the wealth effect dominates, thereby leading to a fall in pension scheme participation. The 7 percent rate of return to pension wealth is included in the table to consider the welfare response in the region of the asymptote for the reported preference specifications. At this rate of return, there remains only a very slight improvement in the welfare effect of the DC pension as the extent of myopia is increased. This is explained by the observation that decisions over pension involvement – particularly early in life – are strongly influenced by myopia at low rates of pension return, but are largely independent of myopia when the return to the pension asset is very high.

5 Conclusion

This study explores how myopic preferences influence behavioural and welfare responses to a DC pension scheme in a realistic policy context that reflects the income and demographic uncertainties that households face in practice. The DC pension scheme is specified around the National Employment Savings Trust that will be introduced in the UK in 2012, and the parameters of the structural model upon which the analysis is based were estimated on survey data for a broad cross-section of the UK population. Particular attention is paid to the influence on the analysis of allowing for the joint decisions of labour supply and saving, given past work that has taken labour supply as exogenous.

The introduction of a DC pension scheme is found to encourage deferment of consumption to later periods in life in all of the policy counterfactuals that are reported here. Myopic preferences are found to exaggerate this wealth response under the central policy scenario, by between 10 and 13 percent, depending upon the adjustment that is made to ensure budget balance and whether labour supply is assumed to be endogenous. Associated sensitivity analysis reported here reveals that the influence of myopia on pension saving increases with the disparity between short-run and long-run discount rates, and decreases with the rate of return earned on pension assets.

Where labour supply is endogenous, I find that the increased wealth held late in the working lifetime that is motivated by the DC pension encourages earlier retirement from pension age. Consistent with the results identified for saving, I find that the reduction in average rates of employment from pension age in context of a DC pension increases from between 11 and 12 percent under time-consistent (exponential) discounting, to between 16 and 18 percent with myopic preferences.

Furthermore, the welfare measures that are reported confirms the potential value of DC pensions as a method of committing saving for retirement in context of time-inconsistent preferences. Nevertheless, I find that the welfare benefits attached to the commitment mechanism in the context of myopia are insufficient to outweigh the full economic cost of providing the pension scheme where labour supply is endogenous. This negative welfare effect of a DC pension is reversed when labour supply is exogenously assumed, which highlights the potential importance of labour supply in an analysis of pension saving.

An important aspect of the design of the NEST is the allowance that is made for behavioural inertia, through the adoption of an auto-enrolment mechanism. This allowance has been made, based on the observation that default options for pensions – regarding the decision to participate, rates of contributions, and investment strategies – tend to have an important bearing on outcomes in practice. This finding is at odds with the implications of the standard life-cycle model, which is based upon the joint assumptions of perfect rationality and no decision making costs. It would be of obvious interest to extend the current analysis to allow for decision making inertia: this is an issue that remains for further research.

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